



BACKonLINE™

Development of an online self-assessment and self-management tool for patients with chronic low back pain

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Declaration and Statements

Declaration

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Conferences and Presentations

Patient self-assessment and self-management-online classification tool (BACKonLINE)

D. Alothman, L. Sheeran, V. Sparkes

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Table of Contents

Declaration and Statements	i
Acknowledgements	iii
Conferences and Presentations	v
Table of Contents	vii
List of Tables	xiii
List of Figures	xvii
List of Abbreviations	xix
Abstract	xxi
Chapter 1. Introduction	1
1.1. Thesis Structure	12
Chapter 2. Literature Review	16
2.1. Introduction	16
2.2. Literature Search Strategy	16
2.3. Pain	19
2.4. Low Back Pain	40
2.5. Assessment of Low Back Pain	54
2.6. Low Back Pain Management	62
2.7. Health Education and Health Behaviour	73
2.8. Summary and Justification for the Study	82
Phase 1: Development of BACKonLINE™- The E-Delphi Study	89
Chapter 3. Phase 1 Literature Review	91
3.1. Introduction	91
3.2. The Delphi Study Technique	92
3.3. Participants: The Expert Panel for the Delphi Study	101
3.4. Rating Scales in a Delphi study	103
3.5. Data Analysis in a Delphi study	107
3.6. Aim of Phase 1	116
3.7. Summary	117

Chapter 4. Phase 1 Methods	119
4.1. Introduction	119
4.2. Study Design.....	120
4.3. Stage 1: Item Generation and Construction of the E-Delphi Study.....	121
4.4. Stage 2A: Two Round E-Delphi study.....	129
4.5. Summary	142
Chapter 5. Phase 1 Results	143
5.1. Introduction	143
5.2. Participants	143
5.3. E-Delphi study: Round 1- Development of BACKonLINE™	145
5.4. E-Delphi Study: Round 2	163
5.5. Summary	164
Chapter 6. Phase 1 Discussion	167
6.1. Introduction	167
6.2. Study Design.....	167
6.3. Selection of Likert Scale Points	169
6.4. The Expert Panel	169
6.5. The E-Delphi Study	172
6.6. Strengths and Limitations:.....	185
6.7. Summary	189
Phase 2: Readability of BACKonLINE™	191
Chapter 7. Readability of BACKonLINE™	193
7.1. Introduction	193
7.2. Background: Assessment of Readability	193
7.3. Phase 2 - Methods	196
7.4. Results.....	200
7.5. Discussion.....	205
7.6. Strengths and limitations	208
7.7. Summary	208
Phase 3: Measurement properties and Participants Experience of BACKonLINE™	211

Chapter 8. Phase 3 Literature Review	213
8.1. Introduction	213
8.2. Reliability	214
8.3. Validity	222
8.4. Pain and Related Symptoms Outcome Measures	234
8.5. Patient Involvement in Tool Development	244
8.6. Behavioural models influencing tool utility.....	246
8.7. Summary.....	256
8.8. Aim of Phase 3	257
8.9. Phase 3 Objectives.....	257
8.10. Phase 3 Research Questions.....	257
 Chapter 9. Phase 3: Methods.....	 259
9.1. Introduction	259
9.2. BACKonLINE™ Scoring	259
9.3. Study Design	260
9.4. Participants.....	261
9.5. Data Collection Procedure:.....	265
9.6. Data Analysis	269
9.7. Summary.....	278
 Chapter 10. Phase 3 Results.....	 281
10.1. Introduction.....	281
10.2. Descriptive Statistics.....	281
10.3. BACKonLINE™ Reliability	283
10.4. BACKonLINE™ validity.....	289
10.5. Participants Experience of BACKonLINE™	297
10.6. Summary.....	306
 Chapter 11. Phase 3 Discussion	 307
11.1. Introduction.....	307
11.2. Summary of Findings	307
11.3. BACKonLINE™ Reliability	309
11.4. BACKonLINE™'s Validity.....	316
11.5. Participants Experience of BACKonLINE™	321
11.6. Strengths and Limitations of Phase 3	329

11.7. Summary	331
Chapter 12. Summary and Conclusion	333
12.1. Summary of the Findings	333
12.2. Comparisons of BACKonLINE™ with Current Management Pathways on Physiotherapy Waiting Lists.....	340
12.3. Comparisons of BACKonLINE™ with Current Chronic Low Back Pain Self- Assessment Tools.....	341
12.4. Clinical Implications	343
12.5. Strengths and Limitations	343
12.6. Future Recommendations and Vision.....	345
12.7. Conclusion.....	346
References.....	349
Appendix 1. NHS Apps library Categories	413
Appendix 2. Ethical Approval Letter for Phase 1: The E-Delphi study	415
Appendix 3. Phase 1 Participants Information Sheet	417
Appendix 4. Phase 1: The E-Delphi Study Round 1 (BACKonLINE™ Version 2).....	423
Appendix 5. Phase 1: The E-Delphi Study Round 1 and 2 Invitation and Reminder Emails	441
Appendix 6. Phase 1: The E-Delphi study Round 2 (BACKonLINE™ Version 3).....	449
Appendix 7. Ethical Approval Letter for Phase 2: The Readability Study	459
Appendix 8. Phase 2 Participants Information Sheet	461
Appendix 9. Phase 2 Participants Consent Form	465
Appendix 10. Phase 2: Stage 3 - Part A: Focus Group Instructions Manual	467
Appendix 11. BACKonLINE™ (Version 5)	483
Appendix 12. Oswestry Disability Index (ODI)	499
Appendix 13. Keele STarTBack Tool	503
Appendix 14. Visual Analog Scale of Pain Questionnaire (VAS).....	505
Appendix 15. Tampa Scale for Kinesiophobia (TSK).....	507
Appendix 16. Pain Anxiety Symptoms Scale short form 20 (PASS 20).....	511
Appendix 17. BACKonLINE™ (Version 5) with scores.....	515
Appendix 18. Ethical Approval Letter for Phase 3: Measurement Properties and Participants Experience of BACKonLINE™	533
Appendix 19. Research Passport.....	609
Appendix 20. Phase 3 Participants Information Sheet	613

Appendix 21. Phase 3 Participants Consent Form.....	621
Appendix 22. Phase 3 BACKonLINE™ Total and Each Domain Normal Distribution Assessment	625

List of Tables

Table 1	Keyword combinations included for all 4 parts of the literature search	Pg 17
Table 2	Number of articles identified and retrieved for all 4 parts of the literature search	Pg 18
Table 3	Indicators of pain mechanisms in available classification systems	Pg 46
Table 4	Low back pain assessment tools	Pg 60
Table 5	Phase 1 checklist for developing a search strategy adapted from Naumann (2007)	Pg 121
Table 6	Keywords used in in the literature search	Pg 122
Table 7	Databases searched in Phase 1	Pg 122
Table 8	Phase 1 BACKonLINE™ (Version 1)	Pg 123
Table 9	Phase 1, Stage 2 Participants inclusion and exclusion criteria	Pg 130
Table 10	Number of participants recruited into the E-Delphi study and sources of recruitment in Phase 1	Pg 143
Table 11	Phase 1 participants demographic data	Pg 144
Table 12	Descriptive statistics of Round 1 of the E-Delphi study in Phase 1	Pg 146
Table 13	Phase 1 E-Delphi study Round 1 and 2 results in order of descending level of agreement	Pg 148
Table 14	Additional self-assessment items suggested by participants in Phase 1 Round 1	Pg 158
Table 15	Low back pain (LBP) management advice suggested by participants of Phase 1 Round 1	Pg 161
Table 16	Descriptive statistics of Round 2 of the E-Delphi study	Pg 163
Table 17	Flesch Reading Ease (FRE) score interpretation (adapted from Paz, Liu et al. 2009)	Pg 194

Table 18	Phase 2, Stage 3: Eligibility criteria for participant selection for the focus group	Pg 197
Table 19	Phase 2, Stage 3: Eligibility criteria for participant selection for the telephone interviews	Pg 199
Table 20	Phase 2, Stage 1: Flesch Reading Ease score (FRE) for BACKonLINE™	Pg 200
Table 21	Phase 2, Stage 2: Changes suggested to BACKonLINE™ by the Plain English Campaign (PEC)	Pg 201
Table 22	Phase 2, Stage 3: Demographics of the focus group	Pg 203
Table 23	Phase 2, Stage 3: summary of thematic analysis and participant contribution in the focus group	Pg 204
Table 24	Phase 2, Stage 3: Demographics of telephone interview participants	Pg 205
Table 25	Reliability matrix adapted from Ponterotto and Ruckdeschel (2007)	Pg 218
Table 26	Phase 3 maximum and minimum achievable score in BACKonLINE™	Pg 260
Table 27	Eligibility criteria for participants in Phase 3	Pg 261
Table 28	Phase 3 data collection procedure	Pg 266
Table 29	Interview questions for Phase 3	Pg 268
Table 30	Phase 3 validated self-reported pain and related symptoms assessment questionnaires	Pg 273
Table 31	Phase 3 demographic data summary	Pg 282
Table 32	Descriptive statistics for BACKonLINE™ for both Observation 1 and 2 in Phase 3	Pg 283
Table 33	Cronbach's Alpha for BACKonLINE™ in Observation 1 and 2 in Phase 3	Pg 284
Table 34	'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (all items included)	Pg 285

Table 35	Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Pain behaviour domain items)	Pg 286
Table 36	Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Impact of low back pain on work and lifestyle domain items)	Pg 286
Table 37	Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Experience with LBP domain items)	Pg 287
Table 38	Phase 3 test retest Reliability of BACKonLINE™	Pg 288
Table 39	Paired samples T-test for composite scores for the validated questionnaires between Observations 1 and 2 in Phase 3	Pg 288
Table 40	Comparison of Item-total correlations with each domain in Observation 1 and 2 in Phase 3	Pg 290
Table 41	Correlations between BACKonLINE™ total and each domain with the nomological network in Observation 1 using Pearson's correlation in Phase 3	Pg 292
Table 42	BACKonLINE™ and STarTBack Crosstabulation	Pg 292
Table 43	Phase 3 Cut-off scores power calculations output from nQuery (sample size calculator software)	Pg 293
Table 44	Phase 3 BACKonLINE™ ROC Curve coordinates (Observation 1)	Pg 296
Table 45	Phase 3 participant Expectations regarding self-management main themes and examples	Pg 301
Table 46	Phase 3 participants' BACKonLINE™ delivery methods preferences main themes and examples	Pg 304

List of Figures

Figure 1	Study Design	Pg 86
Figure 2	The original Likert scale structure, adapted from Uebersax (2006)	Pg 105
Figure 3	Overview of Phase 1: Development of the BACKonLINE™ tool	Pg 120
Figure 4	Example of a question in Phase 1 E-Delphi study developing BACKonLINE™	Pg 128
Figure 5	Thematic analysis process (Adapted from Braun and Clarke (2013)	Pg 136
Figure 6	Phase 1 E-Delphi study data analysis map	Pg 140
Figure 7	Outline of BACKonLINE™ (Version 1) in Phase 1	Pg 145
Figure 8	Summary of the deductive thematic analysis of participants comments on the self-assessment part of BACKonLINE™ in Round 1	Pg 155
Figure 9	Outline of the identified themes in the self-management component of Phase 1 Round 1 of the E-Delphi study	Pg 160
Figure 10	Flow diagram of the readability study (Phase 2)	Pg 196
Figure 11	Phase 3 participant recruitment process	Pg 262
Figure 12	Phase 3 Observation 1 process	Pg 265
Figure 13	Phase 3 ROC curve for BACKonLINE™ (Observation 1) using STarTBack as the reference standard	Pg 295
Figure 14	Phase 3 themes of participants experience after using BACKonLINE™	Pg 298
Figure 15	Phase 3 participants expectations regarding self-management themes and sub-themes	Pg 301
Figure 16	BACKonLINE™ Phase 3 participants' delivery methods preferences	Pg 304

List of Abbreviations

ACP	American College of Physicians
ADL	Activities of Daily Living
AIGS	Abnormal Impulse Generating Sites
ANCOVA	Analysis of Covariance
AUC	Area Under the Curve
CA	Cronbach's coefficient Alpha
CBT	Cognitive Behaviour Therapy
CLBP	Chronic low back pain
CNS	Central Nervous System
CSI	Central Sensitisation Inventory
CV	Coefficient of variance
df	Degrees of freedom
E-Delphi	Electronic Delphi
E-health	Electronic health
ESP	Extended Scope Physiotherapists
FM	Fibromyalgia
fMRI	Functional MRI
FRE	Flesch Reading Ease
GP	General Practitioners
LBP	Low Back Pain
ICC	Intraclass Correlation Coefficient
IQR	Interquartile range
MACP	Musculoskeletal Association of Chartered Physiotherapists
MANOVA	Multivariate analysis of variance
MRST	Musculoskeletal Readiness Screening Tool
MSK	Musculoskeletal
MSK CATS	Musculoskeletal Clinical Assessment Treatment Service

NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NSAIDs	Non-Steroidal Anti-Inflammatory Drugs
ODI	Oswestry Disability Index
OMPQ	Orebro Musculoskeletal Pain Questionnaire
PASS 20	Pain Anxiety Symptoms Scale short form 20
PDQ	Pain Disability Questionnaire
PEC	Plain English Campaign
PNE	Pain Neuroscience Education
PROM	Patient-reported outcome measure
r	Pearson's Product Movement Correlation Coefficient
RCT	Randomised Controlled Trial
SBPR	Society of Back Pain Research
SD	Standard Deviation
SF-36	Short Form Health Survey
TSK	Tampa Scale of Kinesiophobia
UK	United Kingdom
USA	United States of America
WDI	Waddell Disability Index

Abstract

Chronic low back pain (CLBP) is a cause of disability globally. CLBP can lead to psychological, cognitive, behavioural responses and associated amplification in pain processing in the central nervous system (central sensitisation). Centrally sensitised pain is associated with poorer outcomes that require longer management. Timely assessment and appropriate management are therefore paramount.

In the National Health Service physiotherapy services, low back pain patients wait in intermediate care for 14-24 weeks for treatment. This window period can be better used to identify those at risk of centrally sensitised pain and deliver tailored biopsychosocial oriented self-management techniques. An online self-assessment and self-management tool (BACKonLINE™), for discerning between characteristics of predominantly centrally or peripherally sensitised CLBP, was developed in this study in 3 phases.

Phase 1: A 2 Round E-Delphi study, with an international, physiotherapy expert panel, to develop BACKonLINE™ was conducted. From this, 39 self-assessment items were identified, and pain education and exercise were identified as main themes for self-management.

Phase 2: Readability of BACKonLINE™ was assessed in 3 stages and items were amended accordingly.

Phase 3: Test retest reliability and construct validity were assessed and the preliminary cut-off scores of BACKonLINE™ for people with CLBP were determined. Additionally, the patients' experience of using BACKonLINE™ was explored.

The findings showed good test retest reliability, good construct validity, and a potential with BACKonLINE™ in discerning between people with characteristics of predominantly centrally or peripherally sensitised CLBP. Preliminary results show that scores ≥ 42 in BACKonLINE™ indicate centrally sensitised CLBP while scores < 42 indicate peripherally sensitised CLBP. Additionally, participants expected pain education and exercise as self-management and preferred BACKonLINE™ to be delivered online or as a phone app. BACKonLINE™ was conceptualised, within the biopsychosocial framework, to be an autonomous, cost effective, and practical tool to help patients with CLBP in intermediate care.

Chapter 1. Introduction

The United Kingdom (UK) has a high rate of incidence of low back pain (LBP). According to Hoy, Brooks et al. (2010), within a year, 6.3%-15.4% of the UK population experience their first episode of LBP, while 1.5-36% experienced recurring episodes. LBP is common; 60-85% of the UK population experience LBP at least once in their lifetime, and approximately 10% of the population do not recover from LBP episodes within 3 months (Palmer, Walsh et al. 2000, Campbell and Colvin 2013, Stubbs, Koyanagi et al. 2016).

In a UK based cross-sectional study, 15,272 people aged 25 and above were screened for LBP. That study found the prevalence of LBP over a 1-month period to be 28.5%. This peaks at ages 41 to 50 years, with 1 in 4 people over 80 years old experiencing LBP (Macfarlane, Beasley et al. 2012). While the minority of LBP (approximately 5-15%) cases can be traced back to specific causes, such as infection, neoplasm or osteoporotic fracture, 85-95% of the instances of LBP do not have a clear cause (Hoy, Brooks et al. 2010). Chronic low back pain (CLBP) is the term commonly used to describe LBP that has persisted for longer than 6 weeks (Waddell and Schoene 2004, NICE 2016) and has been estimated to have a recurrence rate of 35-39% (Manchikanti 2000).

There are multiple risk factors connected to the reported incidences of CLBP, including ageing (Macfarlane, Beasley et al. 2012) and gender (Maher, Underwood et al. 2017), physical factors such as posture, movement patterns, and spinal loading (Coenen, Kingma et al. 2013), psychosocial factors (Feyer, Herbison et al. 2000), such as low job satisfaction, anxiety, depression (Pineiro, Ferreira et al. 2016). Women have been

found to have a higher rate of LBP episodes, as well as reporting a greater amount of pain (Manchikanti 2000, Chenot, Scherer et al. 2008, Hoy, Brooks et al. 2010). CLBP is often diagnosed based on self-reported pain (Manchikanti 2000), as most cases do not present with a specific aetiology (Snook 2004, Hoy, Brooks et al. 2010).

The effects of CLBP are far-reaching, limiting social or professional activity, affecting the general quality of life as well as specific social relationships (Maniadakis and Gray 2000). CLBP has been shown to chronically disable 3-4% of younger adults (< 45 years old) and 5-7% of older adults (> 45 years old) (Macfarlane, Beasley et al. 2012, NICE CKS 2018). Furthermore, CLBP leads to significant economic burden on the general population, partly due to the limitations to activity directly resulting from CLBP, as well as the consequent inability to work (Hoy, Brooks et al. 2010). With roughly 20% of UK citizens consulting their General Practitioners (GP) about their LBP, LBP is costly to the healthcare system (Noblet, Marriott et al. 2019). CLBP was reported to be responsible for 11-13.5% of lost work time (Sterud and Tynes 2013) and cost the UK an estimated 2.2 million days lost between 2017 and 2018, with an average of each person taking 15.9 days off work citing LBP as a reason (NICE CKS 2018, HSE 2018).

The effects of LBP are widespread; the episodes of pain can affect career development, increase domestic financial pressures, limit the ability to participate in social activities and exercise and put a strain on healthcare resources. These effects lead to challenges for the affected individuals and their families, communities and businesses as well as the healthcare systems supporting them (Waddell and Schoene 2004, Hoy, Brooks et al. 2010). The severity of the repercussions can differ significantly between population

subgroups, due to the ease of access to healthcare, pain perception, socio-economic status, job diversity and other factors related to LBP (Hoy, Brooks et al. 2010).

The financial cost of LBP in the general population cannot be overstated and may severely affect low-income countries with the loss of productivity, indemnity payments, rehiring and retraining of employees, administrative costs and litigation expenses. The United States of America (USA) reported an estimated \$90.7 billion in healthcare costs directly related to LBP in 1998. In the UK, in 2000, £11 billion in expenditure was traced directly and indirectly to LBP. In Australia, the total expense related to LBP was estimated to be at \$9.17 billion, making it 1 of the costliest diseases (Maniadakis and Gray 2000).

When LBP becomes chronic, other factors, un-associated with the initial injury are evident. Factors such as physical deconditioning, depression, and anxiety influence the intensity and presentation of the pain. And these factors contribute to the recurrence of LBP with 2 thirds of people reporting a recurrence of LBP within 12 months of recovery (Da Silva, Mills et al. 2019). When patients report their LBP and the recurrence of their symptoms in primary care, they go through the same process of getting an appointment with their GP, getting a referral to secondary care, and wait for their treatment. The longer a patient with LBP waits for treatment, including physiotherapy, the higher the potential of exacerbation of these factors. Support and advice during any waiting period are therefore essential (Nicholas, Linton et al. 2011, Salisbury, Foster et al. 2013).

In the UK, patients usually wait from 1 week to more than 12 weeks to access the National Health Service (NHS) physiotherapy services (Pearson, Richardson et al. 2016). It is proposed that pain becomes chronic at approximately 6 weeks and many of these

patients develop otherwise avoidable unhelpful pain beliefs and behaviours due to waiting times. Therefore, the time gap between a GP visit and a physiotherapy session can potentially determine the presence of unhelpful pain beliefs such as catastrophising, and the belief that pain means damage (Salisbury, Foster et al. 2013).

Contributing factors of LBP are defined as variables that can be connected to a heightened risk of disease. They are difficult to determine due to the level of heterogeneity shared by research methods, study populations and case definitions. Measuring the occurrence of the condition in 2 or more groups of people may help determine the contributing factors, such as environmental and personal factors. Some of these factors can be manipulated while some cannot, which contribute to the onset and persistence of LBP (Manchikanti 2000, Hoy, Brooks et al. 2010).

Two elements make up psychosocial factors. The first refers to psychological elements such as futility, depression or aggression (Nicholas, Linton et al. 2011). The second element describes structural and social influences, such as work conditions and family dynamics (Singh-Manoux, Adler et al. 2003). However, these 2 elements are not clearly determined as to the manner of their influence on LBP or the degree of their influence (Hartvigsen, Lings et al. 2004).

Multiple mechanisms have been suggested to explain the presence of psychosocial factors which in turn contributes to the continuation of pain past expected tissue healing time. These include:

1. modified perception of pain, due to changes in the processing of nociceptive stimuli that may heighten pain perception (Wand, Catley et al. 2016);

2. prolonged activation of small low-threshold units contributing to degenerative mechanisms and tissue damage (Williams and Craig 2016);
3. changes in movement patterns, posture and external forces increasing the biomechanical load, leading to increased muscle tone and its increased duration (O'Sullivan 2005);
4. changes to neuroendocrine processes where there is synergy between the nervous system and the endocrine system, such as sympatho-adrenomedullary, which is responsible for secreting the hormone adrenaline, and pituitary-adrenocortical processes which may alter low back muscles metabolic activity (Franklin, Saab et al. 2012, Borsook, Youssef et al. 2018).

All the aforementioned mechanisms are said to contribute to the commencement and maintenance of psychosocial influences (Bongers, de Winter et al. 1993, Lundberg and Frankenhaeuser 1999, Hoogendoorn, van Poppel et al. 2000, Hartvigsen, Lings et al. 2004, Waddell and Schoene 2004, Bonde, Mikkelsen et al. 2005, Palmer, Calnan et al. 2005).

The nature of the relationships between LBP and psychological factors such as anxiety, stress, specific types of pain behaviour or depression is not easily determined. Multiple cross-sectional studies have found that there is not only a direct association between reports of LBP and various psychological factors but also that these psychological factors are connected to the transition from acute to chronic LBP (Pincus, Burton et al. 2002, Koes, Van Tulder et al. 2006).

Increased strains at the workplace, job dissatisfaction, monotonous activity at the workplace (Hoogendoorn, van Poppel et al. 2000), and social environment, such as

perceived lack of spousal or family support, are among the social factors reported as being influential on the maintenance of LBP (Vingard and Nachemson 2000). Social factors related to occupation and workplace environment have been demonstrated to be critical contributing factors of LBP in 2 systematic reviews. These reviews found an association between heightened prevalence of LBP and monotonous activities, suffering workplace relations, lack of support in the social environment of the workplace on the job, stress, perceived ability as well as overall job dissatisfaction, which has also been associated with the transition from acute to chronic LBP (Linton 2001, van Tulder, Croft et al. 2002). Lower levels of education appeared to be linked to increased frequency and the heightened levels of LBP (Toropectsova, Benevolenskaya et al. 1995), and was a predictor of poor outcomes of LBP as well as the duration of the pain episode (Dionne, Von Korff et al. 2001). Social status, on the other hand, was found in other studies to have an inverse relationship with the prevalence of LBP (Hoy, Brooks et al. 2010).

Other factors that contribute to the presence of LBP include age, weight, gender, and physical factors. Age was 1 of the leading contributing factors connected to LBP, with incidences being highest in the third decade of the human lifespan (Reigo, Timpka et al. 1999, Waxman, Tennant et al. 2000, Kopec, Sayre et al. 2004). The overall prevalence of LBP increased until ages 60-65 years old and then began to decline beyond that (Dionne, Dunn et al. 2006).

Leboeuf-Yde (2000), in a systematic review of risk factors contributing to LBP, showed that body weight was a weak contributing factor. However, 2 studies have indicated high body mass index (BMI) and obesity (>30 BMI) to be directly connected to increased incidents of LBP (Vogt, Lauerma et al. 2002, Webb, Brammah et al. 2003). This

connection may be more prevalent among women than men according to a study by Croft, Papageorgiou et al. (1999).

Specific physical activities at the workplace have since been shown to represent factors directly associated with LBP. Matsui, Maeda et al. (1997) found a correlation between heightened physical demands in the workplace and the rate of LBP occurrence, except for the lifetime prevalence among female workers. While sedentary male workers showed an 18.3% point of prevalence of LBP, manual workers were found to be at 39% (Matsui, Maeda et al. 1997). Activities such as bending, twisting, manual handling and whole-body vibration (e.g. working with a jackhammer) have shown to be factors contributing to LBP in a systematic review focusing on psychosocial factors at work and everyday life (Hoogendoorn, van Poppel et al. 2000). While the statistical data on occupational contributing factors from low-income regions is sparse, an estimated 90% of the population in these regions are performing heavy work. Therefore, this implied an increase in the prevalence of LBP (Volinn 1997).

The aforementioned factors contributed to the complexity of CLBP, and even though most of these factors are modifiable, current management techniques are generic in nature and are failing to target these factors, therefore, they have a limited influence on reducing pain and disability (Keller, Hayden et al. 2007, Artus, van der Windt et al. 2014, O'Keeffe, Purtill et al. 2015).

These factors contribute to the heterogeneity of LBP, which drove researchers and clinicians to attempt to classify groups of LBP patients into more homogeneous categories based on pattern recognition and common characteristics such as underlying mechanisms of pain, response to treatment, and prognostic profile (Foster, Hill et al.

2013). This move to sub-classify LBP patients was essential to stratify patient care and to offer targeted treatment (Foster, Hill et al. 2013). Due to the need to stratify care, several LBP classification systems with different aims and targets were developed. Some classification systems focused on clinical descriptors of pain, while others aimed to describe prognoses or account for response to treatment (Fairbank, Gwilym et al. 2011). Treatment stratification is also considered the best option to decrease the demand for resource-intensive management approaches (Foster, Hill et al. 2013).

In recent years, self-management has become the aim of CLBP management, with the National Institute for Health and Care Excellence (NICE) advocating for its importance (NICE 2016). A biopsychosocial based self-management approach has become the target of effective self-management with the Lancet LBP series emphasising the importance of psychosocial factors in the management of CLBP (Hartvigsen, Hancock et al. 2018). For some chronic pain patients, getting a probable diagnosis for their pain is the initial step that would encourage them to attempt self-management. People with chronic pain often fear that others, especially healthcare professionals, would think their pain is imagined or unreal. Therefore, involving them in the process of assessing or exploring the reasons behind the pain can help them feel empowered and validated which, in turn, galvanises them to adhere to the self-management techniques (Skuladottir and Halldorsdottir 2011, Wijma, van Wilgen et al. 2016).

Recently, the internet has become 1 of the primary sources for health-related information and self-management with people increasingly using it to obtain guidance and treatment advice (Butler and Foster 2003). However, in the majority of cases, the content on the internet is not peer-reviewed, and information can be uploaded by any

source, making the content variable in quality. The ease and accessibility of the internet is an excellent utility for delivering healthcare content, but ideally, patients should be directed to using evidence-based online interventions. Additionally, current online self-management interventions are designed to impart a breadth of information to the user with little consideration of individual circumstances, which might overwhelm and discourage people from adhering to them (Kostkova 2015). Moreover, people with LBP are rarely included in the design of LBP tools, even though it is established that patient involvement is essential to produce a relevant and valid tool (Trujols, Portella et al. 2013, Wiering, de Boer et al. 2016).

There is currently a need to explore the utility of a digital support system designed to improve self-management of LBP through some form of classification to point patients to advice and guidance relevant to them. There also needs to be direct involvement of people in its design. Therefore, to utilise the popularity and advantages of the internet, evidence-based, peer-reviewed healthcare information should be available (Butler and Foster 2003). Evidence-based online self-management methods for LBP are still in their infancy with 1 systematic review of 9 randomised controlled trials (RCTs) of online interventions for CLBP concluding that even though online interventions showed some positive results, RCTs were limited by small sample sizes and heterogeneity of methods (Garg, Garg et al. 2016). Another systematic review of 9 RCTs exploring the online support for CLBP management concluded that the available literature on the subject is limited with heterogeneous methods and a population predominantly consisting of middle-aged white females with a college degree or higher (Nicholl, Sandal et al. 2017).

In a recent RCT comparing a self-management back pain app (Kaia App) to a physiotherapy treatment (6 sessions over 6 weeks) supplemented with online support (n= 101), pain intensity was monitored at baseline and at 12 weeks follow up. At baseline, pain intensity was statistically similar for both groups (Intervention group: M=5.10, SD=1.07; Control group: M=5.41, SD=1.15), and at 12 weeks follow up, the pain intensity was significantly lower in the intervention group groups (Intervention group: M=2.70, SD=1.51; Control group: M=3.40, SD=1.63) (Toelle, Utpadel-Fischler et al. 2019). Toelle, Utpadel-Fischler et al. (2019) reported significant effect of measuring point for pain intensity, $F(2,168) = 31.38$, $p < 0.001$, $\eta = 0.492$. Both control and intervention groups reported a significant decrease in pain from baseline, 6 weeks and to 12 weeks ($p < 0.01$). Significant interaction of group and measuring point, $F(2,168) = 5.44$, $p = 0.031$, $\eta = 0.043$, was also reported, where the Kaia app group reported significantly lower pain intensity after 12 weeks in comparison to the physiotherapy group, $t(84) = 2.061$, $p = 0.021$. Toelle, Utpadel-Fischler et al. (2019) also reported an insignificant between-group difference at baseline and after 6 weeks ($p > 0.05$). The main effect of group was also insignificant, $F(1,84) = 1.54$, $p = 0.218$, $\eta = 0.018$). The RCT concluded that the self-management back pain app is effective in decreasing LBP in comparison to physiotherapy and online education (Toelle, Utpadel-Fischler et al. 2019).

In another recent systematic review and meta-analysis on the efficacy of E-health and self-management of CLBP on disability and pain intensity, 8 RCTs were identified and included (Du, Liu et al. 2019). Du, Liu et al. (2019) found moderate quality evidence showing the clinically significant effectiveness of online self-management tools for immediate and short term follow up in decreasing pain intensity. Du, Liu et al. (2019) included 5 RCTs in the meta-analysis of pain intensity immediately after intervention

and the E-health self-management group had a small clinically significant improvement in pain intensity [Effect size=-0.16, 95% confidence interval (-0.30, -0.02), P=0.03]. In the short-term meta-analysis, 2 RCTs were included and the E-health self-management group had a moderate, clinically significant improvement in pain intensity [Effect size=-0.27, 95% confidence interval (-0.43, -0.11), P=0.001]. Only one RCT reported pain intensity at the intermediate time period and it found that the E-health self-management group was similar to the control group in improving pain intensity [Effect size=-0.17, 95% confidence interval (-0.45, 0.11), P=0.23] (Du, Liu et al. 2019). For decreasing disability, moderate quality evidence was found for immediate follow up and low quality evidence for short term follow up. Five RCTs were included in the meta analysis of disability immediately after intervention and the E-health self-management group had a moderate clinically significant improvement in disability [Effect size=-0.25, 95% confidence interval (-0.40, -0.11), P < 0.001]. In the short-term meta analysis, 2 RCTs were included and the E-health self-management groups were no better significant effect at improving disability than control groups [Effect size=-0.21, 95% confidence (-0.51, 0.10), P =0.18]. One RCT reported disability at an intermediate time period and found that the E-health self-management group was no better than the control group in improving disability [Effect size=-0.00, 95% confidence interval (-0.28, 0.28), P=0.99]. (Du, Liu et al. 2019). Du, Liu et al. (2019) conducted subgroup analysis on the included RCTs and found that smartphone based self-management programs showed better results than web-based self-management programs during immediate follow up on pain and disability. The subgroup analysis also showed that online self-management programs with durations ≤ 8 weeks had better effect on pain than programs with durations > 8 weeks. Du, Liu et al. (2019) concluded that online self-management

programs may be a positive step in decreasing pain and disability in short-term follow up when used by CLBP patients, however, more rigorous trials are needed to establish the optimal self-management duration, mode of delivery, and long term effect (Du, Liu et al. 2019).

In summary, CLBP is a complex, multi-dimensional condition that requires individualised management, and 1 of the approaches to managing CLBP is online individualised self-management. Online self-management approaches showed positive results in the previously mentioned studies and in the studies highlighted in the next chapter (section 2.7.1), however, more rigorous studies are warranted in order to define the magnitude provided by current literature. Such approaches would be most valuable to patients on the physiotherapy waiting lists to tackle any misconception they might have about LBP before it is instilled in their minds. Therefore, the main aim of this study was to develop a self-assessment and self-management online tool (BACKonLINE™), for patients with CLBP who are on the NHS physiotherapy waiting lists, as well as made freely available for other people with CLBP.

1.1. Thesis Structure

Chapter 2, the next chapter in this thesis, highlights the relevant literature which influenced the study. The chapter begins by detailing the utilised search strategy and then explores the main theories of pain. Afterwards, LBP, its classification, assessment, and management within a physiotherapy context are reported. Next, health education and behaviour, and electronic health (E-health) are outlined. Finally, a summary and justification of the current study are reported, followed by the study questions, aim, and objectives. The chapter concludes with an overview of the overall study design.

This study encompasses 3 phases. Phase 1, Development of BACKonLINE™ - The Electronic Delphi (E-Delphi) study, is reported in Chapters 3, 4, 5 and 6:

- Chapter 3 focuses on the literature review relevant to the Delphi study and concludes with the aim and objectives of Phase 1.
- Chapter 4 explores the methods used in Phase 1, including the study design, BACKonLINE™ self-assessment item generation and construction of the E-Delphi study.
- Chapter 5 reports the findings of Phase 1 of the study for both Round 1 and 2 of the E-Delphi study
- Chapter 6 discusses the findings of Phase 1 and the Delphi method. The chapter concludes by stating the strengths and limitations of this phase.

Phase 2, Readability of BACKonLINE™, is reported in Chapter 7. This chapter begins with a background on the assessment of readability in healthcare. Then, the methods, results, and discussion of Phase 2 is described. This chapter concludes by exploring the strengths and limitations of Phase 2.

Phase 3, the measurement properties and participants experience of BACKonLINE™, is described in Chapters 8, 9, 10, and 11:

- Chapter 8 covers the literature relevant to measurement properties, including reliability and validity, and explores the validated LBP assessment tools used in Phase 3. Then, the literature on patient involvement in tool development is highlighted. The chapter concludes by stating the aim, objectives, and study questions of Phase 3.

- Chapter 9 describes the methods used in Phase 3 of the study. It starts with explaining how BACKonLINE™ was scored, the details of the study design, participant inclusion and exclusion criteria, data collection procedure, and finally data analysis processes used in Phase 3.
- Chapter 10 reports the findings of Phase 3. The chapter starts by providing the descriptive statistics of the sample and BACKonLINE™, then the findings from the reliability and validity component are detailed. Finally, the findings from the interviews exploring participants experience of BACKonLINE™ are reported.
- Chapter 11 discusses the findings of Phase 3. This chapter starts with providing a summary of the findings, then discusses the results of the reliability and validity component of the phase. Afterwards, the results from the interviews exploring participants experience of BACKonLINE™ are discussed. This chapter concludes by reporting strengths and limitations specific to Phase 3.

The thesis concludes with Chapter 12. This chapter begins by providing a summary of findings for all 3 phases. Then BACKonLINE™ is compared with current management pathways in physiotherapy waiting lists and current LBP self-assessment tools. Afterwards, the clinical implications of the current study and overall strengths and limitations are reported. Finally, future recommendations and vision for BACKonLINE™ are detailed, and the thesis ends with a conclusion of the study.

The original contribution of this thesis is the conceptualisation of BACKonLINE™ as an autonomous and practical tool for patient self-assessment and self-management. This

study was focussed on the development of BACKonLINE™, which should be further researched alongside the development of the self-management component of the tool.

Chapter 2. Literature Review

2.1. Introduction

The assessment and management of CLBP have been the focus of research for many decades, and to construct a viable CLBP self-assessment and self-management tool, many elements should be considered. This chapter provides an overview of the elements involved in the development and ongoing presentation of CLBP, its assessment, and its management. This chapter commences by presenting the literature search strategy used, followed by an overview of pain types, models, and theories, and a background on the assessment and management of LBP. Finally, health education and behaviour and E-health is also discussed. This chapter concludes by presenting the research study questions, justification, aims and objectives, along with a detailed study outline.

2.2. Literature Search Strategy

To identify relevant articles concerning the self-assessment and self-management of CLBP, a literature review on pain, its theories, assessment, and management was performed. Additionally, literature review regarding health behaviour, patient education, and E-health was conducted. The literature search was performed in 4 parts:

1. Pain and theories of pain
2. Assessment, classification, and clinical indicators of CLBP
3. Management and self-management of CLBP
4. Health behaviour, patient education, and E-health

A search strategy was developed and revised appropriately for the following electronic databases Cinahl, EMBASE, Medline, AMED, PsycINFO, and PubMed for the time period 2000–2016, using only English text from established peer-reviewed journals. These articles were then reduced based on duplications, and then manually searched for relevance. The reference lists from the included articles were also reviewed for relevant studies and academic books. The search was reviewed again in February 2019 for any new articles between 2016 and 2019. Table 1 details the search strategy combinations of key terms and the inclusion criteria for all 4 searches up to 2019. The results of the search are displayed in Table 2.

Table 1 Keyword combinations included for all 4 parts of the literature searches

Search category 1	Boolean search operators	Search category 2	Boolean search operators	Search category 3
Keywords for pain and theories of pain				
Pain OR somatosensory OR Ache OR Noci*	AND	Definition OR theory OR classification OR Type OR History OR subgrouping OR Aetiology OR location OR duration OR model	AND	Biomedical OR biopsychosocial OR mechanisms OR gate control OR specificity OR intensity
Keywords for assessment, classification, and clinical indicators of CLBP				
Backache OR lumbago OR back pain OR low back pain OR lumbar spine OR lumbar ache OR lumbar pain OR chronic low back OR Non-specific low back pain OR Non-specific chronic low back pain OR	AND	Physical examination OR manual examination OR classification OR symptom response or pain response OR assessment OR subgrouping OR questionnaire OR physiotherapy assessment OR physical therapy assessment OR musculoskeletal assessment OR neuromusculoskeletal examination OR	AND	Clinical indicators OR centralisation OR pain mechanisms OR pain clinical criteria OR peripheral neuropathic pain OR nociceptive pain OR central mechanisms of pain OR clinical reasoning OR central sensitisation

NSCLBP OR LBP OR CLBP		musculoskeletal physiotherapy		
Keywords for management and self-management of CLBP				
Backache OR lumbago OR back pain OR low back pain OR lumbar spine OR lumbar ache OR lumbar pain OR chronic low back OR Non- specific low back pain OR NSCLBP OR LBP OR CLBP	AND	Evidence based OR guidelines	AND	Management OR self- management OR treatment OR therapy OR education OR advice OR care OR physiotherapy OR physical therapy OR intervention OR rehabilitation
Keywords for health behaviour, patient education, and E-health				
Health education OR Health behaviour OR behaviour	AND	Mobile health OR E- health OR M-Health OR Electronic health	NA	NA

Key: NA: Not applicable

Table 2 Number of articles identified and retrieved for all 4 parts of the literature search

Number of articles found				
Category Database	Pain and theories of pain	Assessment, classification, and clinical indicators of CLBP	Management and self- management of CLBP	Health behaviour, patient education, and E- health
PubMed	15	15	162	34
PsycINFO	92	0	54	7
Medline	155	48	34	24
Embase	15	87	98	162
Cinahl	0	23	0	27
AMED	253	6	80	0
Total number of articles	530	179	428	254
Total number of articles after removing duplicates	165	84	231	87
Total number of articles after manually checking their relevance	80	21	32	29

2.3. Pain

The terms pain and nociception are often used interchangeably by healthcare professionals. However, even though they are related, they are not the same. Pain is a sophisticated sensory and emotional experience that could manifest with or without actual tissue damage, while nociception is the central nervous system's (CNS) response to, and encoding of, noxious stimuli (Davis, Bushnell et al. 2015, Davis, Flor et al. 2017, IASP 2017). The pain experience is a conscious, subjective, multi-dimensional individual phenomenon which depends on the subjective self-report of the person experiencing the symptoms. However, nociception can occur with an individual being utterly unaware of it (Davis, Flor et al. 2017). Signs of nociception are indicated by activation of the thalamus, insular cortex and anterior cingulate cortex of the brain. These can even be found in people under anaesthesia (Duerden and Albanese 2013, Mhuircheartaigh, Warnaby et al. 2013).

Neuroimaging techniques, chiefly functional MRI (fMRI), are used to measure nociception-related brain activity, and the presence of pain is inferred from the data generated (Davis, Flor et al. 2017). Inferring the presence of the pain experience using neuroimaging techniques can be misleading since nociceptive stimuli trigger a plethora of processes (e.g. emotional, cognitive, autonomic, motor) besides pain. Brain activities that are linked to pain have also been linked to other experiences and functions, making it difficult to report on pain solely based on current neuroimaging results.

Thus, the subjective self-report of pain is still very relevant. However, one should note that the variation in the reported intensity of pain may be due to factors such as

personality, circumstances, and environment (Davis, Flor et al. 2017). Nonetheless, current research is actively exploring and mapping the brain to discover a valid objective measure for the pain experience (Ung, Brown et al. 2012, Davis, Flor et al. 2017, Woo, Schmidt et al. 2017).

Pain is generally classified according to its duration, location, aetiology, or neurophysiologic types. The following sections details the different classification methods of pain.

2.3.1. Classification of Pain: Pain Duration

Pain is often differentiated as being acute or chronic, with reference to the time period of which the pain is experienced (Merskey and Bogduk 1994). Noxious stimuli such as disease or trauma lead to acute pain (Bonica 1990), in which case pain can be viewed as a homeostatic reaction to aversive stimuli (Craig 2003). As such, pain stimulates action to avoid further, or other potential, harm and functions as a protective system. When the pain duration lasts longer than the actual tissue damage, the pain is categorised as chronic (Bonica 1990, Merskey and Bogduk 1994, Kerns, Sellinger et al. 2011). Malignant, as well as non-malignant (or benign) conditions, may lead to chronic, or persistent, pain. Non-malignant pain lasting longer than 3 months is categorised as chronic (Merskey and Bogduk 1994), yet chronic pain does not function protectively as acute pain does (Gilron, Jensen et al. 2013).

Scientific evidence has led to a reappraisal of the general dichotomous description of pain as 'chronic' or 'acute'. The evidence has indicated that classification of pain according to its duration can, under some circumstances, be too broad and may not account for the presence of certain crucial clinical features of specific pain presentations

(Waddell and Main 1998). It has been suggested that while the cut-off points for classifying chronic pain is at 3 or 6 months traditionally, this may be too late, as there may not even be a clear cut-off time for differentiating between chronic and acute pain. Although a 6 week cut-off time has been proposed as a more fitting cut-off point, in reality, the shift from acute to chronic varies from 1 person to another (Waddell and Schoene 2004, Smart, O'Connell et al. 2008). In their latest guidelines, NICE (2016) has shifted from defining pain in terms of acute and chronic, and instead explained it as a spectrum which better suits the complexity of the pain experience.

Due to the complexity of defining a cut-off point for pain duration, measuring brain mechanisms underlying chronic pain has proven to be difficult. As stated earlier, contemporary research aims to identify an objective measure of pain through neuroimaging. Nevertheless, there are no specific areas of the brain that have been proven to be exclusively connected to chronic pain and several anomalies present in chronic pain was also found in other conditions such as anxiety and depression (Bushnell, Čeko et al. 2013, Davis, Flor et al. 2017). Due to the inability to isolate an area of the brain that concerns chronic pain, self-reports of pain remain as the main indicator of chronic pain (Davis, Flor et al. 2017).

2.3.2. Classification of Pain: Pain Location

When pain is assessed and classified according to location, it is either classified according to body region (e.g. LBP, cervical pain, pelvic pain) or according to body systems (e.g. musculoskeletal (MSK), vascular). Even when the 2 classification systems are used together (e.g. MSK LBP), they are considered limited as a classification system and

should be used in addition to other classification systems (e.g. pain duration) (Turk and Okifuji 2001, Thienhaus and Cole 2002).

2.3.3. Classification of Pain: Aetiology of Pain

Classifying pain according to its aetiology (malignant or non-malignant) is essential to rule out any potentially serious pathology, often termed as red flags (Samanta, Kendall et al. 2003). In LBP patients, red flags may indicate the presence of vertebral fracture, malignancy, or infection, with malignancy and fracture being the most common pathologies (Downie, Williams et al. 2013).

The incidence of serious pathology is rare in primary care; 1-4% of LBP patients have a spinal fracture, and less than 1% have underlying malignancy (Henschke, Maher et al. 2013, Williams, Henschke et al. 2013). Early detection of serious pathology, especially malignancy, would aid the delivery of early treatment and makes screening for serious pathology and appropriate investigation an important first step in the triage of a patient presenting with pain (Loblaw, Perry et al. 2005). The European guidelines suggest the following as an indication of serious pathology (Airaksinen, Brox et al. 2006, Verhagen, Downie et al. 2016):

- Age: younger than 20 years and older than 55 years
- Non-mechanical pain
- Thoracic pain
- Use of steroids
- Spinal structural changes
- History of cancer
- Weight loss

- General unwellness
- Diffuse neurological deficit

In 2016, NICE updated their 'Low back pain and sciatica in over 16s' guidelines which stated that red flags should be excluded during the early stages of LBP, emphasising the need to screen for the following serious pathologies (NICE 2016, NICE CKS 2018):

- Cancer or infection: this must be considered if there are any of the following- (1) pain being described as gradual, progressive, or continuous pain, (2) the pain is worse at night precluding sleep, (3) there is presence of systemic illness or a past history of cancer, and (4) the patient's age is younger than 20 or older than 55 years old.
- Trauma or vertebral fracture: must be considered if there are any of the following (1) if pain is in the central part of the spine (thoracic or lumbar) and arises suddenly and is alleviated by lying down, (2) there is a history of major or minor trauma, (3) there is a history of strenuous activity by people with osteoporosis or people on corticosteroids, (4) there is the presence of structural deformity in the spine and (5) there is marked tenderness over a vertebral body/spinous process.
- Nerve root compression must be considered if there is: (1) presence of numbness or tingling which radiates to the calf, foot, or toes and (2) pain symptoms that are reported as being worse in the lower limbs than lumbar spine region.
- Inflammatory spinal disease should be considered if there is generalised pain and low back morning stiffness for longer than 2 hours.

- Cauda equina syndrome must be considered if there is: (1) severe or progressive bilateral neurological deficit in the lower limbs, (2) recent onset urinary retention and/or urinary incontinence due to loss of awareness of bladder fullness, (3) recent onset faecal incontinence due to loss of awareness of rectal fullness, (4) perianal or perineal sensory loss, (5) laxity of the anal sphincter.

2.3.4. Neurophysiologic Types of Chronic Pain

Generally, pain is divided into centrally and peripherally sensitised pain. Centrally sensitised pain is induced by a lesion or dysfunction in the CNS. Peripherally sensitised pain can be either peripheral neuropathic, or nociceptive pain. Peripheral neuropathic pain stems from a lesion or an inflammation of the somatosensory nervous system, while nociceptive pain arises from non-neural tissue damage (Smart, Curley et al. 2010, Woolf 2011, IASP 2017).

2.3.4.1. Nociceptive Pain

Pain reports that are presumed to be principally generated by the activation of peripheral nociceptive sensory fibres (i.e. excitation of nerve endings) are defined as nociceptive pain (Scholz and Woolf 2002). More precisely, nociceptive pain is defined as pain driven by the pathophysiological processes related to the excitation of the peripheral receptive terminals of primary afferent neurones (A δ and C fibres) stemming from noxious thermal, mechanical or chemical (inflammatory) stimuli (Ekman and Koman 2004, Julius and McCluskey 2006). Peripheral mechanisms that facilitate multiple clinical presentations of MSK pain, including LBP, may include: lowering of tissue pH in reaction to tissue ischaemia from static mechanical (postural) tissue loading or

compression (Butler 2000), and injury or pathology leading to chemically mediated nociception stemming from the excitation of nociceptors by pro-inflammatory chemicals released in response to the injury, rendering mechanical forces that were not painful to become painful (Butler 2000, McMahon 2006).

Since no standardised quantifiable method exists to reliably classify a patient's pain as predominantly nociceptive, the identification must rely on determination through the clinical impression of the patient's subjective reporting. Proponents of mechanisms-based classifications of pain have put forward various pain-related signs and symptoms presumed to indicate a prevalence of nociceptive pain. These include aching pain that may sharpen during movement, the principal signs of inflammation (redness, swelling, heat), and proportionate and predictable pain reaction upon mechanical testing. All of these are generally connected to natural recovery within a timeframe consistent with tissue healing or the resolution of pathology (Butler 2000, Smart, O'Connell et al. 2008, Finnerup, Haroutounian et al. 2016).

2.3.4.2. Peripheral Neuropathic Pain

Pain stemming from dysfunction or lesion in a peripheral nerve, dorsal root or dorsal root ganglion due to ischemia, compression, inflammation or trauma is known as peripheral neuropathic pain (Woolf 2004, Devor 2006). A probable common origin of peripheral neuropathic pain is the entrapment neuropathies of spinal roots, dorsal root ganglia or their peripheral branches (Scadding and Koltzenburg 2006). Various clinical presentations of pain can be traced to combinations of peripheral, nociceptive, neuropathic and central mechanisms, and it has been suggested that peripheral neuropathic pain is likely a result of altered peripheral, spinal, and supraspinal processes

(Bennett 2006, Freynhagen and Baron 2009, Schäfer, Hall et al. 2009). In a Lancet review, Baron, Binder et al. (2010) emphasised the possible involvement of several mechanisms (peripheral, spinal and supraspinal) in the production of peripheral neuropathic pain and how such mechanisms may produce similar symptoms, thus highlighting the complexity of peripheral neuropathic pain.

It is well established in the literature that peripheral neuropathic pain can occur simultaneously with nociceptive pain in what is termed mixed pain (Freynhagen and Baron 2009, Baron, Binder et al. 2010, Ritchie 2011, Freynhagen, Parada et al. 2019). There is no distinctive way of diagnosing mixed pain on its own. Instead, it is assessed and managed as both peripheral neuropathic pain and nociceptive pain (Freynhagen and Baron 2009, Ritchie 2011).

As stated earlier, peripheral neuropathic pain is the result of several complex pathophysiological processes that affect the makeup and function of peripheral nerves and their central terminals in different ways when reacting to injury (Callin and Bennett 2008). Some of the foremost pathophysiological mechanisms thought to be contributing to peripheral neuropathic pain include:

1. Sensitisation of neural connective tissue nociceptors is where damaged intraneural circulation and hypoxia resulting from nerve injury may lead to an inflammatory reaction within neural connective tissues. As a result, nociceptors located in the *nervi nervorum* (small nerve filaments) and sinu-vertebral (nerve branch passing through the intervertebral foramen) nerves may show increased sensitisation to mechanical and chemical stimuli and producing a heightened nociceptive drive (Butler 2000, Nee and Butler 2006).

2. Ectopic excitability, which refers to abnormal impulse generating sites (AIGS) activating spontaneously and regardless of the peripheral stimulus (i.e. stimulus-independent pain), resulting from the upregulation of ion channels at locations of nerve injury. Alternatively, these locations may develop heightened chemo-, mechano-, thermos-sensitivity, resulting in injured nerves becoming abnormally responsive to chemical, mechanical or thermal stimuli (i.e. stimulus-dependent pain). For example, AIGS could also become responsive to chemical mediators or inflammation (e.g. cytokine signalling) as well as catecholamines (adrenaline and noradrenaline) of the autonomic nervous system, to such a degree that sympathetic-sensory neurone coupling and inflammatory processes may amplify peripheral neuropathic pain mechanisms (Butler 2000, Devor 2006, Baron, Binder et al. 2010).
3. Cross-excitation refers to chemically or electrically signalled activation between neighbouring injured and uninjured neurons, which could increase nociceptive signalling (Nee and Butler 2006).
4. Structural changes refer to where there is axonal sprouting of non-nociceptive A β fibres into the dorsal horn laminae processing nociceptive inputs, leading to non-nociceptive peripheral input (such as movement or touch) potentially amplifying onward nociceptive signalling in the ascending tracts (Butler 2000, Nee and Butler 2006).
5. Neuro-immune interactions refer to the activation of immune cells, such as microglia, a type of glial cells located all around the CNS, in the dorsal horn (posterior grey column of the spinal cord), in the central as well as peripheral nervous system. This is in reaction to nerve injury that stimulates the release

of further chemical modulators which could add to the creation and persistence of peripheral neuropathic pain (Beggs and Salter 2010, Filiano, Gadani et al. 2015).

Peripheral neuropathic pain mechanisms are affected by modulation from both descending inhibitory and facilitatory influences of the CNS simultaneously (Finnerup, Otto et al. 2007, Costigan, Scholz et al. 2009). While the extent to which pathophysiological mechanisms which lead to peripheral neuropathic pain occur is challenging to ascertain, their diversity suggests a high degree of heterogeneous central and peripheral nervous system flexibility (Zusman 2008).

Symptoms and signs assumed to reflect a dominance of peripheral neuropathic pain in patients with MSK/LBP disorders include: pain with a burning or electric-shock-like quality, pain in a dermatomal or cutaneous distribution, spontaneous pain, paroxysmal pain, dysesthesias, allodynia and hyperalgesia (Smart, O'Connell et al. 2008, Freynhagen and Baron 2009). All of these symptoms should occur in a neuroanatomically plausible distribution consistent with the site of nerve lesion (Cruccu, Anand et al. 2004).

2.3.4.3. Centrally Sensitised Pain

Centrally sensitised pain is a mechanisms-based type of pain classified depending on the neurophysiological mechanisms chiefly responsible for its generation and/or maintenance. It has been defined as a category of pain distinct from peripheral neuropathic pain and nociceptive pain (Lidbeck 2002, Tracey and Mantyh 2007).

Centrally sensitised pain has been described as hypersensitivity to pain due to heightened neural signalling activity within the CNS (Woolf 2011). It is further defined as the neurophysiological processes which aid, at the cellular level throughout a broadly

spread CNS, in the up-regulation of the nociceptive system, i.e. heightened synaptic excitability, diminished thresholds of activation and growth of receptive fields of central neurons that process nociceptive inputs (Latremoliere and Woolf 2009).

The concept of centrally sensitised pain suggests that stimuli, which would not ordinarily be able to interact with central neurons, can do so due to a lowered CNS activation threshold or sensitivity (Woolf 1991). These stimuli are not limited to physical factors but may also include psychological inputs such as thoughts and feelings, which may clash with the inputs of physical nature and can be processed bilaterally, thus reducing the threshold applied on any input (Butler 2000). The overall effect of these processes results in noxious input that may potentially be amplified, longer-lasting and of higher intensity, while ordinarily non-noxious inputs can access central nociceptive transmission.

A number of studies suggest that within the CNS, glial cells have a more substantial role than neurons in producing and maintaining central sensitisation and chronic pain (Murphy, Ramer et al. 1999, Milligan, O'Connor et al. 2001, Flatters, Fox et al. 2004). Research suggests that glial cells and neurons share the metabolic labour in the CNS and their interaction is essential in maintaining homeostasis (Milligan, O'Connor et al. 2001, Barres 2003).

In acute and subacute pain, glial cells are considered to be responsible for promoting tissue healing and restoring equilibrium since their activation results in the production of inflammatory mediators which alerts the CNS of the presence of tissue damage (Ji, Berta et al. 2013). If the glial activation does not resolve and is persistent, it becomes

pathogenic, damaging adjacent neurons and other glial cells (Kossmann, Stahel et al. 1997, Milligan, O'Connor et al. 2001, Ji, Berta et al. 2013).

Several chronic MSK pain disorders such as whiplash-associated disorders (Curatolo, Petersen-Felix et al. 2001), CLBP (Giesecke, Gracely et al. 2004), fibromyalgia (FM) and rheumatoid arthritis (Vierck Jr 2006, Yunus 2007) could be tracked to processes associated with central sensitisation (Nijs, Van Houdenhove et al. 2010, Woolf 2011). Multiple symptoms have been suggested as being indicative of centrally sensitised pain, ranging from insomnia, pain lasting longer than predicted tissue healing times, disproportionate and/or inconsistent reactions to clinical examination, generally widespread pain, tactile allodynia and hyperalgesia, hypersensitivity to different sensory stimuli such as temperature, sound or light as well as pain related to affective, behavioural and cognitive dysfunction (Butler 2000, Clauw 2005, Smart, O'Connell et al. 2008, Nijs, Van Houdenhove et al. 2010, Woolf 2011).

2.3.5. Theories and Models of Pain

In order to examine the human experience of pain, it is necessary to review the various models and theories that have been developed to explain clinical presentations of pain, and to acknowledge how perspectives of pain have changed throughout history to influence contemporary practice and research. In the following section, the main and more influential models and theories of pain are discussed.

2.3.5.1. The Specificity Theory

The specificity theory proposes that every somatosensory sensation has its own specific receptor, sensory fibre, and brain centre which only activates due to a single, specific stimulus (Dubner, Sessle et al. 1978, Moayedi and Davis 2012). According to this theory,

pain results from disease or tissue damage, and its intensity is directly proportional to the severity of the disease and/or tissue damage (Keefe, Abernethy et al. 2005).

This model states that pain is thought to be a reaction to, or a secondary symptom of, other outstanding physical conditions, and as such it disappears once the underlying condition is alleviated (Turk and Monarch 2002). This traditional biomedical approach clearly distinguishes between the functions of body and mind and does not acknowledge their interconnections (Gatchel, Peng et al. 2007). When lacking an apparent physical cause, pain is attributed to psychological causes and declared to be psychogenic, meaning that the pain is not considered to be real (Gatchel 2004). Yet the degree of pain experience and disability does not always correspond with the physical pathology that is evident (Turk and Monarch 2002, Keefe, Abernethy et al. 2005).

It has been well established in the current literature that pain can occur without any specific reason (i.e. non-specific) (Maher, Underwood et al. 2017). In a longitudinal cohort study, Suri, Boyko et al. (2014) assessed the association between MRI findings and lumbar spine-related symptoms such as pain, weakness or sensation alterations on 123 participants in the course of 3 years. Suri, Boyko et al. (2014) found that only 2-8% of MRI findings coincided with the presence of CLBP, which only explains a very small portion of symptomatic cases.

In another 10 year longitudinal cohort study, Tonosu, Oka et al. (2017) investigated the association between MRI findings and the incidence of LBP on 29 participants and concluded that people with LBP did not have a significantly higher prevalence of structural changes (e.g. disc prolapse or disc degeneration) when compared to pain-free volunteers. However, this study has a low number of subjects, and there is no evidence

of a power calculation, so care should be taken with the interpretation of the data. This lack of association between pain and physical pathology has prompted a shift in the current diagnostic requirements in clinical settings.

In a recent comprehensive literature review, Hegmann, Travis et al. (2019) investigated the viability of using diagnostic tests such as X-rays, MRIs, bone scans, and ultrasounds in the initial diagnosis of LBP disorders. Hegmann, Travis et al. (2019) included 101 articles of moderate or high quality in their review and found that diagnostic testing was not indicated for the vast majority of people with LBP which further emphasised the notion that pain does not mean injury or apparent signs of degeneration.

While the specificity theory is viable when disease or injury is present in tissues, especially in cases of acute injury (Waddell and Schoene 2004), it has been criticised for viewing the body as a machine without acknowledging the effect of the mind on pain (Butler 2000, Waddell and Schoene 2004, Smart, O'Connell et al. 2008). According to this theory, pain is transmitted via specific pain fibres. Therefore treatment should consist of blocking the transmission of pain along these fibres via pharmacological or surgical interventions and focusing treatment on the injured tissue (Benini and DeLeo 1999, Waddell and Schoene 2004). However, this theory has been criticised for its structure-focused approach and its inability to account for the intricacy and variability of clinically observed pain presentations.

It also is unable to account for situations where the injury or pathology does not account for the degree of pain reported, where similar injuries yield wildly varying pain reports or where the pain is reported to continue after healing. It also fails to explain why compressed nerve roots can be observed post mortem without a history of pain

complaint (Butler 2000, Main and Spanswick 2000). It is unable to explain the differences in patients' results in response to treatment methods, since according to this traditional medical model, treating the pathological process should lead to pain relief (Zusman 1999, Butler 2000, Smart, O'Connell et al. 2008).

In summary, the specificity theory falls short of accounting for and aiding the treatment of the complicated experiences of chronic pain (Turk and Monarch 2002), due to solely relying on biological factors and excluding psychosocial or behavioural causes of the disease (Engel 1977).

2.3.5.2. Pattern Theory

The pattern theory proposes that there are no specific pathways for each sensation. Instead, all sensations are encoded in certain activation patterns of peripheral nerves and then decoded by the brain which results in an assigned sensation according to the activated pattern (Perl 2007, Moayedi and Davis 2012). The pattern theory completely opposes the specificity theory which assigns specific receptors to specific sensations (Moayedi and Davis 2012). This theory was criticised for being too general in explaining pain and for its inability to factor in the physiological evidence of the presence of specialised receptors and fibres (Perl 2007, Moayedi and Davis 2012).

2.3.5.3. The Gate Control Theory of Pain

The Gate Control Theory (GCT) provided a framework that brought together the specificity theory and the pattern theory and stipulated that there are nociceptors and tactile receptors which synapse in 2 areas of the spinal dorsal horn: the substantia gelatinosa and the transmission cells. GCT asserted that the spinal cord had a gating

mechanism within the dorsal horn that regulated stimuli from both thin (pain) and large (touch, pressure) diameter nerve fibres (Melzack and Wall 1965).

According to the GCT, signals are transmitted from the stimulated peripheral receptor to the transmission cells and the substantia gelatinosa which acts as a gate where thin fibre activity opens the gate and large fibre activity closes the gate. Transmission cells send signals to the brain where impulses are processed and modulated. When these impulses are processed in the brain, past experiences, memory, emotions and attention influence how the generated sensation is perceived (Melzack and Casey 1968, Moayedi and Davis 2012).

This theory is the first approach to include both physiological as well as psychological variables in accounting for pain experience (Melzack and Wall 1965, Melzack and Wall 1996). It considers that pain may still be occurring after tissue healing and that pain may present in different locations on the body than the area of tissue damage (Melzack and Wall 1996). This indicates that the brain is crucial in its function of interpreting pain signals, rather than passively acknowledging nociceptive stimuli, and interacts with psychological as well as sensory input (Melzack and Wall 1965, Melzack and Wall 1996, Day, Thorn et al. 2012).

The development of the GCT constituted a milestone in advancing pain management and research. Pain experience can now be approached as a multi-dimensional issue, leading to a better understanding of pain mechanisms (Gatchel, Peng et al. 2007). Through the acknowledgement of psychosocial factors and their role in the pain experience, the GCT laid the foundation for a biopsychosocial explanation of pain (Kerns, Sellinger et al. 2011). Furthermore, the GCT has an enormous influence on the

development of psychological treatments in pain management (Keefe, Abernethy et al. 2005).

However, this theory introduced a very simplistic idea about the role of the spinal dorsal horn in the modulation of pain by it focusing on cutaneous pain, without explaining deep or visceral pain. It also fails to explain the reason behind non-specific pain (Moayedi and Davis 2012).

2.3.5.4. The Neuromatrix Model

Following on from the GCT, Melzack and Casey (1968) proposed the existence of 3 components of pain:

1. The sensory-discriminative component: which is responsible for the location and intensity of the stimulus
2. The affective-motivational component: which is responsible for the response to pain
3. The cognitive-evaluative component: which includes all behaviours experienced while in pain (e.g. anxiety) (Melzack and Casey 1968).

Later, Melzack (2001) utilised both the GCT and the proposed pain components to introduce the neuromatrix model of pain. The neuromatrix model proposed that the perception of noxious stimuli is not a result of the brain's processing of tissue trauma but from an active generation of subjective experiences within a network of neurons or 'body-self neuromatrix' which integrates the 3 aforementioned components, in order to generate the experience of pain.

This model was developed based on 2 main factors: that pain can result from the CNS independent of peripheral injury, and that multiple regions in the CNS contribute to formulating the pain experience (Melzack 2001). The neuromatrix model was inspired by the phantom limb phenomenon and spinal cord injuries where people felt pain in amputated or paralysed parts of the body (Melzack 1990, Melzack 1999, Melzack 2001).

The neuromatrix model provides an integrated theoretical framework for exploring the multi-dimensionality of pain perception and the perceived pain experience of an individual's 'self', however, it fails to explain how psychological factors interact and how they affect pain. Also, the neuromatrix model was deemed too general and failed to explain why and how certain regions in the CNS perform certain functions (Derbyshire 2000, Gatchel, Peng et al. 2007). Even though this model contributes to the understanding of unexplained pain phenomenon, it does not contribute to the comprehension of the mechanisms of pain relief (Keefe, Kashikar-Zuck et al. 1996, Gatchel, Peng et al. 2007).

2.3.5.5. Biopsychosocial Approach of Pain

Engel (1977) emphasised the need for expanding on the traditional understanding of pain as a biological occurrence to include psychological and social influences. The biopsychosocial approach has been established as the most broadly accepted approach for the understanding and management of chronic pain (Gatchel, Peng et al. 2007). It is recognised that the pain experience is influenced by the interaction of psychological, physiological and social factors (Gatchel 2004). This approach is viewed as more of a theoretical framework that encompasses biological, psychological, and social factors that contribute to and influence illness behaviours (Lumley, Cohen et al. 2011).

Unlike disease, a pathological process that can be objectively assessed, illness is considered as a subjective behaviour that results from the interaction of biological, psychological, and social factors that is interpreted by a person in order to interpret disease (Boyd 2000, Turk and Monarch 2002, Gatchel, Peng et al. 2007, Van Griensven, Strong et al. 2013). In a review of the literature, Turk and Monarch (2002) proposed that the differentiation between illness and disease corresponds with the differentiation between nociception and pain, both are critical in comprehending the chronic pain experience. Nociception is defined as the sensory communication of physical stimuli such as tissue damage to the brain. Meanwhile, pain is defined as the subjective interpretation of that message (Turk and Monarch 2002, Gatchel, Peng et al. 2007).

Several factors may influence the subjective interpretation of pain experience or illness behaviour, such as socio-cultural influences, genetic predisposition, psychological factors and learning patterns (Turk and Monarch 2002, Gatchel, Peng et al. 2007). Illness behaviour is a dynamic, constantly changing phenomenon, where even if a condition is initiated by a biological factor, psychosocial influences contribute to the maintenance and exacerbation of pain symptoms (Boyd 2000).

Since its inception, the biopsychosocial approach has inspired the development of many models of pain, illness, and disability (Fordyce, Shelton et al. 1982, Waddell and Main 1984, Waddell 1987, Turk and Monarch 2002, Hasenbring, Hallner et al. 2012, Vancleef, Flink et al. 2012). Loeser's model of pain and suffering (Loeser 1980) was 1 of the first biopsychosocial-based models that described the multi-dimensionality of pain by connecting nociception, pain, suffering and pain behaviour in a social context, thus rejecting the mental-physical dichotomy concept of pain (Main, Sullivan et al. 2007). The

Glasgow Illness Model (Waddell, Main et al. 1984) was the earliest application of the biopsychosocial approach in CLBP disorders. The Glasgow Illness Model emphasised all elements within the biopsychosocial approach in explaining CLBP as an illness behaviour that originated from a physiological impairment and is affected by cognition, psychological and social elements (Waddell, Main et al. 1984, Waddell 1987, Waddell, Newton et al. 1993).

Engel (1977) advocated a holistic approach when the biopsychosocial approach was introduced and argued against using reductionist approaches in research and clinical settings. However, Engel (1977) developed this approach by observing medical illnesses (e.g. as a result of myocardial infarction) without taking into consideration possible mental illnesses. Although a holistic approach is desirable in many cases, others require a more reductionist approach (e.g. peptic ulcers) (Ghaemi 2009). When investigating back pain, some argue that serious illness red flags and tissue injury should be ruled out by employing a reductionist approach before considering a more holistic biopsychosocial approach, and how the biological element should not be marginalised in the wake of psychosocial elements dominance in research and clinical setting (Shakespeare, Watson et al. 2017).

Regardless of their differences or their aims, all contemporary biopsychosocial driven models focus on the behaviour of illness rather than a disease (Asmundson, Gomez-Perez et al. 2014). Illness behaviour is a concept where people's responses and perceptions to sensations (e.g. pain, touch, heart palpitation) are different, and that difference can be understood within a psychological and social context (Asmundson, Gomez-Perez et al. 2014). Therefore, it is essential to adopt a biopsychosocial approach

when developing any pain assessment tool, regardless of the specific pain model that was adopted. While using the biopsychosocial approach to develop a CLBP self-assessment and self-management tool, emphasis should be given to the bio (Pain behaviour), psycho (Perception of LBP), and social (Impact of LBP on work and lifestyle) in order to encompass all aspects of this approach.

2.3.5.6. Summary of Theories and Models of Pain

This section provided an overview of some of the most popular theories and models of pain. Historically, pain was viewed in a purely mechanical manner (i.e. damage equals pain). However, there was a shift in the understanding of pain, and contemporary models argued that pain is a complex experience with a variety of neurobiological and sociological layers and should be assessed and managed as such. The usefulness of earlier theories that describe pain as a direct product of injury or physical disease, such as the specificity theory, has been in contention with more contemporary approaches such as the GCT of pain (Melzack and Wall 1965), and the biopsychosocial approach (Waddell and Main 1998) which have demonstrated the frequently inconsistent connection between pathology and pain presentation. Until the development of the GCT, the CNS was not considered a part for pain modulation, or as an explanation of the nonlinear association between injury and perceived pain intensity (Melzack and Wall 1965). This new understanding of pain led to the conceptualisation of the biopsychosocial approach to pain, which recognises the key roles of cognitive, psychological, and environmental elements in the complex pain experience.

The next section focuses on LBP, and related classification systems used within a physiotherapy setting where the mechanisms-based classification system, an extension of the biopsychosocial approach, is presented.

2.4. Low Back Pain

LBP is defined as pain being located between the twelfth rib lower margins and the folds of the gluteus muscles with or without leg pain (Dionne, Dunn et al. 2008, Hartvigsen, Hancock et al. 2018). It is identified as a symptom that can stem from various identifiable (specific LBP) or unidentifiable (non-specific LBP) causes (Hartvigsen, Hancock et al. 2018). Classifying LBP has been recommended in order to focus and plan targeted medical services and to aid in standardising clinical and research observations, which in turn facilitates the exchange of information and data (Woolf, Bennett et al. 1998, Fritz, Cleland et al. 2007, Foster, Hill et al. 2013). However, in the available literature, various methodologies, and recommendations exist for developing LBP classification systems (Fairbank and Pynsent 1992, Deyo, Andersson et al. 1994, Ford, Story et al. 2007, Hill, Dunn et al. 2008). Classic LBP classification systems are predominantly uni-dimensional; however, due to the heterogeneity of LBP, newer models have adopted a multi-dimensional approach to classification (Fritz and George 2000). This section explores the most common examples of LBP uni-dimensional and multi-dimensional classification systems to highlight the complexity and heterogeneity of LBP.

2.4.1. Classification Models for Low Back Pain

Traditionally in physiotherapy clinics, a pathoanatomical approach supplemented with deductive reasoning and radiographic evidence is applied (Nachemson 1999). However, evidence has shown that abnormal radiographs and pathoanatomical findings do not

correlate with pain and disability and are often observed in the pain-free population, rendering them undependable as the sole assessment and classification system for LBP (Nachemson 1999, Jarvik and Deyo 2002, Van Tulder, Becker et al. 2006).

Another classic LBP classification approach is the signs and symptoms system which was championed by McKenzie and May (1981) and Maitland (1986). This system explores the nature, area, and behaviour of pain in order to recognise malfunctions in spinal movements by palpitation, provocation of pain, and the effect of repetitive movement, in order to influence the behaviour of pain (peripheralisation to other parts of the body, or centralisation 'localisation' in 1 area of the spine). This classification system is considered limited especially in the management of CLBP due to its lack of acknowledgement of the multi-dimensionality of CLBP (Maher, Latimer et al. 1999, Bogduk 2004, Elvey and O'Sullivan 2004).

The Quebec Task Force Classification system is considered 1 of the earliest multi-dimensional classification systems for spinal disorders (Spitzer, LeBlanc et al. 1987). This system uses pain duration (acute, sub-acute, and chronic), patho-anatomical findings including the presence or absence of red flags, and signs and symptoms including yellow flags and work status. However, despite its popularity, the Quebec Task Force Classification system was designed from a surgical perspective as an aid for making clinical decisions on whether to follow a conservative or surgical treatment pathway (Dankaerts, O'Sullivan et al. 2006). This system does not account for underlying mechanisms and is considered to be limited and lacks specificity with non-specific LBP, a subgroup that requires conservative, non-surgical treatment (Padfield 2002).

O'Sullivan (2005) proposed a multi-dimensional LBP classification system based on a patho-anatomical, patho-mechanical impairment, neurophysiological changes, and maladaptive coping strategies. This classification system uses available medical history, and subjective and objective examination in order to subclassify people with LBP. This system aims to identify the underlying mechanisms (maladaptive postures, movement patterns, and motor control behaviours) that drive pain and use them to target treatment (O'Sullivan 2005). Even though this system is multi-dimensional, well rounded, and targets LBP, the application can be time-consuming and requires extensive training in order to minimise the margin of error (Dankaerts, O'Sullivan et al. 2006, Fersum, O'Sullivan et al. 2009, Karayannis, Jull et al. 2012).

2.4.1.1. The Mechanisms-Based Classification of Low Back Pain

Another approach to classifying LBP is the mechanisms-based classification, which classifies pain according to the underlying neurophysiological mechanisms connected to its generation and/or maintenance (Woolf 2004). Proponents of a mechanisms-based approach to pain management have argued in favour of its relevancy and usefulness to clinical practice, due to a general trend to move away from describing pain primarily as a symptom of disease or pathology, to viewing pain as a disease and clinical entity in itself (Woolf 2004). Clinicians may benefit from an improved appreciation of the neurobiology of pain to support clinical thinking following mechanisms-based methods, beyond the more simplistic approach intrinsic to biomedical model interpretations (Gifford 2013).

In fact, a mechanisms-based classification system for pain has been suggested to be crucial for physiotherapists to improve their comprehension of the clinical presentations

of pain as well as movement dysfunction, not immediately accounted for by the biomedical model (Butler 2000). It also helps them to better identify aspects leading to the variability and complexity of clinical presentations of pain, such as psychological factors, neurogenic influences and the modulation of nociception in the periphery. Because the borders between these mechanisms are frequently fluid, the key feature appears to be the overlap of mechanisms. The pain experience is complex in nature and mechanisms differ in their contributions to injury, person and injury state over time (Butler 2000, Tracey, Woolf et al. 2019).

Mechanisms-based approaches have been argued to better account for observed differences in the severity and type of various clinical presentations of musculoskeletal pain (such as whiplash associated disorder, low back (\pm leg) pain) under the following conditions (Cheing and Cheung 2002, Smart, O'Connell et al. 2008):

1. where the pain is reported to continue following the healing of an injury of pathology.
2. where the intensity of pain reported by patients with comparable injuries of pathologies varies greatly.
3. where the pain is reported despite the absence of a clearly identifiable pathology, or not in proportion to it.
4. where the pain is not reported although evidence of pathology or injury exists.

Furthermore, mechanisms-based approaches are argued to improve clinical outcomes through the promotion of specific interventions based on the identified prevailing underlying mechanisms of pain.

One of the integrated mechanisms-based approach's strengths is its acknowledgement of the relevance as well as neurophysiological basis of the cognitive-affective mechanisms of pain and their biological substrates, and the way they are closely tied to and impact other pain mechanisms interrelated to the processing and modulation of pain information (Zusman 2002). Acknowledging the undeniable connection between the physiological and psychological and its repercussions for the classification of pain and disability becomes even more prudent when considering the increasing evidence that indicates psychosocial factors to be as or more important than physical ones for the forecast of outcome and for the identification of patients who are at high risk of developing chronic pain.

According to 1 approach, there are 3 main mechanisms-based categories attributed to patients' MSK pain (such as LBP), ranging from peripheral nociceptive to peripheral neuropathic and central pain, which are described previously in section 2.3.4. Neurophysiologic types of chronic pain (Cheing and Cheung 2002). The approach suggests that pain can be clinically categorised based on the prevailing operant mechanisms linked to its generation and/or maintenance, according to available pathophysiology, logic and clinical patterns of symptoms (Cheing and Cheung 2002).

In a review paper, Gifford and Butler (1997) identified that there is a lack of implementation of the mechanisms-based model of pain in clinical settings despite the shift in the understanding of the pain experience in literature which led to the conceptualisation of the model. Gifford and Butler (1997) proposed that the disconnect from literature and clinical practice could be due to the lack of a framework that could be easily integrated within clinical practice. In their review, Gifford and Butler (1997)

suggested several clinical indications for the different pain mechanisms which are presented in Table 3.

In another study, Smart, Blake et al. (2010), conducted a Delphi study that aimed to define the clinical criteria that suggested the dominance of nociceptive, peripherally neuropathic, or centrally sensitised MSK pain. In a 3 Round online Delphi study, the consensus was defined at $\geq 80\%$ agreement, and a panel of pain consultants and MSK physiotherapists (n=62) was utilised (Smart, Blake et al. 2010). In that study, the first Round was purely qualitative asking participants for subjective and clinical indicators for the 3 types of pain mechanisms, while the subsequent Rounds asked the participant to rate the items on a 5 point Likert scale (5=Strongly agree, 4=Agree, 3=No opinion, 2=Disagree, 1=Strongly disagree). As a result, 12 nociceptive pain, 14 peripheral neuropathic pain, and 17 centrally sensitised pain clinical indicators reached consensus (Table 3).

Table 3 Indicators of pain mechanisms in available classification systems

Study	Peripheral nociceptive pain indicators	Peripheral neuropathic indicators	Centrally sensitised pain indicators
Gifford and Butler (1997)	<ul style="list-style-type: none"> • proportionate to the applied force, relieved with the removal of force, eases when the injury is settled, improves either naturally or with traditional treatments (e.g. ice, splinting, range of movement or strength exercises). 	<ul style="list-style-type: none"> • cutaneous or has a segmental distribution (i.e. based on the segments the nerve innervates), • motor deficits corresponding to the affected nerve, • could be evoked mechanically by nerve compression or tension, • deep aching, cramping, superficial burning, stinging, and paraesthesia. 	<ul style="list-style-type: none"> • ongoing even after expected tissue healing time, • unfamiliar anatomic pattern, • allodynia, • hyperalgesia, • increased with emotional or physical stress, presence of affective and cognitive components, poor response to medications such as opioids.
Smart, Blake et al. (2010)	<p>Subjective indicators:</p> <ul style="list-style-type: none"> • Resolves according to expected healing time • Responsive to analgesia/ non-steroidal anti-inflammatory drugs (NSAIDs) • Intermittent and sharp with movement, and might present as constant dull ache or throb at rest • Recent onset • Clear and proportionate anatomical pattern • Associated with trauma or movement/postural dysfunction • Associated with other inflammation symptoms (i.e. heat, redness, swelling) 	<p>Subjective indicators:</p> <ul style="list-style-type: none"> • Pain described as shooting, sharp, burning, or electric shock-like • Nerve injury history • Presence of other neurological symptoms (e.g. weakness, numbness, pins and needles) • Spontaneous or suddenly reoccurring pain • Pain referred in a cutaneous or dermatomal distribution • More responsive to anti-epileptic medications and antidepressants than NSAIDs • Pain of high severity and irritability • Presence of other dysesthesias (e.g. crawling or electric) 	<p>Subjective indicators:</p> <ul style="list-style-type: none"> • Unpredictable pattern, disproportionate, non-mechanical • Pain lasting longer than expected healing time • Widespread • History of failed interventions • Night pain-pain affecting sleep • Constant • Strong association with maladaptive psychosocial factors (yellow flags) • More responsive to anti-epileptic medications and antidepressants than NSAIDs • Spontaneous pain independent from stimulus • High levels of functional disability • Presence of other dysesthesias (e.g. crawling or burning sensations)

Study	Peripherally nociceptive pain indicators	Peripheral neuropathic indicators	Centrally sensitised pain indicators
Mayer, Neblett et al. (2012)	<p>Peripherally nociceptive pain indicators</p> <p>Clinical examination indicators:</p> <ul style="list-style-type: none"> • Pain-relieving postures/movement pattern • Absence of exaggerated findings of hyperalgesia and allodynia • Localised pain on palpitation • Consistent anatomical/movement pattern on mechanical testing of target tissues 	<p>Peripheral neuropathic indicators</p> <ul style="list-style-type: none"> • Mechanical patterns (aggravating and easing factors) involve activities associated with loading or compression of neural tissue. <p>Clinical examination indicators:</p> <ul style="list-style-type: none"> • Symptoms provoked with mechanical/movement tests • Symptoms provoked on palpation of relevant neural tissues • Positive neurological findings • Hyperalgesia, allodynia, and/or hyperpathia within the pain distribution on examination • pain can be relieved by posturing the affected body part <p>NA</p>	<p>Centrally sensitised pain indicators</p> <ul style="list-style-type: none"> • Increased pain severity and easily provoked <p>Clinical examination indicators:</p> <ul style="list-style-type: none"> • Disproportionate and non-anatomical pattern of pain in response to movement testing • Hyperalgesia, allodynia, and/or hyperpathia on examination • Diffused pain/tenderness on palpitation • Identification of psychosocial factors (distress, fear-avoidance, catastrophisation)
	NA	NA	<p>Comorbidities based on a literature search:</p> <ul style="list-style-type: none"> • Insomnia • Sleep-disordered breathing • Restless leg syndrome • Chronic fatigue syndrome • Irritable bowel syndrome • Frequent urination • Pre-menstrual syndrome • Temporomandibular joint disorder • Headache • Whiplash/cervical injury • Cognitive impairments • Multiple chemical sensitivities

Study	Peripheral nociceptive pain indicators	Peripheral neuropathic indicators	Centrally sensitised pain indicators
			<ul style="list-style-type: none"> • Chronic hives • Psychological disturbance, including anxiety, panic and depression • Post-Traumatic Stress Disorder • Childhood abuse/trauma

Key: NA: Not applicable

In a subsequent preliminary reliability study, Smart, Curley et al. (2010) determined the intra- and inter-rater reliability of the aforementioned acquired criteria on patients with LBP (\pm leg pain) and clinician's mechanisms-based classification of LBP (\pm leg pain) using a simultaneous examiner design, where both raters observed the same subjects at the same time. For inter-rater reliability, 1 therapist conducted the examination and the other observed (n=40). For intra-rater reliability, the patients were examined by the primary investigator on 2 different occasions (n=40) (mean number of days between occasions=11 \pm 9). After the examinations, Delphi-derived clinical criteria were completed independently by each rater who then made their independent decision on the type of pain presentation (centrally sensitised pain, peripherally neuropathic pain, nociceptive pain, mixed pain) (Smart, Curley et al. 2010). Inter- and intra-rater agreement based on clinicians' mechanisms-based classifications of LBP (\pm leg pain) was reported as substantial (kappa=0.77; 95% confidence interval (CI): 0.57–0.96; percentage agreement=87.5%) and almost perfect (kappa=0.96; 95% CI: 0.92–1.00; percentage agreement=92.5%), respectively. Smart, Curley et al. (2010) concluded that their study provides preliminary evidence corroborating the reliability of mechanisms-based classification of pain using clinical judgement on LBP (\pm leg pain). It should be noted, however, that the primary investigator who helped develop the criteria was 1 of the raters and his knowledge of the subject could have inflated the results. Furthermore, both raters had more than 10 years of experience in MSK physiotherapy assessment. Therefore, the results of this study cannot be generalised to therapists with less experience or knowledge.

In a following study, Smart, Blake et al. (2012) conducted a cross-sectional, between-subjects study aiming to identify signs and symptoms indicative of centrally sensitised

pain, peripheral neuropathic, or nociceptive pain mechanisms using the criteria identified in the previous Delphi study (Smart, Blake et al. 2010). This study employed 15 experienced physiotherapists (1 of which was the primary investigator) and 4 self-assessment measures (Smart, Blake et al. 2012). In this study, 464 patients with LBP (\pm leg pain) were included. Participating physiotherapists (n=15) received the same training and an instruction assessment manual in order to standardise the procedure (Smart, Blake et al. 2012).

Before the patients were examined by the physiotherapists, they completed 3 questionnaires measuring health-related quality of life (Short Form Health Survey, SF-36), LBP related disability (Roland-Morris Disability Questionnaire), and emotional health (The Hospital Anxiety and Depression Scale, HADs). The physiotherapists assessed patients using the standardised protocol and assessed their pain severity using an 11 point verbal numerical rating scale (Smart, Blake et al. 2012). Physiotherapists using their clinical judgement classified each patient based on the mechanisms-based classification of pain to either centrally sensitised pain, peripherally neuropathic pain, nociceptive pain, or a combination of the 3 types. Following classification, physiotherapists completed the 38 Delphi-derived criteria (Smart, Blake et al. 2010) by reporting whether each item on the 38 item list was absent, present, or inconclusive (Smart, Blake et al. 2012).

Using regression analysis, a cluster of 4 criteria were predictive of centrally sensitised pain (sensitivity 91.8%, 95% (CI): 84.5-96.4; specificity 97.7%, 95% CI: 95.6-99.0):

1. Disproportionate, non-mechanical, unpredictable pattern of pain provocation in response to multiple/non-specific aggravating/easing factors.

2. Pain disproportionate to the nature and extent of injury or pathology.
3. Strong association with maladaptive psychosocial factors.
4. Diffuse/nonanatomic areas of pain/tenderness on palpation).

A cluster of 3 criteria were predictive of peripheral neuropathic pain (sensitivity 86.3%, 95% CI: 78.0- 92.3; specificity 96.0%, 95% CI: 93.4-97.8; diagnostic odds ratio 150.9, 95% CI: 69.4-328.1):

1. Pain referred in a dermatomal or cutaneous distribution.
2. History of nerve injury, pathology or mechanical compromise.
3. Pain/symptom provocation with mechanical/movement tests that move/load/compress neural tissue).

A cluster of 7 criteria were predictive of nociceptive pain (sensitivity 90.9%, 95% CI: 86.6-94.1; specificity 91.0%, 95% CI: 86.1-94.6):

1. Pain localised to the area of injury/dysfunction.
2. Clear, proportionate mechanical/anatomical nature to aggravating and easing factors.
3. Usually intermittent and sharp with movement/mechanical provocation; may be a more constant dull ache or throb at rest.
4. The absence of pain in association with other dysesthesias.
5. The absence of night pain/disturbed sleep.
6. The absence of antalgic postures/movement patterns.
7. The absence of pain variously described as burning, shooting, sharp or electric-shock-like).

Multivariate analysis of variance (MANOVA) assessed construct validity of the developed criteria where they found that centrally sensitised pain patients (n=106) reported significantly more severe pain, lower general health related quality of life, and increased levels of back pain-related disability, depression and anxiety in comparison to peripheral neuropathic pain (n=102) and nociceptive pain (n=256) patients ($p=0.001$; Pillai's Trace=0.33; partial eta squared=0.16). Smart, Blake et al. (2012) concluded that the resulting cluster patterns might assist clinicians identify the dominance of centrally sensitised pain, peripheral neuropathic pain, or nociceptive pain in patients with LBP (\pm leg pain). The well designed and novel series of studies conducted by Smart, Blake et al. (2010), Smart, Curley et al. (2010), and Smart, Blake et al. (2012) aiming to develop and validate a mechanisms-based classification system provided a clearer clinical picture of the presentation of pain mechanisms, however, it should be noted that the lead investigator took part in the inception and psychometric properties testing of the developed criteria which might have affected the results (Smart, Blake et al. 2012).

In another study, Mayer, Neblett et al. (2012), developed the Central Sensitisation Inventory (CSI), which was designed to help clinicians identify the presence of centrally sensitised pain in chronic pain disorders (e.g., FM, CLBP, chronic widespread pain). Mayer, Neblett et al. (2012) aimed to identify comorbidities associated with chronic pain disorders and identified 16 comorbidities (Table 3). An interdisciplinary team (physicians, rehabilitation specialists, clinical psychologists, health psychologists, psychophysiological specialists) then developed the items within CSI which were split into 2 parts.

Part 1 consisted of 25 statements focusing on current health symptoms and rated using a 5 point Likert scale, resulting in a 0-100 cumulative score. Part 2 of the CSI collected patients past history in relation to previous diagnosis of a number of disorders and conditions (Restless Leg Syndrome, Chronic Fatigue Syndrome, FM, Temporomandibular Joint Disorder, migraine or tension headaches, Irritable Bowel Syndrome, Multiple Chemical Sensitivities, neck injury (including whiplash), anxiety or panic attacks, depression). Part 2 does not factor in the cumulative score and was intended to provide additional clinical background information for healthcare professionals.

Following the development of the CSI, Mayer, Neblett et al. (2012), tested its reliability and construct validity. Mayer, Neblett et al. (2012) conducted a reliability study, in the form of internal consistency and test retest reliability, on 149 healthy participants. Reported results indicate high test retest reliability and internal consistency (Pearson's correlation (r)=0.817; Cronbach's alpha=0.879).

To assess construct validity, Mayer, Neblett et al. (2012) compared the scores of 4 patient groups: FM, Chronic Widespread Pain, CLBP, and a healthy control group after hypothesising that the extent of pain centralisation and the resulting score of the CSI would be highest in the FM group and progressively less in the Chronic Widespread Pain, CLBP, and the healthy control group. Using an analysis of covariance (ANCOVA) the results were as follows: Healthy group mean score (n=40)=28.9, CLBP (n=44) mean score=41.6, Chronic Widespread Pain (n=31) mean score=47.5, FM (n=30) mean score=58.2. Mayer et al. (2012) concluded that the CSI demonstrated good structural validity based on their initial hypothesis and subsequent analysis.

A limitation of Mayer, Neblett et al. (2012)'s study was that no demographic data of the interdisciplinary team was reported nor did they report on how they arrived at the final version of CSI. Demographic data are important in research studies in order to compare the results with other studies and for providing information for synthesising the research (Hammer 2011, Connelly 2013). Additionally, the method of item collection (e.g. focus groups, interviews) would affect the comprehensiveness of the developed tool (Streiner, Norman et al. 2015). In a systematic review, Scerbo, Colasurdo et al. (2018) identified 14 studies that assessed the measurement properties of the CSI. Scerbo, Colasurdo et al. (2018) found that the measurement properties in the included studies were of good to excellent quality and concluded that CSI is a valid and reliable tool to assess the severity of centrally sensitised pain-related symptoms (Scerbo, Colasurdo et al. 2018). The results of this systematic review should be interpreted with caution due to the limited amount of studies included. However, this author acknowledges that this limitation is an inherent 1 in research related to a relatively new tool.

In summary, there seems to be an agreement in the literature about the indicators of central sensitisation of pain and using pain mechanisms as a clinical classification criterion appears to be gaining momentum in research.

2.5. Assessment of Low Back Pain

NICE (2016) recommends that any back pain assessment should start with performing a diagnostic triage in order to rule out serious underlying pathology and to identify possible specific causes for LBP through history taking and a physical examination (e.g. infection, cancer, ankylosing spondylitis) (NICE 2016, Oliveira, Maher et al. 2018). In

addition, imaging should only be considered if red flags, which may indicate serious pathologies, are present, and if imaging might redirect the treatment pathway (NICE 2016). Other guidelines also recommended against routine imaging of LBP (Elleuch, El et al. 2015, Bardin, King et al. 2017, Van Wambeke, Desomer et al. 2017). Despite the current evidence and recommendations, imaging is still routinely requested in clinical practice, and imaging of LBP appears to have increased over the past 21 years (Kendrick, Fielding et al. 2001, Downie, Hancock et al. 2019).

After excluding serious pathology, the assessment of psychosocial factors (yellow flags) is recommended during either the first or second assessment session using a validated screening tool (e.g. STarTBack) (NICE 2016, Oliveira, Maher et al. 2018).

In physiotherapy, clinical judgment developed through a reasoning process is used in order to assess and plan treatment for patients. Clinical judgement refers to the process where healthcare professionals observe signs, process available information, and investigate the patient's past and present medical history in order to set appropriate goals, plan and implement treatment, and evaluate the outcome (Higgs, Jones et al. 2008, Langridge, Roberts et al. 2015). Within physiotherapy, the hypothetico-deductive reasoning process is the most commonly used approach in developing clinical judgement (Doody and McAteer 2002, Langridge, Roberts et al. 2015). The hypothetico-deductive reasoning approach is a form of judgement based on the collection of initial signs regarding the problem from the patient (subjective assessment) where an initial hypothesis is formed by the therapist (Valderas and Alonso 2008). The formation of an initial hypothesis is then followed by collecting further data using a physical examination

(objective assessment) which might confirm or reject the formulated hypothesis (Edwards, Jones et al. 2004).

Current models and theories of pain have a significant influence on clinicians' judgement on the presentation of pain. Using a qualitative multiple case studies design, Smart and Doody (2007) investigated the influence of such models on clinical judgement and indicated in their results that therapists' clinical judgement was dynamic and multi-dimensional, drawing on multiple established models of pain. They described 5 main categories of clinical judgement based on pain: irritability, biomedical, psychosocial, pain mechanisms, severity and chronicity. The therapists' planning of physical assessment and treatment, as well as their prognostic course of action, were shown to be influenced by deliberating within these categories (Smart and Doody 2007). The participants' clinical judgement of pain in the Smart and Doody (2007) study seemed to indicate the assimilation of various theories and models of pain into contemporary clinical practice. It was the first published study to examine mechanisms-based reasoning of pain in MSK physiotherapy but reported different results than a study by Rivett and Higgs (1997), which reported, when investigating the clinical reasoning of manual therapists, no evidence of reasoning connected to the neurophysiological mechanisms of pain. The greater awareness of knowledge related to mechanisms of pain within the field of physiotherapy since Rivett and Higgs (1997) study may account for the discrepancy between their findings and Smart and Doody's (2007) study. However, Smart and Doody (2007) only included MSK physiotherapists with more than 10 years of experience and a postgraduate degree which decreased the applicability and generalisability of their results.

Regardless of the physiotherapist's choice of pain models when formulating a clinical judgement, assessment of LBP and following recommended guidelines, where the use of a biopsychological approach is emphasised, is essential and it allows healthcare professionals to focus on the patient as a whole instead of solely trying to identify the pathoanatomic cause of their symptoms.

Even though the use of a biopsychosocial approach is recommended, there is evidence that many physiotherapists still base their chronic pain assessment on biomedical and somatic signs and symptoms and feel unequipped to assess or treat patients by investigating psychosocial influences on pain management (Bishop and Foster 2005, Derghazarian and Simmonds 2011, Alexanders, Anderson et al. 2015, Singla, Jones et al. 2015, Synnott, O'Keeffe et al. 2015, Peters, Faller et al. 2016, Qasem and Canby 2016, Roussel, Neels et al. 2016). In order to mitigate this limitation, and in order to minimise the risk of poor outcome, the use of questionnaires and treatment stratification tools is recommended (NICE 2016, Wijma, van Wilgen et al. 2016).

2.5.1. Low Back Pain Self-Assessment Tools

Self-assessment tools could either be generic or condition specific. Generic tools are used to measure generic health quality of life or a condition specific health quality of life. For example, the SF-36 health survey is a generic self-assessment tool that assesses the quality of life but is also used when measuring quality of life for people with LBP (Dawson, Doll et al. 2010, Natour, Cazotti et al. 2015, Pozzobon, Nogueira et al. 2019). A condition specific tool is only used with specific conditions like LBP for example (Rowen, Brazier et al. 2017). Several LBP self-assessment tools exist, and they are usually used to help therapists determine the most appropriate treatment pathway and guide

them in exploring certain aspects of pain (Wijma, van Wilgen et al. 2016). When searching the available literature, 13 LBP specific self-assessment tools were identified:

- STarTBack (Hill, Dunn et al. 2008).
- The Oswestry Disability Index (ODI) (Fairbank, Couper et al. 1980).
- The Roland–Morris Disability Questionnaire.
- (Roland and Morris 1983).
- Quebec Back Pain Disability Scale (Kopec, Esdaile et al. 1995).
- Waddell Disability Index (Waddell and Main 1984).
- Million Visual Analogue Scale (Million, Hall et al. 1982).
- Low Back Outcome Score (Greenough and Fraser 1992, Holt, Shaw et al. 2002).
- Clinical Back Pain Questionnaire (Aberdeen Low Back Pain Scale) (Ruta, Garratt et al. 1994).
- Low Back Pain Rating Scale (Manniche, Asmussen et al. 1994).
- Resumption of Activities of Daily Living Scale (Williams and Myers 1998).
- Fear-Avoidance Beliefs Questionnaire (Waddell, Newton et al. 1993).
- Back Pain Function Scale (Stratford, Binkley et al. 2000).
- Orebro MSK Pain Questionnaire (OMPQ) (Linton and Boersma 2003).

The search was limited to self-administered LBP specific, validated tools (Kopec 2000, Roland and Fairbank 2000, Longo, Loppini et al. 2010, Smeets, Köke et al. 2011). This list was not meant to be exhaustive but was meant to shed light on the similarities of the available tools. All the aforementioned tools are paper-based or conducted via an interview and then scored by a healthcare professional who utilised the information accordingly. This method of administering self-assessment tools is effective in helping

therapists decide the best management pathways and establishing a baseline measure of function in some cases. However, it does not support patient autonomy and empowerment by allowing them to use a tool without the presence or supervision of a healthcare professional. In the NHS, patients wait an average of 14 weeks to receive physiotherapy (StatisticsWales 2018), and yet, an autonomous self-assessment tool does not exist to help them manage their symptoms during the wait time, which might feed into their fears and insecurities (Pincus, Burton et al. 2002, Koes, Van Tulder et al. 2006). Table 4 provides a summary of the main available tools, their intended sample, mode of delivery and a description of their function.

Table 4 Low back pain assessment tools

Assessment tool	Intended sample	Mode of delivery	Description
STarTBack (Hill, Dunn et al. 2008)	Primary care LBP patients	Pen and paper	Screen primary care patients with LBP for prognostic psychosocial indicators that are relevant to initial decision making and risk-based treatment stratification
The Oswestry Disability Index (ODI) (Fairbank, Couper et al. 1980)	LBP patients	Pen and paper or telephone	Measures disability in LBP patients in the clinical setting using the following domains: Pain intensity; personal care; lifting; walking; sitting; standing; sleeping; sex life; social life and travelling
The Roland–Morris Disability Questionnaire (Roland and Morris 1983)	LBP Patients aged 16–64 years from all social classes	Pen and paper or telephone	Used to follow patient improvement in clinical settings. Measures functions that are affected by LBP such as working, walking, standing, bending, going to bed, sleeping, dressing, Activities of daily living
Quebec Back Pain Disability Scale (Kocec, Esdaile et al. 1995)	Back pain patients	Pen and paper, mail or telephone	Measures the level of physical disability by measuring activities of daily living that are concerned with bed/rest, sitting/standing, ambulation, movement, bending/stooping, handling of large/heavy objects
Waddell Disability Index (Waddell and Main 1984)	LBP/sciatica Patients aged 20–55	Pen and paper	Measures disability using items concerned with activities of daily living lifting, sitting, standing, travelling, walking, sleeping, social life, sex life, and putting on footwear)
Million Visual Analogue Scale (Million, Hall et al. 1982)	CLBP patients	Pen and paper/ Interview administration*	Investigates pain intensity, disability and function, by assessing body functions (pain, sleep, stiffness and twisting), activities of daily living (walking, sitting, standing and work) and social life
Low Back Outcome Score (Greenough and Fraser 1992, Holt, Shaw et al. 2002)	LBP patients	Pen and paper	Measures current pain, employment, domestic and sport activities drugs and medical services usage, rest, sex life, and activities of daily living
Clinical Back Pain Questionnaire (Aberdeen Low Back Pain Scale) (Ruta, Garratt et al. 1994)	LBP patients	Pen and paper	Investigates the effect of activities of daily living on pain level, location and duration. It also assesses the use of painkillers, weakness, days spent in bed, and pain interference with sleep, physical activities, work, sex life, and leisure

Assessment tool	Intended sample	Mode of delivery	Description
Low Back Pain Rating Scale (Manniche, Asmussen et al. 1994)	Post lumbar surgery for disc prolapse patients	Pen and paper or interview administration*	Investigates the level of pain and disability by assessing activities of daily living such as sleep, housework, walking, sitting, lifting, working, dressing, driving, running, getting up from a chair, climbing stairs, contact with people and expectations of future pain) and physical impairment (back muscle endurance, spinal mobility, patient mobility and use of analgesics)
Resumption of Activities of Daily Living Scale (Williams and Myers 1998)	Injured workers with acute LBP	Pen and paper	Measures the resumption of usual activities since the onset of injury. The activities measured include sleep, sex life, self-care, housework, shopping, social activities, travelling, recreational activities, and employment.
Fear-Avoidance Beliefs Questionnaire (Waddell, Newton et al. 1993)	Acute or chronic LBP	Pen and paper/ interview administered*	A self-report questionnaire assessing fear-avoidance beliefs regarding the effects of physical activities and work on LBP. The Fear-Avoidance Beliefs Questionnaire assesses patient beliefs with regard to the effect of physical activity and work on their LBP. The Fear-Avoidance Beliefs Questionnaire is a patient-reported questionnaire which specifically focuses on how a patient's fear-avoidance beliefs about physical activity and work may affect and contribute to their low back pain and resulting disability.
Back Pain Function Scale (Stratford, Binkley et al. 2000)	LBP patients aged 18-79 years old	Pen and paper	Evaluates the functional status of LBP patient by asking questions about their activities (work, hobbies, and housework) and questions about physical functions (bending, dressing, lifting, sleeping, standing, walking, climbing stairs, sitting and driving)
Orebro Musculoskeletal Pain Questionnaire (OMPOQ) (Linton and Boersma 2003)	Working people with regional pain problems	Pen and paper	This tool is a yellow flag instrument comprised of items focusing on attitudes and beliefs, response to pain, work perception and activities of daily living. This tool was designed in order to aid healthcare professionals in choosing the appropriate intervention that might decrease the risk of long-term disability and failure to return to work.

Key: *Interview administration questionnaires could be completed by healthcare professionals; CLBP: Chronic Low Back Pain; LBP: Low Back Pain

2.6. Low Back Pain Management

For physiotherapists managing patients with LBP it is vital, once screened for red flags, to identify potential risks of chronicity, disability and potential for/or actual repeated sick leave as early as possible, in order to determine timely and specific management techniques for this subgroup of patients (Pincus, Burton et al. 2002, Koes, Van Tulder et al. 2006). As recovery becomes less likely the longer CLBP and disability persist, it is crucial to intervene early. There appears to be a multitude of biopsychosocial factors of how acute LBP becomes chronic, with mounting evidence pointing to psychosocial factors playing a particularly relevant role. Feelings of depression, distress, and somatisation have been reported as contributors to CLBP (Pincus, Burton et al. 2002, Koes, Van Tulder et al. 2006).

A growing focus has been on self-management strategies (self-monitoring of health and health-promoting activities) as critical aspects of the management of LBP (May 2010, Balagué, Mannion et al. 2012). Secondary measures of management range from analgesics to cognitive behaviour therapy (CBT), Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) and multidisciplinary rehabilitation (Koes, Van Tulder et al. 2006, NICE 2016). Antidepressants have been reported as a moderately effective second-line treatment for patients with ongoing LBP (Savigny, Watson et al. 2009).

There is evidence to indicate that exercise, as well as intensive multidisciplinary pain treatment programmes, are effective in managing CLBP. Anti-depressants, analgesics, NSAIDs, CBT as well as spinal manipulation and back schools have some evidence to back their effectiveness. The majority of common management plans only have small and

short-term effects, and several frequently applied treatments have insufficient data to demonstrate clinically relevant long-term benefits (Koes, Van Tulder et al. 2006).

In their most recent guidelines, NICE (2016) emphasised the need to focus on self-management of CLBP by providing patients with individualised advice and information, and to urge people to continue with their normal activities of daily living (ADL). NICE (2016) also stated the need to include CBT as part of a treatment plan. The use of NSAIDs should be considered. However, opioids should only be considered for acute LBP and never prescribed for CLBP (NICE 2016).

It should be emphasised that the guidelines recommended providing information on the nature of LBP (i.e. patient education) as a part of their non-invasive intervention (NICE 2016). Patient education has been described as a tool to enhance self-management and patient empowerment, an increasingly popular concept in healthcare (Glanz, Rimer et al. 2008). Patient empowerment is a concept where patients are given more control and autonomy in order to increase their self-worth and decrease their conformity, which in turn help them in managing their conditions (Anderson and Funnell 2010, Umar and Mundy 2015, Daruwalla, Thakkar et al. 2019). Patient empowerment is usually achieved by providing relevant information, knowledge and education to patients in order to help them reach an informed decision regarding their condition (Daruwalla, Thakkar et al. 2019). However, classic educational approaches focused on biomedical models of pain (Moseley, Nicholas et al. 2004) or a broad explanation of the biopsychosocial approach (George and Engel 1980) are too broad and lack specificity to achieve patient empowerment.

More recently, pain neuroscience education (PNE) has been utilised in order to provide patients with a more specific and detailed explanation of pain (Clarke, Ryan et al. 2011). PNE involves describing and explaining pertinent neurobiology and neurophysiology of pain to patients with relevant conditions (Moseley and Butler 2003, Nijs, Van Wilgen et al. 2011). In order to explain the complex neurobiology and neurophysiology of pain, PNE uses various methods including pictures and metaphors with a focus on the brain's role in people's thoughts and attitudes towards pain and how psychological elements contribute on ongoing pain and disability (Moseley and Butler 2003). PNE can be delivered to patients either individually or in groups, in 1 or multiple sessions (Clarke, Ryan et al. 2011). PNE was first used in 2002 to compliment physiotherapy intervention for people with CLBP and differs from traditional educational strategies like back schools and biomechanical approaches (Moseley 2002, Clarke, Ryan et al. 2011). PNE explains to patients the concept of central sensitisation and how chronic pain is more likely to be caused due to brain hyperexcitability of the CNS than peripheral tissue damage, hence more holistic and comprehensive management is required (Nijs, Girbés et al. 2015).

In a systematic review evaluating the effects of PNE on chronic MSK pain, it was concluded that PNE significantly decreased pain, catastrophising, and perceived disability (Louw, Diener et al. 2011). However, Louw, Diener et al. (2011) included 8 heterogeneous studies in their review (6 RCTs, 1 comparative study, 1 pseudo RCT) which prevented them from performing a meta-analysis on the results. Louw, Diener et al. (2011) were not able to determine the most beneficial PNE quantity or duration with included studies reporting different session numbers lasting between 30 minutes to 4 hours. Moreover, this review included 3 chronic conditions (LBP, whiplash, chronic fatigue syndrome) which could lower its generalisability in the management of CLBP.

In another systematic review and meta-analysis, Clarke, Ryan et al. (2011) investigated the effect of PNE in the management of CLBP. Clarke, Ryan et al. (2011) only included 2 moderate-quality RCTs in their review and found statistically, but not clinically, significant short-term reduction in pain (5 mm on 100 mm VAS; 95%- CI 0, 10.0). The reviewers reported clinically insignificant improvements in physical and psychosocial aspects, and they concluded by stating their inability to list any clinical recommendations due to the small number of studies included. It should be noted that both studies included in this review were performed by 1 of the authors of the PNE manual which might have introduced a conflict of interest and potential bias should be considered (Clarke, Ryan et al. 2011).

A more recent systematic review and meta-analysis exploring the long-term and short-term effects of PNE on pain and disability in CLBP concluded that the addition of PNE to a physiotherapy intervention decreases short-term disability (Wood and Hendrick 2019). This review included 8 RCTs and found that PNE decreased disability with or without physiotherapy intervention. However, the results were more clinically significant with an intervention. This review included 8 moderate quality RCTs with heterogeneous outcome measures which limited the meta-analysis and increased the possibility of indirect effects which might have led to imprecision of the findings (Wood and Hendrick 2019).

Despite the limitations observed in the aforementioned reviews, PNE seems to be a strong candidate for an educational pathway that could be included in a biopsychosocial rehabilitation of CLBP (Moseley and Butler 2015).

During the last 2 decades, there has been a shift in allied health professionals' jobs where they adopted a specialist role in providing more efficient health services. This shift was necessary in order to decrease the waiting times for secondary services and to decrease the workload on GPs. Approximately 20% of LBP patients consult their GPs in the UK, which increases the load on an already understaffed profession (Majeed 2017, Noblet, Marriott et al. 2019). One of these developed services is the MSK Clinical Assessment Treatment Service (MSK CATS) which is delivered in intermediate care (i.e. between primary and secondary care). MSK CATS aims to decrease the stress on secondary services (e.g., physiotherapy, orthopaedic services) by triaging MSK cases, and performing a timely assessment in order to decrease inappropriate referrals, decrease waiting times, and improve efficiency (Dixey and Bamji 2006, Hussenbux, Morrissey et al. 2015). In a systematic review exploring the effectiveness of MSK CATS, Hussenbux, Morrissey et al. (2015) identified 23 studies (1 RCT, 19 observational, 2 audits, 1 prospective quasi-experimental) and found that 72-97% of MSK patients could be managed solely in intermediate care, decreasing the referral rates to secondary care by 20-60%. Hussenbux, Morrissey et al. (2015) also reported that in 46% of the cases, MSK CATS was performed by physiotherapists whose clinical decision making and referral accuracy were on par with physicians in 68 to 96 % of cases. The systematic review concluded that MSK CATS supplied appropriate services to MSK patients by providing timely assessment, self-management advice, and proper referrals to secondary care services (Hussenbux, Morrissey et al. 2015). Even though MSK CATS is a good approach in order to manage NHS services waiting lists, it requires an experienced physiotherapy staff with an appropriate level of skill mix to perform it. Such skills call for further training and governance.

In another effort to decrease the workload on GPs and to decrease the waiting times for secondary care, extended scope physiotherapists (ESP) were introduced in the NHS as first contact practitioners. ESPs are physiotherapists with advanced skills essential in order to assess, diagnose, and manage MSK conditions. Within this service, patients with MSK conditions can self-refer themselves directly to a physiotherapy service or see an ESP based in general practice (Trøstrup, Juhl et al. 2018). In a recent audit reviewing the first contact practitioners service for MSK conditions in the NHS primary care practice, data was captured for 2 years of the service in 2 different practices (Monteith, Turner et al. 2019). This audit included 8417 patients and found that the majority of these patients (87.3%) were managed within primary care, and 60.4% of those patients only needed self-management, while less than 1% of patients needing to see a GP after ESP assessment (Monteith, Turner et al. 2019). The audit concluded that ESPs could effectively serve as first contact practitioners for people with MSK conditions (Monteith, Turner et al. 2019). ESPs are a viable option that could help decrease the overload on physiotherapy waiting lists; however, specialised education is needed in order to fill in the demands across the NHS. Furthermore, concerns have been raised that expanding the role of physiotherapists into first line of contact could increase the legal vulnerability of the system due to the lack of available competency standards examining the liability and responsibility of ESPs as first contact practitioners (Lahey and Currie 2005, Crane and Delany 2013)

In a decision to help patients on waiting lists and decrease the load on physiotherapy services, another service that was developed in a number of regions in the UK where PhysioDirect, a telephone-based free NHS physiotherapy assessment and advice treatment pathway, was introduced (Mant and Pape 2017). PhysioDirect is an approach

where patients call a physiotherapist for an initial, subjective assessment and advice, then receive written self-management advice via post (Salisbury, Foster et al. 2009). This approach is managed by qualified MSK physiotherapists who follow a computerised algorithm in order to conduct a structured assessment and appropriate advice. In this approach, patients are only invited to a face-to-face physiotherapy session if the telephone assessment determined there is a need for further investigation or if patients did not improve after following the telephone and written advice (Salisbury, Foster et al. 2009).

Liu, Dickerson et al. (2018) investigated the usefulness of PhysioDirect where they surveyed 30 physiotherapists and interviewed 4, all of whom had experience within the back pain services (57% of participating physiotherapists were directly involved with PhysioDirect). The study concluded that while the concept of early physiotherapy intervention was essential, PhysioDirect had a few limitations. PhysioDirect seemed to assume and depend on patients capabilities in memorising the suggested verbal advice, understanding the posted advice, describing symptoms or knowing certain anatomical features (Liu, Dickerson et al. 2018). In a large pragmatic trial, Salisbury, Montgomery et al. (2013) assessed the effectiveness and cost-effectiveness of PhysioDirect. In this study, patients were allocated to 2 pathways; PhysioDirect (n=1506), and usual care (n=743) where their data was collected at baseline, 6 weeks, and 6 months via postal questionnaires and clinical records by researchers blinded to patient allocation. Out of the PhysioDirect pathway sample, 97% were of white ethnicity. However, no further elaboration on ethnicities or accent variations were reported. Salisbury, Montgomery et al. (2013) found that patients were less satisfied with PhysioDirect than usual care, the costs were similar for both services (£198.98 and £179.68 for PhysioDirect and usual

care respectively), and the gained quality of life was similar in both arms (difference in means=0.007). The RCT concluded that PhysioDirect is as clinically effective as usual care but with faster access to care. PhysioDirect is a good pathway for earlier physiotherapy involvement; however, being a telephone-based service that involves the time of both physiotherapists and patients, a few problems might arise. These include the limited 'opening hours' of the service, busy or unclear telephone connections, and misunderstandings due to language and accent barriers (Mant and Pape 2017).

In another study, Geraghty, Stanford et al. (2015) developed SupportBack, an online intervention platform for LBP. SupportBack was designed in order to provide tailored self-management packages for people with LBP with the aim of supporting their gradual goal setting, assist in tracking their activities, and supplement them with personal feedback. It also focuses on providing advice, reassurance and promotion of physical activity. The content of SupportBack was developed using a person-based approach, which is a process that involves in-depth qualitative research methods utilising the target population (Yardley, Morrison et al. 2015). The content of SupportBack was realised by interviewing 22 patients with LBP and exploring their opinions on the content of SupportBack based on their Experience with LBP (Geraghty, Stanford et al. 2015).

In a feasibility RCT, the viability of SupportBack, which was delivered in 6 sessions, was explored using 3 arms: (1) usual care from a GP without SupportBack, (2) usual care with SupportBack, (3) usual care with SupportBack and additional physiotherapist telephone support up to 1 hour. Several self-assessment questionnaires were used in this feasibility RCT to measure the change in each arm. The questionnaires were completed at the beginning of the trial and after 3 months follow up and included the following:

1. Physical disability was measured using the Roland-Morris Disability Questionnaire.
2. Pain intensity was measured using a numerical rating scale for current, average and least pain in the last 2 weeks.
3. Troublesome days in pain over the past 4 weeks was measured using a single item.
4. STarTBack was used to measure the risk of continuing disability.
5. Fear of movement was assessed using the Tampa Scale of Kinesiophobia (TSK).
6. Catastrophising was measured using the Pain Catastrophising Scale.
7. Physical activity was measured using the International Physical Activity Questionnaire Short Form.
8. The impact of intervention and quality of care was measured using the Patient Enablement Instrument.

In addition, participants were questioned on frequency and type of back pain relief activities they did within the 3 month period. In this feasibility RCT, 87 patients with current LBP were recruited during follow up it appears that usual care with SupportBack and physiotherapists telephone support had an improved Roland-Morris Disability Questionnaire and numerical rating scale when compared to the other 2 arms. Geraghty, Stanford et al. (2018) also reported small improvements in fear-avoidance beliefs across all arms, and an increased number of patient classified as low risk in STarTBack in the usual care with SupportBack (60%–70%) and the usual care with SupportBack and physiotherapist telephone support arms (33%–74%). The results indicate the viability of having SupportBack and physiotherapy support as a primary care intervention approach.

As a conclusion, the authors confirmed the feasibility of an RCT to examine SupportBack's clinical and cost-effectiveness in primary care LBP patients. Geraghty, Stanford et al.'s (2018) study showed some positive results for internet interventions in NHS primary care. However, it would be interesting to see if SupportBack is able to improve symptoms associated with LBP without the GP usual care or physiotherapy support. The theoretical underpinning of the content of SupportBack was not reported in this feasibility protocol (Nicholl, Sandal et al. 2017). However, the RCT of the clinical and cost-effectiveness of SupportBack is being conducted (Geraghty, Stanford et al. 2018) and the results could shed more light on the tool, its measurement properties, and theoretical underpinnings.

Other self-management apps are available online. However, they lack transparency in their development, and they usually require payment which limits the availability. For example, Physiowizard® (www.physiowizard.com) is a subscription-based, online self-assessment triage tool for MSK conditions which is available to customers (e.g. private practices, NHS clinics) who hire their services. However, upon searching available literature, no psychometric or proof of concept studies or development of the tool could be found.

The NHS 24 MSK help app (NHS 24 MSK 2019) is available for free online. NHS 24 MSK provides generalised exercises and advice for people with MSK problems depending on their target location (e.g. back, knee, elbow). The developers of this app stated on their website that "The NHS 24 MSK Help app was developed with the help of Scottish patients, doctors, MSK therapists, pharmacists and employment services." but no additional information or studies were found, and no explanation of a theoretical

background was provided by the developers. Physiowizard® and NHS 24 MSK are 2 examples of many available apps that lack methodological foundations and evidence of robustness in terms of reliability and validity.

Self-management has gained momentum in healthcare and its potential downsides should be acknowledged. Self-management could prove to be disadvantageous to some older adults with chronic pain who are already socially and physically isolated. For those adults, a home visit from social and healthcare personnel could possibly be their only regular interaction (Mort and Philip 2014). Therefore, unsupervised self-management could potentially increase their isolation and in extension, increase their psychosocial risk factors. Providing low cost online self-management could also decrease the priority of its user in the healthcare system which might further increase their pain related negative emotions (Griffiths, Lindenmeyer et al. 2006). Another factor that could be a potential barrier to self-management is the possible waning of motivation over time (Devan, Hale et al. 2018). An online self-management tool user could start with high levels of motivation but the lack of external support might decrease that motivation and increase exhaustion over time. Researchers should factor in the aforementioned possible limitations of online self-management and address them accordingly. These limitations could be mitigated by providing intermittent support techniques such as peer support groups and booster treatment sessions (Devan, Hale et al. 2018). BACKonLINE™ is designed to be an early support mechanism for people who are affected by back pain and it is intended to be used while people wait for their physiotherapy appointments. However, if the usage of BACKonLINE™ is extended beyond its original target, intermittent support techniques should be considered and explored.

In summary, despite the abundance of self-assessment questionnaires that can be utilised in a clinical setting and the availability of self-management options in intermediate care, there seems to be a lack of a self-sufficient option for people with CLBP where they can follow an individualised management pathway without waiting for external help from healthcare professionals.

2.7. Health Education and Health Behaviour

Health behaviour is 1 of the most important components affecting a person's responsiveness to treatment, and their general well-being (Gochman 2013). Health behaviour is defined as any personal trait (e.g. motives, beliefs, expectations, values, perceptions), cognitive aspects, personality characteristics, and overt behavioural patterns and habits that influence health, maintenance, restoration, and improvement (Gochman 2013). Preventing permanent disability and decreasing mortality rates through changing health-related behaviour received an increased focus from public health authorities (Glanz, Rimer et al. 2008).

Health education can be defined as the attempt at reconciling the discrepancies between acknowledged theoretically optimal health practices and the actually practiced methods and it can be viewed as being based on the realisation of behavioural change in individuals and groups that would strive to prevent behaviours with detrimental health outcomes and promote behaviours with positive and preventive health outcomes (Glanz, Rimer et al. 2008). Other definitions focused on voluntary, informed behaviour changes where health education is seen as any construct of informative methods aimed at enabling voluntary engagement in behaviours resulting in positive health outcomes (Green, Kreuter et al. 1980, Glanz, Rimer et al. 2008).

The Role Delineation Project defined health education as the active process of providing information to individuals or collectives on matters relevant to their personal health or affecting others (Bruess, Hendricks et al. 1987). Health education today is based on Kurt Lewin's research on group process and development field theory during the 1930s and 1940s. It is not solely the educational effort to affect individual health behaviour. It also involves policy directives, organisational labours, economic aids, environmental processes, community programs and mass media (Glanz, Rimer et al. 2008).

The past 2 decades have seen a dramatic interest in approaches to alter health behaviour, such as adjustments to one's lifestyle and increasing activity to improve health. A reason for this increased concern on behaviour change has been triggered by increasing healthcare costs, the increase in numbers of an ageing population as well as research outcomes connecting individual behaviours to causes of disability including CLBP. International organisations are raising awareness of the growing pressures of diseases and health inequalities and the heightened interest in behavioural and social determinants of health behaviour change has led to multiple public and commercial service programs as well as training programs (Short and Mollborn 2015).

This growing challenge of disease is not an isolated one, but a global concern. According to 1 study of the effect of chronic diseases conducted in 23 low to middle-income nations, chronic disease accounts for 50% of disease burden in 2005 and projects an estimated loss of nearly 84 billion U.S. dollars by 2015 if no measures are taken to improve the situation (Mathers and Loncar 2006). Measures such as adjustments to the health care system can create new opportunities for health education of the public.

Improving patient-centred communication, as well as increasing respect for patients' rights, can help enhance health outcomes (Arora 2003, Epstein and Street 2007).

Shared decision making is also acknowledged today as crucial for effective health care (Levinsky 1996). There is also a growing level of awareness of problems related to shared decision making (Elwyn, Edwards et al. 1999), as patients are more frequently searching for health information independently via the internet (Hesse, Nelson et al. 2005), yet differences in search activity levels persist between groups of lower and higher socioeconomic status (e.g. people with higher income seek information more than those with lower income) (Ramanadhan and Viswanath 2006).

Research in health education and behaviour has quickly expanded during the past few years, and health education is being increasingly acknowledged globally as a method to optimise public health interventions and fulfil public health aims. The improved results of interventions based on a theoretical basis compared to interventions developed without a theoretical framework have been demonstrated by multiple systematic reviews (Ammerman, Lindquist et al. 2002, Legler, Meissner et al. 2002).

2.7.1. The Emergence of E-Health

The continued development of electronic communication technologies, as well as innovative applications of older technologies like the telephone, bring with them new challenges as well as opportunities. A wide range of electronic media for interactive health communication, such as apps, the internet in general or CD-ROMs, can function as providers of personal health information, schedules and social support for adjustments to health behaviours (Viswanath and Tse 2005, Ahern, Phalen et al. 2007).

Using these new technologies, individuals may globally interact with others with comparable health challenges (Bukachi and Pakenham-Walsh 2007).

Yet not all populations benefitted from the results of this communications revolution equally (Viswanath and Tse 2005). E-health strategies are becoming an increasingly relevant part of the various available methods for individuals in health behaviour and education. Many health behaviour and education strategies can benefit from the use of wireless technology as well as the internet and software applications.

The internet has been used in healthcare to deliver related services for over a decade and its viability has been a focus of research (Wantland, Portillo et al. 2004, Murray, Warm et al. 2005, Stinson, Tucker et al. 2009, Dobson, Hinman et al. 2014, Rod 2016). In a scoping review, Amann, Zanini et al. (2016) included a total of 144 studies from the year 2000 to 2014 in order to explore the impact of online platforms on people living with chronic conditions and noted that more than half of the included articles (n=86) were published between 2012 and 2014. Amann, Zanini et al. (2016) concluded that online platforms have great potential in contributing to a patient-centred approach in healthcare. However, they failed to assess the quality of the included studies which might affect the viability of their results. Despite the lack of quality assessment of the articles, Amann, Zanini et al. (2016)'s study highlighted the rapid increase of E-health related articles in the literature.

In another study by Malone, Harris et al. (2004), the impact of online information presented by patients in the UK's primary care service was explored. Malone, Harris et al. (2004) surveyed 272 healthcare professionals (GPs, nurses, and other healthcare professionals) and interviewed 8 healthcare professionals from their sample. Malone,

Harris et al. (2004) concluded that 134 of the healthcare professionals (74% of the sample) reported that their patients disclosed that they looked up their symptoms online before their consultation. However, the study did not report the sources of the internet information, provide detailed demographics of the sample, or investigate the reasons from a patient point of view. Therefore their results should be interpreted with caution.

In the UK, the NHS launched 2 websites (NHS.UK and NHS Direct Online), in order to give the general population a reliable source of information and care online (Agrell and Wålinder 2002). These websites gained popularity with the public, and it was estimated that 6 million people accessed them within 2 years of their launch enabling better-informed decision making, educating the public, and enhancing patient's quality of care (Stroetmann, Jones et al. 2006). This evident popularity indicates that the general public is ready and receptive to using the internet to seek help for their respective condition, and it shows their awareness of how to find reliable sources.

In a study that evaluated the effects of an individualised online self-management programme on 645 people with chronic pain conditions, quality of life has increased, and pain intensity decreased at 1 and 6 months from baseline (Nevedal, Wang et al. 2013). In a Cochrane review, online psychological management programmes (e.g. CBT) showed a decrease in pain, depression, anxiety, post-intervention and disability on follow up (Eccleston, Fisher et al. 2014). In a pilot study evaluating the effectiveness of an online self-management programme, it was suggested that such programmes might result in statistically significant improvements in health efficacy, fatigue, and depression (Poole, Mendelson et al. 2014).

Bender, Radhakrishnan et al. (2011) conducted a systematic review exploring if pain can be managed via the internet and searched for RCTs from 1990 to 2010. Bender, Radhakrishnan et al. (2011) included 17 studies in their review, 6 of which were of high quality. The results of the review showed that the majority of cognitive and behavioural studies reported a decrease in pain (n=7), functional limitations (n=4), and treatment costs (n=3). However, the effects of an online programme on anxiety (n=2) and depression (n=2) were inconsistent (Bender, Radhakrishnan et al. 2011). The review concluded that online management programmes are beneficial for people who are experiencing pain. However, it is unclear what type of patient would achieve the most benefit (Bender, Radhakrishnan et al. 2011).

In a more recent RCT, teaching people (n=417) simple positive activities via the internet has shown to decrease pain, and it was suggested that the internet could provide a sustainable, and accessible health intervention option (Hausmann, Parks et al. 2014). Moreover, other studies concluded that people are relying more on the internet for health information and people in pain will seek out online resources and will share their pain experience and advice on social media (Vance, Howe et al. 2009, Ahlwardt, Heavilin et al. 2014, Wicks, van Staa et al. 2014).

However, there is the risk of technological opportunities, rather than theories of health behaviour, influencing the use of new technologies (Ahern, Phalen et al. 2007). Furthermore, new technologies can negatively affect outcomes by providing false or misleading information, influencing the patient-provider relationship or suggesting inappropriate methods of self-management (Eng, Gustafson et al. 1999, Neuhauser and Kreps 2003).

Health behaviour and health education are being increasingly impacted by these emerging interactive health communications (Hesse, Nelson et al. 2005). They also present new opportunities for behavioural medicine and preventive medicine (Noell and Glasgow 1999, Fotheringham, Owies et al. 2000). However, the deficiency of individualised and tailored information online and the abundance of general, and often untrustworthy, information results in a knowledge gap and confusion for people seeking guidance regarding their CLBP (Schulz, Rubinell et al. 2007). In a recent systematic review, Ferreira, Traeger et al. (2019) investigated the credibility, accuracy, and comprehensiveness of endorsed online LBP treatments (acute, chronic, and radicular) and recommendations. Ferreira, Traeger et al. (2019) focused on freely accessible websites that have been endorsed by a trustworthy source (i.e. government agencies, universities, hospitals, professional societies) and compared the LBP treatments available on the websites to 2 guidelines: the NICE (2016) guidelines and the American College of Physicians (ACP) LBP (2017) guidelines (Qaseem, Wilt et al. 2017). After reviewing 79 websites from 6 English speaking countries (UK, Australia, Canada, New Zealand, South Africa, USA), and a total of 1125 treatment recommendations, Ferreira, Traeger et al. (2019) found that only 43.28% of the treatments were accurate (i.e. followed either NICE 2016 or ACP 2017) and concluded that freely accessible LBP websites had low credibility standards, lacked comprehensiveness, and generally provided inaccurate information.

In addition, online back pain websites tend to be too general (Payne and Kiel 2005), fail to capture patients interests, and usually fail to meet user expectations (Weissenberger, Jonassen et al. 2004, Schulz, Rubinelli et al. 2010). Online back pain management advice websites tend to provide access to a large amount of information, leaving the burden of

choice on what to follow on the patient, which might overwhelm them or lead them to follow an inappropriate self-management pathway (Schulz, Rubinelli et al. 2010). In order to create helpful, effective, and tailored guidance and self-management online, and to limit unverified and unrecommended advice, healthcare professionals must assume an active role in developing and maintaining online information and self-management strategies (Butler and Foster 2003). However, due to the heterogeneity, poor description and lack of detail of online interventions in literature, implementing digital self-management clinically is proving to be a challenge (Nicholl, Sandal et al. 2017).

Moreover, online information has been shown to positively affect people with LBP (Koestler, Libby et al. 2005). Results from an RCT conducted on 580 people suffering from recurrent CLBP showed that an e-mail discussion group had a positive effect on health status and decreasing disability (Lorig, Laurent et al. 2002). In this study, the participants were split into a control group and an intervention group. The intervention group received a back pain help book and a videotape explaining how to maintain an active lifestyle with back pain (Moore, Lorig et al. 1999, Lorig, Laurent et al. 2002). Even though this study concluded that the discussion group reduced disability by 34% (effect size=0.3), it could be argued that the result is due to the supplemented back book and/or videotape rather than the discussion group itself.

In an RCT by Buhrman, Fältenhag et al. (2004) (n=56), it was concluded that an 8-week online back pain education and CBT-based self-help programme had a significant positive effect on improving catastrophising and decrease pain. Buhrman, Fältenhag et al. (2004) had intended to assess the effectiveness of self-help. However, they provided

weekly support via telephone with additional individualised education which could be the reason for the observed positive outcomes.

In a systematic review evaluating smartphone apps for the self-management of LBP, 61 apps were evaluated (Machado, Pinheiro et al. 2016). This review targeted apps that provided self-management suggestions and cross-referenced them with the NICE (2016) guidelines in order to assess if the apps provided evidence-based self-management techniques. Apps were only included in the review if they were in English, available to the general public, and self-contained (i.e. does not require external assistance). This review used a mobile application rating scale, a 23-item questionnaire that measured engagement, functionality, aesthetics, information quality, and overall quality (Stoyanov, Hides et al. 2015). According to Machado, Pinheiro et al. (2016), only 3 apps included interventions not recommended by NICE (2016). These 3 were based on (1) graded motor imagery, (2) Qigong exercises (holistic exercises comprised of repetitive, coordinated movements, breathing, and meditation), and (3) brainwave entrainment, which is the brain's hypothesised ability to sync its brainwave frequencies with rhythmic external visual, auditory, or tactile stimuli (Fredricks 2008). The remainder of the apps included either biomechanical exercises, mind-body exercises, and education plus biomechanical exercises. Interestingly, only 6 (10%) apps included a combined education and exercise program, an approach which is endorsed by NICE (2016). Machado, Pinheiro et al. (2016) concluded that available LBP self-management apps were of poor quality according to mobile application rating scale, however, Machado, Pinheiro et al. (2016) did not investigate the effectiveness of these apps on patient outcomes, nor did they investigate whether or not they are based on any theoretical framework.

In a move to promote health technology usage and filter health-related apps to meet the NHS standards, NHS digital started an NHS Apps Library which launched on April 2017 aiming to provide a gateway to available, NHS approved apps (NHS Digital 2018). NHS Apps Library includes 70 apps to date divided into 16 categories (Appendix 1) with only 1 spine-related app (SpineWise App) available to date. The SpineWise app is a desk exercise app developed by an NHS Spinal Specialist Physiotherapist in order to prevent or treat neck and back pain. However, other than the app description on the App store, no further information could be found regarding the process of development, credibility standards criteria used, or validation of the app and no peer review sources could be identified.

In summary, there is an abundance of generalised information online, and there seem to be acceptance from patients to use online resources. However, there is a lack of an evidence-based, peer-reviewed, self-contained self-assessment and self-management online resource for people with CLBP.

2.8. Summary and Justification for the Study

CLBP has a lifetime prevalence of up to 84%. Around one-third of the adult UK population suffer from CLBP annually. The most common process for management of CLBP is a face to face appointment with a physiotherapist. The problem is that currently, the maximum wait for physiotherapy services is 14 weeks, with 6.1% of patients waiting over 14 weeks for these services (StatisticsWales 2018).

Contemporary literature supports the notion that pain is a complex experience that might extend beyond tissue healing and can be influenced by biological, social, and psychological factors. This new understanding of pain led to the conceptualisation of the

biopsychosocial approach of pain in order to provide targeted and comprehensive management. Within the biopsychosocial model, the mechanisms-based classification of pain is being utilised in physiotherapy literature in order to guide management (Chimenti, Frey-Law et al. 2018). The mechanisms-based classification of pain proposes that persistent LBP is associated with amplification in pain processing in the CNS (central sensitisation), which may drive symptoms, resulting in poorer outcomes and requiring longer management. However, according to this classification system, pain cannot be purely segregated into centralised or peripheralised. Instead, it is presented as a mixture of both types with different degrees of dominance (Tracey, Woolf et al. 2019). A self-assessment and self-management online tool that focuses on the dominance of either centrally sensitised pain or peripherally sensitised pain does not exist to the author's knowledge.

The purpose of this study was to develop a self-assessment and self-management online tool (BACKonLINE™), which can be used by people with CLBP who are on physiotherapy waiting lists. BACKonLINE™ aims to assess CLBP according to a mechanisms-based classification within a biopsychosocial construct. Once BACKonLINE™ was developed, its readability, reliability, and validity were assessed. Participating physiotherapy experts were asked to provide potential relevant self-management techniques. In addition, the study also explored the patient experience while using BACKonLINE™ in terms of potential mode of delivery for BACKonLINE™, and their perception of what constituted self-management techniques.

2.8.1. Study Questions

This study attempted to answer the following questions:

1. Can consensus by MSK physiotherapists be achieved on self-assessment items to differentiate between predominantly centrally sensitised CLBP and predominantly peripherally sensitised CLBP?
2. Will BACKonLINE™ be able to discern between centrally sensitised and peripherally sensitised LBP?
3. Is BACKonLINE™ readable and would people with CLBP be able to understand BACKonLINE™?
4. Will BACKonLINE™ have test retest reliability when completed by the same CLBP patient twice, 1 week apart?
5. Is BACKonLINE™ a valid tool for discerning between centrally sensitised and peripherally sensitised CLBP when compared to other validated questionnaires?
6. What is the patient experience when using BACKonLINE™?
7. How does physiotherapist recommended self-management techniques compare to LBP patients expected self-management techniques?

2.8.2. Aims of the Study

This study has 3 main aims:

- To develop a self-assessment and self-management online tool (BACKonLINE™) which could be used by people with CLBP on NHS physiotherapy waiting lists.
- Assess the readability of the self-assessment part of BACKonLINE™
- Test the reliability and validity of the self-assessment part of BACKonLINE™

2.8.3. Objectives

Phase 1: To develop the self-assessment part of BACKonLINE™ and establish a preliminary conceptualisation of the self-management strategies using a modified E-Delphi study

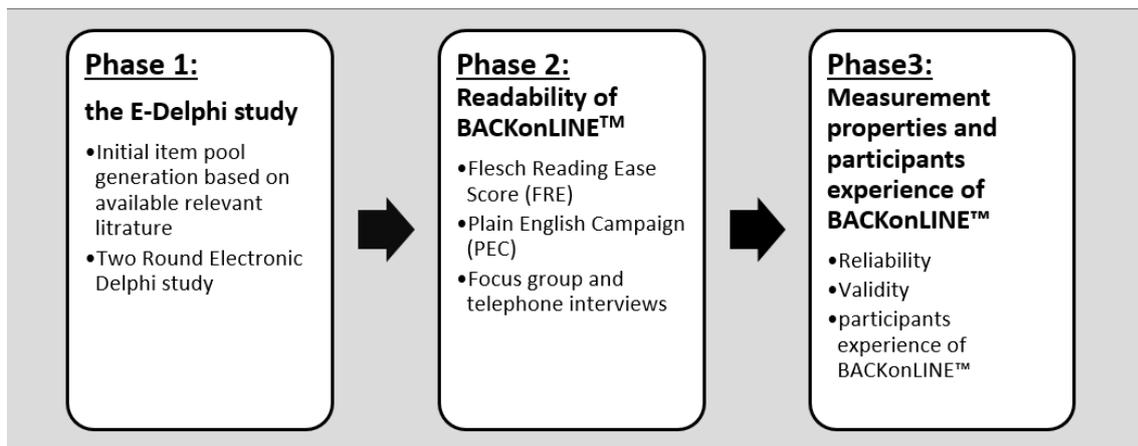
Phase 2: To explore the readability and clarity of the self-assessment part of BACKonLINE™ in people with CLBP

Phase 3: To assess the test retest reliability and construct validity of BACKonLINE™, establish the cut-off scores in discerning between centrally sensitised and peripherally sensitised CLBP and explore the CLBP patients' experience with using it BACKonLINE™

2.8.4. Study Design

This study was divided into 3 phases, and each phase had several stages within it (Figure 1). As a result of Phase 1 and 2, the self-assessment component of BACKonLINE™ was developed. Suggestions for the self-management part were explored using experts in Phase 1 and CLBP patients in Phase 3. Phase 3 also tested the measurement properties of BACKonLINE™ and explored the patient's experience while using it.

Figure 1 Study Design



In Phase 1, the self-assessment items of BACKonLINE™ were developed using the following stages:

- Stage 1: Initial item pool generated based on the literature search. This resulted in BACKonLINE™ Version 1
- Stage 2: Two round E-Delphi study. Round 1 of the E-Delphi study resulted in Version 2 of BACKonLINE™, and experts suggested self-management advice for predominantly centrally sensitised, and peripherally sensitised (neuropathic and nociceptive) LBP. Round 2 of the E-Delphi study resulted in Version 3 of BACKonLINE™.

Phase 2 assessed the readability of BACKonLINE™ Version 3 in 3 stages:

- Stage 1: BACKonLINE™ Version 3 was assessed using the Flesch Reading Ease (FRE)
- Stage 2: BACKonLINE™ Version 3 was assessed by the Plain English Campaign (PEC) resulting in BACKonLINE™ Version 4
- Stage 3:
 - Part A: Focus group resulting in BACKonLINE™ Version 5.

- Part B: individual telephone interviews were conducted in order to assess the readability of BACKonLINE™ Version 5, resulting in maintaining BACKonLINE™ Version 5 as the final version.

Phase 3 assessed the measurement properties and the participants' experience of using BACKonLINE™ Version 5 with the following stages:

- Stage 1: Reliability: assessment of test retest reliability and internal consistency of BACKonLINE™ Version 5.
- Stage 2: Validity:
 - Part A: construct validity of BACKonLINE™ Version 5 was assessed.
 - Part B: cut-off scores: BACKonLINE™ Version 5 was explored using the Receiver Operating Characteristic (ROC) analysis.
- Stage 3: Participant's experience with using BACKonLINE™ Version 5 was explored using individual face-to-face interviews.

Phase 1: Development of BACKonLINE™ - The E-Delphi Study

Phase 1 is detailed in Chapters 3, 4, 5 and 6:

- Chapter 3: Phase 1 literature review
- Chapter 4: Phase 1 methods
- Chapter 5: Phase 1 results
- Chapter 6: Phase 1 discussion

Chapter 3. Phase 1 Literature Review

3.1. Introduction

A key focus during the development of any questionnaire or assessment tool is the determination of the items it contains, and these, in turn, constitute its inherent worth (Streiner, Norman et al. 2015). In order to develop a comprehensive assessment tool, it is necessary to utilise a method of surveying a wide range of expert opinions (Streiner, Norman et al. 2015). Appropriate methods may include focus groups or interviews, in order to gather multiple viewpoints (Streiner, Norman et al. 2015), together with techniques based on consensus such as the Delphi technique (Keeney, Hasson et al. 2001).

Focus groups can take many forms but have the advantages over interviews in that they benefit from the exchange of opinions and interactions between participants, in addition to the available variety of individual viewpoints and the number of opinions gathered (Pett, Lackey et al. 2003). However, focus groups encounter difficulties in the logistical aspects of the organisation such as determining suitable dates and venues for all participants, as well as differences in personality which may lead to dominant voices in the group (Leung and Savithiri 2009). These difficulties can be overcome by utilising a consensus-based technique such as the Delphi technique, which can be delivered online, especially when more than a single meeting is necessary or a wide (international) group opinion is required (Parahoo 2014). Focus groups were considered as a method of

gathering expert opinions in this study, however, due to the recruitment of an international expert panel, and the disadvantages inherent in a focus group, the E-Delphi method was chosen. An E-Delphi is a Delphi study conducted online without the use of any postal surveys. This chapter reviews the merits of the different types consensus methods with a focus on Delphi techniques.

3.2. The Delphi Study Technique

The Delphi study technique was originally developed in the 1950s by Dalkey and colleagues at the Research and Development Corporation, as a method of forecasting the development of new technologies (Vernon 2009), and now the Delphi technique is a commonly applied consensus method of opinion gathering in a variety of fields including education, business, policymaking, economics, technology and health sciences field (Hasson, Keeney et al. 2000, Hilbert, Miles et al. 2009, Vernon 2009). It has merit as a method of arriving at a consensus of the most critical elements of a topic which has previously had few or inconclusive definitions (Hasson, Keeney et al. 2000), and has been applied in the prediction of future models of disease and management as well as the creation of clinical guidelines (Mullen 2003).

There are other consensus methods such as the Nominal Group Technique, which is a structured face-to-face meeting with experts in a focus group setting (Harvey and Holmes 2012). The Nominal Group Technique has the ability to generate ideas and acquire answers quickly. However, it has been criticised for the lack of a well documented and agreed-upon numerical level of agreement (McMillan, King et al. 2016). Additionally, getting participants in 1 place at the same time has been proven to be 1 of the main disadvantages of this technique (McMillan, King et al. 2016).

As an iterative process where the experts receive multiple rounds of data which they rank or vote on until a degree of consensus is achieved (Keeney, Hasson et al. 2001), the Delphi technique has multiple advantages and disadvantages.

Delphi studies are conducted with people knowledgeable on the subject matter, who form a panel of informed people (McKenna 1994). Such people are generally named “experts”, which is a highly debated term, especially in terms of how to correctly identify an individual as an expert. Strauss and Zeigler (1975) have dismissed the practice of defining 1 group representing expert opinion as scientifically untenable since participants in Delphi studies are usually interested and engaged with the topic being investigated. The controversy of defining an expert continues to the present day, and the term is still debated in the literature (Keeney, Hasson et al. 2001, Mullen 2003, Baker, Lovell et al. 2006, Jorm 2015). In order for the results to be representative of contemporary perceptions and knowledge, selected experts should be as impartial as possible, while still being interested in the research topic (Goodman 1987).

It is acknowledged that participants may be more likely to engage in the Delphi process if they would be affected by the result, and thus the method is susceptible to both subject and researcher bias (Hasson, Keeney et al. 2000). Researcher bias is where the expectations or desires of the research team regarding the results of the investigation influence the final results, which endangers internal validity (Smith and Noble 2014).

As the correspondence with Delphi participants takes place via email or mailing documents, the Delphi technique mitigates the risk of domineering individuals and

would lower the potential for group setting bias which is considered a strength of the Delphi technique (Williams and Webb 1994).

Another strength of the Delphi technique is that it ensures the anonymity of the participant and potentially an equal share of contribution by participants, although this cannot be guaranteed as participants may only complete a percentage of the questionnaire (Whitman 1990). Other positive aspects are that Delphi techniques, particularly online versions, have low costs for delivery and are not hindered by as many potential locational limitations including living in different time zones, and potential transport difficulties (Jones and Hunter 1995, Keeney, Hasson et al. 2001). This compares to the Nominal Group Technique, which has expert panels meeting personally to discuss items and agree on a consensus (Jones and Hunter 1995, Vernon 2009).

The advantages of an E-Delphi study are numerous: it is environmentally friendly, it potentially facilitates more rapid feedback to panel members and the research team and being electronic speeds up analytical processes due to almost simultaneous data transfer to statistical analytical packages (Keeney, Hasson et al. 2011). An E-Delphi also eradicates the need for printing forms and postage. Electronic questionnaires also have the potential of being more readily accessible, as recipients may deem the page-by-page e-mail to be easier than completing a printed-out form. A further benefit of conducting E-Delphi studies, which was utilised in this phase, is the automatic prevention of duplicate or missing answers, as the selected online survey generator (www.onlinesurveys.ac.uk) provided the option of reminding participants to answer the questions and did not accept duplicate replies.

However, there are some challenges in an E-Delphi study as it obviously relies on potential participants having an e-mail account. E-Delphi studies encounter the same problem that all questionnaire studies are faced with, namely that the participants are busy and may fail to engage as it may not be a priority in their workload. In the case of experts with administrative staff, anonymity may be in danger due to assistants or secretaries having access to their e-mail accounts. It is crucial for all correspondence to be tagged as confidential and private. Lastly, firewalls in some organisations, particularly in health settings, could potentially block E-Delphi forms or automatically classify them as junk mail.

In summary, the E-Delphi method is easy, inexpensive, and fast and can be used to conduct both classic and modified Delphi studies. The classic Delphi method has been modified by researchers throughout the years, and the following section will highlight both the classic and modified Delphi methods.

3.2.1. The Classic and Modified Delphi Methods

A classic Delphi method follows a procedure that begins with participants determining a catalogue of items, which are then reviewed and rated in the subsequent rounds to determine the consent level of the individual items (Linstone and Turoff 2002). Round 1 in a classic Delphi study generally takes place in the form of an open-ended questionnaire, with the aim of obtaining specific data on a particular topic from the Delphi participants (Custer, Scarcella et al. 1999). The participants' data must then be adapted into the formation of a questionnaire, which serves as the Delphi survey method for Round 2 of data collection (Hsu and Sandford 2007).

A modified Delphi method is any Delphi method that does not follow the form of the classic Delphi. There are no universally agreed-upon rules for the application of the Delphi method, which has led to various modifications and adaptations since its inception (Keeney, McKenna et al. 2010). A widely acknowledged and applied adaptation of the Delphi process is the use of structured questionnaires in Round 1, informed by a comprehensive search of the available literature (Hsu and Sandford 2007, Gobat, Kinnersley et al. 2015, Luedtke, Boissonnault et al. 2016, Wassenaar, van den Boogaard et al. 2017). According to Hsu and Sandford (2007), it is acceptable to adapt and modify the Delphi format where general data on the subject area is already available and applicable. Moreover, the disadvantage of the open-ended nature in Round 1 of a classic Delphi can be too broad and vague which can lead to biased statements from the participating experts, which in turn would lead to biased results (Hsu and Sandford 2007).

Therefore, using items of a closed nature in a predetermined questionnaire via a modified Delphi would establish face and content validity of the questionnaire prior to sending it to the identified experts. In addition to providing the participants with the opportunity to suggest new items in Round 1 of a modified Delphi questionnaire ensured that all areas of interest are covered, and the new suggested items would be rated by all participants in subsequent rounds (Lopopolo 1999, Cook, Brismée et al. 2010, Keeney, McKenna et al. 2010, Rao, Anderson et al. 2010).

Other advantages of a modified Delphi study with close-ended items as highlighted by McCampbell and Stewart (1992) include:

1. Optimisation of study time: using close-ended questions in Round 1 would save time usually spent in a classic Delphi to collect and edit the qualitative data gathered from participants.
2. Minimise dropout rate: participants are usually more inclined to complete a close-ended questionnaire than to write 'essay type' answers. From the participants' point of view, if a questionnaire is fast and easy to complete, they are more likely to be able to fit it in their schedule and submit their answers.
3. Quality control: by having close-ended, literature driven items, the researcher ensures that important items, that could have been omitted or forgotten by participants, would be included in Round 1 of the Delphi study.

Since there is literature concerning LBP mechanisms (central and peripheral sensitisation of LBP) available, it was decided that a modified, close-ended E-Delphi method for developing BACKonLINE™ while giving participants the option to suggest new items in Round 1 was most suitable for this study. This decision was made due to the aforementioned advantages of a modified Delphi study with close-ended items.

In the current study, after deciding the mode and type of the Delphi study (modified E-Delphi study), it was essential to determine the level of consensus. The next section presents the level of consensus within a Delphi study.

3.2.2. Level of Consensus in a Delphi Study

The level of consensus does not have a universally agreed-upon value and is usually individualised to the aim of the study, available resources, and sample number (Hasson, Keeney et al. 2000). It has been argued that the level of consensus should reflect the gravity of the subject research.

For example, a life or death situation like taking a person off life support would require a 100% consensus, but if the subject was about choosing an appropriate colour or design for a nurse's uniform, 51% could be regarded as adequate (Keeney, Hasson et al. 2006). A level of consensus equal to or higher than 51% was suggested by McKenna (1994) in a methodological article reviewing the Delphi method in nursing research. However, in a more recent methodological article by Keeney, Hasson et al. (2006), a level of consensus equal to or higher than 75% was proposed.

In other studies, Green, Jones et al. (1999) when seeking consensus on information requirements for GPs, and Finger, Cieza et al. (2006), aiming to determine the International Classification of Functioning, Disability and Health by physiotherapists, consensus was set to 80% or higher (Green, Jones et al. 1999, Finger, Cieza et al. 2006), while Sumsion (1998) preferred a consensus setting of 70% or higher.

In another study by McCarthy, Rushton et al. (2006) that covered physiotherapy examinations of non-specific LBP, using a Delphi method, a consensus degree of 75% \pm 5% was deemed appropriate. Although McCarthy, Rushton et al. (2006) stated that they set the level of consensus for their study prior to data analysis, they did not explain the rationale behind their chosen level of consensus.

Numerous Delphi studies are used to develop policies for service development or research funding. Therefore, having a consensus of 51% might decrease morale or elicit dissension among the participants who voted for the items that only received a 50% consensus. A mere 1% difference between whether there is consensus on the subject or not appears to be too severe and might be challenging to legitimise (Keeney, Hasson et al. 2006). Whatever level of consensus is chosen for a Delphi study, a research team

should establish consensus before the start of data collection in order to decrease the chance of researcher's bias (Keeney, Hasson et al. 2006).

In a systematic review by Foth, Efstathiou et al. (2016) exploring the use of consensus methods in nursing, it was revealed that 88.2% of the studies included in the review (101 articles included) utilised the Delphi method. However, Foth, Efstathiou et al. (2016) concluded that even though the Delphi method is widely used in nursing and other healthcare literature, the reporting of consensus methodologies to be generally weak. They identified poor reporting in several areas including defining and selecting of experts, defining consensus, stating the number of rounds, generation of initial items, reporting of results and protocol in each Round and number of participants in each Round (Foth, Efstathiou et al. 2016). Therefore, declaration of the level of consensus and reporting of the areas identified by Foth, Efstathiou et al. (2016) were deemed important in the current study in order to increase the quality of the E-Delphi study.

3.2.3. Reliability and Validity of the Delphi Technique

The Delphi technique has faced much criticism in the past, including claims that it has no evidence of reliability, the argument being that 2 or more panels would never be guaranteed to arrive at the same result based on the same information (Williams and Webb 1994, Walker and Selfe 1996). However, other researchers such as Ono and Wedemeyer (1994) have found the method does generate valid data. In their study, they replicated a Delphi study carried out 16 years earlier, after including both experts who had participated in the original study as well as newly added experts. Ono and Wedemeyer (1994) concluded that that the findings of the previous study accurately

matched current findings with respect to the forecasting of communication development.

Criticism has been raised with respect to the technique in terms of its validity. According to Goodman (1987), the researcher should have no part in the process of the survey itself or any of its rounds, as it may have significant implications for face validity, which can be affected by what the researcher perceives to be logical. However, Goodman (1987) further stated that if the participants of the study are appropriate to the field of expertise relevant to the subject, then the content can be expected to be valid.

Given how the criticisms reported above could be directed at any qualitative research method, it may be prudent not to review the Delphi method following the psychometric criteria intended for more post positivistic (quantitative) methods, and instead follow more fitting constructivist (qualitative) criteria such as applicability, confirmability, credibility or transferability of results (Hasson, Keeney et al. 2000).

The Delphi method combines the assumption that multiple viewpoints arriving at the same conclusion are less likely to be wrong than an individual, with the strength of critical discussion and review, thus increasing validity. Such validity may be endangered primarily by the need for aligning predictions (Hill and Fowles 1975), which puts the Delphi's forecasting potential in doubt. However, Goodman (1987) stated that the use of participants' knowledge of and engagement with a subject as well as multiple rounds of a questionnaire aid in improving the content validity.

3.3. Participants: The Expert Panel for the Delphi Study

The experts selected for the panel of any Delphi study must be suited to the research topic, depending on how specialised it is and what expertise is required, a homogeneous panel may be necessary; thus purposive sampling is utilised (Vernon 2009).

Purposive sampling (also referred to as selective, subjective or judgement sampling) is a sampling method in which the selection of participants is based on the researcher's own assessment of the available candidates (Polit, Beck et al. 1997). This sampling technique is part of a field of non-probability sampling techniques (Hasson, Keeney et al. 2000), which do not ensure representativeness since the selection process is not random. Instead the selection process is based on a specific purpose, namely, to obtain their expert opinion on a specific issue, informed by criteria derived from inherent nature of the subject being investigated (Hasson, Keeney et al. 2000). Where the aim is to obtain expert input, a purposive sample is required in order not to find a broadly representative sample, but instead a sample of expert knowledge related to challenges posed by the research (Fink and Kosecoff 1985). The purposive sampling method has been demonstrated to be 1 of the most efficient and effective sampling methods in use, especially where only a limited number of participants can provide primary data due to a study's specific research aims and design (Hasson, Keeney et al. 2000, Black, Edsberg et al. 2011). Even though purposive sampling is efficient and convenient, it is subject to the researcher's bias since it does rely on the researcher's judgement. However, this subjective element of purposive sampling can be reduced by clear pre-set inclusion and exclusion criteria. Another disadvantage of purposive sampling is the potential lack of

representativeness of the sample which will affect the generalisability of the results (Acharya, Prakash et al. 2013).

3.3.1. Expert Panel Sample Size for the Delphi study

The Delphi method has no required number of participants (Hasson, Keeney et al. 2000, Vernon 2009), rather the sample should relate to the resources at hand and be representative of the population group it was taken from (Whitman 1990, Sumsion 1998). In order to achieve the most optimal reliability possible, Delphi studies have been recommended to use panels equal to or greater than 20 participants (Mullen 2003, Baker, Lovell et al. 2006). This is due to the reliability potentially diminishing when a panel includes fewer than 6 members, but reliability generally increases above this number of participants (Murphy, Black et al. 1998, Mullen 2003).

However, according to Murphy, Black et al. (1998), including more than 12 participants in the panel does not definitely increase the reliability any further, and reliability is affected by dropout rates. Furthermore, heterogeneous samples require larger sample sizes than homogeneous samples (Baker, Lovell et al. 2006). The Delphi method has been frequently adapted to contain larger panels, in order to include subjects with a greater variety of experiences, rather than the previously common smaller samples of exclusively subject-related experts (Whitman 1990).

Whitman (1990) described sample sizes of 10-50 as appropriate, whereas other researchers (McCarthy, Oldham et al. 2005, Henschke, Maher et al. 2007) have conducted Delphi studies with sample sizes equal to or greater than 50 panel members. Whitman (1990) also argues that larger sample sizes are beneficial to obtaining more diverse opinions and information, which may enhance the validity of the data (Hasson,

Keeney et al. 2000). The drawbacks to very large sample sizes (some previous studies contained ≥ 1000 subjects) (Reid 1988, Butterworth and Bishop 1995) lie in the challenges posed by dealing with an inflated amount of data (Vernon 2009), as well as the increase in time spent after each round to analyse responses (Whitman 1990, Hasson, Keeney et al. 2000).

3.4. Rating Scales in a Delphi study

Rating scales can be subcategorised into summated rating scales, discrete visual analogue scales, Likert-type scales, and Likert scales (Uebersax 2006, Guerra, Gidel et al. 2016). Likert scales enable the ratings of agreement/approval of behaviours or viewpoints along a bipolar linear scale to be recorded (Oppenheim 2000, Pett, Lackey et al. 2003). The linear scale's aim is to produce results separated by equal intervals (Oppenheim 2000), but since descriptive adjectives are being interpreted subjectively, the resulting equality of the adjectives cannot be guaranteed (Streiner, Norman et al. 2015).

Whether the data should be defined as interval or ordinal has been debated at length in literature (Jakobsson 2004, Rhemtulla, Brosseau-Liard et al. 2012, Sullivan and Artino Jr 2013, Streiner, Norman et al. 2015), as some researchers postulate that a numeric value being applied to Likert scale descriptor might more clearly describe interval ranges and further enhance the data's quantitative attributes (Streiner, Norman et al. 2015). Streiner, Norman et al. (2015) also expand on the data from individual Likert scales generally being described as interval data, which allows it to be statistically analysed.

However, other researchers treat data collected with Likert scales as ordinal, since answers are ordered according to numeric values that represent levels of attitude while

presuming a lack of equal space between categories (Hildebrand, Laing et al. 1977). An ordinal scale is defined as a topological scale depicting qualitative attributes that can be arranged into a rank order (1st, 2nd, 3rd and so on). This study used a rating scale of 1–7 for the level of importance. As determining the distance between ranks is not feasible, it can be presumed not to be equal.

Likert scale ranks describe roughly “more or less of something”, such as participant attitudes toward a specific subject or pain intensity values, for example. It should be noted that verbal categories within the ranks are also mutually exclusive and comprehensive (Uebersax 2006).

Hypotheses based on ordinal data are analysed using non-parametric tests, as they do not assume the data is normally distributed. The presumed differentiation may not be homogenous, and the tests are not based on numerical values are placed equally apart. As an example, when completing a test retest reliability trial for a 7 point Likert scale on satisfaction, a participant may choose “3” the first time and “6” the second time. In ordinal scales, this would imply that the responder’s satisfaction had grown from the 3 to the 6 on the scale, yet following interval scales, this information simply indicates that the participant was twice as satisfied the second time compared to the first time, which could interfere with internal consistency (Knapp 1990, Uebersax 2006). Therefore, non-parametric tests order result variables from best to worst, or from low to high (Motulsky 1995), and if the data is not normally distributed, then even interval and ratio data would also need to be analysed using non-parametric tests. It is because of these circumstances that data analysis must prioritise the research question and aims which informs the intent and type of the scale (DeVellis 2016).

The separate items in Likert scales are usually summated into either an overall score of the questionnaire where scores of all items within a questionnaire are added together at the end or as subscales within it where each item is scored individually (Oppenheim 2000, Pett, Lackey et al. 2003, Sullivan and Artino Jr 2013). These summated scores produce a wider range of scores and larger numbers of values that lead to the data being treated as either continuous or interval (Wild 2000). The original Likert scale had a 5 point structure (Figure 2) which served as a base for developing other variations including the 7 point and the 10 point Likert scales (Likert 1974, Pett, Lackey et al. 2003).

Figure 2 The original Likert scale structure, adapted from Uebersax (2006)

Please indicate how much you agree or disagree with each of these statements:			Neither agree nor disagree		
	Strongly disagree	Somewhat disagree		Somewhat agree	Strongly agree
The president is doing a good job.	1	2	3	4	5
The Congress is doing a good job.	1	2	3	4	5
The Secretary of Defense is doing a good job.	1	2	3	4	5

According to Uebersax (2006), a Likert scale is described by the following, widely acknowledged attributes:

1. It comprises of multiple items.
2. Response levels are affixed with successive integers.
3. Response levels are also affixed with verbal tags which signify roughly evenly aligned gradations.

4. Response levels are displayed horizontally.
5. Verbal tags are bivalent (clearly has 2 anchors) and symmetrical around an impartial middle. Being symmetrical indicates an odd number of response levels. Ordinarily, there are 5 levels, but occasionally 7, 9, or 11 levels are utilised.
6. A Likert scale invariably estimates attitude according to the level of agreement/disagreement with a particular item.

In Uebersax (2006)'s estimation, the first 4 characteristics represent the core conditions for what defines a Likert scale. Uebersax (2006) indicates that only the 5th attribute (mentioned above), which specifies that verbal tags must be bivalent and symmetrical, can be treated more leniently, in which case the end result would be a Likert-type item. A scale not fulfilling criteria 2-4 is not really a Likert type scale (Uebersax 2006).

It is established that the number of points on the Likert scale should appropriately represent the participants' ability to differentiate between options (Pett, Lackey et al. 2003, Streiner, Norman et al. 2015). The smaller the number of responses, the less detailed the information produced will be (Streiner, Norman et al. 2015). According to Dawes (2008), 5 and 7 point Likert scales show improved reliability and validity over scales with fewer points.

Although Likert scales are widely used, several factors may endanger the validity and reliability of the scale. Streiner, Norman et al. (2015), discuss an end-aversion bias which saw participants avoiding the bipolar ends of the scale. Furthermore, Likert scales have been known to show a tendency among participants to give only positive answers, or to follow a perception of social desirability in their answering patterns since they have verbal labels unlike other scales that might only have numbers (Pett, Lackey et al. 2003,

Streiner, Norman et al. 2015). Some scales implement reverse scoring in their questionnaires in order to attempt a reduction of this bias effect. Reverse scoring is when an item in a Likert scale goes in the opposite direction (Agree is scored as a disagree and vice versa), however, reverse scoring may increase the complexity of the scale and produce incidentally inaccurate results (Streiner, Norman et al. 2015, DeVellis 2016). Due to the length of some Delphi studies, and the fact that some participants might be fatigued or tired while completing them, reverse-scored items are not generally utilised in order to decrease the potential of accidental inaccuracies (Streiner, Norman et al. 2015, DeVellis 2016).

3.5. Data Analysis in a Delphi study

A Delphi study may have 2 types of data, qualitative and quantitative. The following section shall present the typical types of analysis used with both types of data.

3.5.1. Qualitative Data Analysis

Qualitative data analysis is a multi-faceted process of creating, reducing and coordinating concepts and evaluating large amounts of qualitative data. Through multiple iterations, data are re-examined as concepts and arranged to elaborate on these concepts (Spencer, Ritchie et al. 2003).

Of all the stages that encapsulate the qualitative research process, data analysis has been described as the most complicated as well as the most under-represented in the literature (Thorne 2000). It is argued that the data analysis process must be transparent to the readers with respect to what researchers are doing, how they are doing it and what their methods of analysis are; yet qualitative methods are often underreported

(Thorne 2000, Attride-Stirling 2001, Malterud 2001, Tuckett 2005, Braun and Clarke 2006). The benefit of transparency in qualitative research is clear: if readers are not aware of how data presented to them was analysed, or how researchers arrived at their conclusions, the trustworthiness of the research becomes questionable (Sandelowski 1995, Malterud 2001).

In qualitative data analysis, researchers are responsible for the coding, thematising, and drawing conclusions from the available data, making them the core instruments for analysis and bias (Starks and Brown Trinidad 2007). The various qualitative research methods have their individual techniques for the documentation and evaluation of data analysis processes, but establishing rigour and trustworthiness is the researcher's responsibility (Attride-Stirling 2001, Côté and Turgeon 2005, Ryan, Coughlan et al. 2007). Numerous methods of qualitative data analysis exist (e.g. content, thematic, and framework analysis), differentiated by the approach to data collection and the nature of the data itself (Spencer, Ritchie et al. 2003).

Content analysis is the process of observing and coding data found in text into themes to indicate similar ideas (Morse and Field 1996). In this type of analysis, the content in a text is systematically labelled, its frequency is counted across the text, and divided into major themes. In content analysis, the themes are inductively produced from the collected data and then analysed accordingly (Leedy and Ormrod 2005, Neuendorf 2016). This method of analysis was deemed inappropriate since this study focuses on specific frameworks for the understanding and assessment of CLBP.

Framework analysis is an iterative method where data is organised and managed by the process of summarisation followed by the development of a framework matrix which is

used to analyse the data both contextually and thematically (Parkinson, Eatough et al. 2016). Framework analysis was considered for this study however it was not utilised because it can lead away from the research question due to its nature of drawing from both the data and the themes. It is also a time-consuming process that requires a lot of time and resources that were not available in this research (Parkinson, Eatough et al. 2016).

One of the most widely used qualitative analysis methods is thematic analysis, which is a flexible qualitative method for discovering, examining, and interpreting patterns (themes) within a data set (Braun and Clarke 2006). The next section elaborates further on thematic analysis, which is the analysis method used throughout the current study.

3.5.1.1. Thematic Analysis

Thematic analysis can be described as the pursuit of themes that are essential in understanding and describing a certain event or data (Daly, Kellehear et al. 1997, Rice and Ezzy 1999). During the analysis process, data is examined for recurring patterns, which are grouped into categories and analysed (Braun and Clarke 2006). Thematic analysis has been termed as a translator by Boyatzis (1998) for qualitative and quantitative researchers, because of its ability to bridge the communication gap between the 2 research methods which makes it a desirable analysis process in mixed-method research (Nowell, Norris et al. 2017).

While some authors view thematic analysis as a core method of qualitative analysis processes, given how it provides key skills applied in various other methods of qualitative analysis (Braun and Clarke 2006), others insist that thematic analysis is not a separate method at all, but rather a tool to be drawn upon by researchers for multiple

other qualitative analysis methods (Boyatzis 1998, Ryan and Bernard 2000, Holloway and Todres 2003). Within this study, thematic analysis was considered to be a separate method entirely (Leininger 1992, Thorne 2000, King, Cassell et al. 2004, Braun and Clarke 2006).

There is no generally accepted standard for the required sample size in thematic analysis (Guest, Bunce et al. 2006, Onwuegbuzie and Leech 2007, Emmel 2013), with various authors having proposed sizes of 6 to over 400, changing according to the form of data collection and the scope of the topic (Braun and Clarke 2013, Fugard and Potts 2015). The number is generally not set at the beginning and is instead informed by the research process itself (Sandelowski 1995, Hammersley 2015), as more material is added (such as interviews), and more themes detected up to the point of data saturation (Glaser 1965). Data saturation is commonly described as the cut-off point at which the data begins to yield fewer unexpected findings, and fewer patterns and themes can be identified (O'reilly and Parker 2012).

3.5.1.2. Trustworthiness in Qualitative Research

The measure of methodological rigour in qualitative research is understood as trustworthiness (Lincoln and Guba 1986). While in some research rigour and trustworthiness are used in tandem or even synonymously, in this research, trustworthiness is used to refer to rigour in qualitative research, (Hadi and Closs 2016). Qualitative research has often been criticised for a low level of rigour, when compared to quantitative studies when using the same quantitative measures of rigour (Krefting 1991). A differentiation of the term rigour, as used in quantitative research, from trustworthiness, as used in qualitative research, is required. Agar (1986) has argued that

terms used in quantitative research rigour, like reliability and validity, for example are not congruent to the aims of qualitative research and therefore are not relevant to qualitative research (Krefting 1991). A different language is thus imperative to align with the aims and nature of qualitative research (Agar 1986; Krefting 1991).

As qualitative research is manifold and flexible in its methods, criteria to determine trustworthiness in qualitative research have been developed to address this problem across these approaches (Murphy, Dingwall et al. 1998, Ryan-Nicholls and Will 2009).

These criteria account for the epistemology, methodology, axiology and ontology of qualitative research, such as in the context of bias and sample size. Braun and Clarke (2006) stated that a rigorous thematic analysis could deliver reliable and insightful results; by identifying themes and patterns emerging in the qualitative data through the repeated evaluation of the data across all sources and coding the patterns (Morse and Field 1996). Trustworthiness comprises several elements: truth value (or credibility), applicability (or transferability) of the presented results, consistency (or dependability), and neutrality (or confirmability) (Lincoln and Guba 1986; Sandelowski 1995; Forero et al. 2018).

3.5.1.2.1. Truth Value (Credibility)

Truth value (credibility) is determined by how well the data correlates with the participants' knowledge (Sandelowski 1995, Ryan-Nicholls and Will 2009). One particular method that has been utilised to elevate the degree of credibility of the findings in qualitative studies is respondent's validation of the data (member checking) (Sandelowski 1995). Respondents may be asked to check their own transcripts or validate the general conclusions and findings. Even though member checking could

confirm findings, it could also add challenges if the responders and/or researchers understand the data reported (i.e. the text of the interview transcript for example) findings differently (Murphy, Dingwall et al. 1998, Barbour 2001, Ryan-Nicholls and Will 2009). Participants may also tend to conflate their own opinions with those of the collective group and is generally viewed as an added obstacle to participation (Barbour 2001).

3.5.1.2.2. Applicability (Transferability)

Applicability of data is the extent to which the results can be used in other contexts or settings, and the ability to generalise the findings to a larger population and is usually viewed in 2 ways in qualitative research (Krefting 1991). According to the first view, applicability in qualitative research is unattainable since the research is usually conducted in a naturalistic setting with minimal controlling factors and without manipulating the environment, making every study singular and less prone to generalisation. Generalisability is therefore difficult to achieve since each research project contains a specific researcher in a specific interaction with specific participants. Statistical generalisability is not viewed as relevant to qualitative research, given that qualitative research aims to discuss a specific event or phenomenon instead of arriving at generalisations (Sandelowski 1995).

The second view to applicability was reported by Guba (1981), who defined fittingness (or transferability) as the key criterion under which to evaluate the applicability of qualitative data. When the results of the study setting are found to apply to other settings according to the level of similarity between the settings (goodness of fit), this criterion is fulfilled. The burden of transferability falls on the person who's trying to

transfer the results to a different context or new population, not the original researcher whose only responsibility is to provide enough descriptive data to facilitate comparison (Lincoln and Guba 1981).

3.5.1.2.3. Consistency (Dependability)

The third element of trustworthiness is based on the consistency of the data, meaning whether results would reoccur if the study were conducted under the same conditions, or with the same participants at a different time. Qualitative research deals with subjective experiences, and it naturally provides various different responses within a sample, and it is acknowledged that the responses may even change from 1 point in time to another (Murphy, Dingwall et al. 1998). Although this diverseness of data can be a feature in qualitative research, it conflicts with the standards for consistency (or reliability) of repeated results (Sandelowski 1995).

Consistency is improved through transparent documentation of the data collection and analysis process in order to simplify an eventual repetition with each participant in a study or replicate the methods in other studies (Sandelowski 1995). As the variables being examined for consistency in qualitative research are the respondents' input and the researcher themselves, with variations occurring across the research project itself, the criterion for qualitative research should be to learn from the differences, rather than to seek to eliminate them.

Qualitative research focuses on the singularity of the human experience, highlighting the differences and individuality of people (Field and Morse 1985). Differences are therefore expected in qualitative work, and consistency must be viewed in the context of dependability, meaning the degree to which the differences are explicable and

traceable to their causes (Guba 1981). Examples of explicable variations would be participant fatigue, changes in the participant's life situation or increased researcher awareness. Qualitative research also considers the range of experiences instead of the average. Therefore atypical circumstances are key parts to incorporate into the findings and add to the variability of the method. If approached from a quantitative perspective, atypical findings could be described as the outliers that have to be defined in order to report the borders of the phenomenon. Even if an individual may not represent the group, their input is viewed as important in qualitative research (Krefting 1991).

3.5.1.2.4. Neutrality (Confirmability)

The fourth element of trustworthiness is neutrality, described as the extent to which the research processes and findings are free of bias (Sandelowski 1995), and to which the findings are based exclusively on the participants and circumstances of the project, and not on any other perspectives, motives or bias (Guba 1981). It is in the nature of qualitative work for the interactions between participants and researchers to be quite close, to the point that researchers could even be viewed as participants in the research themselves (Sandelowski 1995). Qualitative researchers must be aware of and acknowledge their own influence on the process as a whole, the data collection and the influence of their individual background and bias on the interpretation of the findings. By acknowledging their influence, researchers add reflexivity to the qualitative data analysis and thus increase trustworthiness (Murphy, Dingwall et al. 1998).

3.5.2. Quantitative Data Analysis: Distribution, Central tendency, and Dispersion

In a Delphi study, univariate analysis, which is the examination of a single variable in a data set, is commonly used (Keeney, Hasson et al. 2011). Three key components are essential for a univariate analysis; distribution, central tendency, and dispersion (Trochim 2006).

Distribution is the summation of the frequency of individual or ranges of values for a variable. The most popular method for describing a single variable (univariate) is with frequency distribution. When conducting frequency distribution, all the individual data may be represented (discrete frequency distribution) or data may be grouped into ranges or categories first (Trochim 2006, Hinton 2014).

The central tendency of a distribution is an approximation of the centre of the spread of values and can be determined by the mean, median, and the mode. The mean (average) is the most widely applied way of representing central tendency, being shown in more than half of all mainstream medical research studies and is used to describe continuous data (Harris and Taylor 2003). The median is the value found in the middle of the set of values, and it separates the higher half from the lower half of values. It is usually utilised to describe skewed data. The mode is the most frequently occurring value in a data set. In general, the utilisation of the median is favoured in the literature considering the anticipated skew that would result from achieving consensus (Hill and Fowles 1975, Hsu and Sandford 2007).

Dispersion is the distribution of values around the central tendency (Trochim 2006, Hinton 2014). The simplest and most common methods of measuring dispersion are the

range, the interquartile range (IQR), and the standard deviation (SD). The range is simply the difference between the highest and lowest value, yet this only yields a minimal understanding of the distribution of the values. IQR is the mid spread or middle 50% (25%-75% of values), which is better at expressing the dispersion of data (Lohninger 1999).

SD is applied when data sets are normally distributed (Harris and Taylor 2003, Hinton 2014). However, data from Likert-type scales frequently present as polarised or skewed distribution (the majority of experts agree or disagree) and thus cannot be viewed as a normal distribution of data, which makes the application of SD inappropriate (Jamieson 2004).

3.6. Aim of Phase 1

The aim of this phase of the study was to ascertain the opinion of an international group of physiotherapy experts. Therefore, face-to-face interviews, focus groups, nominal group technique, or a paper-based, postal Delphi were inappropriate methods. For this study a web-based, E-Delphi method was chosen as the most appropriate approach of gathering opinion to negate the limitations inherent in other consensus-gathering methods as noted in this chapter.

This current study follows extensive work that has already been established on the definition and description of predominantly centrally and predominantly peripherally sensitised LBP, and a list of items for possible inclusion was drafted based on the existing research (Butler 2000, Linton and Boersma 2003, Jones and Rivett 2004, Waddell and Schoene 2004, Dankaerts, O'Sullivan et al. 2006, Weiser and Rossignol 2006, Smart, Blake et al. 2010, Nicholas, Linton et al. 2011, Watson and Kendall 2013, Clauw 2015).

In addition to the literature search, 2 experienced physiotherapists (V.S., L.S.) were consulted and identified additional items to be included in the first draft of BACKonLINE™ (Avery, Savelyich et al. 2005). The current study followed a modified Delphi format based on existing work conducted by other researchers (Cook, Brismée et al. 2010, Rao, Anderson et al. 2010, Gobat, Kinnersley et al. 2015, Luedtke, Boissonnault et al. 2016, Ogden, Culp Jr et al. 2016), where Round 1 opens with a structured questionnaire based on an extensive search of the literature on the subject.

Due to time constraints and manageability of data, this phase placed more focus on the self-assessment part of BACKonLINE™. The self-management part of this E-Delphi study only served to outline key themes. These key themes were compared with patient expectations of self-management advice in Phase 3.

3.6.1. Phase 1 Objectives

- To obtain consensus on the self-assessment items of BACKonLINE™ from international physiotherapists (the expert panel) via an E-Delphi study.
- To supplement the self-assessment items with suggestions by the expert panel.
- To outline the self-management component of BACKonLINE™

3.7. Summary

The Delphi method is a flexible research process that aims to gain consensus on a specific subject. This chapter attempted to shed light on the various approaches to Delphi studies used in literature and to highlight the lack of standardisation within Delphi methods.

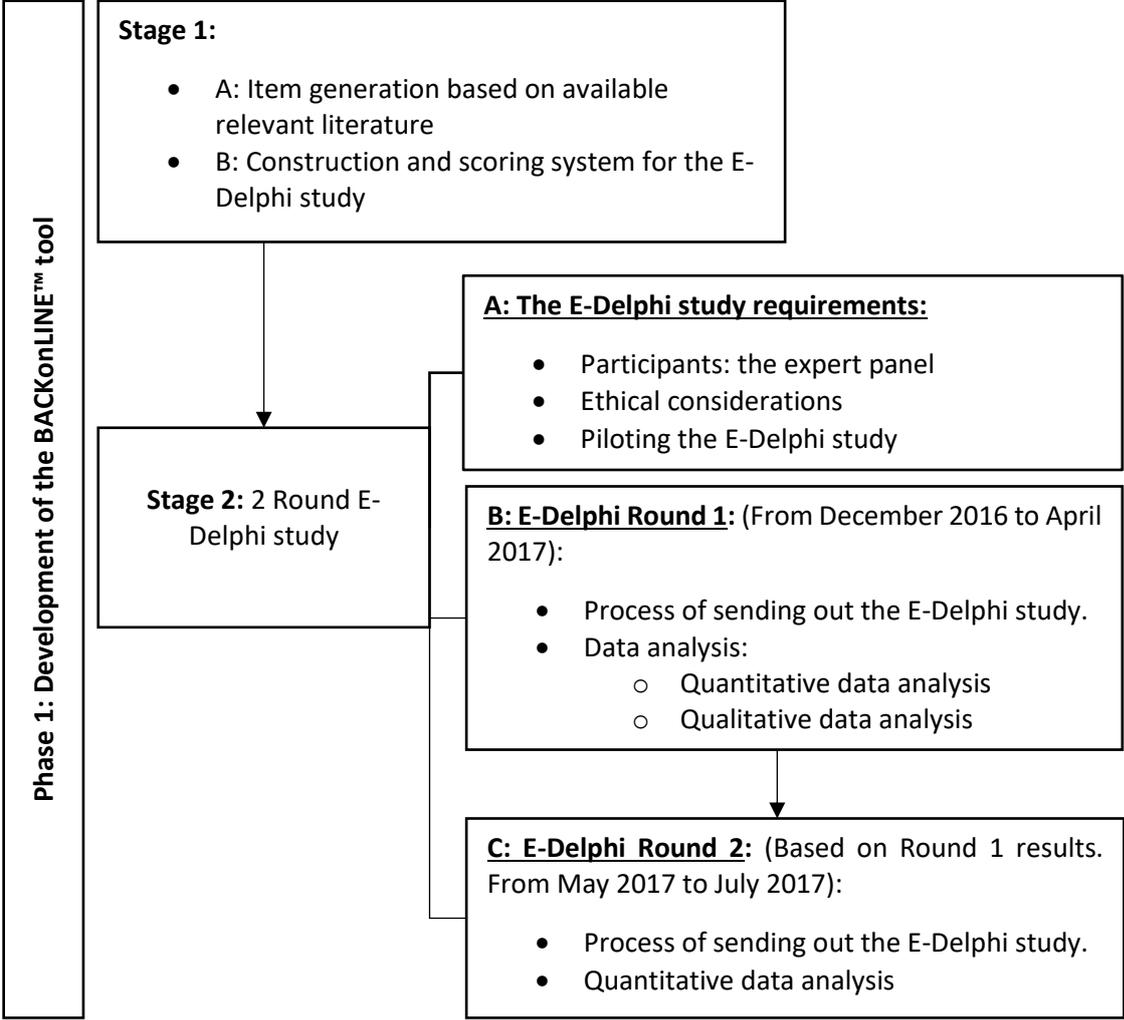
The next chapter (Phase 1 Methods) describes the E-Delphi method chosen and utilised in this phase, and how the results from the E-Delphi study were processed and analysed.

Chapter 4. Phase 1 Methods

4.1. Introduction

In Phase 1, a self-assessment and self-management online tool (BACKonLINE™) for people with CLBP was developed. It was proposed that BACKonLINE™ could potentially differentiate between people with symptoms that appear to be predominantly centrally or peripherally sensitised. An E-Delphi method was implemented in this phase to ascertain what questions should be included in the development of this tool. In this chapter, the use of the E-Delphi method, the selection criteria of the expert panel, and the process of the 2 stages are reported. Figure 3 provides an overview of this phase of the study. Within Phase 1, there are 2 stages (Stages 1 and 2), and within Stage 2 there are 3 parts A, B and C.

Figure 3 Overview of Phase 1: Development of the BACKonLINE™ tool



4.2. Study Design

This phase is a 2 Round electronic modified (E-Delphi) study. The E-Delphi in this phase provided a list of items for the experts to vote on and provided the experts with the opportunity to comment on these items and suggest any additional items that they thought should be included. The following sections explain the process of the item generation and the E-Delphi study.

4.3. Stage 1: Item Generation and Construction of the E-Delphi Study

In this stage, the items within the initial version of BACKonLINE™ were drafted and the E-Delphi study was designed. The following sections (Stage 1A, and 1B) explains the process in detail.

4.3.1. Stage 1A: Items Generation (Database Search to Develop BACKonLINE™ Version 1)

The first draft of items to be implemented in BACKonLINE™ was developed through a review of the available literature, targeting any publication covering surveys and tests among LBP populations which were performed in a physiotherapy environment. The Cochrane Haematological Malignancies Group search strategy and checklist were adapted for this search (Table 5) (Naumann 2007). Articles published before July 2016 were searched via Cinahl, EMBASE, Medline, AMED, PsycINFO, and PubMed using the keywords listed in Table 6 and employing Boolean search operators OR/AND (Table 6). Following this search, the resulting articles were manually searched for relevant references; only literature published prior to July 2016, written in English and using the keywords listed above in an abstract, title or both was covered. The reference lists of included articles were manually searched for additional relevant literature. The Cochrane Library was also searched for any relevant reviews.

Table 5 Phase 1 Checklist for developing a search strategy adapted from Naumann (2007)

1-Define text words
2-Determine synonyms for text words
3-Using truncations check for variations of spelling (e.g. British vs American spelling)
4-Perform the first test search

5-Check if you have the correct spelling for all the keywords
6-Establish the type of search in every database and define the search fields
7-Combine search terms as appropriate (Boolean –OR/AND)
8-Perform the second test search

Table 6 Keywords used in the literature search for Phase 1

Search category 1		Search category 2		Search category 3
Backache OR lumbago OR back pain OR low back pain OR lumbar spine OR lumbar ache OR lumbar pain OR chronic low back OR Non-specific low back pain OR Non-specific chronic low back pain OR LBP OR CLBP	AND	Physical examination OR manual examination OR classification OR symptom response or pain response OR assessment OR subgrouping OR questionnaire OR physiotherapy assessment OR physical therapy assessment OR musculoskeletal assessment OR neuromusculoskeletal examination OR musculoskeletal physiotherapy	AND	Clinical indicators OR centralisation OR pain mechanisms OR pain clinical criteria OR peripheral neuropathic pain OR nociceptive pain OR central mechanisms of pain OR clinical reasoning OR central sensitisation

The database search identified 502 articles, after removing duplicate articles, 170 articles remained. The remaining articles' abstracts were manually assessed for relevance which resulted in a total of 21 articles. Table 7 shows the number of articles identified per database searched.

Table 7 Databases searched in Phase 1

Database	Number of articles found
PubMed	115
PsycINFO	1
Medline	10
Embase	108
Cinahl	30
AMED	0
Cochrane library	238
Total number of articles	502

Total number of articles after removing duplicates	170
Total number of articles after manually checking their relevance	21

After reviewing the articles and relevant references, 55 items were identified and included in the first version of BACKonLINE™ (Table 8). The items were grouped into 3 main domains, which were informed by the biopsychosocial approach to pain (Gatchel, Peng et al. 2007). The domains included are:

- Pain behaviour domain (physiological pathology aspect of LBP)
- Impact of LBP on work and lifestyle domain (social aspect of LBP)
- Perception of LBP domain (psychological aspect of LBP)

In phase 1, the Impact of LBP on work and lifestyle domain was divided into 2 sections:

a) Impact of LBP on work, b) and Impact of LBP on lifestyle in order to ensure all relevant questions are focused on by the expert panel.

Table 8 Phase 1 BACKonLINE™ (Version 1)

Item ID	Item	References
Pain behaviour domain		
PB1	Do you know what caused your low back pain?	(Smart, Blake et al. 2010, Petty 2011, Nijs, Apeldoorn et al. 2015)
PB2	If yes, what caused your low back pain?	(Smart, Blake et al. 2010, Petty 2011)
PB3	When did you have your first episode of low back pain?	(Smart, Blake et al. 2010, Petty 2011)
PB4	Have you ever received treatment for low back pain?	(McCarthy, Rushton et al. 2006, Smart, Blake et al. 2010, Petty 2011)
PB5	If you have been treated for low back pain, were you satisfied with the treatment you received?	(Smart, Blake et al. 2010, Nicholas, Linton et al. 2011, Petty 2011)

Item ID	Item	References
PB6	Are you currently on any medication for your low back pain?	(Smart, Blake et al. 2010, Nicholas, Linton et al. 2011, Petty 2011, Clauw 2015)
PB7	What medication do you take to manage your low back pain?	(Petty 2011, Clauw 2015)
PB8	How often do you take your medication?	(Smart, Blake et al. 2010, Petty 2011)
PB9	How effective is the medication in reducing your low back pain?	(Smart, Blake et al. 2010, Petty 2011)
PB10	Where is your pain located? Please tick all body regions that apply: Neck -Shoulder -Arm -Upper back -Lower back -Leg -Other	(Linton and Boersma 2003, Smart, Blake et al. 2010, Mayer, Neblett et al. 2012, Clauw 2015)
PB11	Are you experiencing any other types of sensations (such as pins and needles, numbness) beside pain?	(Smart, Blake et al. 2010, Petty 2011, Clauw 2015, Nijs, Apeldoorn et al. 2015)
PB12	What type of sensation is it?	(Smart, Blake et al. 2010, Petty 2011, Nijs, Apeldoorn et al. 2015)
PB13	Please tick all the regions where you experience this type of sensation: Neck -Shoulder -Arm -Upper back -Lower back -Leg -Other	(Smart, Blake et al. 2010, Petty 2011, Clauw 2015, Nijs, Apeldoorn et al. 2015)
PB14	On average, how many hours do you sleep?	(Nijs, Van Houdenhove et al. 2010, Mayer, Neblett et al. 2012, Clauw 2015, Burton, Campbell et al. 2016)
PB15	Does your low back pain wake you up at night?	(Nijs, Van Houdenhove et al. 2010, Smart, Blake et al. 2010, Clauw 2015, Burton, Campbell et al. 2016)
PB16	If your sleep is disrupted because of low back pain, are you able to get back to sleep?	(Nijs, Van Houdenhove et al. 2010, Smart, Blake et al. 2010, Clauw 2015, Burton, Campbell et al. 2016)
PB17	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain right now	(Von, Deyo et al. 1993, Linton and Boersma 2003, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015)
PB18	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your typical or average low back pain	(Von, Deyo et al. 1993, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015)
PB19	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its best (How close to "0" does your pain get at its best?)	(Von, Deyo et al. 1993, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015)

Item ID	Item	References
PB20	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its worst (How close to "10" does your pain get at its worst?)	(Von, Deyo et al. 1993, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015)
PB21	Is your pain constant?	(Smart, Blake et al. 2010)
PB22	Are you able to ease your low back pain?	Smart, Blake et al. 2010 Linton and Boersma 2003
PB23	How do you ease your low back pain?	(Smart, Blake et al. 2010)
PB24	How much time on average does it take for your pain to go away?	(Smart, Blake et al. 2010)
PB25	From the list below, please tick all the activities that trigger or increase your pain: Slouched Sitting- Sitting up straight- Standing up straight- Walking- Fast walking- Lying on your side curled up- Running- Lifting-Forward bending (stooping)- Cycling- Overhead reaching- Everything I do aggravates my pain	(Dankaerts, O'Sullivan et al. 2006, Smart, Blake et al. 2010)
PB26	Do you agree with this statement: "My pain is there no matter what I do"	(Smart, Blake et al. 2010)
PB27	From the list below, please tick all the activities that stop or decrease your pain: Slouched Sitting- Sitting up straight- Standing up straight- Walking-Fast walking- Lying on your side curled up-Running- Lifting-forward bending	(Dankaerts, O'Sullivan et al. 2006, Smart, Blake et al. 2010, Petty 2011)
Impact of LBP on work and lifestyle domain: Impact of LBP on work section		
W1	What is your current work status?	(Waddell and Schoene 2004, McCarthy, Rushton et al. 2006, Watson and Kendall 2013)
W2	What is your occupation?	(Waddell and Schoene 2004, McCarthy, Rushton et al. 2006)
W3	How satisfied are you with your job?	(Linton and Boersma 2003, Waddell and Schoene 2004, Smart, Blake et al. 2010, Watson and Kendall 2013)
W4	"I believe that my work is significantly contributing to my low back pain" how strongly do you agree with this statement?	(Waddell, Newton et al. 1993, McCarthy, Rushton et al. 2006, Smart, Blake et al. 2010, Nicholas, Linton et al. 2011, Watson and Kendall 2013)
W5	Have you ever had time off work because of low back pain?	(Waddell and Schoene 2004, Watson and Kendall 2013)
W6	Are you off work right now because of your low back pain?	(Petty 2011, Waddell and Schoene 2004)

Item ID	Item	References
W7	If you answered yes to the previous question, how long have you been off work?	(Petty 2011, Waddell and Schoene 2004, Linton and Boersma 2003)
W8	Is your employer understanding when it comes to your low back pain?	(Waddell and Schoene 2004, Petty 2011, Smart, Blake et al. 2010, Nicholas, Linton et al. 2011)
W9	How likely it is that you would return to work within 6 months?	(Linton and Boersma 2003, Waddell and Schoene 2004, Weiser and Rossignol 2006, Petty 2011)
Impact of LBP on work and lifestyle domain: Impact of LBP on lifestyle section		
<i>How important is each statement?</i>		
L11	"I am unable to do my normal daily activities because of my low back pain. "	(McCarthy, Rushton et al. 2006, Smart, Blake et al. 2010, Watson and Kendall 2013)
L12	" My low back pain is decreasing my overall daily productivity"	(Smart, Blake et al. 2010, Mayer, Neblett et al. 2012, Watson and Kendall 2013)
L13	"I am unable to perform my daily activities without external help."	(Smart, Blake et al. 2010, Mayer, Neblett et al. 2012, Watson and Kendall 2013)
L14	"My low back pain is negatively affecting my social life"	(Chew-Graham and May 1999, Weiser and Rossignol 2006, Watson and Kendall 2013)
L15	"My low back pain is affecting my relationship with my significant other"	(McCarthy, Rushton et al. 2006, Weiser and Rossignol 2006, Watson and Kendall 2013)
Perception of LBP domain		
<i>How important is each statement?</i>		
P1	"Because of my low back pain, I feel stressed/ anxious all the time."	(Smart, Blake et al. 2010, Nicholas, Linton et al. 2011, Mayer, Neblett et al. 2012, Watson and Kendall 2013, Clauw 2015)
P2	"Feeling stressed increases my low back pain"	(Smart, Blake et al. 2010, Watson and Kendall 2013, Clauw 2015)
P3	"Physical activity will increase my low back pain"	(Waddell, Newton et al. 1993, Linton and Boersma 2003, Waddell and Schoene 2004)

Item ID	Item	References
P4	"I believe that my low back pain should go away completely before I can move on with my life."	(Waddell and Schoene 2004, Watson and Kendall 2013)
P5	"I seem to be more sensitive to things like loud noises, bright light, and odours."	(Nijs, Van Houdenhove et al. 2010, Clauw 2015, Sanzarello, Merlini et al. 2016)
P6	"Since my low back pain started, I seem to feel more tired."	(Nijs, Van Houdenhove et al. 2010, Mayer, Neblett et al. 2012, Clauw 2015)
P7	"Since my low back pain started, I seem to have problems remembering things."	(Nijs, Van Houdenhove et al. 2010, Mayer, Neblett et al. 2012, Clauw 2015)
P8	"Since my low back pain started, I seem to be moody."	(Weiser and Rossignol 2006, Watson and Kendall 2013)
P9	"I believe that what I do on a daily basis is significantly contributing to my low back pain"	(Smart, Blake et al. 2010, Watson and Kendall 2013)
P10	"I have no interest or pleasure in doing things anymore because of my low back pain"	(Smart, Blake et al. 2010, Watson and Kendall 2013)
P11	"I don't think my family and friends understand what I'm going through in relation to my low back pain"	(Petty 2011, Watson and Kendall 2013)
P12	"My back is weak and fragile"	(Main, Foster et al. 2010, Smart, Blake et al. 2010, Watson and Kendall 2013)
P13	"My low back pain will only improve with an intervention from a healthcare professional"	(Waddell and Schoene 2004)
P14	"I do not think my low back pain will ever recover"	(Main, Foster et al. 2010, Smart, Blake et al. 2010, Weiser and Rossignol 2006)

Key: PB: Pain behaviour domain item, W: Impact of LBP on Work section item, L: LBP and lifestyle section item, P: Perception of LBP domain

4.3.2. Stage 1B: Construction and Scoring System for the E-Delphi Study

In this section, the level of consensus and the utilised scale for grading the level of importance (Likert scale) in both Rounds of the E-Delphi study are reported.

4.3.2.1. Level of Consensus

A level of consensus was predetermined before launching Round 1 in order to reduce researcher bias (Williams and Webb 1994). A level of consensus $\geq 70\%$ was adopted for

the present study since this value is the most widely applied percentage in Delphi studies (Williams and Webb 1994, Vernon 2009). In order to calculate the level of consensus, a 7 point Likert scale was used. In the next section, the Likert scale is presented.

4.3.3. The Likert Scale

Having considered literature regarding Likert scales, and by adhering to Uebersax (2006)'s guidelines on what constitutes a Likert scale, it can be concluded that the current E-Delphi study has used a Likert scale to obtain expert consensus. Figure 4 shows an example of the Likert scale utilised in the BACKonLINE™ questionnaire.

Figure 4 Example of a question in Phase 1 E-Delphi study developing BACKonLINE™

The screenshot shows a questionnaire interface with a question and a 7-point Likert scale. The question is 'Do you know what caused your low back pain? (73.6%)'. The scale options are: 1 (Not at all important), 2 (Moderately unimportant), 3 (Slightly unimportant), 4 (Neither important or unimportant), 5 (Slightly important), 6 (Moderately important), and 7 (Extremely important). Each option has a radio button next to it, and all are currently unselected.

How important is each question?	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)
Do you know what caused your low back pain? (73.6%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

In both Rounds of the present E-Delphi study, a 7 point Likert scale was utilised, in order to allow for greater variability of the responses, thus leading to greater discrimination between levels of importance (Gobat, Kinnersley et al. 2015, Streiner, Norman et al. 2015). For this study the adopted Likert scale used the following values: 1='Not at all important/Extremely unimportant', 2='Moderately unimportant', 3='Slightly unimportant', 4='Neither important or unimportant', 5='Slightly important', 6='Moderately important', 7='Extremely important'.

In order to permit participants to stay ambivalent on an item, an odd number of options was applied to the Likert scale, so as not to coerce participants into including or excluding an item in BACKonLINE™ (Pett, Lackey et al. 2003). This was made possible by providing the ‘Neither important or unimportant’ middle option to indicate indecision and to avoid forced answers, which could produce untrue results or lead to participants failing to complete the survey (Pett, Lackey et al. 2003).

4.4. Stage 2A: Two Round E-Delphi study

In this section, the requirements for conducting an E-Delphi study and both Rounds of the current study are presented (Figure 3).

In order to launch the E-Delphi study, experts should be identified and invited, ethical issues should be considered, and the E-Delphi study platform must be piloted in order to detect and address any practical problems and to ensure clarity of the survey.

4.4.1.1. Participants: The Expert Panel and Sample Size

As BACKonLINE™ is related to patients with LBP on physiotherapy waiting lists and may assist physiotherapists by reducing required assessment time and increasing patients’ awareness and ability to self-manage pain, a homogenous panel of physiotherapists was chosen for the study. An international sample was chosen in order to ensure an adequate sample size and to capture a wider range of thinking and experience (Okoli and Pawlowski 2004, Mokkink, Terwee et al. 2010). Participants were invited through purposive sampling (Hasson, Keeney et al. 2000). Table 9 summarises the inclusion and exclusion criteria for the participants.

Table 9 Phase 1, Stage 2 participant inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> • Qualified physiotherapists • Work primarily with patients with LBP • Have an active e-mail and able to access an online survey • Fluent in English 	<ul style="list-style-type: none"> • Non-physiotherapists • No Experience with LBP • Inability to access an online survey or an inactive e-mail • Lack of fluency in English

Since most homogenous Delphi study panels usually contain 15 to 30 subjects, panel size of around 30 experts was the target for this study (Linstone and Turoff 2002, De Villiers, De Villiers et al. 2005, DeVellis 2016).

The participants were identified through recommendations, personal contacts, broadcast in social media (Facebook, Twitter, Instagram, LinkedIn) and a review of authors of the relevant healthcare literature. Recruitment flyers were also distributed in the 9th Interdisciplinary; World Congress on Low Back and Pelvic Girdle Pain, Singapore (2016). An invitation to participate was also sent to members of the Musculoskeletal Association of Chartered Physiotherapists (MACP) (n=1245), and Society of Back Pain Research (SBPR) (n=147) in the UK. Participants were also invited via telephone call (after being approached via e-mail and gaining consent to call), email and/or face-to-face interaction in order to personalise the approach. During the invitation interaction, participants were invited to recommend further appropriate colleagues, who then received additional invitations.

When participants agreed to participate in the current study, they received the links to the survey in 1 of 2 ways. Those experts who had initially agreed to participate via telephone, face-to-face interaction or by e-mailing the researcher in reaction to social

media alerts or the recruitment flyer received an invitation e-mail. This e-mail included an information sheet, further details on the study and a link to the online survey. In order to ease the process for them, experts from SBPR and MACP received a link as part of a general broadcast e-mail.

4.4.1.2. Ethical Considerations:

Ethical approval for the E-Delphi study was granted by the Cardiff University School of Healthcare Sciences Research Governance and Ethics Committee on the 17th of June 2016 (Appendix 2).

In order to ensure confidentiality and anonymity of all participants, all broadcast e-mail correspondence between the researcher and participants (including invitation and reminder e-mails) was conducted using the blind carbon copy (Bcc) option to avoid participants in the E-Delphi study being identifiable to others. At the same time, the main recipient of the e-mail (the "To" field) was set as the researcher to prevent the e-mail from being delivered into spam folders, which commonly occurs with broadcast e-mails

When conducting an online study, it is difficult to gain verbal consent from participants. Therefore all of the study's information, researcher's details, and participants rights should be declared at the beginning of the online survey (Knussen and McFadyen 2010, Regmi, Waithaka et al. 2016). In this E-Delphi study, an information sheet was sent with the survey link via email to experts who agreed to participate (Appendix 3). At the beginning of the survey, the study was explained to the participants, and a consent form followed the full explanation of the study, their rights, and the details of the research

team. Participants were only able to access the survey after they had checked each statement of the consent form (Appendix 4).

4.4.1.3. Piloting the E-Delphi Study

In order to ensure accessibility and clarity of the E-Delphi survey, a pilot study was conducted using 2 physiotherapists who had experience treating patients with LBP, 1 based in the UK (qualified in 2008) and 1 in Kuwait (qualified in 2005). Both physiotherapists were e-mailed a link to the E-Delphi survey and were asked to follow instructions in the link. No further explanation was provided to them in order to ensure that they did not have an advantage over potential participants. The 2 physiotherapists were asked to record, via e-mail, any issues they may have encountered while completing the survey as well as any challenges to clarity, comprehension and accessibility of the E-Delphi as well as to assess the ease of completing it. Neither physiotherapist reported any issues in accessing or understanding the survey or reported any other problems. Thus, no changes were made to the survey (Appendix 4).

4.4.2. Stage 2B: E-Delphi Study Round 1

The first iteration of BACKonLINE™ for the E-Delphi study included open as well as closed-ended questions (Appendix 4) (Gobat, Kinnersley et al. 2015, Luedtke, Boissonnault et al. 2016, Wassenaar, van den Boogaard et al. 2017). The participants were requested to rate the level of importance of each item in discerning between predominantly centrally sensitised and predominantly peripherally (nociceptive or neuropathic) sensitised LBP in BACKonLINE™. They were also asked to provide additional

comments as they wished, including any further items they suggested for inclusion in any of the domains.

On the 1st of December 2016, an invitation e-mail with an information sheet and a link to Round 1 of the E-Delphi study were sent to potential participants. The e-mail included a short introduction including the purpose of the study, completion deadline, and a link to Round 1 (<https://cardiff.onlinesurveys.ac.uk/backonline>) which was hosted on www.onlinesurveys.ac.uk (formerly known as Bristol Online Survey tool- Appendix 4). During Round 1, 2 reminder e-mails were sent to non-responders and an e-mail was sent to responders to thank them (Appendix 5).

The survey started with an introduction, aim, then definitions of terms used within it (Appendix 4). After explaining the amount of time it would take to complete the survey, anonymity and data protection measures, the participants were then asked to rate each question as to whether questions should be included in the BACKonLINE™ tool to discern between people with characteristics of predominantly centrally or predominantly peripherally (neuropathic or nociceptive) sensitised LBP.

After the introduction section, participants had to complete a consent form within the survey then provide their demographic data (name, e-mail, speciality, professional qualification, job title, status of clinical activity, and country of residence) (Appendix 4).

This survey was divided into 2 parts. Part 1 included 3 domains, and each domain had a brief explanation of what was required from the participants. The 3 domains were presented as follows:

Part 1:

Domain A: Pain behaviour.

Domain B: Impact of LBP on work and lifestyle:

1. Impact of LBP on work section
2. Impact of LBP on lifestyle section

Domain C: Perception of LBP

Each domain ended with a comment box so that the participants could express any thoughts they had regarding that specific part, justify their answers, and suggest any additional items to be included in BACKonLINE™. Providing the option to justify their responses has been shown to help engage participant interest and motivation (Streiner, Norman et al. 2015).

Part 2 focussed on the management of CLBP, targeting predominantly centrally sensitised and predominantly peripherally sensitised (neuropathic and nociceptive) LBP. The experts were asked to suggest the best pieces of advice they could provide patients with predominant characteristics of peripherally (neuropathic and nociceptive) sensitised or centrally sensitised LBP.

The survey concluded by thanking the participants and providing them with the researcher's details in case they wish to contact her in regards to anything related to the study (Appendix 4).

For Round 1 of the E-Delphi study, recruitment started in August 2016 and it was launched on the 1st of December 2016. This Round was originally intended to close on February 6th, 2017; however, during the launching of the Round 1, additional experts

were identified and invited to the study on the 24th of December 2016. Since the recruitment process was hindered by the holiday season, response rate was very low (only 12 people of the approached 78 people completed the survey). Recruitment was also slowed down due to delays in obtaining access to SBPR and MACP (access was granted in March 2017). Due to the aforementioned reasons, it was decided to extend Round 1 until the 28th April 2017 in order to give participants a chance to complete the survey, and as a result, 41 people completed this Round.

4.4.2.1. Round 1 Data Analysis

The objective of Round 1 of the E-Delphi study is to determine experts' level of agreement on presented items on a 7 point Likert scale, generate new assessment items based on suggestions by participants, and outline the self-management suggestions provided by the expert panel.

Likert scale data were transferred to Microsoft® Excel and IBM SPSS Statistics® version 25 (SPSS Inc., Chicago, Illinois). The consensus percentage of each item presented by the tool was calculated. Due to www.onlinesurveys.ac.uk having been configured not to accept missing and/or duplicate answers and to remind participants to choose only 1 option or point out empty fields before they were able to proceed with the survey, there was no possibility of missing and/or duplicate answers.

4.4.2.1.1. Round 1 Quantitative Data Analysis

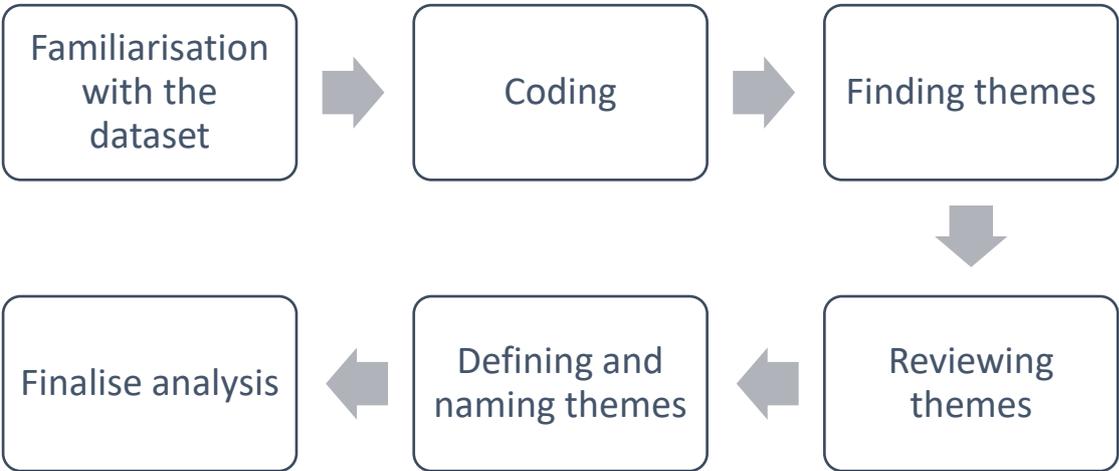
The first objective of Round 1 was analysed by applying descriptive statistics. This analysis was done using univariate analysis (distribution, central tendency, and dispersion) (Trochim 2006).

In this current study, since the data was ordinal, and probably skewed (skewness is expected in a Delphi study aiming to gain consensus) the median was deemed the best measure for reporting central tendency, and distribution was plotted using histograms for each self-assessment item (Knapp 1990). IQRs were used to show the dispersion of data (Lohninger 1999).

4.4.2.1.2. Round 1 Qualitative Data Analysis

In order to meet the remaining objectives of Round 1 (to generate new self-assessment items based on participants suggestions and outline self-management advice suggested by participants), thematic analysis was employed. In order to conduct thematic analysis, the researcher begins with reading and rereading the data in order to get familiar with it. Afterwards, the data is coded (i.e. labelled) while considering the aim of the study, and resultant codes are gathered into themes. The resulting themes are reviewed to ensure they relate to the codes and the dataset. The themes are then defined, and the analysis is finalised (Figure 5).

Figure 5 Thematic analysis process (Adapted from Braun and Clarke (2013))



There are 2 processes of thematic analysis: inductive and deductive. The deductive process begins with a predetermined framework or structure in a particular subject used to guide data analysis. This process is commonly termed a top-down approach since it starts with a specified theory that specifies the main themes and deemed useful when the study already identified the main categories or themes used to group the data (Braun and Clarke 2006, Vaismoradi, Turunen et al. 2013, Chapman, Hadfield et al. 2015).

The inductive process (also known as the bottom-up approach) takes the opposite steps, starting with the data and moving up to more general theories. It starts with observing and locating patterns within the dataset, which is used to generate themes, and ultimately arrive at conclusions or theories (Figure 5).

All participants' comments were gathered in a word document and all qualitative data obtained in Round 1 were entered into NVivo 11. Deductive thematic analysis was used in order to organise them into general themes (Braun and Clarke 2006):

1. Using the biopsychosocial framework, the derived domains of BACKonLINE™, "Pain behaviour", "Impact of LBP on work and lifestyle", and "Perception of LBP", were used as codes.
2. All participants' comments were gathered in a word document and all qualitative data obtained in Round 1 were entered into NVivo 11.
3. The participant's comments were then coded using the list of codes in step 1. The data was thus categorised into their relevant domains

4. It was identified that within each domain, the data could be further categorised into distinct themes i.e. new items suggested under each respective domain. The data was then further coded. The codes assigned were short phrases that summarised what was mentioned in the data.

5. Similar codes were gathered, and the common theme was identified for each cluster. Codes that were used repeatedly were promoted to themes. For example, the code “New Item” was used several times and thus was promoted from being a code to becoming a theme. The themes were worded with close reference to key words used in the biopsychosocial approach.

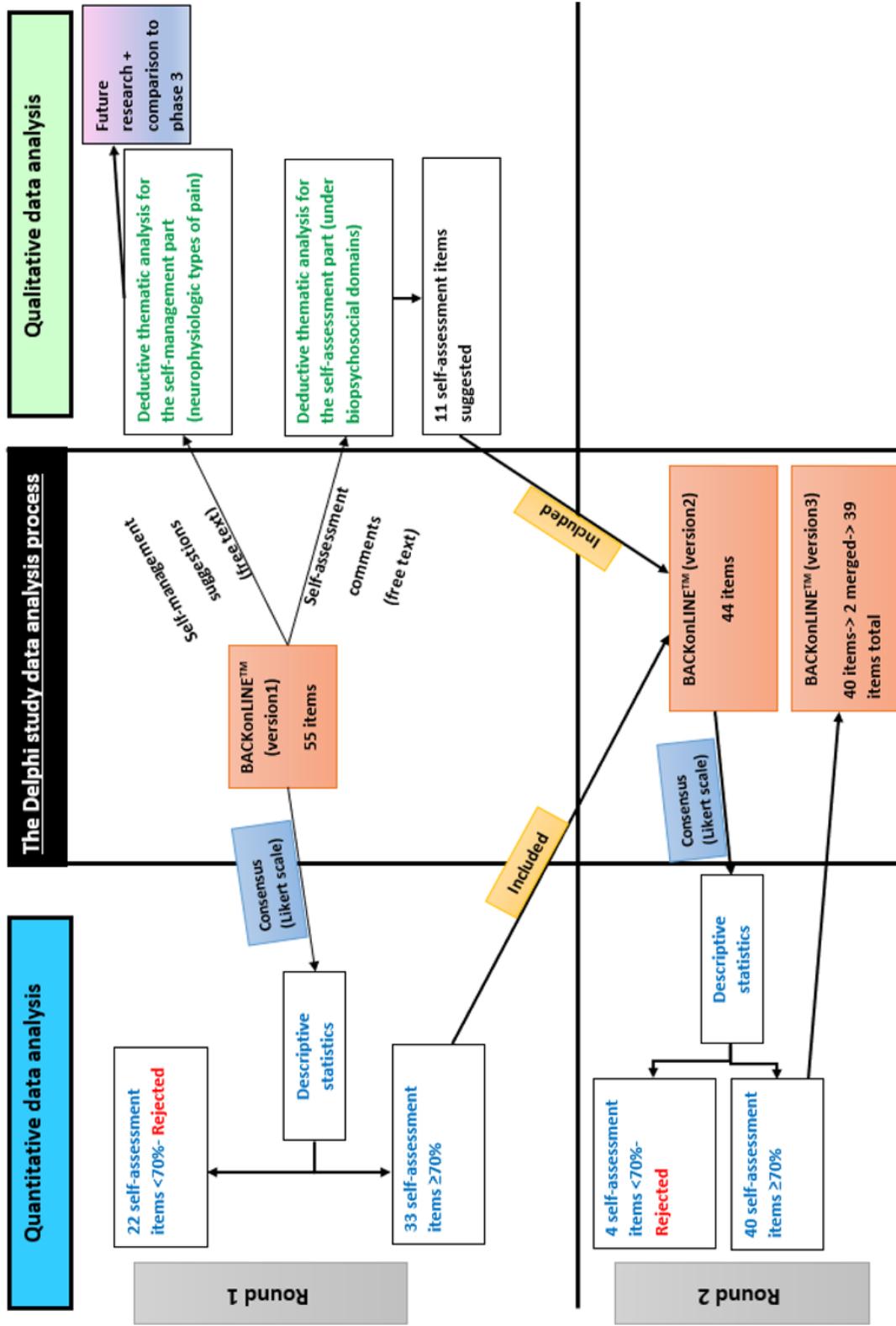
6. A thematic map was then put together to show the organisation of the data and the identified themes.

Self-assessment items suggested during the process were included in Round 2 of the E-Delphi study in order to obtain consensus on them (Lopopolo 1999, Cook, Brismée et al. 2010, Keeney, McKenna et al. 2010, Rao, Anderson et al. 2010).

In order to analyse the self-management suggestions provided by participants in Round 1, the mechanisms-based classification of pain was used as a framework and deductive thematic analysis was employed similar to the process in the analysis of the self-assessment data. The mechanisms-based classification specifies 3 neurophysiologic types of pain, centrally sensitised, peripherally neuropathic, and peripherally nociceptive pain, which were used as themes for the coded data. Within each of these pain domains, the data was further coded, and similar codes were clustered and the representative themes were identified.

This E-Delphi study utilised both qualitative and quantitative data in order to reach consensus. Figure 6 summarises both quantitative and qualitative data analysis in Round 1 and Round 2, and it outlines the evolution of BACKonLINE™ from Version 1 to Version

Figure 6 Phase 1 E-Delphi study data analysis map



4.4.3. Stage 2C: E-Delphi Study Round 2

Items that received consensus $\geq 70\%$ in Round 1 were included in Round 2 and each item had the percentage score it received in Round 1 noted next to it. Additional items that were suggested by participants in Round 1 have been integrated within this Round and defined as New Item (N.I.).

On the 2nd May 2017, an invitation to participate in Round 2 was sent to all Round 1 participants via e-mail. Round 2 aimed to achieve final consensus on items to be included in BACKonLINE™. Upon clicking on the link provided in the invitation e-mail, participants were redirected to the survey (Appendix 6). Round 2 consisted of an introduction reminding the participants of the aims and objectives of the study, followed by a summary of Round 1 results. Basic identifying information was gathered (name, e-mail). Participants were asked to evaluate the importance of every item using a 7 point scale (1=not at all important/ extremely unimportant, 7=extremely important), with consideration for the results and comments from Round 1. This Round was concluded by asking the participants if they wish to be informed about the results of the E-Delphi study (Appendix 6).

4.4.3.1. Round 2 Data Analysis

Results from Round 2 were analysed using Microsoft® Excel and IBM SPSS Statistics® version 25 was used. No comments were gathered in this Round since it was the final Round of the E-Delphi study. The same quantitative analysis used in Round 1 were used in this Round (Figure 6). Items were included in BACKonLINE™ if they received consensus $\geq 70\%$.

4.5. Summary

In this chapter, the process used in the development of BACKonLINE™ was presented. This process was divided into 2 stages. Stage 1 focused on generating the initial pool of self-assessment items within BACKonLINE™ from the available literature. Stage 1 also presented the construction and the scoring system used in the E-Delphi study (7 point Likert scale). Stage 2 highlighted the requirement needed in order to launch the E-Delphi study starting from the required participants, ethical considerations, and ending with piloting the E-Delphi study on 2 qualified physiotherapists. Both Rounds of the E-Delphi study were then presented, explaining the process and data analysis of each Round. In the next chapter, the results from the E-Delphi study are presented.

Chapter 5. Phase 1 Results

5.1. Introduction

This chapter presents the results from the 2 Round E-Delphi study, including the respondents' demographics, and level of agreement in Round 1 and Round 2. The results from a deductive thematic analysis of new self-assessment items and suggestions for self-management for BACKonLINE™ from Round 1 are also presented.

5.2. Participants

Out of 41 potential participants expressing interest 3 were excluded for not meeting specific inclusion criteria (occupation: One osteopath and 2 surgeons). This resulted in a total of 38 participants in Round 1. Out of the 38 participants in Round 1, 28 (74%) completed Round 2 of the E-Delphi study (Table 10). The sample included national as well as international physiotherapists.

Table 10 Number of participants recruited into the E-Delphi study and sources of recruitment in Phase 1

Type and mode of recruitment	Number of people approached (n)	Number of people responded to Round1 (n=38)	Number of people responded to Round2 (n=28)
Social media broadcasts	Undetermined	11	5
Individually approached participants	87	18	15
The 9th Interdisciplinary; World Congress on Low Back and Pelvic Girdle Pain, Singapore	Undetermined	7, of which 3 were excluded	4
Musculoskeletal Association of Chartered Physiotherapists (MACP) – Society of Back Pain Research (SBPR)	1245	5	4

Participants covered a whole spectrum of physiotherapy professional qualifications ranging widely between BSc to PhD, combined with years since qualification (1 to 30 years of professional activity) (Table 11).

Table 11 Phase 1 participants demographic data

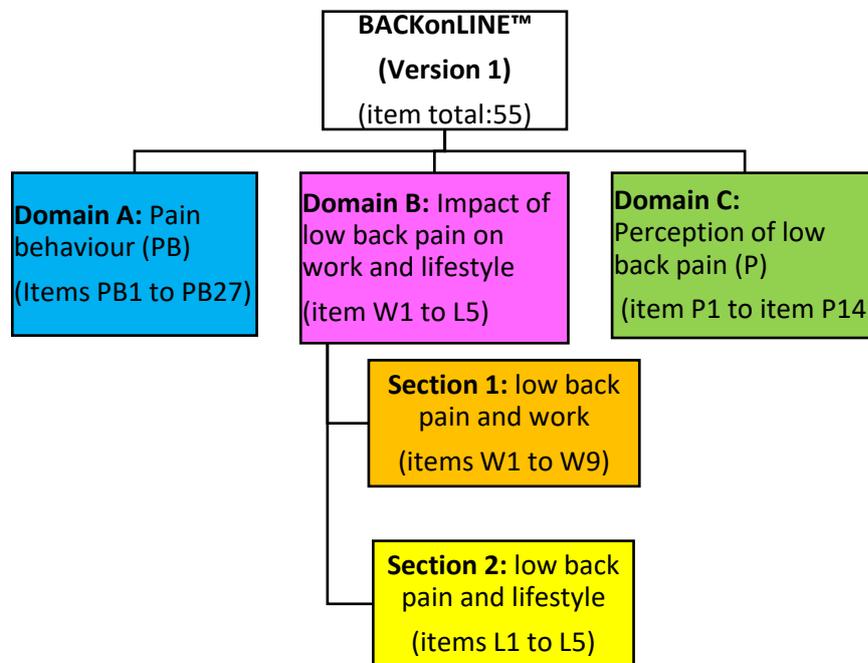
Demographic variable	Round 1 (n=38)		Round 2 (n=28)	
	Number	Percentage	Number	Percentage
Discipline/ Speciality				
Physiotherapy	19	(50%)	13	(46.4%)
Musculoskeletal Physiotherapy	12	(31.5%)	9	(32.1%)
Orthopaedic Physiotherapy	4	(10.5%)	4	(14.2%)
Sports Physiotherapy	1	(2.6%)	1	(3.5%)
Healthcare Sciences	2	(5.2%)	1	(3.5%)
Gender				
Female	12	(31.6%)	9	(32.1%)
Male	26	(68.4%)	19	(67.9%)
Highest Professional Qualification				
PhD	12	(31.6%)	8	(28.6%)
DPT	2	(5.3%)	0	0
MSc	16	(42.1%)	14	(50%)
BSc	8	(21.1%)	6	(21.4%)
Job title				
Physiotherapist	13	(34.2%)	11	(39.3%)
Senior Physiotherapist	3	(7.9%)	2	(7.1%)
Specialist Physiotherapist	4	(10.5%)	3	(10.7%)
Lecturer	5	(13.2%)	5	(17.9%)
Senior lecturer	2	(5.3%)	1	(3.6%)
Consultant Physiotherapist	1	(2.6%)	1	(3.6%)
Professor	3	(7.9%)	2	(7.1%)
Assistant Professor	1	(2.6%)	0	0
Associate Professor	4	(10.5%)	3	(10.7%)
Doctoral candidate	1	(2.6%)	0	0
Currently clinically active?				
Yes	27	(71.1%)	20	(71.4%)
No	11	(28.9%)	8	(28.6%)
Region				
Europe	20	(52.6%)	13	(46.4%)
Middle East	10	(26.3%)	10	(35.7%)
Asia	4	(10.5%)	4	(14.3%)
Australia	1	(2.6%)	0	0
North America	3	(7.9%)	1	(3.6%)
Years since professional qualification: mean(range)	14.1(1-31)		13.7(1-30)	

Key: PhD: Doctor of Philosophy, MSc: Master of Science, BSc: Bachelor of Science, DPT: Doctor of Physical Therapy

5.3. E-Delphi study: Round 1- Development of BACKonLINE™

Items within Version 1 of BACKonLINE™ were developed by reviewing the available literature and divided into 3 main domains. Each item refers to a question aiming to discern between predominantly centrally sensitised and predominantly peripherally (nociceptive or neuropathic) sensitised LBP. Figure 7 details the domains of BACKonLINE™ with each domain and section colour coded (Version 1)

Figure 7 Outline of BACKonLINE™ (Version 1) in Phase 1



Key: PB: Pain behaviour; W: Low back pain and work; L: Low back pain and lifestyle; P: Perception of low back pain

In Round 1, 38 physiotherapists participated and were required to vote on 55 items in total. Out of the 55 items presented within the 3 domains of Round 1 and rated using a 7 point Likert scale, 33 (60%) received $\geq 70\%$ agreement. 66.6% items in Pain behaviour domain received $\geq 70\%$ agreement, followed by the 60% of items in Impact of LBP on

lifestyle section, 57.1% of items in Perception of LBP domain with least number of items 44.4% receiving agreement in Impact of LBP on work section. A total of 11 new items were suggested by participants, mostly in the Pain behaviour and Impact of LBP on work and lifestyle domains (Table 12).

Table 12 Descriptive statistics of Round 1 of the E-Delphi study in Phase 1

Items \ Domain	Pain Behaviour	Impact of LBP on work and lifestyle		Perception of LBP
		Impact of LBP on work	Impact of LBP on lifestyle	
Number	27	9	5	14
Items that received ≥70% agreement	18 (66.6%)	4 (44.4%)	3 (60%)	8 (57.1%)
Items that received < 70% agreement	9 (33%)	5 (55%)	2 (40%)	6 (43%)
New items suggested by participants	6	4	1	0
Total number of items generated for Round 2 after excluding items that did not reach consensus and including new items=44				

Key: LBP: Low Back Pain

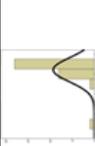
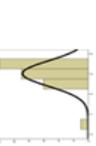
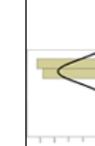
Individual agreement for each item within each domain is presented in Table 13 organised by level of agreement from highest to lowest level of agreement. Median, distribution of responses, dispersion, skew and level of agreement for each item is also presented in Table 13. Most items are negatively skewed, which is to be expected and desired in a Delphi study aiming to gain consensus (Hsu and Sandford 2007, Lantz 2013).

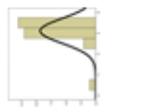
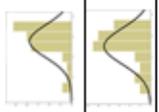
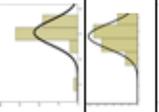
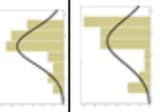
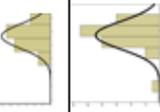
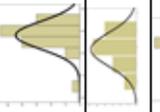
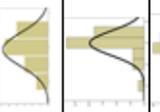
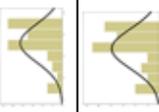
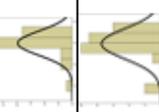
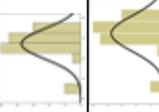
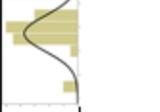
In Round 1, items related to pain location PB 13: 'Please tick all the regions where you experience this type of sensation', PB 10: 'Where is your pain located?' received a high

level of agreement (95% and 92%, respectively). Items relating to experiencing other sensations than pain, PB 11: 'Are you experiencing any other types of sensations?' and PB 12: 'What type of sensation is it?' also received a high level of agreement (90% and 87%, respectively).

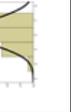
Item number P7: 'Since my low back pain started, I seem to have problems remembering things.' in the Perception of LBP domain, and item W2: 'What is your occupation?' in the Impact of LBP on work received the lowest agreement score (50 % and 55% respectively) (Table 13).

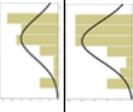
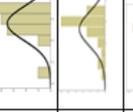
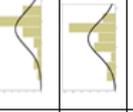
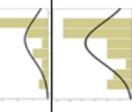
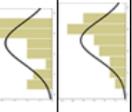
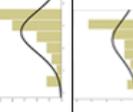
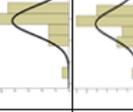
Table 13 Phase 1 E-Delphi study Round 1 and 2 results in order of descending level of agreement

Item ID	Item	Round 1				Round 2				Item Rank order		
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR		Distribution of responses	LoA (%)
Pain behaviour domain (PB)												
PB13	Please tick all the regions where you experience this type of sensation: Neck - Shoulder -Arm -Upper back -Lower back -Leg - Other	6.5	-2.37	1		95%	7	-2.03	0		100%	1
PB10	Where is your pain located? Please tick all body regions that apply: Neck -Shoulder -Arm -Upper back -Lower back -Leg -Other	7	-2.49	1		92%	7	-2.13	0		100%	2
PB11	Are you experiencing any other types of sensations (such as pins and needles, numbness) beside pain?	7	-2.34	1		90%	7	-3.7	1		97%	3
PB12	What type of sensation is it?	6	-1.64	2		87%	7	-1.73	1		96%	4
PB21	Is your pain constant?	6	-1.26	2		76%	6	-2.45	2		96%	4
PB22	Are you able to ease your low back pain?	6	-1.58	2		84%	6	-1.27	1		96%	4
PB25	Please tick all the activities that trigger or increase your pain: Slouched Sitting-Sitting up straight- Standing up straight- Walking-Fast	6	-1.37	2		84%	6	-3.23	1		96%	4

Item ID	Item	Round 1					Round 2					Item Rank order	
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)		
	walking- Lying on your side curled up- Running- Lifting-Forward bending (stooping)- Cycling- Overhead reaching- Everything I do aggravates my pain												
PB27	Please tick all the activities that stop or decrease your pain: Slouched Sitting- Sitting up straight- Standing up straight- Walking-Fast walking- Lying on your side curled up-Running- Lifting-forward bending (stooping)- Cycling- Overhead reaching- Nothing I do relieves my pain- Painkillers	6	-1.37	2		82%	6	-3.23	1		96%	4	
PB23	How do you ease your low back pain?	6	-1.46	2		84%	6	-2.66	1		96%	5	
PB14	On average, how many hours do you sleep?	5	-0.92	2		74%	6	-0.14	1		89%	8	
PB15	Does your low back pain wake you up at night?	6	-1.15	2		79%	6	-1.82	1		89%	8	
PB32	In general, is your back pain getting better/staying the same/ getting worse?*					NA	6	-0.48	2		89%	8	
PB9	How effective is the medication in reducing your low back pain?	5	-1.04	2		76%	6	-1.87	1		89%	9	
PB16	If your sleep is disrupted because of low back pain, are you able to get back to sleep?	5	-0.79	3		71%	6	-1.79	1		89%	9	
PB28	Is this the first time you experience this type of pain?*					NA	6	-1.86	1		89%	9	

Item ID	Item	Round 1						Round 2						Item Rank order
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)			
PB31	What type of pain is it? Deep/nagging/dull/sharp/shooting/dull ache/bright/lightninglike/burning/pressure like/stinging/aching/throbbing/diffused*					NA	6	-2.37	1		89%			9
PB1	Do you know what caused your low back pain?	5	-0.93	3		74%	6	-1.80	2		86%			11
PB5	If you have been treated for low back pain, were you satisfied with the treatment you received?	5.5	-1.17	1		76%	6	-1.98	1		86%			12
PB2	If yes, what caused your low back pain?	5	-1.03	2		76%	6	-1.45	1		82%			14
PB7	What medication do you take to manage your low back pain?	5	-0.99	3		71%	6	-1.26	2		79%			16
PB29	If you answered no to the previous question, how did you relieve the pain previously?*					NA	5	-1.09	2		79%			16
PB30	Do you have less pain in the morning or at the end of the day? *					NA	5.5	-1.13	2		79%			16
PB33	What have you been previously told about why you have low back pain? *					NA	6	-1.09	2		72%			18
PB6	Are you currently on any medication for your low back pain?	5	-0.92	3		71%	6	-1.07	3		68%			19
PB20	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its worst (How close to "10" does your pain get at its worst?) **	5	-0.82	3		69%					NA			22

Item ID	Item	Round 1					Round 2					Item Rank order
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)	
PB3	When did you have your first episode of low back pain? **	5.5	-0.83	3		68%					NA	23
PB17	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain right now **	6	-0.85	3		68%					NA	23
PB18	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your typical or average low back pain **	6	-0.93	2		68%					NA	23
PB26	Do you agree with this statement: "My pain is there no matter what I do" **	6	-0.84	3		68%					NA	23
PB19	If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its best (How close to "0" does your pain get at its best?) **	5	-0.79	3		66%					NA	25
PB8	How often do you take your medication? **	5	-0.58	3		61%					NA	28
PB4	Have you ever received treatment for low back pain? **	5.5	-0.55	4		61%					NA	29
PB24	How much time on average does it take for your pain to go away? **	5	-0.57	3		58%					NA	30
Impact of LBP on work and lifestyle domain: impact on work section (W)												
W4	"I believe that my work is significantly contributing to my low back pain" how strongly do you agree with this statement?	6	-1.16	2		76%	6	-0.70	2		96%	4
W7	If you answered yes to the previous question, how long have you been off work?	6	-1.21	2		79%	6	-2.27	2		93%	6
W13	How is your back pain affecting your work? *					NA	6	-0.97	2		89%	8

Item ID	Item	Round 1					Round 2					Item Rank order
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)	
W6	Are you off work right now because of your low back pain?	5.5	-1.06	3		74%	6	-2.34	1		89%	9
W9	How likely it is that you would return to work within 6 months?	5	-0.94	2		71%	6	-1.69	2		86%	11
W12	Do you feel supported by your boss and/or co-workers? *					NA	6	-1.31	1		79%	15
W11	How is your relationship with your supervisor/line manager/ boss? *					NA	5.5	-0.95	2		64%	20
W1	What is your current work status? **	6	-1.02	3		68%					NA	23
W3	How satisfied are you with your job? **	6	-0.92	3		68%					NA	24
W8	Is your employer understanding when it comes to your low back pain? **	5.5	-0.76	2		66%					NA	25
W5	Have you ever had time off work because of low back pain? **	5	-0.63	2		58%					NA	30
W2	What is your occupation? **	6	-0.59	4		55%					NA	31
W10	Are there other people in your occupation who have had similar issues?*					NA	4.54	4.50	3		50%	33
Impact of LBP on work and lifestyle domain: impact on lifestyle section (L)												
L1	"I am unable to do my normal daily activities because of my low back pain."	6	-1.35	2		76%	6	-1.96	2		89%	8
L4	"My low back pain is negatively affecting my social life"	6	-1.25	2		76%	6	-1.96	2		86%	11
L5	"My low back pain is affecting my relationship with my significant other"	6	-1.19	3		74%	6	-1.73	2		82%	13

Item ID	Item	Round 1					Round 2					Item Rank order
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)	
L6	"I don't know what aggravates or eases my low back pain and it seems to vary greatly" *					NA	6	-1.44	3		75%	17
L3	"I am unable to perform my daily activities without external help." **	5	-0.69	4		66%					NA	26
L2	"My low back pain is decreasing my overall daily productivity" **	5.5	-0.69	3		63%					NA	27
Perception of LBP domain (P)												
P1	"Because of my low back pain, I feel stressed/ anxious all the time."	6	-1.20	2		79%	6	-2.62	1		96%	4
P2	"Feeling stressed increases my low back pain"	6	-1.24	2		79%	6	-2.41	1		93%	7
P3	"Physical activity will increase my low back pain"	6	-1.07	2		79%	7	-2.46	1		93%	7
P14	"I do not think my low back pain will ever recover"	6	-0.95	4		71%	7	-2.43	1		89%	9
P11	"I don't think my family and friends understand what I'm going through in relation to my low back pain"	6	-0.99	3		74%	6	-1.79	2		86%	10
P6	"Since my low back pain started, I seem to feel more tired."	5	-0.96	2		71%	6	-1.35	2		82%	14
P10	"I have no interest or pleasure in doing things anymore because of my low back pain"	6	-1.09	3		74%	6.5	-1.69	2		82%	14
P5	"I seem to be more sensitive to things like loud noises, bright light, and odours."	5	-0.90	2		71%	6	-0.99	3		64%	20
P4	"I believe that my low back pain should go away completely before I can move on with my life." **	6	-0.79	3		69%					NA	21

Item ID	Item	Round 1					Round 2					Item Rank order
		Median	Skew	IQR	Distribution of responses	LoA (%)	Median	Skew	IQR	Distribution of responses	LoA (%)	
P12	"My back is weak and fragile" **	6	-0.58	4		66%					NA	25
P13	"My low back pain will only improve with an intervention from a healthcare professional" **	6	-0.62	4		61%					NA	29
P8	"Since my low back pain started, I seem to be moody." **	5	-0.53	2		58%					NA	30
P9	"I believe that what I do on a daily basis is significantly contributing to my low back pain" **	6	-0.43	5		58%					NA	30
P7	"Since my low back pain started, I seem to have problems remembering things." **	4.5	-0.40	3		50%					NA	32

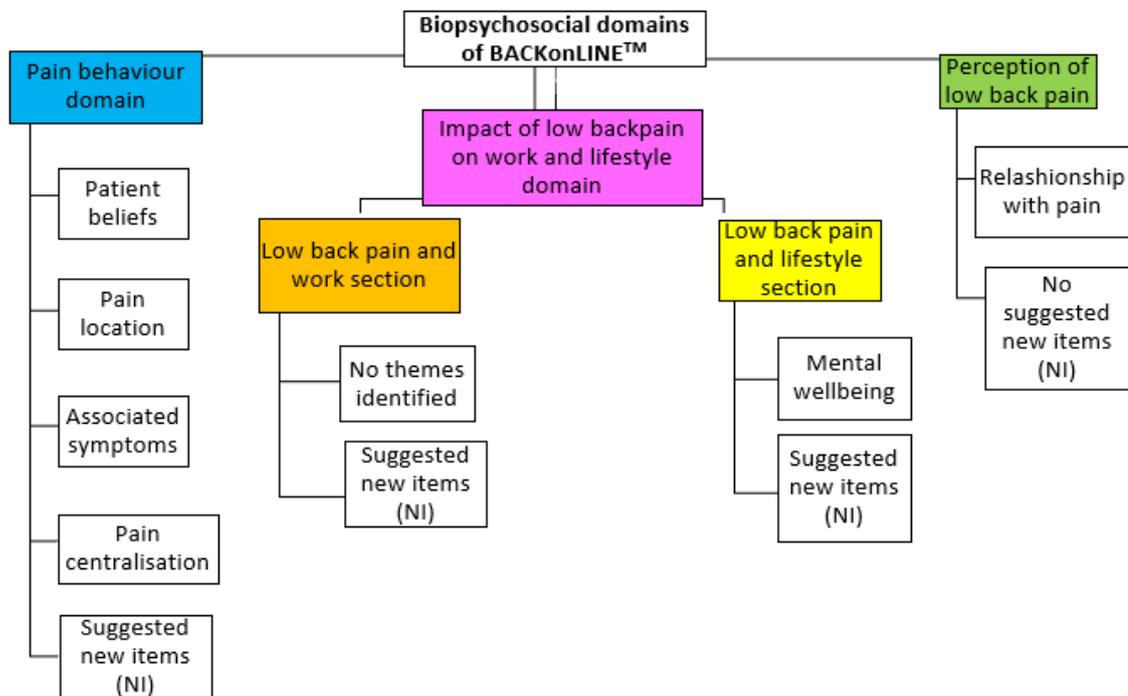
Key: PB: Pain behaviour domain item; W: Impact of LBP and Work section item; L: LBP and lifestyle section item; P: Perception of LBP domain item; NA: Not Applicable, IQR: Interquartile range (dispersion); LoA: level of agreement

* Items suggested by participants in Round 1, ** Items excluded after Round 1

5.3.1. Round 1 Thematic Analysis

In Round 1, participants were given an opportunity to comment on each self-assessment item, justify their score, and suggest new self-assessment items to be included in BACKonLINE™ and deductive thematic analysis was conducted on the participants' comments using the biopsychosocial model of pain as a theoretical framework (Figure 8).

Figure 8 Summary of the deductive thematic analysis of participants comments on the self-assessment part of BACKonLINE™ in Phase 1 Round 1



Key: NI: New item

From this analysis, 4 themes were identified in the Pain behaviour domain: (1) patient beliefs, (2) pain location, (3) associated symptoms and (4) pain centralisation. Participants reported that patients' beliefs could drive their symptoms:

“Perception of cause is linked to many things. For example cultural beliefs, employment issues, clinician opinion”

Expert33

“Getting an idea of their own understanding of their symptoms and how they impact on their life can help to lead management decisions”.

Expert03

Participants also emphasised the association of pain centralisation with the widespread pain:

“Widespread body pain may be an indicator of central pain”

Expert06

“Central pain is often accompanied by widespread pain pattern”

Expert33

Participants linked associated symptoms to centralisation of LBP (Figure 8):

“Associated symptoms such as sensitivity and formication may suggest central pain.”

Expert06

“Symptom characteristics are crucial to clinically reason through a diagnosis and screen patients properly.”

Expert03

Pain centralisation was identified as a theme in this domain with participants highlighting the link between centralisation and chronicity and widespread pain:

“Chronicity has proven links with central mechanisms.”

Expert33

“Widespread pain indicative of central”

Expert25

In the Impact of LBP on work and lifestyle domain, participants did not comment on the Impact on work section, with 1 participant indicating their discomfort with linking pain to social behaviours:

"I am uncomfortable making assumptions between pain mechanisms and social behaviours"

Expert25

However, 1 theme was identified in the Impact on lifestyle section. Mental wellbeing was identified as the main theme with participants emphasising the importance of this section as a whole:

"This is important as it is related to their general mental wellbeing and this is related to central pain."

Expert17

"These questions link more to psychology and dealing with pain."

Expert26

In the Perception of LBP domain, pain relationship with other symptoms was identified as the main theme:

"Relationship with fatigue and centrally driven processes."

"Relationship with other sensory input."

Expert25

Participants suggested 6 new self-assessment items for the Pain behaviour domain with the main themes focusing on pain recurrence, presentation, and history. In the impact on work section, 2 themes were identified, work relationships and effect of pain on work with 3 suggested self-assessment new items. In the Impact on lifestyle section, 1 theme

was identified, pain aggravating factors, with 1 suggested new self-assessment item as a result.

No new self-assessment items were suggested for the perception of low back pain domain resulting in a total of 11 suggested new self-assessment items. The identified themes and the new self-assessment items suggested by participants in Round 1 are presented in Table 14.

Table 14 Additional self-assessment items suggested by participants in Phase 1 Round 1

BACKonLINE™ Domain	Theme	Suggested additional self-assessment items
Pain behaviour	Pain recurrence	01. Is this the first time you experience this type of pain? 02. If you answered no to the previous question, how did you relieve the pain previously?
	Pain presentation	03. Do you have less pain in the morning or at the end of the day? 04. What type of pain is it? Deep/nagging/dull/sharp/shooting/dull ache/bright/lightning-like/burning/pressure like/stinging/aching/throbbing/diffused 05. In general, is your back pain getting better/staying the same/ getting worse?
	Pain history	06. What have you been previously told about why you have low back pain?
Impact of LBP on work and lifestyle domain: Impact on work section	Work relationships	07. Are there other people in your occupation who have had similar issues? 08. How is your relationship with your supervisor/line manager/ boss? 09. Do you feel supported by your boss and/or co-workers?
	Effect on work	10. How is your back pain affecting your work?
Impact of LBP on work and lifestyle domain: Impact on lifestyle section	Aggravating factors	11. "I don't know what aggravates or eases my low back pain and it seems to vary greatly" do you agree with this statement?
Perception of low back pain	No comments from participants	NA

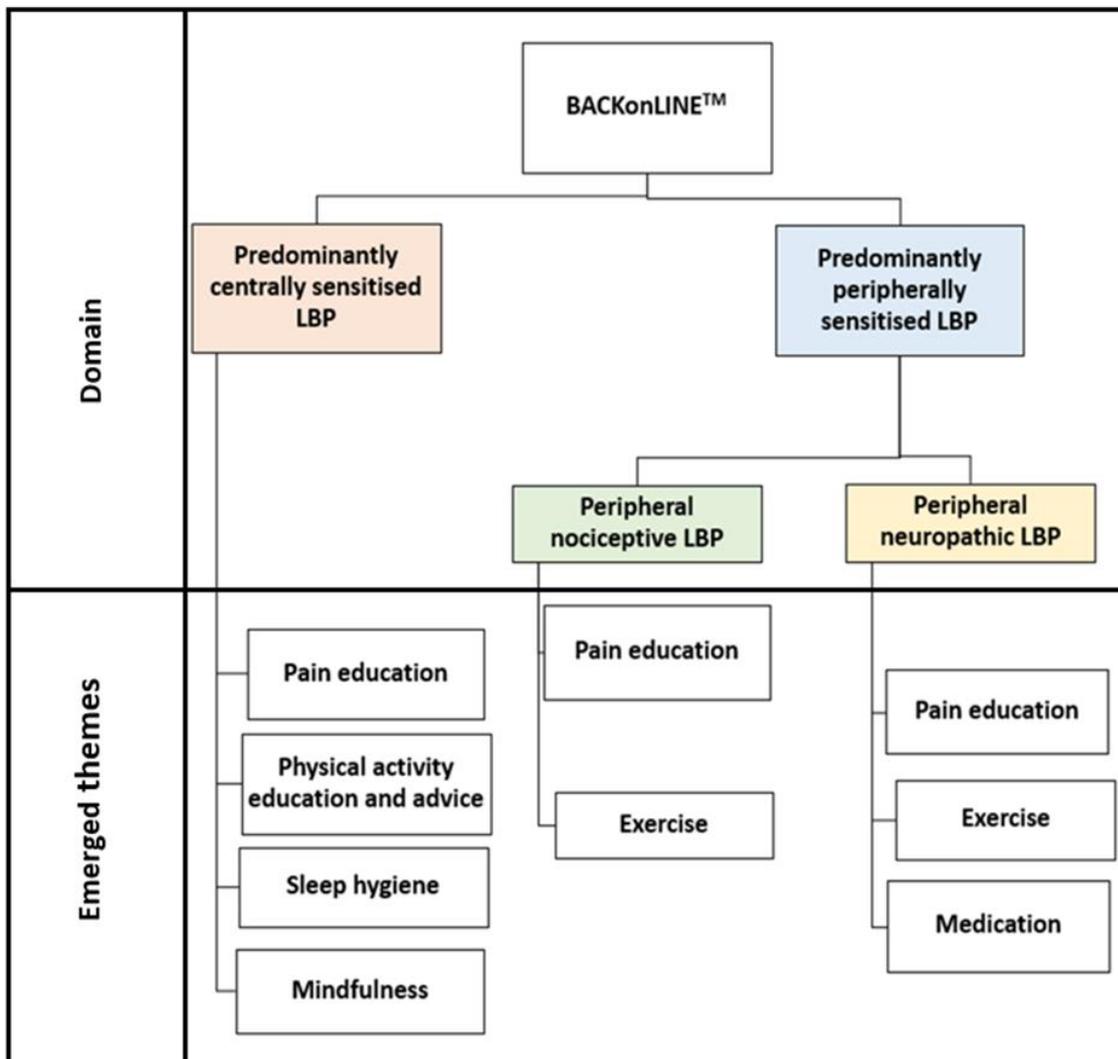
Key: NA: Not applicable

5.3.1.1. Suggested Self-Management Advice in Round 1

Within Round 1 of the E-Delphi study, participants had an opportunity to make suggestions as to the possible content of self-management of the different groups of LBP as proposed in the BACKonLINE™ self-assessment. The following section presents suggestions made by the participants.

Participants were asked to suggest what self-management advice would they offer for predominantly centrally sensitised, and predominantly peripherally (neuropathic and nociceptive) sensitised LBP. All comments were gathered in a Microsoft Word document and deductive thematic analysis was performed using the neurophysiologic types of pain as a theoretical framework (Nijs, Apeldoorn et al. 2015). Figure 9 summarises the identified themes from the participants' comments.

Figure 9 Outline of the identified themes in the self-management component of Phase 1 Round 1 of the E-Delphi study



In the predominantly centrally sensitised LBP domain, 2 common themes were identified, pain education, and physical activity and exercise education and advice. Other themes in this domain included sleep hygiene and partaking in programs or methods to train mindfulness.

In the predominantly peripherally (nociceptive) sensitised LBP domain, the most common themes that was identified were the same as the ones identified in managing centrally sensitised LBP: pain education (including the need to explain mechanisms of

pain), exercises and staying active. In this domain, participants emphasised the need to explain the condition and concept of pain to people suffering from it.

In the predominantly peripherally (neuropathic) sensitised LBP domain, education and exercise were identified again as common themes, with use of medication also being frequently mentioned.

Some participants were specific in their recommended advice for self-management while others chose to give more specific advice (i.e. pain education vs pain physiology behind central sensitisation). Table 15 Summarises the main themes that were identified in each domain with examples of suggested self-management advice.

Table 15 Low back pain (LBP) management advice suggested by participants of Phase 1 Round 1

Pain type	Identified themes	Examples of participants comments
Centrally sensitised LBP	Pain education	<p><i>“Information regarding pain mechanisms” Expert14</i></p> <p><i>“Patient Education” Expert04</i></p> <p><i>“Pain physiology behind central sensitisation and reframing it in a non- threatening way” Expert12</i></p>
	Physical activity education and advice	<p><i>“Education - pain doesn't always equal harm, importance of activity management.” Expert31</i></p> <p><i>“Learn how to move again - movement does not equal damage” Expert03</i></p> <p><i>“There are no bad forms of exercise and this will improve pain, mood and sleep. Exercise may increase your back pain initially but this is not related to damage.” Expert38</i></p>
	Sleep hygiene	<p><i>“Sleep well” Expert07</i></p> <p><i>“Sleep hygiene and relaxation or mindfulness may help” Expert03</i></p>

		<i>"Try to get quality 8 hours sleep daily" Expert15</i>
	Mindfulness	<i>"Explore mindfulness and other overall interventions that target mood and wellbeing" Expert18</i> <i>"Suggesting mindfulness resource (again depending on the patient might be Prof Mark Williams and /or Headspace App)" Expert06</i>
Peripherally (nociceptive) sensitised LBP	Pain education	<i>"Information regarding pain mechanisms (tailored explain pain) but maybe more with a focused understanding of mechanism if possible" Expert06</i> <i>"Explaining their pathology to them/ cause for their pain." Expert30</i> <i>"Explain pain" Expert19</i>
	Exercise	<i>"Exercise, Posture and movement." Expert03</i> <i>"If they are sedentary, Get them exercising!" Expert06</i> <i>"Try to do the therapeutic exercises regularly to relieve the pain" Expert15</i>
Peripherally (neuropathic) sensitised LBP	Pain education	<i>"Information regarding pain mechanisms (tailored explain pain) but also add focus on natural course" Expert14</i> <i>"Explanation of pain e.g. Explain pain" Expert35</i> <i>"Patient Education" Expert04</i>
	Exercise	<i>"Gentle exercise daily will help your nervous system become less irritated and help it get used to movement which is what your back is designed to do." Expert03</i> <i>"Movement and exercise will help the nerve to behave itself." Expert33</i> <i>"Therapeutic exercise." Expert04</i>
	Medication	<i>"Take appropriate pain medication" Expert16</i> <i>"Take your analgesia as prescribed not just when your pain is aggravated." Expert03</i> <i>"keep on medication." Expert26</i>

5.4. E-Delphi Study: Round 2

BACKonLINE™ (Version 2) (Appendix 6) included the items that reached consensus in Round 1 and new items suggested by participants and was sent to the participants in Round 2. A total of 28 physiotherapists (74%) participated in this Round.

In BACKonLINE™ Version 2, 44 items (33 gaining $\geq 70\%$ agreement from Round 1 and 11 new items) were sent to the same participants as part of Round 2. Participants were required to rate the presented items on a 7 point Likert scale. There were no open-ended questions or comment boxes included in this Round.

Out of the 44 items, 40 (91%) achieved $\geq 70\%$ agreement (Table 16). In the Pain behaviour domain, 23 items (96%) achieved consensus. In the Impact of LBP on work and lifestyle domain, 6 items (75%) achieved consensus in the Impact of LBP on work section and all 4 items of the Impact of LBP on lifestyle achieved consensus. In the Perception of LBP domain, 7 items (87.5 %) achieved consensus in Round 2 (Table 16).

Table 16 descriptive statistics of Round 2 of the E-Delphi study

Domain Category	Pain behaviour	Impact of LBP on work	Impact of LBP on lifestyle	Perception of LBP
Number of items	24	8	4	8
Items that received $\geq 70\%$ agreement	23 (96%)	6 (75 %)	4 (100%)	7 (87.5%)
Items that received < 70% agreement	1 (4%)	2 (25 %)	0	1 (12.5%)
Total number of items generated after Round 2=40*				

*Two items were merged into 1 resulting in 39 questions that currently make up BACKonLINE™.

Items PB 13,10, and 11 retained their top 3 scoring items as in Round 1 with 100%, 100%, and 97% agreement in Round 2 respectively. Two new items added by participants in

Round 1 in the Impact of LBP on work and lifestyle domain: work section 'How is your relationship with your supervisor/line manager/boss' and 'Are there other people in your occupation who have had similar issues' did not achieve consensus in Round 2 with a score of 64% and 50% respectively.

One item in the Pain behaviour domain PB6: 'Are you currently on any medication for your low back pain?' which had 71% agreement in Round 1 did not reach consensus in Round 2 with a score of 68%. One item in the Perception of LBP domain P5: 'I seem to be more sensitive to things like loud noises, bright light, and odours' which had 71% consensus in Round 1 only achieved 64% consensus in Round 2 (Table 13).

Two items, PB11 'Are you experiencing any other types of sensations?' and PB12 'What type of sensation is it?' were consequently merged by the researcher to form: 'Other than your back pain, do you experience any of the following? Pins and needles /Numbness /Tingling /Burning /Stinging /Pressure /None of the above/Other', reducing the total number of items within BACKonLINE™ to 39 in order to decrease fatigue and burden on potential users of BACKonLINE™.

5.5. Summary

BACKonLINE™ (version 1) is divided into 3 domains (Pain behaviour, Impact of LBP on work and lifestyle, and Perception of LBP) with a total of 55 self-assessment items being included in Round 1 of the E-Delphi study. Due to not meeting the inclusion criteria, 3 interested experts were excluded and 38 experts participated In Round 1. Out of 55 items, 33 (60%) reached agreement. Participants added 11 new items to be included in Round 2. During Round 1, participants were asked to suggest advice for the self-

management of predominantly centrally sensitised and predominantly peripherally sensitised LBP. Pain education was identified as a theme for predominantly centrally sensitised and predominantly peripherally sensitised LBP, while sleep hygiene and mindfulness were only identified as themes for the predominantly centrally sensitised LBP. Exercise was identified as a theme for peripherally sensitised LBP (neuropathic and nociceptive). Medication was identified as a theme for predominantly peripherally neuropathic LBP.

Round 2 (BACKonLINE™ Version 2) included 44 items which were sent to Round 1 participants. Forty (90.9%) items reached agreement in Round 2. Two items were merged into 1, resulting in 39 items that currently make up BACKonLINE™ (Version 3). Interestingly, the top 3 scoring items were similar in Round 1 and 2. In the next chapter, the results of the E-Delphi study are discussed.

Chapter 6. Phase 1 Discussion

6.1. Introduction

As a result of the E-Delphi study, the content of the self-assessment part of BACKonLINE™ was developed, and the self-management part was outlined. This chapter discusses the design of Phase 1 and the expert panel. The results of the E-Delphi with respect to self-assessment items are discussed for both Rounds. The final section discusses the strengths and limitations of this E-Delphi study.

6.2. Study Design

The aim of Phase 1 of the E-Delphi study was to develop the self-assessment items to be included in a self-assessment and self-management online tool (BACKonLINE™) in order to discern between people with predominantly centrally or peripherally sensitised LBP.

A modified, E-Delphi technique was conducted in order to include an international group of physiotherapists both based in the UK and overseas and to allow them to take part in their own time. A further benefit of this particular modification was the potential reduction of outside influences on the experts' choices, although it can never be guaranteed that others have not influenced the results. The technique selected had proven to be a valid choice since participants seemed interested in developing BACKonLINE™, as indicated by the detailed comments they provided in Round 1, and the high response rate in Round 2 (response rate=74%). In order to maintain rigour, a response rate of $\geq 70\%$ was desired between Rounds which was achieved in this study

(Mullen 2003). A technique other than the E-Delphi study might not have been able to gather responses from an international audience of experts which might have hindered the development of BACKonLINE™.

A particular challenge during the design process of the survey lay in the inherent diversity of expertise among the participants in this study. Although all experts were physiotherapists, they still came from different countries, worked in different fields (researchers, educators, clinicians) and areas, with varying levels of academic pedigree (BSc, MSc and PhD) and had varying years of experience. Thus, it was prudent to ensure that the study was understandable and easily accessible to all participants equally, especially since the study format may influence the conclusions participants may arrive at (Murphy, Black et al. 1998, Hsu and Sandford 2007).

Murphy, Black et al. (1998) proposed that when developing the content of a Delphi round, a structured approach, such as searching relevant and available literature and providing participants with ample opportunities to express their opinions is recommended. This recommendation was adopted in designing the current study. Once the survey was developed, the design of it was shaped by the testing of items on 2 experienced physiotherapists (an LBP specialist, and a sports physiotherapist), with special focus on ensuring lack of technical issues, understandability of the phrasing as well as lack of bias or vague language.

Despite the caution taken while designing the survey to avoid influencing the responses, it is still likely that participants replies were shaped by the process and questions created to gather them. Additionally, results should be viewed while considering the

circumstance that this is a consensus of opinion among physiotherapists that do not represent the whole profession where around 27.5 thousand physiotherapists actively practice in the United Kingdom in 2016 alone (Eurostat 2018).

6.3. Selection of Likert Scale Points

The choice of the number of scale points is informed by the subject that is being evaluated as well as the capacity for discerning and level of knowledge present in the target population (Komorita and Graham 1965, Weng 2004).

For this E-Delphi study, the 7 point Likert scale was selected to represent levels of importance. Although the evidence only points towards minor variations in reliability between 5 and 7 point scales, a 7 point scale has been shown to result in better quality of the received information. The use of 7 point scales enabled a more precise and sensitive reading of a respondent's real views, as it facilitates a greater precision of ratings between opposite end scale points. Recent studies have also indicated that participants in 5 point scales are more likely to attempt to place their selections between extreme ends of the scale, compared to 7 point scales, seeming to point towards a potential lack of scale sensitivity (Finstad 2010). As such, a 7 point scale was deemed appropriate for this E-Delphi study, given its increased sensitivity.

6.4. The Expert Panel

The Delphi technique has no standardised target number of expert panels (Hasson, Keeney et al. 2000, Vernon 2009), with the sample being representative of both the relative resources as well as the population which it has been drawn from (Whitman

1990, Sumsion 1998). For the present study, a sample size of approximately 30 experts was deemed appropriate in order to select the content of BACKonLINE™ (Linstone and Turoff 2002, De Villiers, De Villiers et al. 2005, DeVellis 2016). The number of experts who completed both E-Delphi Rounds (Round 1 n=38, Round 2 n=28) was deemed sufficient (Linstone and Turoff 2002, De Villiers, De Villiers et al. 2005).

This is a strength of this study as consensus methods using panels that have fewer than 6 experts may be less reliable than panels with more than 6 experts (Murphy, Black et al. 1998, Mullen 2003). Panels comprising greater than 20 participants are generally recommended for Delphi studies in order to achieve the optimal level of reliability (Mullen 2003, Baker, Lovell et al. 2006). A response rate of $\geq 70\%$ is generally considered adequate between Round 1 and subsequent Rounds in order to keep up rigour (Sumsion 1998, Mullen 2003). In this study, 73.6% response rate (n=28) was attained for Round 2 of the E-Delphi study, maintaining rigour.

This study's panel of experts was selected using purposive sampling, which may create bias. In order to control the extent of this bias, recruiting a larger sample of physiotherapists was aimed for. The sample consisted of international physiotherapists from varying backgrounds and with different training and experience (Jackson 2009). In order to be included in the study, participants had to fulfil 3 criteria (1) be qualified physiotherapists (2) work with patients with LBP and (3) be fluent in English.

According to Baker, Lovell et al. (2006), there is currently no standardised definition of an expert in relation to the Delphi technique, and such a definition may even be viewed as capricious (Williams and Webb 1994, Baker, Lovell et al. 2006). The descriptor

“expert” may include varying attributes and has long since expanded beyond academic attainment or prestige. Contemporary approaches to defining the term “expert” include specialised skills or experience in a certain field (Whitman 1990, Baker, Lovell et al. 2006). For expert opinion to provide relevant data, the experts must both be knowledgeable in the subject at hand, as well as representative of their respective population (Sumsion 1998, Baker, Lovell et al. 2006). In relation to the current study, experts were selected from international physiotherapy backgrounds with an average of 14 years of experience of working with people with LBP. It is questionable whether experience in terms of the numbers of years in practice alone can reliably indicate a certain level of expertise (Baker, Lovell et al. 2006). This study included a sample of physiotherapists from Europe, Asia, the Middle East, Australia, and North America in Round 1. The response rate per region in Round 2 decreased in Europe and North America, and the 2 participants from Australia did not participate in Round 2 (Table 11). It should be noted that experts’ objectivity may be questionable, as it is anticipated that those participants completing the Delphi study may represent those who are more invested and passionate about the subject, rather than just experts on it (Keeney, Hasson et al. 2001). Strong views may introduce bias in any way on the panel (Hasson, Keeney et al. 2000), as participants’ experiences and working practices will logically shape their opinions (Keeney, Hasson et al. 2001). In the present study, whether impartiality was achievable or realistic or in fact relevant is questionable since the study sought expert opinion on a specific way of assessing CLBP and naturally, experts who were interested in the subject would be involved. However, in order to minimise such

bias, experts were reminded that their answers were completely anonymous, emphasising that there was no right or wrong answer (Appendix 3).

6.5. The E-Delphi Study

6.5.1. Round 1

In this Round, participants were asked to rate the included self-assessment items (n=55) on a 7 point Likert scale, suggest new relevant items, and suggest self-management advice for centrally and peripherally (neuropathic and nociceptive) sensitised LBP (Appendix 4).

Even though the initial item pool was generated from the available literature, the open-ended questions and comment boxes were provided in order to ensure that no useful items were overlooked (Mead and Moseley 2001). While having both open-ended questions and comment boxes may result in a large amount of inapplicable data, the specificity of the research question made that possibility highly unlikely (Binkley, Finch et al. 1993, Murry Jr and Hammons 1995, Murphy, Black et al. 1998, Mead and Moseley 2001).

The Pain behaviour domain, which had the highest level of items reaching consensus (18 out of 27 items reached consensus), had the highest number of comments and subsequent identified themes. It also had the highest amount of suggested new self-assessment items (n=6) which could be due to the fact that physiotherapists usually use similar questions in their subjective assessment in their clinical practice which might make them more comfortable associating LBP with this domain rather than the 2 other domains.

Interestingly, items PB 17 (If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain right now) , PB 18 (If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your typical or average low back pain), PB 19 (If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its best (How close to “0” does your pain get at its best?)), and PB 20 (If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its worst (How close to “10” does your pain get at its worst?)), all of which focuses on pain intensity, did not reach consensus (consensus achieved=68%, 68%, 66%, and 69% respectively) even though high pain intensity was linked to centralisation in CLBP (Von, Deyo et al. 1993, Mccracken, Gross et al. 1996, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015).

For instance, in a study by Severeijns, Vlaeyen et al. (2001) that assessed 211 people with chronic pain problems (54 of the sample had back pain), a correlation between pain intensity and catastrophising of pain was identified. Severeijns, Vlaeyen et al. (2001) reported that people with chronic conditions who tend to catastrophise reported higher pain intensity than those who did not show any catastrophising tendencies. The link between central mechanisms was further confirmed by Peters et al. 2005, who found a link between fear avoidance and increased pain intensity.

In this study, participants did not elaborate on why they thought pain intensity was not important. However, 1 participant commented that pain intensity relates to perceived pain rather than neurophysiologic type of pain “This relates to perceived severity, not type of pain” (Expert33). This lack of consensus on the pain intensity self-assessment

items could be due to the diverse sample of international physiotherapy experts who participated in this phase who might have different levels of pain education. Perhaps, some physiotherapists did not acquire knowledge in the mechanisms-based classification of pain and therefore did not see the relevancy of pain intensity within BACKonLINE™ (Moseley 2003).

Inadequate pain education for healthcare professionals has been reported in the UK and internationally (Briggs, Carrl et al. 2011, Bond 2012, Briggs, Battelli et al. 2015). In a UK study exploring the adequacy of pain education in 10 higher education institutes for healthcare studies, it was found that only 1% of the overall curriculum focused on pain education. It was often delivered as a part of another subject instead of being a stand-alone subject (Briggs, Carrl et al. 2011). An important point to be considered by education institutions would be that introducing knowledge on the neuroscience of pain to physiotherapists has been shown to enhance their understanding of the experience of pain (Cox, Cormack et al. 2016, Colleary, O'Sullivan et al. 2017).

All the new self-assessment items (n=11) suggested by participants were included in the analysis of Round 1 and added to Round 2 with minimal editing in order to allow the expert panel to voice their opinions without any influence from the researcher (Hasson, Keeney et al. 2000). Even though the inclusion of all suggested items conserves the authenticity of the process, some items might reflect opinions of situations that are very rare in practice which might decrease the reliability of the tool (Murphy, Black et al. 1998).

It is interesting that the expert panel is predicting and commenting on the types of LBP using the mechanisms-based classification of pain in a questionnaire that was divided into domains according to the biopsychosocial theory approach. For example, 1 participant pointed out that satisfaction with treatment (PB5: If you have been treated for low back pain, were you satisfied with the treatment you received?) in the Pain behaviour domain could indicate centralisation of pain:

“Perceived injustice may drive central pain”.

Expert34

In another example, 3 participants emphasised the link between widespread pain and pain centralisation (PB10: Where is your pain located?)

“widespread body pain may be an indicator of central pain.”

Expert06

“widespread pain indicative of central”

Expert25

“Central pain is often accompanied by widespread pain pattern”

Expert33

The association participants made between the mechanisms-based classification and the biopsychosocial approach demonstrated their grasp of the approach used in the study and in extension, their grasp of what BACKonLINE™ was intended for.

After rating each item and suggesting new items, participants were asked to suggest self-management advice for predominantly centrally and peripherally (nociceptive and neuropathic) sensitised LBP. Deductive thematic analysis was employed to extract

relevant themes from the suggestions. Pain education was identified as a theme in self-management which is supported by findings in other studies exploring the management techniques for LBP (Moseley 2004, Brox, Storheim et al. 2008, Louw, Diener et al. 2011).

Physical activity and exercise were identified as a theme which is also reflected in the current literature (Liddle, Gracey et al. 2007). Although participants were asked to suggest self-management advice, the focus of this study was to develop the self-assessment items in BACKonLINE™, and the self-management suggestions were requested in order to be used in future research and to compare them with patients experience which is discussed in Phase 3.

6.5.1.1. Round 1: Self-Management

In Phase 1, the E-Delphi study, physiotherapy experts were asked to provide suggestions for the self-management component in BACKonLINE™ for predominantly centrally sensitised, and peripherally sensitised (neuropathic and nociceptive) LBP. Pain education and exercise were identified as the 2 themes for all 3 categories with the addition of medication for peripheral neuropathic pain category.

Some participants in Phase 1 broadly suggested patient education without elaborating on what education means to them. Education programs for MSK patient populations are usually based on anatomic and biomechanical models (Maier-Riehle and Härter 2001, Brox, Storheim et al. 2008). Strategies used in these models include back schools, and educational materials (i.e. the back book). However, there is no standardised approach to the type or mode of delivery of this education which produces mixed results for their

effectiveness (Maier-Riehle and Härter 2001, Brox, Storheim et al. 2008, Louw, Diener et al. 2011, Van Middelkoop, Rubinstein et al. 2011, Geneen, Martin et al. 2015).

Some experts in Phase 1 of the current study seem to agree with the PNE approach by specifically listing it as a self-management technique and recommending the 'Explain Pain' book, which is a PNE book aimed at patients (Butler and Moseley 2013):

"Explanation of pain eg. Explain pain"

Expert35

"neuroscience pain education"

Expert27

"explain pain": provide insights in hyperalgesia, allodynia and the positive effects of activity, exercise"

Expert23

"Information regarding pain mechanisms (tailored explain pain)"

Expert14

"Pain physiology behind central sensitisation"

Expert12

"Person centred educational approach...contributor to ongoing pain. Explanation of physiological / neurochemical links between these and pain."

Expert06

In recent years, neuroscience education was identified as another approach to patient education. Neuroscience education strives to explain the neurobiology, neurophysiology, and processing of pain by the nervous system (Louw, Diener et al. 2011). This educational approach aims to describe the process of central and peripheral

sensitisation, and how the brain interprets all information and the resulting effect on the pain experience. Within this approach, patients are educated on the CNS' processing of injuries, associated psychosocial elements, and how pain does not have a linear relationship with injury (i.e. pain does not equal harm) (Moseley and Butler 2015). PNE has shown to improve physical performance, decrease catastrophisation, and decrease pain (Clarke, Ryan et al. 2011, Louw, Diener et al. 2011, Gallagher, McAuley et al. 2013, Van Oosterwijck, Meeus et al. 2013, Pires, Cruz et al. 2015).

Interestingly, in Phase 3, LBP patients also expected and wanted education as a self-management approach. Even though this study has small sample sizes, it is evident from the findings and the available literature that PNE could be a main aspect of self-management within BACKonLINE™. Further studies exploring this aspect of self-management within an autonomous online tool should be investigated and reported before confirming or rejecting the inclusion of PNE in BACKonLINE™.

The other major theme that was identified in Phase 1 for all 3 types of LBP is exercise and physical activity. Participants suggested exercise but most of them did not elaborate on the type, or duration of the exercise.

“Discussing gentle range of movement activities to encourage movement.”

Expert30

“Stay active”

Expert26

“Movement advice: Tips and strategies to improve movement. Activity advice: Improve overall physical activity”

Expert21

“Advice to remain physically and socially active”

Expert16

“For some people give specific / individualised pain relieving exercises”

Expert06

“Work on stretching exercise”

Expert07

In the self-management of centrally sensitised LBP section, 2 minor themes were identified: sleep hygiene and mindfulness. The following section highlights the importance of the 2 themes and their connection to centrally sensitised LBP.

Abnormal glial (connective tissue of the CNS that contributes to centrally sensitised pain) activity might be triggered by poor sleep which triggers inflammatory responses (Haack, Sanchez et al. 2007, Haack, Lee et al. 2009). A single night of complete sleep deprivation has been shown to cause generalised hyperalgesia and anxiety in asymptomatic people (Onen, Alloui et al. 2001, Schuh-Hofer, Wodarski et al. 2013). In CLBP, sleep disturbances are known comorbidity where people are 18 times more susceptible to insomnia, and whether it's the cause or effect of CLBP is different from 1 person to another (Tang, Wright et al. 2007, Pigeon, Pinquart et al. 2012). When insomnia is a symptom in people with CLBP, it greatly increases the severity of the pain, and if it is not addressed, then it would affect other otherwise effective CLBP management techniques (Tang, Wright et al. 2007, Nijs, Clark et al. 2017).

Insomnia is usually treated using CBT, which usually includes altering sleep-related negative thoughts, improving sleep hygiene, and introducing relaxation techniques (Currie, Wilson et al. 2000, Jungquist, O'Brien et al. 2010). Interestingly, only 1 person in

Phase 1 of this study suggested CBT as a self-management technique. However, 17 people suggested sleep hygiene as a self-management technique. Sleep hygiene, which is a term used to describe the promotion of good bedtime habits, has been suggested as a management technique against insomnia in current literature and is usually a component of CBT for insomnia (Nijs, Clark et al. 2017). It is unclear however what the E-Delphi expert panel meant by sleep hygiene as they did not elaborate on their suggestions.

“Try to get quality 8 hours sleep daily”

Expert15

“Find strategies to sleep better.”

Expert18

“Sleep well.”

Expert07

Only 4 people broadly suggested mindfulness as a form of self-management in Phase 1 of the current study, a pathway that should be explored in future studies.

“Explore mindfulness and other overall interventions that target mood and well being.”

Expert18

“Suggesting mindfulness resource.”

Expert06

“Sleep hygiene and relaxation or mindfulness may help.”

Expert03

Stress has been associated with centrally sensitised pain and is recognised as another activator of the glia (Delpech, Madore et al. 2015, Nijs, Clark et al. 2017). In order to

reduce stress, mindfulness, a psychological technique that brings a person's attention to the present moment, has been suggested as a management technique for stress and chronic pain (Khoo, Small et al. 2019). In a systematic review that explored the effects of mindfulness-based interventions on chronic pain, Jackson, Kulich et al. (2016) reviewed 21 studies with a total of 1626 patients and found strong evidence that mindfulness resulted in small improvements in self-reported physical function (Jackson, Kulich et al. 2016). In a more recent systematic review, Khoo, Small et al. (2019) reviewed 21 studies and found that mindfulness-based intervention could potentially be used as a management option for chronic pain alongside CBT.

In Chapter 2, the literature review, 3 main neurophysiologic types of pain were explored: centrally sensitised pain, peripheral neuropathic pain and nociceptive pain. Accordingly, the E-Delphi study was designed to differentiate between the 3 neurophysiologic types and to identify general themes of self-management for each type. Within Phase 1, education and exercise was identified as the main themes for self-managing all 3 types with the addition of medication as management of peripheral neuropathic LBP.

Due to the similar identified self-management themes, and the current NICE guidelines that encourage exercise and education as self-management for CLBP and discourage the use of medication (NICE 2016), the author believes that CLBP in this context could be self-managed by the amount of centralisation of pain as a first step (Neblett, Hartzell et al. 2017). Even though pain can be any of the 3 types, it is a complex experience, and 1 or more types could overlap, therefore, targeting the degree of centralisation was

deemed as an important focus (Smart, O'Connell et al. 2008, Nijs, Apeldoorn et al. 2015, Sanzarello, Merlini et al. 2016, Nijs, Clark et al. 2017).

6.5.2. Round 2

The aim of this Round was to establish consensus and stability from the expert panel (Murry Jr and Hammons 1995). Since this was the final Round, no open-ended questions or comment boxes were provided but items were scored on the same 7 point Likert scale. The items that achieved consensus in this Round comprised the final content of BACKonLINE™. Interestingly, items PB 10 (Where is your pain located?), PB11 (Are you experiencing any other types of sensations (such as pins and needles, numbness) beside pain?), PB12 (What type of sensation is it?), and PB 13 (Is your pain constant?) in the Pain behaviour domain which focuses on pain location, and experience and type of other sensations (Table 13, Chapter 5) achieved the highest consensus in both Rounds despite the difference in the expert panel's sample size (Round 1 n=38, Round 2 n=28) and the items excluded in Round 2 were significantly less than the items excluded in Round 1 (22 items excluded in Round 1 versus 4 items excluded in Round 2) which indicated stability in consensus.

These findings concurred with the findings by Smart, Blake et al. (2010)'s Delphi study aiming to identify clinical indicators for centrally sensitised pain, peripheral neuropathic, and nociceptive pain presentations where constant, widespread pain and the presence of other dysesthesias (constant pain=91.5%, widespread pain=96.6%, and other dysesthesias=84.8% consensus) were identified as a indicators of centrally sensitised pain. Smart, Blake et al. (2010) also found that pain localised to the area of injury is

indicative of nociceptive pain (100% consensus) whereas burning, shooting, sharp, aching or electric shock-like pain (93.2% consensus) referred in a dermatomal or cutaneous distribution (94.9% consensus) is indicative of peripheral neuropathic pain.

Items PB 25 (Please tick all the activities that trigger or increase your pain) and PB 27 (Please tick all the activities that stop or decrease your pain) in BACKonLINE™ were also similar to findings by Smart, Blake et al. (2010) where clear anatomical/mechanical aggravating and easing factors are associated with nociceptive pain (100% consensus), aggravating and easing factors which involve movements/postures that causes loading or compression of neural tissue are indicative of peripheral neuropathic pain (84.8% consensus), and unpredictable patterns of easing/aggravating factors are indicative of centrally sensitised pain (98.3% consensus). Items PB14 (On average, how many hours do you sleep?) PB15 (Does your low back pain wake you up at night?) and PB16 (If your sleep is disrupted because of low back pain, are you able to get back to sleep?) in BACKonLINE™ (Round 2 consensus=89% for all 3) were also comparable to the findings by Smart, Blake et al. (2010) where night pain/disturbed sleep were indicative of centrally sensitised pain (79.7% consensus).

In summary, the items that reached consensus in the current E-Delphi study seem to be consistent with symptoms identified in the literature, which further increases the content validity of the acquired results (DeVellis 2016).

6.5.3. Qualitative Rigour in the Delphi Study

According to Keeney, Hasson et al. (2001), the Delphi technique incorporates both qualitative and quantitative methods and may, therefore, fulfil more qualitative

constructivist than quantitative postpositivist requirements (Hasson, Keeney et al. 2000, Keeney, Hasson et al. 2001). Therefore, the Delphi technique should consider rigour, which can be enhanced by demonstrating objectivity and integrity (Krefting 1991, Mauthner and Doucet 2003).

In order to achieve high rigour and valid interpretation of data, 4 criteria should be observed, these being truth value, neutrality, consistency, and applicability (Hasson, Keeney et al. 2000, Krefting 1991, Sandelowski 1995, Mauthner and Doucet 2003). In this current study, it was believed that accumulating items from searching relevant literature, encouraging participants to comment, suggest further items, and having them decide on items that achieved consensus enhanced the rigour of the study. Truth value may be increased by member checking, which was achieved in this study by allowing participants to leave comments in Round 1 as well as reporting the results back to the participants (Sandelowski 1995).

Neutrality denotes the acknowledgement and awareness of bias (Sandelowski 1995). The Delphi technique has been acknowledged as having the potential for researcher bias (Vernon 2009). In this study, the researcher invited the expert panel, formulated the open-ended questions for Round 1, analysed the data, presented this data to the panel and, when necessary, sent reminder emails which may have introduced bias (Vernon 2009).

In qualitative research, consistency is explained as the repeatability and replicability of both the procedure and resulting data in a study (Leung 2015). In this study, consistency is achieved through the iterative Rounds of the E-Delphi technique, where both Rounds

employed the same 7 point Likert scale. A past study also indicated the Delphi technique's consistency by drawing on 2 separate panels (n=16 and 34) to define nursing management competencies where both panels arrived at a high level of agreement for 93% of the items (Duffield 1993). The homogenous panels making up the 2 samples in Duffield (1993)'s study consisted of nurses employed in comparable fields.

Applicability is defined as the transferability of the results of a study to a larger population. This sample is not meant to be statistically representative of the population (Sandelowski 1995), and the sample should therefore not be evaluated in a qualitative study as it would be in quantitative studies (Krefting 1991, Mullen 2003). The applicability of the sample may be deduced by reporting the sample's given demographics (Krefting 1991).

6.6. Strengths and Limitations:

Although the Delphi method was created to satisfy the requirements of scientific research, there are few methodological studies that have been conducted on the Delphi process in healthcare sciences (Black 1994, Murphy, Black et al. 1998). Both validity and reliability of the Delphi method are not well established (Walker and Selfe 1996). Furthermore, there is scant scientific proof demonstrating the effectiveness of such techniques on quality and/or cost of healthcare (Black 1994). Yet some researchers claim that methodologies such as those practised in a Delphi study are not reviewable under traditional concepts of scientific evaluation (Mullen 2003). One of the most common limitations of a Delphi study may take the form of the team or persons observing the study having bias which alters the findings, abuses the privacy of

participants or shapes too rigid a structure for respondents, this not enabling participants to arrive at a consensus (Wilson, Averis et al. 2003).

Ensuring participant anonymity has been proposed as a way of minimising the potential effect of bias. It has the benefit of letting participants respond truthfully without feeling judged by other participants (Williams and Webb 1994). Yet the anonymity inherent to the Delphi technique could be considered a form of quasi anonymity, as the researchers know the names of participants, and individual participants could be aware of each other in their respective areas of interest or specialisations (Keeney, Hasson et al. 2001). This quasi anonymity may even be endangered if participants were employed in the same locations or discussed the study (Keeney, Hasson et al. 2006). Even though the resulting data was processed by using participants' randomly generated study codes, the researcher knew the participants' identities and full anonymity was thus impossible.

Quasi anonymity is essential in the Delphi method in order to enable the researcher to continue with further Rounds (Keeney, Hasson et al. 2006). Various precautions were taken in order to reduce the risk of bias: setting the level of consensus before the start of the study, clearly explaining rules and guidelines to participants, chances for participants to add, suggest or change items in Round 1 as well as limited editing of items suggested by participants (Keeney, Hasson et al. 2006). All the aforementioned precautions help minimize the researcher's influence on the study (Williams and Webb 1994). Another precaution was the determination of the number of Rounds before the start of the study. Additionally, every answer given by an individual participant, both

comments and Likert score ratings, had equal weight and importance, thus decreasing the potential of bias (Keeney, Hasson et al. 2001).

The results of the Delphi technique may be viewed as containing both face validity (i.e. logical), as participants suggested items for inclusion. It also contains content validity (i.e. literature-based), since participants arrived at a consensus on items extensively mentioned in the literature (Murphy, Black et al. 1998, Williams and Webb 1994). As such, the items contained within BACKonLINE™ appear to align with numerous aspects of pain mechanisms as described in the current literature thus achieving face and content validity (Butler 2000, Lidbeck 2002, Woolf 2004, Yunus 2005, Smart, Blake et al. 2010, Clauw 2015).

Some critics of the Delphi technique argued that it does not lead to group discussions (Keeney, Hasson et al. 2001), and that since participants expressed views without any need to demonstrate reason (Hasson, Keeney et al. 2000), they are therefore possibly less accountable for their responses (Vernon 2009). In the present study, participants were encouraged to provide feedback and multiple participants used this option to justify their responses. As with other surveys, the Delphi technique may produce responses that participants consider socially acceptable or responses that are seen as likely to be helpful to the researcher (Keeney et al. 2001). Additionally, because the scores from Round 1 were presented in Round 2, participants might have simply followed the majority opinion, following notions that they were previously wrong (Keeney, Hasson et al. 2006).

The total time for completion of the current E-Delphi study lasted longer than anticipated, a necessary limitation in order to achieve an adequate number of participants (Round 1: December 2016 to April 2017, Round 2: May 2017 to July 2017). This may be due to the fact that Round 1 took place during the Christmas holiday season, the volume of qualitative data received which led to a large body of data to process, as well as providing participants with a longer time window to respond.

Compared to a single questionnaire, the Delphi technique can generally be considered a time-consuming technique, which is often considered a limitation (Keeney, Hasson et al. 2006). The Delphi method's longer duration and multiple Rounds may lead to a loss of motivation and growing attrition rates (Vernon 2009), yet a single questionnaire, unlike the Delphi method, does not endeavour to arrive at group consensus (Keeney, Hasson et al. 2006).

It should be noted that even though the consensus was reached on 40 self-assessment items for BACKonLINE™, with 2 self-assessment items merged into 1 resulting in 39 items total, it cannot be presumed that "right" consensus was arrived at (Hasson, Keeney et al. 2000, Vernon 2009). In fact, a different panel discussing the same items may have produced alternate results (Hasson, Keeney et al. 2000). Neither should it be assumed that all possible opinions relating to pain mechanisms have been discussed. A different sample comprising other health professionals and/or patients could have suggested other aspects, producing consensus on alternate items (Murphy, Black et al. 1998). Furthermore, alternate open-ended questions in Round 1, or a different research

team could have produced different items, so the reliability of the Delphi technique is in question (Keeney, Hasson et al. 2001).

Even though the validity of the Delphi method can be contested, content validity is generally accepted if the expert panel is representative of the target population (Keeney, Hasson et al. 2001). This is definitely the case in this study, as BACKonLINE™ is intended for people on physiotherapy waiting lists, helping them better self-manage and cope with their symptoms until they are seen by a physiotherapist.

6.7. Summary

As the assessment and management of LBP have produced varying opinions in the past, the Delphi method was a suitable approach to use in the development of BACKonLINE™. While BACKonLINE™ draws on the descriptions of LBP symptoms prevalent in contemporary literature, it is intended to function as an inclusive self-assessment and self-management online tool.

In this phase, a 2 Round E-Delphi study was conducted using an expert panel of international physiotherapists in order to reach consensus on items to be included in BACKonLINE™. In Round 1, the experts (n=38) were asked to rate the importance of each item on a 7 point Likert scale (initial item pool derived from literature=55 items) and provide suggestions of new items they think should be included in BACKonLINE™. The experts were also asked to provide suggestions on self-management advice that people with LBP could use to help alleviate their centrally or peripherally sensitised LBP.

During Round 2, the expert panel that responded (n=28) rated the items that were identified from Round 1 (n=44) on the same 7 point Likert scale, resulting in the final pool of items within BACKonLINE™ (n=39) which was tested for readability in Phase 2.

To the author's knowledge, this is the first study employing a homogenous panel of physiotherapists in the development of an online self-assessment and self-management online tool, for the management of centrally and peripherally sensitised CLBP, using the mechanisms-based classification of pain.

Phase 2: Readability of BACKonLINE™

Phase 2 is described in Chapter 7, which reports phase relevant background, methods, results, discussion, and phase-specific strengths and limitations.

Chapter 7. Readability of BACKonLINE™

7.1. Introduction

Evaluating readability has gained focus and importance, as research has indicated that easily read texts are more easily understood (Paz, Liu et al. 2009). Readability refers to the level of difficulty regarding the comprehension of a written text. The meaning of items or wording must be consistently discernible, in order to reduce the potential for random errors and to increase reliability. Thus the phrasing and clarity of items are key. DeVellis (2016) stated that developers of text-based documents should factor in the readability level of the writing style of items and should refrain from writing particularly long and complex items (DeVellis 2016). In healthcare, majority of readability studies have been implemented in consent forms, educational material and online or web-based health information (Calderón, Morales et al. 2006, Wallace, Keenum et al. 2007, Paz, Liu et al. 2009, Rogers, Spalding et al. 2009). In this phase, the readability of BACKonLINE™ was assessed in 3 stages. The methods used in each stage are presented and the results are discussed.

7.2. Background: Assessment of Readability

Several computerised, as well as manual formulae, are applicable in the estimation of the readability of a text. These formulae present a precise and quick way to determine readability, and it is commonly found in widely utilised computer software (Stockmeyer

2009). These formulae work on the premise of evaluating the 2 key determinants of readability: the number of syllables in each word and the number of words in every sentence (Meade and Byrd 1989). From the results of the formulae, researchers may be able to use easier vocabulary and syntax in their studies. When applied, the formulae give an idea of the reading level required in order to process and understand a particular text. The Flesch Reading Ease (FRE) is 1 of the most frequently utilised formulae, and in any tool being prepared for use by the general public. One should aim to achieve a reading level between 5th and 7th grade (which in the UK would mean Year 6, or age 10-11) with FRE (Calderón, Morales et al. 2006, DeVellis 2016, Paz, Liu et al. 2009) (Table 17).

Table 17 Flesch Reading Ease (FRE) score interpretation (adapted from Paz, Liu et al. 2009)

FRE Score	Education level
100.00-90.00	5 th grade: Very easy to read. Easily understood by an average 11-year-old student.
90.0–80.0	6 th grade: Easy to read. Conversational English for consumers.
80.0–70.0	7 th grade: Fairly easy to read.
70.0–60.0	8 th -9 th grade: Plain English. Easily understood by 13- to 15-year-old students.
60.0–50.0	10 th -12 th grade: Fairly difficult to read.
50.0–30.0	College: Difficult to read.
30.0–0.0	College graduate: Very difficult to read. Best understood by university graduates.

However, when using this method, the FRE score presents only a rudimentary estimate of readability, as the score does not indicate whether a piece of text makes sense. The FRE score would be identical if the words were placed randomly (Paz, Liu et al. 2009). Nonetheless, it has been commonly applied in the evaluation of readability of healthcare brochures and questionnaires due to its simplicity and accessibility within common

software like Microsoft Word, with reliable results (Hill and Bird 2007, Pothier, Day et al. 2008, Paz, Liu et al. 2009). Being able to draw on digital calculations has advantages, due to a diminished potential for human error, but also presents difficulties in the calculation of scale items, as most of them include truncated syntax and do not follow the required structure of complete formatting (Paz, Liu et al. 2009).

Previous studies in the field of readability had found that the reader's competency level in the language, as well as various typographic factors, influence the speed at which a text is read as well as the level of text comprehension (Carey, Morrison-Beedy et al. 1997). Multiple typographic factors exist that impact the readability of printed or digital text, such as line length, line spacing, typeface selection, font size, character spacing, contrast and resolution among other variables (Smith, Gooding et al. 1998, Paz, Liu et al. 2009). As FRE is limited in scope to the number of syllables in each word and the number of words in each sentence and does not consider typographic factors in determining readability, qualitative methods are usually utilised in order to investigate typographic factors and comprehension.

The Plain English Campaign (PEC) (<http://www.plainenglish.co.uk>) is 1 option for assessing readability and typographic factors. PEC is a UK based private editing and training company. This organisation has become a world leader in plain-language promotion, lobbying to make communication between various organisations and the English-speaking worldwide community easier. PEC has worked with industry, and global organisations around the world, as well as most of the local government and council departments in the UK. Multiple forms and bills used by UK administration have

the PEC seal of approval, such as the British passport application form. Another way of assessing readability and typographic factors is the utilisation of interviews and focus groups (Oakland and Lane 2004).

7.2.1. Phase 2 Aim

The aim of this phase is to test the readability of BACKonLINE™ and check the clarity of each item. This phase was deemed important to conduct before the measurement properties phase in order to ensure that the reliability of BACKonLINE™ is not affected by the participant’s lack of comprehension of the tool that would be completed.

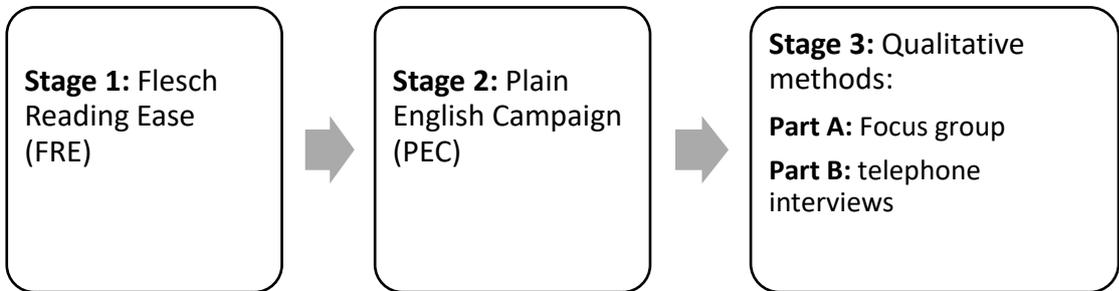
7.2.1.1. Phase 2 Objectives

- Assess the readability and the typographic factors of BACKonLINE™.
- Apply any readability enhancing suggestions generated from this phase to BACKonLINE™

7.3. Phase 2 - Methods

In this study, BACKonLINE™’s readability was assessed in 3 stages (Figure 10).

Figure 10 Flow diagram of the readability study (Phase 2)



Stage 1: An initial FRE test was performed on each individual item and on the tool as a whole to acquire preliminary data about the readability of BACKonLINE™, Table 17 summarises the potential scores of FRE and their interpretations.

Stage 2: BACKonLINE™ was then sent to PEC for further readability review and to establish whether the items contained in BACKonLINE™ (Version 3) were clear and easy to read. Both BACKonLINE™ self-assessment items and answer options were sent to PEC to ensure readability of the tool.

Stage 3: After obtaining ethical approval from Cardiff University’s Research Governance and Ethics Committee (Appendix 7), volunteers were recruited using flyers and word of mouth, and they were given the option to either participate in the focus group or the subsequent telephone interviews. An information sheet and a copy of the consent form (Appendix 8 and 9) was sent to people who showed interest in participating in the study.

Part A - the focus group: the readability of BACKonLINE™ (Version 4) was first discussed in a focus group that comprised people with current or a past history of LBP after checking their eligibility against the set criteria (Table 18). Informed consent was obtained at the beginning of the focus group.

Table 18 Phase 2, Stage 3: Eligibility criteria for participant selection for the focus group

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> • Adults (18 years old and above) • Current or past history of low back pain • Ability to read and write in English 	<ul style="list-style-type: none"> • Not fulfilling the inclusion criteria • Inability to give informed consent • Inability to commit to the focus group’s set time

Seven people with varying degrees of education volunteered to be part of the focus group. They were sent an instructional manual at least a week before the focus group took place (Appendix 10). The instructional manual contained an explanation of the purpose of the focus group, what participants were being asked to assess (typographic factors), a paper copy of BACKonLINE™ (Version 4), and the researcher's contact information in case they had any questions.

Audio recordings of the focus group were transcribed by the researcher using the intelligent verbatim method (i.e. coughs, laughs etc. were omitted) and revised twice to ensure accuracy. After the revision, the participants' names were switched to labels to ensure anonymity. Then, transcriptions were sent back to the participants via e-mail or post for member checking depending on their preference. Member checking is a process where the researcher sends the transcription to the participants so they can verify and confirm what has been said.

The data was then analysed using deductive thematic analysis (Holloway and Galvin 2016). The transcripts were entered into NVivo 11 and coded. The codes were categorised under their respective themes. Since the aim of this phase was to check the readability of BACKonLINE™, typographic factors and comprehension were the main themes. Within typographic factors, font colour, style, size and spacing between the items were identified as themes. Within comprehension, the wording of the items and the wording of the domains were identified as themes.

The new version of BACKonLINE™ (Version 5) was uploaded on www.onlinesurveys.ac.uk, ensuring that the results of the focus group analysis were applied.

Part B - the telephone interviews: Volunteers with current or a history of LBP were recruited for a telephone interview to further assess the readability of BACKonLINE™ (Table 19). Participants provided the researcher with their e-mail addresses which were used in order to send them a link to BACKonLINE™ (Version 5) with an online consent form in the beginning of BACKonLINE™ with instructions on what would be discussed during the telephone interviews. Dates and times were then set by the researcher to conduct the telephone interviews after gaining consent from the participants. Each participant was called by the researcher in the agreed-upon time, and at the beginning of the call, the researcher informed the participants that the call was audio recorded. Since this is the last step in phase 2, readability of BACKonLINE™ was assessed using participants personal computer at home to ensure readability is assessed in the same format that would be presented in phase 3. Table 19 summarises the inclusion and exclusion criteria of the telephone interviews participants.

Table 19 Phase 2, Stage 3: Eligibility criteria for participant selection for the telephone interviews

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> • Adults (18 years old and above) • Current or past history of low back pain • Ability to read and write in English • Ability to use a computer without assistance • Ability to be interviewed via telephone 	<ul style="list-style-type: none"> • Not fulfilling the inclusion criteria • Inability to give informed consent

7.4. Results

7.4.1. Stage 1: Flesch Reading Ease (FRE)

Each individual item in BACKonLINE™ and the whole tool was assessed using FRE, for readability. Table 20 includes the acquired score for each individual item and the whole tool. In summary, it was determined that BACKonLINE™ (Version 3), with a score of 92.2 (which is equivalent to 6th grade reading level and therefore ‘easy to read’) was readable according to FRE criteria (Table 17).

Table 20 Phase 2, Stage 1: Flesch Reading Ease score (FRE) for BACKonLINE™

BACKonLINE™ Self-assessment item	FRE Score
Pain behaviour domain	
PB1. Do you know what caused your current back pain?	100
PB 2. If yes, choose the most appropriate cause from the list below	0
PB 3. What do you think is wrong with your back?	100
PB 4. If you have been treated for back pain, were you satisfied with the treatment you received?	83.8
PB 5. What medication do you take to manage your back pain?	78.2
PB 6. How effective is the medication in reducing your back pain?	52.8
PB 7. Where is your pain located? Please tick all body regions that apply	100
PB 8. Is your pain there all the time?	100
PB 9. What type of pain is it?	100
PB 10. When is your pain at its worst?	100
PB 11. Are you able to ease your back pain?	100
PB 12. How do you ease your back pain?	100
PB 13. In general, is your back pain getting better/staying the same/ getting worse?	71.7
PB 14. From the list below, please tick all the activities that make your pain worse.	83.8
PB 15. From the list below, please tick all the activities that stop or decrease your pain.	78.8
PB 16. Is this the first time you have experienced this type of pain?	95.9
PB 17. If you had a previous episode of back pain, what helped in making your pain better?	74.2
PB 18. Other than your back pain, do you experience any of the following?	67.7
PB 19. Please tick all the areas where you experience this feeling	0
PB 20. On average, how many hours do you sleep?	82.3
PB 21. Does your back pain wake you up at night?	100
PB 22. If you wake up with back pain, can you get back to sleep?	100
Impact of LBP on work and lifestyle domain: Impact on work section	
WL1. How strongly do you agree with this statement?: ‘I believe that my work caused /contributed to my back pain’	67.3
WL2. Do you feel supported by your boss and/or co-workers?	78.2
WL3. How is your back pain affecting your work?	92.9
WL4. Are you off work right now because of your back pain?	100
WL5. How long have you been off work?	100

BACKonLINE™ Self-assessment item	FRE Score
WL6. How likely it is that you would return to work within six months?	89.5
Impact of LBP on work and lifestyle domain: Impact on lifestyle section	
WL7. "I am unable to do my normal daily activities because of my back pain."	0
WL8. 'My back pain is negatively affecting my social life'	0
WL9. 'My back pain is affecting my relationship with my significant other'	0
WL10. 'I don't know what makes my back pain worse or what eases it '	0
Perception of low back pain domain	
P1. 'My back pain makes me feel stressed/anxious'	0
P2. "Feeling stressed increases my back pain"	0
P3. "Physical activity will increase my back pain"	0
P4. "Since my back pain started, I seem to feel more tired."	0
P5. "I have no interest or pleasure in doing things anymore because of my back pain"	0
P6. 'I don't think my family and friends understand what I'm going through with my back pain.'	0
P7. 'I don't think my back pain will ever go away.'	0
FRE score for BACKonLINE™ as a whole	92.2

Key: PB: Pain behaviour domain item; WL: Impact of LBP on work and lifestyle item; P: Pain perception item; FRE: Flesch Reading Ease

7.4.2. Stage 2: Plain English Campaign (PEC)

After reviewing BACKonLINE™ (Version 3), PEC suggested minor changes to the wording of BACKonLINE™ (e.g., change the word region to area), the suggested changes were applied to the tool thus forming the 4th version of BACKonLINE™. Table 21 details all the changes suggested by PEC with every change highlighted in green.

Table 21 Phase 2, Stage 2: Changes suggested to BACKonLINE™ by the Plain English Campaign (PEC)

Self-assessment Items from BACKonLINE™ Version 3	Changes suggested by PEC
PB2. If yes, choose the most appropriate cause from the list below:	PB2. If yes, choose an option from the list below:
PB4. If you have been treated for back pain, were you satisfied with the treatment you received? -Yes, I was satisfied with the treatment I received -I am neither satisfied nor dissatisfied with the treatment I received -No, I was not satisfied with the treatment I received	PB4. If you have been treated for back pain, were you satisfied with your treatment? -Yes, I was satisfied with the treatment -I was neither satisfied nor dissatisfied with the treatment -No, I was not satisfied with the treatment

Self-assessment Items from BACKonLINE™ Version 3	Changes suggested by PEC
PB6. How effective is the medication in reducing your back pain? -Effective -Not sure -Not effective -I don't take any medication for my back pain	PB6. How effective is the medication in reducing your back pain? -Effective -Not sure -Ineffective -I don't take any medication for my back pain
PB7. Where is your pain located ? Please tick all body regions that apply	PB7. Where is your pain? Please tick all body areas that apply
PB9. What type of pain is it? Please tick all options that apply -Deep -Nagging -Dull -Sharp -Shooting -Dull ache -Bright -Lightning like -Burning -Pressure like -Stinging -Aching -Throbbing -Diffused	PB9. What type of pain is it? Please tick all options that apply -Deep -Nagging -Dull -Sharp -Shooting -Dull ache -Bright -Like lightning -Burning -Pressure -Stinging -Aching -Throbbing -Spread over a wide area
PB11. Are you able to ease your back pain?	PB11. Are you able to ease your back pain?
PB13. In general, is your back pain getting better/staying the same/ getting worse? - My pain is getting better - My pain is staying the same -My pain is getting worse	PB13. In general, is your back pain getting better, staying the same or getting worse? - My pain is getting better - My pain has stayed the same -My pain is getting worse
WL1. How strongly do you agree with this statement? 'I believe that my work caused /contributed to my back pain'	WL1. How strongly do you agree with this statement? 'I believe that my job caused /contributed to my back pain'
WL7. " I am unable to do my normal daily activities because of my back pain.'	WL7. 'I can't do my normal daily activities because of my back pain.'
P2. " Feeling stressed increases my back pain"	P2. 'Stress increases my back pain.'
P3. "Physical activity will increase my back pain"	P3. 'Physical activity increases my back pain.'

Self-assessment Items from BACKonLINE™ Version 3	Changes suggested by PEC
P4. "Since my back pain started, I seem to feel more tired."	P4. 'Since my back pain started, I feel more tired.'
P5. "I have no interest or pleasure in doing things anymore because of my back pain"	P5. 'I have lost interest or pleasure in doing things because of my back pain.'
P7. "I do not think my back pain will ever recover"	P7. 'I do not think my back pain will ever go away.'

Key: PB: Pain behaviour domain item; WL: Impact of low back pain on work and lifestyle item; P: Perception of low back pain item. Items highlighted in green signify the changes made by PEC

7.4.3. Stage 3: Qualitative methods - Focus group and Telephone Interviews:

In this stage, 7 people agreed to participate in the focus group, and 5 people agreed to participate in the telephone interviews.

7.4.3.1. Part A: Focus Group Results

Out of the 7 people who agreed to participate, 5 people attended the focus group that was held on the 17th of October 2017. Table 22 summarises the demographics of the participants who attended the focus group.

Table 22 Phase 2, Stage 3: Demographics of the participants of the focus group

ID	Gender	Age	Occupation	First language	Second language (if applicable)
RFG1	Female	57	Caretaker	English	Not applicable
RFG2	Female	39	Cleaner	English	Not applicable
RFG3	Female	29	PhD student/engineer	English	Not applicable
RFG4	Female	40	Researcher	English	Not applicable
RFG5	Female	55	cleaner	English	Welsh

Key: RFG: Readability focus group

The focus group participants were asked to comment on typographic factors and comprehension of BACKonLINE™. Table 23 summarises findings from the focus group, including the main themes, subsequent codes, and contributing participants and examples of their contributions.

Table 23 Phase 2, Stage 3: summary of thematic analysis and participant contribution in the focus group

Theme	Code	Contributing participants	Examples
Typographic factors	Font colour	RFG1, RFG2, RFG3, RFG4, RFG5	<p>“Personally, I probably wouldn't put red. I'm not sure if that's going to appear as red online, because red usually signals problem” RFG4</p> <p>“Any other colour. Blue.”RFG2</p> <p>“It's simple, it's easy to read, you don't mind reading it because it's not taking you hours. Just the red print. Change the red print.” RFG5</p>
	Font style	RFG3, RFG4, RFG5	“Yeah, it's readable, it's clear, and not annoying, you know? Like, when it's extra-curlly.”RFG3
	Font size	RFG1, RFG2, RFG3, RFG4, RFG5	“I'd put the question in a font a size higher. A size bigger” RFG4
	Spacing of the items within BACKonLINE™	RFG3, RFG4	“I can see where one questions stops and the other one starts” RFG3
Comprehension	Wording of the items within BACKonLINE™	RFG1, RFG2, RFG3, RFG4, RFG5	“In my view, the questions were clearly phrased, and visually everything was okay, so it's easy to go through it.”RFG3
	Wording of the domains within BACKonLINE™	RFG1, RFG2, RFG3, RFG4, RFG5	<p>“Is perception the correct word to use? That's what I wondered.” RFG4</p> <p>“perception is a really difficult concept to handle. I would say, my experience, for me.” RFG3</p>

Key: RFG: Readability focus group

7.4.3.2. Part B: Telephone Interviews Results

In Part B, 5 volunteers agreed to be interviewed. Their demographics are summarised in Table 24.

Table 24 Phase 2, Stage 3: Demographics of telephone interview participants

ID	Gender	Age	Occupation	First language	Second language (if applicable)
RI1	Female	40	Midwifery Educator	Arabic	English
RI2	Male	32	teacher	German	English
RI3	Female	36	Radiographer	Arabic	English
RI4	Female	55	Store clerk	English	Not applicable
RI5	Male	20	Student	Arabic	English

Key: RI: Readability interview

When asked about the clarity and readability of BACKonLINE™, participants only answered yes or no to the questions and did not elaborate further despite being prompted by the researcher. No changes were made after the conclusion of the telephone interviews and version 5 remained as the latest version of BACKonLINE™.

7.5. Discussion

7.5.1. Stage 1: Flesch Reading Ease (FRE)

When assessing individual items using FRE, it was noted that several items scored 0 (i.e. difficult to read) which is probably due to the fact that reading formulae are generally used for long paragraphs (more than 100 words) in order for them to give an accurate estimate of readability (Homan, Hewitt et al. 1994, Lenzner 2014). Questions could be grouped together to obtain a substantial amount of text that would give a better indication of readability. However, this method does not provide readability information for individual items, increasing the risk of vague items thus decreasing the reliability of

an assessment tool (Oakland and Lane 2004, Lenzner 2014). This limitation can be mitigated by employing human judgement as an accompanying method to assess readability (Meade and Smith 1991). Human judgement was acquired by sending BACKonLINE™ to PEC, and by conducting a focus group and subsequent interviews with people with LBP.

7.5.2. Stage 2: Plain English Campaign (PEC)

The PEC group did not report any significant difficulties in BACKonLINE™ and only suggested a few changes. All the suggested changes were applied after revising them and ensuring they did not change the meaning of items. It should be noted that all items were sent with their answer options to PEC in order to give a complete picture and get their readability advice on every aspect of the tool that would move to Phase 3 of this study. The most important change in answer options was changing the word 'diffused' into 'spread over a wide area' in item PB9 (what type of pain is it?) as it is essential to identify widespread pain considering its association with centrally sensitised LBP.

7.5.3. Stage 3: Qualitative methods - Focus group and Telephone Interviews

In the focus group, when typographic factors were explored, participants indicated that they preferred the answers in a different colour to the questions. They unanimously agreed that it should not be red since this colour signified danger to them. The colour blue was suggested and agreed upon by all participants. They also agreed that the font style (Calibri) was clear and easy to read, but 2 participants suggested making the font

larger since they were struggling to read it. No issues with line spacing were reported (Table 23).

“Personally, I probably wouldn't put red. I'm not sure if that's going to appear as red online, because red usually signals problem” RFG4

As for the focus group's participants comprehension of BACKonLINE™, they found all the items to be understandable and unambiguous. However, participants did not agree with the name of 1 of the domains (Perception of low back pain domain). Participants were unanimous in wanting to change the name of the domain since they did not understand the meaning of the word perception in this context (Table 23).

“perception is a really difficult concept to handle. I would say, my experience, for me.”
RFG3

After analysing the data from the focus group, a few changes were applied to BACKonLINE™. The font of the questions remained in black while the answer options were changed from red to blue, and the font size was increased from 12 to 16 in Microsoft Word. Also, the 'Perception of low back pain' domain was reworded to Experience with low back pain (Appendix 11).

The new version of BACKonLINE™ (Version 5) was uploaded on www.onlinesurveys.ac.uk, making sure all the changes suggested by the focus group were applied. Volunteers with current or a history of LBP were recruited for a telephone interview to assess the readability of BACKonLINE™ further. All 5 participants thought BACKonLINE™ was clear and they understood each item in it. There was no further readability - related issues reported during the interviews, the readability phase of the

study was concluded (Coyne 1997), and version 5 of BACKonLINE™ was confirmed as the final version and was used in the next phase of the study.

7.6. Strengths and limitations

In Phase 2, readability was assessed and confirmed at 3 stages, supplementing FRE with PEC consultation, a focus group and telephone interviews. This ensures the ease of completing BACKonLINE™. However, the tool was provided to the focus group in paper form; using a computer might have changed the results. This limitation was unavoidable in the timeframe due to the difficulty of preparing 7 computers in an easily accessible meeting room (e.g. no stairs). However, this limitation was reduced by providing an online version of BACKonLINE™ in the subsequent readability telephone interviews following the focus group in order to confirm readability.

7.7. Summary

Phase 2 assessed the readability of BACKonLINE™ in 3 stages; quantitatively using FRE, externally using PEC, and qualitatively using a focus group and telephone interviews. The FRE total score for the tool was 92.2, which meant that it was very easy to read. PEC did not find any significant difficulties in the text, and their suggested changes were applied to the tool after ensuring they did not change the meaning of the tool.

Then, the new version of BACKonLINE™ (Version 4) was discussed by a focus group comprised of volunteers with a past history or current LBP who suggested topographic changes (font size and colour). The focus group also suggested changing the name of the domain from 'Perception of low back pain' to 'Experience with low back pain'. All new

suggestions that resulted from the focus group were applied to BACKonLINE™, resulting in Version 5 of the tool. No new additional data was obtained from the readability telephone interviews regarding any aspect of readability. After testing and ensuring the readability of BACKonLINE™, the development part was concluded and the next and final phase of the study (Phase 3) tested the measurement properties of BACKonLINE™ (Version 5).

Phase 3: Measurement properties and Participants Experience of BACKonLINE™

Phase 3 is detailed in Chapters 8, 9, 10, and 11:

- Chapter 8: Phase 3 literature review
- Chapter 9: Phase 3 methods
- Chapter 10: Phase 3 results
- Chapter 11: Phase 3 discussion

Chapter 8. Phase 3 Literature Review

8.1. Introduction

Phase 3 assessed the measurement properties of BACKonLINE™. Measurement properties are concerned with testing the objective measures of knowledge, skills, and tools. When developing a new tool, 2 main measurement properties are assessed, reliability, and validity. A reliable and valid measurement scale is crucial in both research and clinical settings (DeVellis 2016).

Reliability is described as the estimation of the degree to which a tool delivers the same results while applied to the same person on several occasions, and a reliable scale reduces random measurement error (Peat 2001, Twycross and Shields 2004). The validity of a scale is its ability to measure exactly what it is supposed to measure, and a valid scale reduces systematic measuring error (Portney and Watkins 2009). For a scale to be valid, it must be reliable, though a reliable scale is not automatically valid. Therefore, it is common practice to determine a scale's reliability before validity (Fischer and Corcoran 2007). After investigating the reliability and validity of a tool, the cut-off scores, a form of concurrent validity, and a tool's diagnostic accuracy are determined.

Establishing reliability, validity, and accuracy for BACKonLINE™ is an important step in order to determine the interpretability and the generalisability of the tool and to investigate its fittingness in distinguishing between centrally sensitised LBP and

peripherally sensitised LBP. The aforementioned fundamental measurement properties in scale development were explored, and the different symptom clusters required in order to investigate the presence of centrally sensitised LBP are highlighted. This chapter concludes by addressing the importance of patient involvement in tool development.

8.2. Reliability

Reliability is a key aspect of scale development and dealing with random error in the measurement process (McDowell 2006). A scale that is reliable is both internally consistent and continues to deliver consistent outcomes over multiple applications. Four general categories of reliability measures exist, with each of them evaluating reliability in a distinct way: internal consistency, test retest, inter-rater and parallel forms reliability (McDowell 2006, Trochim 2006). Of the 4 existing categories, 2 are important in assessing self-reported scales; internal consistency, and test retest reliability; therefore, those 2 categories were used to assess BACKonLINE™'s reliability. The following section describes both categories and their properties.

8.2.1. Internal Consistency

Internal consistency is the degree to which items in a scale correlate with one another, thus indicating whether all items within the assessment tool measure the same subject (DeVellis 2016). Cronbach's coefficient alpha (CA), which describes the extent of intercorrelation within a scale, is typically used to determine internal consistency (Cronbach 1951). The calculation result ' α ' is a value ranging from 0 to 1, where 1 stands for a scale with perfect internal consistency (Streiner, Norman et al. 2015).

Within reliability, 2 concepts exist: uni-dimensionality and interrelatedness. Uni-dimensionality refers to items belonging to the same construct (i.e. homogeneous or measuring the same concept), whereas interrelatedness refers to the internal consistency of items (i.e. intercorrelations). Internal consistency of a construct is important but not adequate for measuring uni-dimensionality (Cortina 1993, Miller 1995). It should be noted that homogeneity between all items within a construct is assumed and if this assumption is invalid then reliability is compromised (Miller 1995, Tavakol and Dennick 2011). This assumption of homogeneity could lead to an inappropriate application of CA, which in turn might lead to scales being discredited and criticised for lack of reliable results. This situation can be mitigated by confirming uni-dimensionality of scale items.

It is important to understand that multi-dimensional scales (i.e. scales with more than 1 construct) do not necessarily have low CA in comparison to uni-dimensional scales (Miller 1995, Tavakol and Dennick 2011). Essentially, multi-dimensional scales need a detailed calculation and interpretation of CA (Cortina 1993, Miller 1995, Tavakol and Dennick 2011). Therefore, to measure internal consistency for scales with multiple constructs, it is recommended to report CA for each dimension alongside CA for the whole scale.

In order to calculate CA for each dimension within a scale, these dimensions must be identified, which could be done by applying statistical analysis to investigate whether there is a conceptual structure (i.e. construct) for a scale. Generally, factor analysis is performed to interrogate the conceptual structure of a scale (Boelen and Reijntjes

2008). Factor analysis is a statistical data reduction process which can be used when developing a new tool in order to measure a certain construct, and/or dimensions of a construct (e.g. the existence of sub-domains within a tool) (Rattray and Jones 2007). Conducting reliable factor analysis is dependent on the number of participants per item in the tool (Field 2009, Hof 2012). With small samples, there is a higher probability of correlation coefficients between items to be different than correlation coefficients between items in other samples. Therefore, it is recommended that studies acquire at least 10 to 15 participants per item (Field 2009, Hof 2012). Other statistical methods exist for identifying uni-dimensional constructs (Tavakol and Dennick 2011). One method to provide an indication of different constructs is to calculate the correlation of individual items with the total item score (item-total statistics). When using this method, items with low correlations (close to 0) are typically deleted, and items with extremely high CA ($CA > 0.90$) might suggest redundancy (Tavakol and Dennick 2011). Item-total statistics measure 2 assumptions: (1) corrected item-total correlation, which is correlation between every item and a scale's total score after excluding that item, and (2) CA if item is deleted, which measures if CA increased or decreased if an item was deleted (Field 2009).

A definitive value for CA in scale development does not exist since the objective of these scale affects the required standard of measurement (DeVellis 2016). For instance, an attitude scale (e.g. self-measure to assess beliefs) would not need an internal consistency as high as would be required of a diagnostic scale (e.g. a measure that assesses suitability for surgery) in a clinical setting.

Streiner, Norman et al. (2015) believed a CA greater than 0.90 could point towards the items being somewhat redundant, seeing how such a CA would mean that each independent variable would be a replication of another thus failing to add any predictive value to the analysis. Other methodologists maintain that a CA of 0.90 or higher should be aimed for, in particular for scales intended for decision making and diagnosis in clinical use (Kline 2000). Hill, Dunn et al. (2008) defined redundancy as a CA > 0.90 when assessing STarTBack, a primary care back pain screening tool, however, in another study testing the psychometric properties of the French version of STarTBack, a CA 0.70 was considered acceptable without the mention of redundancy (Bruyère, Demoulin et al. 2012). On the other hand, a study measuring the psychometric properties of the Finnish version of STarTBack stated that a CA around 0.80 is recommended and items that are too high indicate redundancy, but they did not specify the meaning behind 'too high' (Piironen, Paananen et al. 2016). Although all 3 studies shared some common authors, the definition of redundancy and adequate CA was not consistent. In this current study, it was decided to adhere with Streiner, Norman et al. (2015) recommendation that was followed by Hill, Dunn et al. (2008) and define redundancy as CA > 0.90.

Although researchers set CA according to scale importance, other factors in determining an adequate CA is considered in the literature (Ponterotto and Ruckdeschel 2007). The number of items within this scale and the sample size should be taken into consideration. Taking those 2 criteria into consideration, Ponterotto and Ruckdeschel (2007) developed a reliability matrix based on Classical Test Theory (Table 25). Classical Test Theory estimates outcomes of psychological tests like the level of difficulty of items within a test and the ability of people taking the test. Classical Test Theory is based on

the concept that a person's score in a test equals the total of their true score plus an error score (Novick and Lewis 1966, Allen and Yen 2001). In phase 3 of the current study, Ponterotto and Ruckdeschel (2007)'s reliability matrix was utilised in order to interpret the achieved CA and determine the internal consistency of BACKonLINE™.

Table 25 Reliability matrix adapted from Ponterotto and Ruckdeschel (2007)

Items per subscale	Sample size (N)			
	Rating	N < 100	N=100-300	N > 300
≤ 6	Excellent	0.75	0.80	0.85
	Good	0.70	0.75	0.80
	Moderate	0.65	0.70	0.75
	Fair	0.60	0.65	0.70
7-11	Excellent	0.80	0.85	0.90
	Good	0.75	0.80	0.85
	Moderate	0.70	0.75	0.80
	Fair	0.65	0.70	0.75
≥ 12	Excellent	0.85	0.90	0.90
	Good	0.80	0.85	-
	Moderate	0.75	0.80	0.85
	Fair	0.70	0.75	0.80

Key: internal consistency coefficient (Cronbach's Alpha) falling below the "Fair" rating for its particular cell would be deemed "Unsatisfactory."

Split-half reliability is another form of internal consistency that could be used when developing scales. Split-half reliability offers the second measure of internal consistency and is arrived at through separating the scale into random halves and computing the correlation between the scores for both halves of the scale (Kline 2000). Guttman's split-half coefficient is commonly used in order to determine split-half reliability (Hinton 2014). The split-half internal consistency method could be problematic since it depends on which items are chosen for each half. This issue can be resolved by making every possible item combination in each half and calculate the average. Calculating the average of every possible split-half internal consistency within a scale is essentially

calculating CA. Therefore, calculating CA was chosen in preference to Guttman's split-half coefficient in this study. (Howitt and Cramer 2003, Streiner, Norman et al. 2015).

8.2.2. Test Retest Reliability

In test retest reliability, a sample of participants takes the same test 2 separate times, while trying to maintain all testing conditions as stable as possible. Should the test prove reliable, the participants' scores should be similar across several occasions, if the context remains the same, with the level of variation between scores being viewed as measurement error (DeVellis 2016, Portney and Watkins 2009).

There are 2 potential sources of error in measurements: humans, and the instrument used, which makes it impossible for a measurement scale to be absolutely reliable (Batterham and George 2000, Bruton, Conway et al. 2000). Due to the aforementioned sources of error, observed measurements comprise both a true-value and an error-value elements, with the true-value being defined as the variable predicted to have stable results on multiple measurements, and the error-value being the difference between the true-value and the observed value (measurement error) (Bruton, Conway et al. 2000).

Measurement error is a term applied to all unexplainable sources of variability and can be divided into random and systematic errors (Bruton, Conway et al. 2000, Portney and Watkins 2009). Random errors are unpredictable in nature and can stem from biological, psychological, or mechanical factors (lack of concentration, for example), and they do not have a constant effect on the whole sample. Their lack of consistency affects the reliability of a measure (Bruton, Conway et al. 2000). However, systematic errors are

predictable, ongoing and uni-directional which may cause an over or underestimation of predicted values of measurement outcomes across the whole sample (Portney and Watkins 2009). Since systematic errors are constant across the entire sample, they do not affect the reliability of the instrument but do affect the validity of it (Bialocerkowski and Bragge 2008, Portney and Watkins 2009).

Since the stability of the response variable is an important factor, it is critical to plan well for the intervals between trials. They should be large enough to help reduce learning, memory or fatigue effects, but sufficiently short not to cause actual changes in the measurement outcome which is particularly relevant when measuring symptoms that may fluctuate. The main factors in selecting a suitable interval are the test's intended function as well as the stability of the response variable (Streiner, Norman et al. 2015, Portney and Watkins 2009). BACKonLINE™ is intended for people with CLBP where fluctuation of symptoms is unlikely within short periods of time. Therefore, 1 week was deemed appropriate in order to reduce memory effects while maintaining stability in symptoms.

Test retest reliability is usually assessed by correlations coefficients which inform the extent of association between 2 variables but not the degree of agreement between them (Chinn 1990, Keating and Matyas 1998). The Intraclass correlation coefficient (ICC), the kappa coefficient, and Pearson's Product Movement Correlation Coefficient (r) are usually used in test retest reliability analysis with both ranging from 0 to 1. Spearman's correlation coefficient, another correlation coefficient used in reliability studies, is not recommended since it only takes into account the rank order of the numbers, not the

number themselves, therefore omitting a lot of potentially useful information (Streiner, Norman et al. 2015, Portney and Watkins 2009). In their STarTBack psychometric study, Hill, Dunn et al. (2008) reported substantial reliability for their total score and psychosocial subscale (weighted kappa=0.73-95%, CI=0.57–0.84; 0.69 -95% CI =0.51–0.81 respectively).

Although Cohen kappa is used extensively in healthcare literature (Davidson and Keating 2002, Sim and Wright 2005, Hill, Dunn et al. 2008, Legault, Cantin et al. 2014), psychometric literature notes the superiority of ICC over kappa for the following reasons (Berk 1979, Streiner, Norman et al. 2015):

- The ability of ICC to separate factors affecting reliability
- Flexibility and simplicity of ICC in studies with multiple observers or multiple response options
- The ability of ICC to either include or exclude systematic bias
- The ability of ICC in handling missing data

Moreover, in reliability studies, the ICC is the preferred method since it measures both correlations and associations and usually decreases when the measurement error occurs (Hopkins 2000, Peat 2001).

Relying on just the ICC to establish the extent of reliability is not sufficient, despite the ICC being simple to interpret and representative of the correlation and association between repeated measurements. The ICC fails to provide an estimate of the level of agreement between multiple measurements and is affected by between-subjects

variation, and the reliability of participants score over time (Rankin and Stokes 1998, Batterham and George 2000, Streiner, Norman et al. 2015).

The coefficient of variance (CV) can be an additional analysis for the purpose of examining the test retest reliability and is an approach entirely free from between-subjects variation. The CV, which is the ratio of the SD to the mean and usually conveyed as a percentage, is a standard measure of the dispersion of a probability distribution or frequency distribution. It is commonly used to calculate the precision of a technique and measure the level of variability within a sample (Shoukri, Elkum et al. 2006).

A test retest sample stemming from a homogeneous group of participants, who scored very similarly, would produce a low ICC despite the values being very reliable over time, because of the lack of variance among participants. By determining within-participant CVs, it is possible to obtain data that may help distinguish between these 2 contributors of influence on the ICC (Rankin and Stokes 1998, Learmonth, Hubbard et al. 2014, Streiner, Norman et al. 2015).

After assessing a tool's reliability, validity is investigated. The next section presents the types of validity and how they are measured.

8.3. Validity

Establishing validity after confirming reliability is a crucial measure while developing a new scale (Portney and Watkins 2009, DeVellis 2016). The importance of this aspect cannot be overstated. While a scale might have established reliability by having participants deliver the same score every time, further evidence that demonstrates that the scale measures what it is assumed to measure is required in order for the scale to

be useful in a practical setting. When developing a new scale, the trinitarian model of validity is assessed. The next section expands on the Trinitarian model of validity and how it is measured.

8.3.1. The Trinitarian Model of Validity

The Trinitarian model of validity includes 3 types of validity: content, construct, and criterion and is commonly used in scale development research (Guion 1980, Landy 1986, Portney and Watkins 2009). However, some researchers disagree with this traditional model stating that it is fragmented and does not represent the true picture of validity and a more uniform model of validity, unitary validity, should be adopted (Guion 1980, Landy 1986). Unitary validity is a modern, cohesive approach to validity that explores the meaning of achieved scores and its value and interpretation within the targeted population (Messick 1995). Therefore, assessing validity within the unitary model is viewed as testing a hypothesis which can only be limited by the researcher's abilities to design a test. Even though the unitary model gained momentum in some research areas, the majority of scale development researchers still utilise the traditional trinitarian model. The next section explores the 3 C's of the trinitarian model of validity: content, construct, and criterion.

8.3.1.1. Content Validity

Content validity is a subjective process that describes the extent to which a certain test or scale represents a specific theoretical subject, and a scale is considered to have content validity if it covers all aspects of that theoretical subject (DeVellis 2016, Portney and Watkins 2009). Content validity is usually established by obtaining a consensus

among recognised experts about whether or not a developed scale represents the content of the targeted subject (Portney and Watkins 2009). The concept of content validity was expanded by Feinstein (1987), who suggested that it should be referred to as sensibility. Sensibility is a principal used in Clinimetrics - a methodological field that concentrates on the quality of tests in the medical field and clinical practice (Feinstein 1987, Fava, Tomba et al. 2012). Sensibility is assessed subjectively and can be broken down into 5 distinctive topics:

- The purpose of the scale: the intent and justification for developing the scale
- The clarity of the scale: consider if the scale is comprehensive
- Face validity: consider if it looks appropriate for the targeted theoretical subject
- Content validity: consider if it represents all aspects of the targeted theoretical subject
- The simplicity of the scale: consider how much time and effort does it require to complete

In this study, content validity was established in Phase 1: the E-Delphi study by using available literature to produce self-assessment items, then having physiotherapy experts rate them and add new items.

8.3.1.2. Construct Validity

Construct validity refers to the amount to which a scale is able to measure an abstract concept or construct (Cronbach and Meehl 1955, Portney and Watkins 2009). A construct is usually multi-dimensional, which makes it challenging to determine if the

scale is measuring what we want it to measure. Construct validity cannot be evidenced by a single measure; therefore, scale developers should test their newly developed scale against more than 1 measure (McDowell 2006). Cronbach and Meehl (1955) developed what they termed as a 'nomological network' in order to test the construct validity of a newly developed tool. The nomological network is a portrayal of constructs in a study which links theoretical ideas with empirical evidence and test whether the new scale has convergent or divergent validity (Cronbach and Meehl 1955).

One hypothesis to test was convergent validity, which is whether the scale correlated well with scales intended to measure comparable constructs without reaching the point of singularity. The point of singularity refers to extreme correlations between variables ($r > 0.9$) which indicates a lack of unique contribution by the newly developed tool (Field 2009). Generally speaking, when using a Pearson's correlation coefficient, when r is < 0.30 it is considered low correlation, $r=0.30-0.70$ as moderate, $r=0.70-0.90$ as strong, and when $r > 0.90$ is the point of singularity (Chiu, Hsueh et al. 2014, Streiner, Norman et al. 2015).

Another hypothesis to test was whether the scale correlated well with other scales designed to measure unrelated subjects. This has been termed as "definition by exclusion" or "divergent validity" (Kline 2000). When measuring a complex multi-dimensional construct like LBP, convergent validity is usually measured rather than divergent validity seeing how LBP is an experience that affects all aspects of a person's life, therefore, finding a tool that is unrelated could prove to be challenging.

Luo, George et al. (2003) assessed the construct validity of the Short Form 12-Item Survey in patients with LBP by correlating it with other measures with comparable theoretical constructs (LBP severity single item question, overall wellbeing single item question, ODI, age, stress, and depression was examined). Luo, George et al. (2003) measured the physical and mental components of the Short Form 12-Item Survey separately and hypothesised that both components are negatively correlated with LBP severity, ODI, age, depression, and stress, whereas both components are positively correlated with overall wellbeing. Luo, George et al. (2003) conducted a correlation analysis and found that back pain severity was negatively correlated with the physical component ($r=-0.405$, $p < 0.0001$) and mental component scores ($r=-0.326$, $p < 0.0001$). ODI was also negatively correlated with the physical component ($r=-0.63$, $p < 0.0001$) and mental component scores ($r=-0.55$, $p < 0.0001$). While overall general wellbeing correlated with both physical component ($r=-0.283$, $p < 0.0001$) and mental component scores ($r=-0.29$, $p < 0.0001$) scores. Also, age was observed to have a negative correlation with the physical component scores ($r=-0.167$, $p < 0.0001$), but no correlation with the mental component ($r=0.028$, $p=0.162$).

Furthermore, depression was significantly correlated with both physical component scores ($r=-0.127$, $p < 0.0001$) and mental component scores ($r=-0.31$, $p < 0.0001$) and stress was correlated more with the mental component scores ($r=-0.328$, $p < 0.0001$) than with physical component scores ($r=-0.067$, $p=0.0008$). Luo, George et al. (2003) concluded that the results of the analysis support their initial hypothesis and that Short Form 12-Item Survey showed construct validity. However, Luo, George et al. (2003) did

not use a validated measure for stress or depression and opted for directly asking participants if they suffered from either, putting their methodology in question.

Hill, Dunn et al. (2008) statistically measured construct-divergent validity of STarTBack against several reference standards (TSK; Pain Catastrophising Scale; the Patient Health Questionnaire-2; Roland-Morris Disability Questionnaire) using ROC analysis and 2 different samples of LBP patients (developmental sample (n=131) and internal sample (n=500)).

In another study, Smart, Blake et al. (2012) assessed the classification of pain into centrally sensitised pain, peripheral neuropathic pain and nociceptive pain by using a battery of self-reported questionnaires (Roland-Morris Disability Questionnaire), Hospital Anxiety and Depression Scale, Verbal numerical rating scale, Health Survey) and a standardised interview and physiotherapy assessment on a sample of 464 participants across 4 hospitals and 2 physiotherapy clinics. Smart, Blake et al. (2012) analysed their data using MANOVA and concluded that mechanisms-based classification of pain might be useful in a clinical setting by distinguishing relevant physical and emotional components. This approach to measuring divergent construct validity can only be viable in studies with large samples such as those presented by Hill, Dunn et al. (2008) and Smart, Blake et al. (2012).

Another approach to determine construct validity is to investigate group variances, described as “known-groups validation” (DeVellis 2016). The scores of groups who are predicted to perform differently in the conceptual model are compared statistically in this approach. A scale designed to measure the level of pain, for instance, could be run

on 2 groups, a pain-free group versus a group with CLBP, for example. If the scores showed noticeable variances it would disprove the null hypothesis that states that the scale cannot distinguish between the 2 groups (McDowell 2006). For example, in a study assessing the measurement properties of the Portuguese version of the Pain Disability Questionnaire, a questionnaire that assesses the clinical outcome of MSK disorders by measuring disability caused by pain (Anagnostis, Gatchel et al. 2004), construct validity using the known groups method was utilised (Giordano, Alexandre et al. 2012). In this study, 119 patients with MSK disorders and 76 asymptomatic healthy participants completed Pain Disability Questionnaire. Giordano, Alexandre et al. (2012) observed a significant difference between the MSK disorders group (Mean=89.6, SD= \pm 29.2) and the healthy group (Mean=15.9, SD= \pm 3.4) indicating construct validity of the Pain Disability Questionnaire.

A different method to test construct validity is to demonstrate a scale's capacity for identifying occurring changes (McDowell 2006, Streiner, Norman et al. 2015). A score measuring pain, for instance, would normally be predicted to see a difference in the score if a proportion of patients were taking pain medication.

For example, Walsh, Hanscom et al. (2003) assessed the responsiveness of the general Short Form Health Survey against the ODI, and The Musculoskeletal Outcomes Data Evaluation and Management System scale (Morlock, Ward et al. 1998), in a LBP population by having 970 patient with LBP complete the aforementioned questionnaires at baseline and at the 3 month follow up (Walsh, Hanscom et al. 2003). In this study, 68% of patients completed the questionnaires at the 3 month follow up, and ROC

analysis was used to analyse the responsiveness of the questionnaires. Walsh assessed the responsiveness of pain components in each questionnaire and the combined pain and function components. Walsh utilised a ROC curve analysis for the function component of The Musculoskeletal Outcomes Data Evaluation and Management System scale (ROC=0.755); the pain component from the Short Form Health Survey (ROC=0.753); the combined pain and function components from the Short Form Health Survey (ROC=0.745); the function component from ODI (ROC=0.723); and the physical function measure from the Short Form Health Survey (ROC=0.721). The study concluded that the Short Form Health Survey is a sufficient measure in assessing pain and function in the LBP population (Walsh, Hanscom et al. 2003). In this current study, construct validity was measured in the form of convergent validity with a nomological network. Section 8.4 explores the chosen validated questionnaires and highlights their measurement properties.

8.3.1.3. Criterion Validity

Criterion validity investigates a scale's accuracy which can be achieved by illustrating an empirical connection between the scale and a different measure of the same construct, a gold standard that has been well established and acknowledged in the field (Streiner, Norman et al. 2015). Criterion validity consists of 2 categories: predictive validity and concurrent validity. Predictive validity is an assessment of a scale's capability to produce an outcome of relevance ahead of time (Twycross and Shields 2004). Concurrent validity is reached by comparing the developed scale with the gold standard when administered at the same time. Concurrent validity may be employed to measure the extent of

concurrence among the 2 measures by calculating the correlation between their overall scores. Furthermore, whenever gold standard deals in dichotomous results, for instance in the case of a medical diagnosis, a threshold or cut-off score can be computed which illustrates how accurately the new scale discerns between groups (such as between those with specific diagnosis and those with no diagnosis). Pain is a complex subjective experience, as such, no true gold standard exists for measuring LBP, and the closest reference standard available is a healthcare professional's comprehensive assessment (Ware Jr, Kosinski et al. 1996, Luo, George et al. 2003, Hill, Dunn et al. 2008, Smart, Blake et al. 2012).

The next section provides a clearer picture of cut-off scores, a form of concurrent validity, and explores the concepts of sensitivity and specificity.

8.3.1.3.1. Establishing Cut-Off Scores

Cut-off scores of a test are the optimal decision threshold points to use in order to differentiate between 2 subgroups, usually a group who have the condition (N+) or a group who do not have a condition (N-) (McDowell 2006). When establishing the cut-off scores, 2 types of error might occur. The assessment might incorrectly categorise subjects without the condition as having it, or it could fail to correctly categorise subjects that do have the condition. The ratio of subjects correctly identified to have the condition is described as sensitivity, also known as true positive rate, while the ratio of subjects being correctly identified to not have the condition is referred to as specificity, also known as the true negative rate (McDowell 2006). Heightened sensitivity generally

goes hand in hand with diminished specificity. Thus the goal for scale developers is to determine the score delivering the optimal balance between specificity and sensitivity.

Since cut-off scores impact the number of false positives and false negatives, determining the score has clinical as well as economic repercussions. A heightened level of false positives can inflate healthcare costs, while increased numbers of false negatives can lead to numerous patients having to deal with unrecognised conditions (Vodermaier and Millman 2011).

Several statistical methods determining cut-off scores exist, including the mean \pm 2SD method, ROC curve analysis method, and Discriminant Analysis method (Sharma and Jain 2014). The mean \pm 2SD method is considered a crude measure for determining cut-off scores. In this method, an interval where the mean \pm 2SD is calculated by subtracting $2 \times \text{SD}$ from the mean, and by adding $2 \times \text{SD}$ to the mean. This method predicts that the chance of a score occurring outside of this interval is less than 5%. The cut-off point is either the lower (i.e. mean-2SD) or upper (i.e. mean+2SD) end of this interval (Singh 2006). If the cut-off was at the lower end of the interval, the person is considered healthy or non-diseased when they score lower than the cut-off score and diseased if they scored higher than the cut-off point. The lower end interval method is susceptible to false negative cases, lowering its sensitivity.

Alternatively, the upper end interval might be used. Where if a score is higher than this cut-off value then the score is considered positive (i.e. diseased) (Singh 2006). In this approach, false positive cases might occur, lowering its specificity. A large sample of subjects is required for this method in order to determine an accurate cut-off score

(Indrayan 2012). In the discriminant function analysis method, a function is generated from a sample of known positives and known negatives. Afterwards, the generated function is used for new cases in order to classify them as either positive or negative (Indrayan 2012). This method assigns each case a discriminant score and calculates correlations between the new cases and the known cases of known positives and negatives. This method is rarely used in self-assessment scale development and is usually utilised in administered diagnostic tests (Indrayan 2012, Singh 2006).

A frequently used method to calculate the cut-off score is to plot sensitivity (true positives) against specificity (false positives) results for every potential cut-off score in a scale, making up the ROC curve (McDowell 2006, Streiner, Norman et al. 2015). This curve demonstrates the interchange between sensitivity and specificity, with the Area Under the Curve (AUC) representing the quantity of data supplied by the test and the level of accuracy of this test (Streiner, Norman et al. 2015). An AUC of 0.5 points represented a 50/50 chance of a subject being correctly classified and a score greater than 0.5 demonstrates that the scale can potentially serve as a screening tool (McDowell 2006).

It is established in the literature that scores ranging from 0.5 to 0.7 indicate low accuracy, with scores from 0.7 to 0.9 presenting moderate accuracy for a diagnostic scale, and scores over 0.9 representing a highly accurate scale (Swets 1988, Streiner, Norman et al. 2015).

An example of methods used to establish cut-off points is a study by Scholz, Mannion et al. (2009) who developed Standardised Evaluation of Pain, a tool combining 6 pain-

related interview questions, and 10 physical tests in order to identify neuropathic pain by discriminating between radicular and axial LBP. In order to establish the required sample needed in determining a cut-off score, Scholz, Mannion et al. (2009) conducted sample calculations and determined that a sample size of 65 participants per diagnostic group is required to achieve 80% power in a 2-sided test at the 0.05 significance level.

Employing a sample of LBP patients with neuropathic pain (n=130) and axial pain (n=57), Scholz, Mannion et al. (2009) compared Standardised Evaluation of Pain with the neuropathic pain diagnostic questionnaire using a ROC curve analysis and determined that a score of 4 or higher is indicative of radicular LBP with a 92% sensitivity and 97% specificity (95% CI=83%-97% and 89%-100% respectively) and the AUC was 0.98 ± 0.01 indicating high diagnostic accuracy. Whilst this is an accurate and well-described method, the goal of having 65 participants per diagnostic arm was not met. Therefore, the results should be interpreted with caution (Kumar and Indrayan 2011).

Another example of a study that utilised ROC curve analysis was conducted by Terry, Kramer et al. (2015) for the development of the Musculoskeletal Readiness Screening Tool (MRST) designed to predict injury specifically in the military population (n=141). In the military, there are specific fitness tasks that are usually individually scored (e.g. unilateral wall sit hold, weight-bearing forward lunge), and the MRST was designed to merge these tasks into 1 composite score. The purpose of Terry, Kramer et al. (2015)'s study was to investigate whether the MRST composite score was better in predicting MSK injury than the classic broken down tasks. The ROC analysis showed that a score of ≤ 12 of the MRST was the best available cut-off option (sensitivity 0.50, and specificity

of 0.57) with AUC=0.53 (95% CI=0.44-0.63). The study concluded that with an AUC of 0.53, the MRST was no better than pure chance in predicting future MSK injury. In summary, ROC curve analysis consists of 2 main components. The first component is plotting sensitivity and specificity against each other in order to determine a viable cut-off score (i.e. a score where both specificity and sensitivity are close to each other). The second component is to determine the AUC in order to investigate if the developed tool possesses diagnostic accuracy and the level of this accuracy.

In the next section, validated questionnaires that were used in Phase 3 are presented, along with their purpose and established measurement properties. And 1 of those measures, STarTBack, was used to achieve a preliminary cut-off score of BACKonLINE™ using ROC curve analysis.

8.4. Pain and Related Symptoms Outcome Measures

In the mechanisms-based classification of pain approach, the clinical presentation of pain could result from the dominance of 1 type over another where centrally and peripherally sensitised pain could be discernible by clustering signs and symptoms (Bennett 2006, Smart, O'Connell et al. 2008). In this study, BACKonLINE™ was assessed according to the aforementioned clustering of signs and symptoms approach in order to categorise LBP into symptoms of predominantly centrally or peripherally sensitised. People with centrally and peripherally sensitised LBP may be different in several categories such as health-related quality of life, self-reported pain intensity, anxiety, depression, functional disability and fear of movement (kinesiophobia). It has been

proposed that people with predominant features of centrally sensitised pain report diminished health-related quality of life, higher levels of pain intensity, higher levels of disability, anxiety, fear avoidance and depression when compared to people with peripherally sensitised LBP (Bennett 2006, McCarthy, Rushton et al. 2006, Smart, O'Connell et al. 2008). The following section provides an overview of the constructs usually involved when assessing the construct validity of a newly developed LBP tool. The validated tools chosen for the current study are also highlighted.

8.4.1. Health-Related Quality of Life and Functional Disability

Health-related quality of life, also described as health outcome, health or functional status in both literature and clinical settings (Jette 1993, Coons, Rao et al. 2000), has become a widely accepted outcome measure for people with LBP. Health-related quality of life measures are usually self-reported questionnaires that describe a person's level of activity and difficulties while performing the measured activity (Delitto 1994, Jette 1995, Enebo 1998, Resnik and Hart 2003). Health-related quality of life scales can be divided into condition specific, and generic. Generic scales are intended for general application in different types of patient populations, while condition specific scales are intended for particular patient groups, for example patients presenting with LBP. As clinical tools, condition specific scales are beneficial for therapists in several ways. For one, they measure particular aspects of function that are the most crucial for the condition or disease in question and are potentially more responsive than generic scales (Patrick and Deyo 1989). Many of such scales may also be scored faster in clinical settings, and the interpretation of the results is simpler (Resnik and Hart 2003). In the

current study, 2 health-related quality of life tools were utilised, the ODI, and The Keele STarTBack Tool (STarTBack). The following section provides an overview of both tools.

8.4.1.1. Oswestry Disability Index (ODI)

The ODI, a self-reported questionnaire, is reported as a valid and reliable tool in a condition specific health-related quality of life in the assessment of people with LBP (Fairbank, Couper et al. 1980, Stratford, Gill et al. 1995, Beurskens, De Vet et al. 1996, Leclaire, Blier et al. 1997). The ODI comprises 10 sections of questions, dealing with ADLs and pain and can be completed in roughly 5 minutes. Each section has 6 statements, which describe the level of pain severity experienced during a particular activity and are scored from 0 to 5. The total score achieved from each section is then added together and multiplied by 2 to get a percentage of disability. Scoring of the ODI takes approximately 1 minute and the higher the calculated percentage, the higher perceived level of disability (Fairbank, Couper et al. 1980, Beurskens, De Vet et al. 1996, Fritz and Irrgang 2001).

Originally developed in 1980, the ODI has seen multiple modifications (Fairbank, Couper et al. 1980), with the first being the substitution of a statement relating to the usage of pain medication with a question dealing with pain intensity (ODI Version 2) (Beurskens, De Vet et al. 1996). In a second alteration of the ODI, a statement on sex life was changed to one concerning altering pain patterns (Beurskens, De Vet et al. 1996, Resnik and Hart 2003). ODI version 2 (Appendix 12) is generally recommended and used worldwide (Baker 1989, Roland and Fairbank 2000). The 3rd version of the ODI was published by a chiropractic study group in the UK with the aim to increase the sensitivity of the scale

for the minimally disabled population (Hudson-Cook 1989). However, this version has been criticised for confusing impairment with disability, having complex wording, and not allowing for the absence of symptoms (i.e. inapplicable) in some sections (Fairbank and Pynsent 2000). Versions 1 and 2 of the ODI showed excellent test retest reliability with high reported correlation coefficients ($r=0.99$ reported by Fairbank et al. (1980), $r=0.83$ reported by Baker, Pynsent et al. (1989), and $ICC=0.94$ reported by Kopec, Esdaile et al. (1995).

In another study, the Rasch analysis, a psychometric approach that uses a simple logistic model 'Rasch model' to assess the suitability of adding up item scores (Rasch 1960), was used in order to determine construct validity of the ODI (Davidson 2008). Both versions 1 and 2 showed adequate fit to the Rasch model ($X^2 p >.01$) while version 3 failed to fit the model ($X^2 p=0.006$) (Davidson 2008). According to Davidson (2008) Versions 1 and 2 of the ODI show good construct validity, while version 3 showed below average construct validity (Davidson 2008). In another study, when correlated to the VAS, the ODI showed moderate construct validity ($p=0.62$) (Roland and Fairbank 2000).

In summary, the ODI is a frequently used, reliable, and validated, condition specific health-related quality of life tool. And it was deemed appropriate to use the ODI in order to determine diminished physical function, which is indicative of centrally sensitised LBP (McCarthy, Oldham et al. 2005, Bennett 2006, Smart, Blake et al. 2012).

8.4.1.2. The Keele STarTBack Tool

The Keele STarTBack tool (STarTBack) is a self-administered, 9 item questionnaire that consists of treatment modifiable biomedical, psychological, and social risk factors

(spread of pain, disability, and psychological factors). LBP patients are stratified into 3 groups (low, medium, or high risk of poor clinical outcome) in order to match them with a specific care pathway (Appendix 13) (Hay, Dunn et al. 2008, Hill, Dunn et al. 2008). The STarTBack tool was developed in the UK in a primary care setting and became popular in both research and clinical settings and was recommended in the latest NICE LBP guidelines as a treatment stratification tool (NICE 2016).

STarTBack was reported to have excellent test retest reliability ($\kappa=0.73$) and discriminative validity that ranges from acceptable (AUC=0.73 for leg pain) to outstanding (AUC 0.92 for disability) (Hill, Dunn et al. 2008). Discriminative validity for external samples in the UK, Denmark, and the US was also reported as high for both the physical and psychosocial constructs within STarTBack (Hill, Dunn et al. 2008, Fritz, Beneciuk et al. 2011, Traeger and McAuley 2013). When correlated with the OMPQ, which is used as a reference standard, STarTBack showed good concurrent validity (Spearman's $\rho=0.8$) (Hill, Dunn et al. 2010). Although direct comparison of predictive validity was not reported, both STarTBack and OMPQ showed comparable AUCs (OMPQ=0.68–0.83, STarTBack=0.8) (Hill, Dunn et al. 2010). When correlated with expert clinical opinion, STarTBack displayed poor agreement (Cohen's $\kappa=0.22$) (Hill, Vohora et al. 2010).

STarTBack is a validated and reliable tool that is embedded in the biopsychosocial approach, where high scores indicate the occurrence of a number of modifiable risk factors. As previously mentioned, the presence of a cluster of modifiable

biopsychosocial risk factors is linked to centrally sensitised pain, making STarTBack an appropriate tool to use in the current study (Bennett 2006, Nijs, Apeldoorn et al. 2015).

8.4.2. Pain Intensity

Pain intensity is a frequently used measure in research and is a common outcome measure in pain management (Perl 2007, Ferreira-Valente, Pais-Ribeiro et al. 2011, Hjermstad, Fayers et al. 2011, Aicher, Peil et al. 2012, Sullivan and Ballantyne 2016). Even though, pain intensity can be measured in various ways like “current”, “past 24 hours”, “worst pain”, and “least pain”, average pain intensity is the focus of pain management and research (Pathak, Sharma et al. 2018).

In order to properly select appropriate pain management interventions, it is essential to establish a measure of pain intensity. But it should be noted that pain intensity is a subjective, self-reported measure and no objective measure exist for measuring it (Salaffi, Stancati et al. 2004). The next section provides an overview of the visual analogue scale (VAS), which was used in the current study to assess pain intensity.

8.4.2.1. Visual Analogue Scale (VAS)

The VAS is a self-administered pain intensity measure which consists of a horizontal or vertical straight, 10 cm (100 mm) line anchored by extreme limits (i.e. no pain and worst possible pain) (Haefeli and Elfering 2006, Hawker, Mian et al. 2011). The VAS is administered by paper and pencil by asking the participant to mark their pain on the line and cannot be adapted to be used verbally or by telephone (Appendix 14). No training is required when administering or grading VAS as only a ruler is used to calculate the results (Hawker, Mian et al. 2011).

In a study where the VAS was tested on a Chinese population sample, the horizontal version showed more error than the vertical version, however, in a study done on an English speaking sample, the error was higher in the vertical version compared to the horizontal version (Scott and Huskisson 1979, Aun, Lam et al. 1986, Hawker, Mian et al. 2011). These findings imply that the orientation of the VAS (horizontal versus vertical) should reflect the normal reading pattern of the sample population (Hawker, Mian et al. 2011).

Test retest reliability of the VAS appears to be higher among literate ($r=0.94$, $P < 0.001$) than illiterate people ($r=0.71$, $P < 0.001$) (Ferraz, Quaresma et al. 1990). Other studies showed excellent test retest reliability with ICC ranging from 0.97 to 0.99 (Bijur, Silver et al. 2001, Gallagher, Bijur et al. 2002, Williamson and Hoggart 2005).

Since pain intensity is a subjective measure, criterion validity cannot be assessed and instead construct validity is evaluated (Hawker, Mian et al. 2011). For construct validity, in patients with a variety of rheumatic diseases, the VAS appeared to be highly correlated with the numeric rating scale ($r=0.62-0.91$) and a 5-point verbal descriptive scale ($r=0.71-0.78$) (Downie, Leatham et al. 1978). The horizontal and vertical orientations of the VAS showed an excellent correlation that reached the point of singularity ($r=0.99$) (Scott and Huskisson 1979). Increased self-reported pain intensity has been shown to be indicative of centrally sensitised LBP. Therefore, it was decided to include the VAS in the current study as a measure of self-reported pain intensity (Linton and Boersma 2003, Peters, Vlaeyen et al. 2005, Nijs, Apeldoorn et al. 2015).

8.4.3. Pain-Related Fear of Movement, Anxiety and Depression

Cognitive-behavioural models of chronic pain highlight the important role beliefs and cognition have in the assessment and management of chronic pain (Turk and Rudy 1986, Turk and Okifuji 2002). Some beliefs and coping mechanisms have positive effects on chronic pain while others might actually increase pain. Therefore, understanding and identifying pain-related beliefs and cognitions might increase the effectiveness of pain management plans (Jensen, Turner et al. 1994).

Negative cognitions, which are self-expressions used in response to an environmental event, have been reported to predict distress, pain and disability in individuals with chronic pain (Jensen, Turner et al. 1991, Boothby, Thorn et al. 1999, Stroud, Thorn et al. 2000). Negative cognitions have also shown to contribute to higher usage of health care resources and pain medication (Stroud, Thorn et al. 2000).

The cognitive-behavioural model defines beliefs as pre-existing concepts of the nature of reality, that inform our view of our surroundings and ourselves, and function as the anchor that helps people understand events that they experience (Lazarus and Folkman 1984). Subsequently, individuals who seem to believe that pain is understandable respond to treatment better than individuals who seem to believe that pain is an ambiguous construct, and thus tend to catastrophise their pain and increase psychosocial distress (Williams, Robinson et al. 1994, Turner, Jensen et al. 2000). Jensen, Turner et al. (1994) reported that when people change their pain-related beliefs, they exhibit fewer depressive symptoms and improved physical function. Woby, Watson et al. (2004) stated that fear-avoidance beliefs were highly related to a greater tendency

to catastrophise and that fear-avoidance beliefs concerning physical activity were indicative of greater disability in people with CLBP. It has been theorised that a decrease in pain-related fear and catastrophising improves engagement in daily activity and recovery while an increase in pain-related fear and catastrophising contributes to the avoidance of daily activities and a slow recovery (Vlaeyen, Kole-Snijders et al. 1995, Vlaeyen and Linton 2000). It was reported that disability, activity level, and work status could be predicted using a person's fear-avoidance beliefs and catastrophising (Stroud, Thorn et al. 2000, Denison, Åsenlöf et al. 2007).

8.4.3.1. Tampa Scale for Kinesiophobia (TSK)

Fear of movement and (re)injury (kinesiophobia) in patients with pain is generally best assessed with the Tampa Scale for Kinesiophobia (TSK) (Appendix 15) (Miller, Kori et al. 1991, Vlaeyen, Kole-Snijders et al. 1995, Lundberg, Grimby-Ekman et al. 2011). TSK is a self-administered questionnaire made up of 17 items, which are scored on a 4 point Likert scale (0: strongly disagree to 3: strongly agree). To determine the total score, the replies for questions 4, 8, 12 and 16 must be inverted in value. Higher values point to a stronger level of kinesiophobia, with 37 figuring as the cut-off point in score between high and low levels (Vlaeyen, Kole-Snijders et al. 1995). The TSK has demonstrated good reliability for patients with chronic pain, with a reported CA of 0.77 for the total scale (Vlaeyen, Kole-Snijders et al. 1995) and a test retest reliability of 0.78 (Swinkels-Meewisse, Swinkels et al. 2003). People with centrally sensitised pain have shown a tendency to experience symptoms of fear of movement (Mayer, Neblett et al. 2012, Smart, Blake et al. 2012, Watson and Kendall 2013).

8.4.3.2. Pain Anxiety Symptoms Scale Short Form 20 (PASS 20)

The PASS 20 is an abbreviated version of the initial 40 item Pain Anxiety Symptoms Scale (Appendix 16) (McCracken, Zayfert et al. 1992), and is used to determine levels of pain-related anxiety and fear by drawing on 4 subcategories: escape and avoidance, fearful thoughts, physiological and cognitive anxiety (McCracken and Dhingra 2002). The PASS 20 purpose was to improve the applicability of the scale in clinical practice by making it less time-consuming.

Each PASS 20 subcategory comprises 5 items, being rated following a 6 point Likert scale (0=never to 5=always), with higher values pointing to greater anxiety and fear (McCracken and Dhingra 2002). The PASS 20 has demonstrated good internal consistency for each subcategory (CA=0.75-0.86) during its validation on the basis of 282 patients with chronic pain, and its shortened form produced comparable measures of disability, depression and pain as the initial 40 item scale.

The PASS 20 also displayed high correlations with the first PASS, which points towards a satisfactory level of convergence validity (McCracken and Dhingra 2002). On the PASS 20 scale, a total score higher than 30 indicates a high degree of anxiety related to pain and thus, increasing the risk of pain chronicity and disability (Abrams, Carleton et al. 2007). Contemporary literature indicates the presence of a link between anxiety and centrally sensitised pain (Nicholas, Linton et al. 2011, Mayer, Neblett et al. 2012, Smart, Blake et al. 2012, Watson and Kendall 2013, Clauw 2015), as such, it was deemed necessary to measure the level of anxiety in the sample who participated in Phase 3 of the current study.

8.4.3.3. Pain and Related Symptoms Outcome Measures: Summary

Based on features and associated presentation of people with predominant features of centrally sensitised pain and nociceptive pain health-related quality of life, pain intensity, and pain-related fear of movement, anxiety and depression measures would all be predicted to differ between the subgroups. The section above explored the measurement properties of tools typically used to evaluate LBP within their respective categories. ODI, STarTBack, VAS, TSK, and PASS 20 are validated and widely implemented tools in healthcare research. Therefore, these tools were deemed appropriate to administer alongside BACKonLINE™ in order to assess its construct validity and arrive at a preliminary cut-off score for the new tool.

8.5. Patient Involvement in Tool Development

In the last decades, there has been a paradigm shift towards patient involvement in healthcare (Graffigna, Barelllo et al. 2015, Menichetti, Libreri et al. 2016). In healthcare, the essential role of patients has been established in current research where researchers are encouraged to actively involve patients in the research process (Crawford, Rutter et al. 2002, Davis, Schoenbaum et al. 2005, Clancy 2011, Graffigna, Barelllo et al. 2015, Menichetti, Libreri et al. 2016). Engaging patients in healthcare increases their adherence, improves clinical outcomes and their satisfaction towards care, and decreases healthcare costs (Bellardita, Graffigna et al. 2012, Coulter 2012, Barelllo, Graffigna et al. 2014, Kovacs Burns, Bellows et al. 2014, Graffigna, Barelllo et al. 2015).

One area where patient involvement has been implemented is tool development since it was deemed important to understand a patient's perspective and explore the tool's

relevance to them (Trujols, Portella et al. 2013, Wiering, de Boer et al. 2016). Patients can be involved in the development of items, assessing comprehension, and relaying their experience with the usage of a newly developed tool (Sacristán, Aguarón et al. 2016, Wiering, de Boer et al. 2016). Even though patient involvement is essential, many studies fail to report any involvement in their methods. Involving patients in tool development provides a unique point of view since only those who suffer from a condition can determine which outcome measure is relevant to them. Furthermore, if a questionnaire fails to capture the patient's interest or represent their perspective, it might result in patients not completing the questionnaire, which might negatively impact validity (Meadows 2011).

In a scoping review, Wiering, de Boer et al. (2016) investigated the extent of patient involvement in patient-reported outcome measures (PROM) development. In that review, 189 studies were included with 59 focusing on chronic pain populations. Wiering, de Boer et al. (2016) found that in 25.9% of the included studies, no patients were involved in any stage of the development, while other studies involved patients in item development and PROM comprehensibility (58.5% and 50.8% respectively).

The review concluded that more than 25% of PROM development studies failed to record any patient involvement which might impact how representative are those PROMs of their intended populations, which might compromise the effectiveness of these PROMs on individualized care (Wiering, de Boer et al. 2016). Following the scoping review, Wiering, de Boer et al. (2017) investigated the lack of patient involvement from PROM developers' point of view. In this study, 21 PROM developers were telephone

interviewed and 3 answered questions via e-mail. All PROM developers showed acceptance and enthusiasm in involving patients in PROM development, however, the study identified lack of resources, logistics, and time constraints as the main reasons for lack of patient involvement (Wiering, de Boer et al. 2017).

Patient involvement in research is not a new concept. However, it is still not implemented in every study due to different, study specific reasons. In the current study, patients were involved in Phase 2 and 3. In Phase 2, people with LBP were involved in assessing readability and comprehension of BACKonLINE™, and in Phase 3, patients experience in filling in BACKonLINE™, expectations of self-management, and their preferred mode of delivery was also explored.

8.6. Behavioural models influencing tool utility

In order to develop a tool such as BACKonLINE™, it is important to consider factors affected by the pain phenomenon. Pain is a subjective and elusive phenomenon that cannot be directly observed and thus, the boundaries of this phenomenon must be identified in order for such a tool to target relevant domains without drifting away from the target phenomenon, which can be achieved by basing a tool on a theoretical framework (DeVellis 2016). Within this section, several overarching theoretical frameworks are considered and their limitations are discussed. Each framework may potentially be applicable for the future development and utility of BACKonLINE™, however it is crucial for researchers to pay attention to the limitations of these theoretical frameworks before applying them.

In order to further our understanding of differences in distribution of health across the population, it is necessary to examine the various factors which contribute to them. By doing so, we may be able to better comprehend and predict which individuals tend to practice health behaviours (health behaviour is defined in chapter 2, section 2.7) as well as pinpoint potential targets for interventions aimed at correcting these behaviours.

Social cognitive factors such as attitudes, awareness and beliefs, separate individuals from similar backgrounds according to the likelihood for them to engage in health behaviours. These factors have been at the centre of several models of determinants of health behaviour, for they constitute long term characteristics which differentiate based on behaviour learned through socialisation processes. They are however changeable and thus represent an opportunity to influence health behaviour patterns. These cognitive factors have since formed the basis for a few models of health behaviour that are widely applied. They have been designated social cognition models (SCM) due to them drawing on cognitive variables to explain individual social behaviours, such as health behaviours (Glanz, Rimer et al. 2008).

SCM have been tested by predicting health-related behaviour based on the variations in self-reported cognitions. These differences have been successfully used to predict the reported outcome of preventative actions. Self-reported measures following these models have shown to differentiate between those that do and do not perform a variety of health behaviours. It has been argued that interventions aimed at cognitions described by these models have the potential to promote health-enhancing behaviour as well as improve the efficacy of healthcare services. Research has backed this

argument through generally supportive findings, as interventions created to influence theory-specified cognition have been demonstrated to improve health-related behaviour (Glanz, Rimer et al. 2008).

Additionally, interventions based on SCMs have been more effective than those without a comparable theoretical basis, based on the research on some areas. The health belief model (HBM), the theory of planned behaviour (TPB) as well as the transtheoretical model (TTM) are the most commonly applied health behaviour models (Glanz and Bishop 2010).

The HBM was developed as a psychosocial model, applicable to the uptake of long-term changes in behaviour during chronic conditions (Glanz, Rimer et al. 2008). As such, it has been demonstrated to be able to predict health behaviours ranging from smoking to dieting and exercising (Ogden 2007). Additionally, the HBM has been applied in studies reviewing sick-role behaviour and illness (Glanz, Rimer et al. 2008). A person's beliefs about medical conditions are often more relevant than the actual symptoms, which is what the HBM is based on (Glanz and Bishop 2010). Since chronic pain might not always have a medical explanation, treatment of the underlying condition entails changing behaviours and beliefs, instead of the symptom of pain, and it is this area that the HBM has relevance. The HBM is based on managing health behaviours according to the perceived threat of a condition, as well as the beliefs of the benefits of said health behaviour (Polit, Beck et al. 2001).

HBM is frequently used as a guideline by researchers when developing a new program in order to understand the reasons of lack of compliance. In detail, the HBM in its original

form accounted for the following factors: perceived severity, perceived susceptibility, perceived barriers and cues to action as well as perceived benefits (Glanz and Bishop 2010). 'Perceived susceptibility' refers to the perceived possibility of illness and re-susceptibility, along with beliefs concerning the validity of a medical diagnosis (Glanz, Rimer et al. 2008). The HBM was expanded in 1988 to include self-efficacy on top of the other four aspects: perceived susceptibility, severity, benefits and barriers. Self-efficacy, which is described as a person's perception of his or her ability to carry out a behaviour, was added to the HBM to help account for differences between individual health behaviours (Glanz, Rimer et al. 2008).

Initially, the HBM was created to illustrate factors leading to one-time health-related behaviours such as receiving an immunisation or screening for diseases. It was subsequently expanded to apply to long-term behaviour changes like addiction, exercise or diet changes. The HBM's developers acknowledged early on that an important aspect of health behaviour change lay in trusting one's ability to carry out changes (such as self-efficacy) (Glanz, Rimer et al. 2008).

The HBM is subject to multiple restrictions and limitations which inhibit its applicability in tool development, including the following:

- It does not reflect an individual's stance or beliefs that may determine whether or not an individual is receptive of a health behaviour.
- It does not consider accustomed behaviours and habits, such as smoking, that could influence the willingness to adopt a recommended course of action.

- It does not account for socially motivated behaviours that are not engaged in for health-related reasons.
- It does not acknowledge economic or environmental variables that could encourage or prevent the recommended action (e.g. debt or dangerous neighbourhoods)
- It is based on the assumption that everyone is equally informed on the condition or illness.
- It follows the assumption that “health” behaviours are the overriding aim of decision-making processes, and that cues to action are commonly predominant factors in motivating individuals to act.

The HBM does not put forward any plans for changing health-related actions and is informative rather than instructive. Early studies indicated that, where preventive health behaviours are concerned, the targeted health behaviour was frequently associated with perceived benefits, susceptibility and barriers, whereas perceived severity was less frequently associated with the hoped-for health behaviour. For certain desired outcomes, the particular constructs are practical, but in order to apply the model optimally, it should incorporate other environmentally aware and strategic models (Glanz, Rimer et al. 2008).

Another popular theory in tool development is the theory of planned behaviour (TPB) which has been frequently used to analyse various forms of behaviour (Conner and Sparks 2005). It describes the elements that lead to a person’s choice to engage in a particular behaviour, and, as a concept, explains the course of behavioural change, acknowledging it as a multidimensional process (Glanz and Bishop 2010). The TPB is

itself an expansion of the theory of reasoned action (TRA). TRA was introduced by Ajzen and Fishbein (1969) and is known as a model of persuasion and commonly used to explain communication behaviours (Fishbein and Ajzen 1980, Ajzen 1991, Glanz and Bishop 2010). Both theories (TPB and TRA) describe structures of motivation leading to engaging in a behaviour and both are supported by the notion that the intent to engage in a behaviour will define the process of acting it out (Polit, Beck et al. 2001, Montano and Kasprzyk 2002). Ajzen (1991) explained behavioural intention as the individual's drive and resolution to adopt a certain behaviour and emphasised that intention is directly proportional to implementation. The TRA explains behavioural intentions with subjective norms and attitudes (Polit, Beck et al. 2001, Montano and Kasprzyk 2002), yet according to Ajzen (1991) the TRA is restricted to changes in behaviour that are entirely controlled by the individual performing them. Other aspects such as financial or time expenditure, injury or environmental elements are not accounted for by the TRA, and this weakness was acknowledged in the 1980s with the inclusion of "perceived behavioural control" into the theory to become the TPB (Ajzen 1991, Norman, Conner et al. 2000, Montano and Kasprzyk 2002).

According to the TPB, the most relevant elements deciding behaviour are perceptions of control over as well as intention to perform a particular behaviour. Intention is defined as an individual's willingness to expend energy to exercise action and adopt a behaviour. Intention is controlled by three elements: subjective norms, attitudes, and perceived behavioural control. Subjective norms are an individual's perception of social acceptance, rejection, or expectations and the motivation to live up to and comply with these expectations which might result in a perceived social pressure for the individual.

Attitudes, which are a person's positive or negative stand towards a certain behaviour, are centred around two perceptions: the probable results or effects of said behaviour and the evaluation of resulting effects. And perceived behavioural control, being the person's impression of the supposed difficulty or ease of performing a behaviour and the anticipation of the degree to which the performance of a behaviour is within his or her control. Control is described as a range of conditions and factors ranging from low effort behaviours to complex behavioural objectives involving opportunities, resources and skillsets. Perceived behavioural control is determined by beliefs held about the access to or lack of access to required resources and circumstances to engage in the behaviour successfully, tempered by the perceived ability of each factor to enable to prevent the performance of the behaviour. these factors can be either internal control factors such as information, personal deficiencies, skills, emotions and abilities; or external control factors like dependency, obstacles, opportunities (Norman, Conner et al. 2000).

The TPB is subject to multiple limitations within tool development, including the following:

- It works under the assumption that the individual in question has access to the resources and conditions required to successfully engage in the desired behaviour, whether or not the intention of performing the behaviour is apparent.
- It does not consider other behavioural motivators such as mood, past experience, threat or fear.

- Although it does account for subjective norms, it does not reflect economic or environmental aspects that could affect an individual's motivation to engage in a behaviour.
- It works under the condition that behaviour exists as a linear process of choice, without taking into account that it may change with time.
- Although perceived behavioural control was a relevant supplement to the model, it does not cover actual behavioural control.
- The TBP does not expand on the time frame implied between intention and implementation of the behaviour.

While the TPB has seen more applications in public health than the Health Belief Model, it is nonetheless restricting in its failure to account for economic and environmental influences. In recent years, in order to compensate for some of the TPB's limitations in tackling public health concerns, researchers have utilised select constructs from the TPB and integrated them into more comprehensive models along with other constructs from behavioural theory.

Another frequently utilised theory is The Transtheoretical Model (TTM) which is a multifaceted, biopsychosocial construct designed to describe the mechanics of intentional changes in behaviour (Glanz, Rimer et al. 2008). As the field of psychotherapy had gradually grown into over 300 distinct theories, the TTM represented an attempt to integrate it through comparative analysis of the predominant theories of changes in behaviour, and by adopting mechanics and principles of change from a wide range of major models of intervention into stages of change (Glanz, Rimer et al. 2008). While

other theories, such as those predominantly describing social or biological influences, tend to examine particular aspects of behaviour change, the TTM aims to incorporate essential components from other models to form a widely applicable model of change to describe a range of behaviours, populations and settings (Glanz, Rimer et al. 2008).

According to the TTM, individuals engage in evaluative, affective and cognitive processes in order to advance through the stages of change. These processes produce methods to assist individuals in accomplishing and sustaining change.

The TTM promotes the evaluation of a person's immediate stage of change and takes setbacks in people's decision-making into account. The TTM includes recommended strategies for health interventions that apply to people at differing stages of the decision-making process, which may lead to individually appropriate and effective interventions (such as media that has been designed to target specific populations with certain levels of awareness and motivation).

However, the TTM has several limitations that need to be acknowledged when developing a tool:

- The theory works under the condition that people make logical and predictable decisions, which is not always true.
- The distinctions between the stages do not always follow any defined set of criteria, and the questionnaires intended to categorise an individual according to a stage of change are frequently not validated or standardised.

- It does not account for social environment or context of the behavioural change, be it income, socioeconomic status or other.
- It is not fully clear as to the timespan allotted to individual stages, nor how much time a person can or should spend in any given stage.

Even though the aforementioned theories have been widely utilised in healthcare, they do not specifically focus on the role of technology and its influence on the targeted population. In order to explain the technological aspect of human behaviour, Davis (1989) proposed the Technology Acceptance Model (TAM) which is another extension of the TRA (the first one being TPB explained above). The TAM was specifically designed in order to explain a user's acceptance of technology and the factors influencing it. In addition to the factors included in TRA, The TAM proposed 2 additional factors that influence an individual to use technology: perceived ease of use and perceived usefulness (Charness and Boot 2016). According to TAM, an individual who perceives digital programs as too difficult or useless will most likely reject that technology, but if an individual who perceives digital programs as helpful and stimulating will probably use the target technology (Charness and Boot 2016). The TAM has been widely criticised for being too general and too simplistic for focusing only on perceived ease of use and perceived usefulness and not factoring in extrinsic influences such as societal and organizational influences and consequences (Kurniabudi and Assegaff 2014, Ajibade 2018).

The TAM model has been chosen in phase 3 of this study in order to inform the interview questions regarding the usability of BACKonLINE™ (Chapter 9, section 9.5). However,

phase 3 interviews are exploratory in nature, and future research focusing on BACKonLINE™ should explore all the aforementioned models and their limitations in order to arrive at a more comprehensive model for the usability and implementation of BACKonLINE™.

8.7. Summary

Reliability and validity represent 2 crucial aspects of scale development. Reliability can be described into 4 major categories: internal consistency, test retest, inter-rater and parallel forms reliability. In self-administered measures, internal consistency and test retest reliability are the appropriate methods of choice. Validity is a more complex metric, which has to be demonstrated during the ongoing scale development. Both content and face validity can be established during the beginning development stages. Construct validity can be demonstrated by empirical tests of hypotheses such as the nomological networks and convergent validity as well as its conceptual factor structure. Concurrent validity can be demonstrated through the comparison of a new scale against an established reference standard.

One method of assessing concurrent validity is by using ROC curve analysis in order to determine the AUC and to calculate the cut-off score against a reference standard. ROC curve analysis is a common method in determining cut-off scores by plotting a tool's sensitivity against its specificity. In addition, in ROC curve analysis, the AUC is used in order to calculate the diagnostic accuracy of a newly developed tool.

When a new LBP tool is under development, 3 main categories should be explored: health-related quality of life, pain intensity, and pain-related fear of movement, anxiety

and depression. A few tools representing the highlighted categories were presented in this chapter, and these tools were chosen as part of the nomological network due to their ability to identify clusters of symptoms that are associated with centrally sensitised LBP.

Another important concept in tool development is patient involvement which can take more than 1 form. Patients can be involved in item generation, assessment of tool comprehension, or sharing their experience with the tool's usability. In Chapter 9, the details of the methods used in Phase 3 shall be presented

8.8. Aim of Phase 3

The aim of Phase 3 of the study was to examine the reliability and validity of the latest version of BACKonLINE™ (Version 5), establish the cut-off score, and to explore the participants' experience when using the tool.

8.9. Phase 3 Objectives

- To determine the internal consistency and test retest reliability of BACKonLINE™
- To establish preliminary construct validity and cut-off score for BACKonLINE™
- To explore the patient's experience with BACKonLINE™.

8.10. Phase 3 Research Questions

1. Does BACKonLINE™ have high internal consistency?

Null Hypothesis 1: BACKonLINE™ has unsatisfactory internal consistency.

2. Does BACKonLINE™ have acceptable test retest reliability?

Null Hypothesis 2: BACKonLINE™ has low test retest reliability.

3. Does BACKonLINE™ have moderate to strong convergent validity with the nomological network?

Null Hypothesis 3: BACKonLINE™ does not have moderate to strong convergent validity with the nomological network

4. Does the Pain behaviour domain have moderate to strong convergent validity with VAS, ODI, and STarTBack?

Null Hypothesis 4: The Pain behaviour domain does not have moderate to strong convergent validity with VAS, ODI, and STarTBack

5. Does the Impact of LBP on work and lifestyle domain have moderate to strong convergent validity with STarTBack, TSK, and PASS 20?

Null Hypothesis 5: The Impact of LBP on work and lifestyle domain does not have moderate to strong convergent validity with VAS, ODI, and STarTBack

6. Does the Experience with LBP domain have moderate to strong convergent validity with STarTBack, TSK, and PASS 20?

Null Hypothesis 6: The Experience with LBP domain does not have moderate to strong convergent validity with STarTBack, TSK, and PASS 20.

7. Can BACKonLINE™ moderately differentiate between people who have predominantly centrally sensitised LBP and people who have predominantly peripherally sensitised LBP ($AUC \geq 0.70$) when compared to STarTBack as a reference standard?

Null Hypothesis 7: BACKonLINE™'s ability to distinguish between people who have predominantly centrally sensitised LBP and people who have predominantly peripherally sensitised LBP is low ($AUC < 0.70$)

Chapter 9. Phase 3: Methods

9.1. Introduction

As a result of the E-Delphi study (Phase 1) and the readability study (Phase 2), version 5 of BACKonLINE™ was developed. This chapter presents the methodology of Phase 3 to evaluate the measurement properties of BACKonLINE™ as well as participants' experiences using it. The chapter details Phase 3 study design, including its justification. This chapter describes the method of establishing reliability, validity together with establishing the maximum and minimum achievable scores and BACKonLINE™ cut-off score distinguishing between CLBP patients with predominant features of peripherally sensitised LBP and centrally sensitised LBP. Participant recruitment, sampling, data collection, processing and analysis are fully explained. The chapter begins by detailing how BACKonLINE™ was assigned scores prior to the measurement properties assessment.

9.2. BACKonLINE™ Scoring

When designing a new tool, the number of response formats should be considered. Some formats allow for an increased number of answer options or even infinite responses (open-ended answers). Other formats allow for a limited response. A response format should have enough variability in the answers in order to avoid forcing participants into extreme responses. For example, if people were to describe their back pain but were given 2 answer options: No back pain at all and crippling back pain, they

are forced into an extreme and the lack of variability will give a false picture about the pain. Adding more options such as ‘comes and goes’ ‘manageable’ and so forth to the previous example will provide a better presentation about the pain (DeVellis 2016).

However, the length of the scale should be considered when adding variability to answer options. For a 2 item scale, a large number of answer options (e.g. 0-100 answer scale) will achieve good variability, but for longer scales (e.g. a scale with 50 items) a binary yes/no answer options would add enough variability. In fact, when a longer scale has a large number of answer options, the probability of fatigue and boredom increases, thus decreasing the reliability of the answers (DeVellis 2016).

In BACKonLINE™, there are no negative scores in any item, answers get a minimum score of 0, and the highest achievable score is 3 (Appendix 17). Several items in the Pain behaviour domain are multiple answer questions where the patient is able to check more than 1 answer, scores for those questions are added together. Table 26 summarises the maximum and minimum achievable scores in BACKonLINE™

Table 26 Phase 3 maximum and minimum achievable score in BACKonLINE™

Domain	Maximum achievable score	Minimum achievable score
Pain behaviour	111	3
Impact of low back pain on work and lifestyle	21	0
Experience with low back pain	14	0
BACKonLINE™ total	146	3

9.3. Study Design

A preliminary same subject repeated-measures study design was used to evaluate the reliability and validity of BACKonLINE™ and to determine the cut-off score for centrally

sensitised LBP and peripherally sensitised LBP (Streiner, Norman et al. 2015). Additional evaluation of the participant’s experience of using BACKonLINE™ was employed using semi-structured interviews (Harrell and Bradley 2009). This phase had 2 measurement points labelled as Observation 1 and Observation 2. The semi-structured interviews were conducted during Observation 1.

Preliminary studies are usually conducted in order to refine the design, test its feasibility, cost, and estimate the time required to recruit participants, and to test the methods used for data collection, storage, and analysis (Smith, Morrow et al. 2015).

9.4. Participants

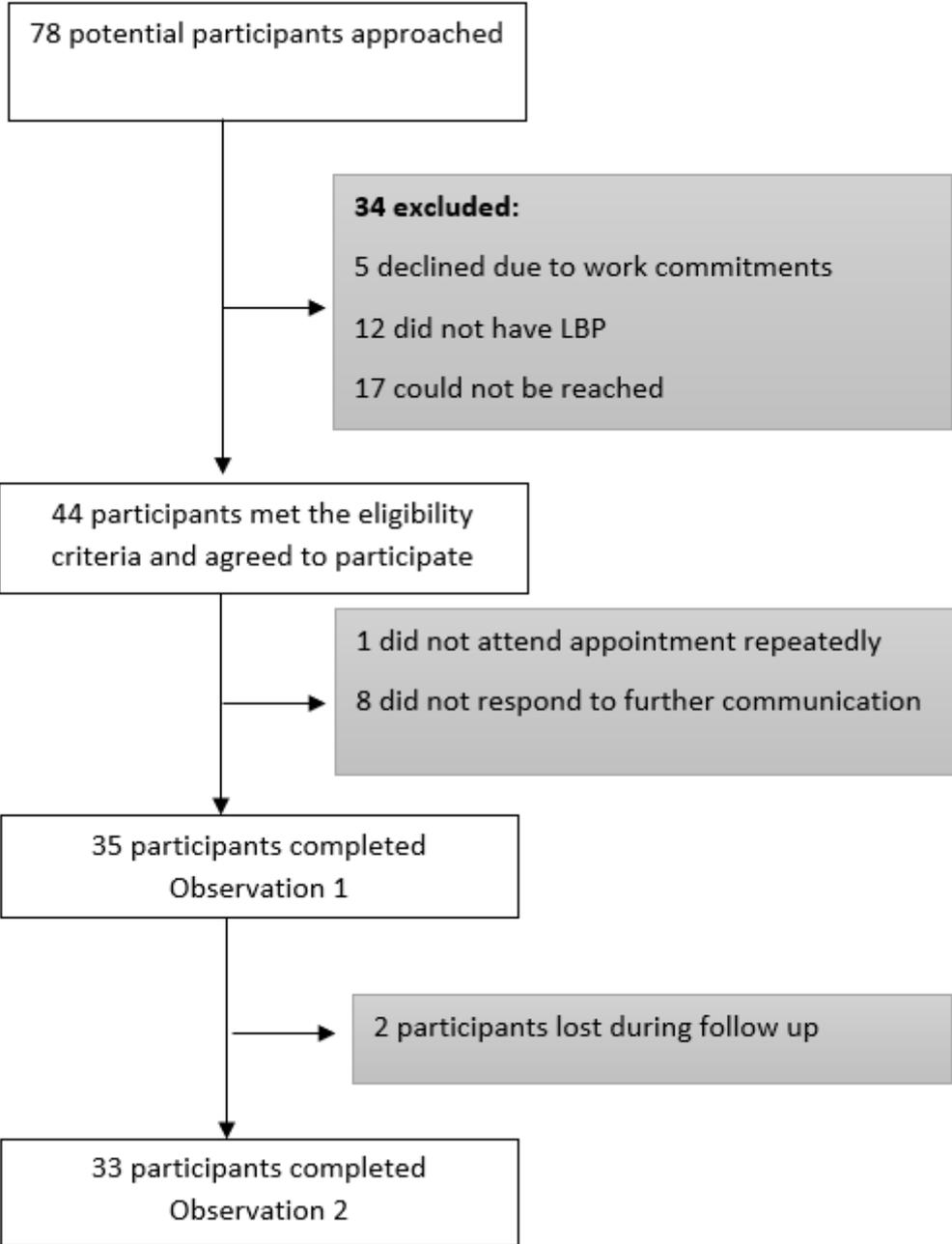
9.4.1. Recruitment

The study used purposive sampling with a total of 78 people with CLBP, who had previously participated in a separate, externally funded research study and agreed to be contacted for future research. Potential participants were screened according to the eligibility criteria (Table 27). The participants’ recruitment process is detailed in Figure 11.

Table 27 Eligibility criteria for participants in Phase 3

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> • Adults (18 years old and above) 	<ul style="list-style-type: none"> • Inability to give informed consent
<ul style="list-style-type: none"> • LBP for >12 weeks 	<ul style="list-style-type: none"> • Presence of red flags
<ul style="list-style-type: none"> • Pain in the lumbar and buttock region 	<ul style="list-style-type: none"> • Pregnancy and breastfeeding
<ul style="list-style-type: none"> • Ability to read and write in English 	
<ul style="list-style-type: none"> • Ability to use a computer without assistance 	

Figure 11 Phase 3 participant recruitment process



9.4.2. Ethical Considerations

Phase 3 of the development of BACKonLINE™ was approved by Cardiff and Vale University Health Board Research and Development office as part of the NHS ethics of Biomechanics and Bioengineering Research Centre Versus Arthritis (Appendix 18). The researcher acquired a research passport (Appendix 19) from the Cardiff and Vale University Research and Development Office. Participants were sent the information sheet (Appendix 20) and a consent form (Appendix 21) via email at least 3 days before visiting the research laboratory. All participants consented face to face on the day of the visit. During the initial telephone call, participants were screened using the inclusion and exclusion criteria. They were also screened for red flags using the criteria listed in Chapter 2, section 2.3.3. Participants were screened again during Observation 1 before signing the consent form (Appendix 21).

In order to ensure confidentiality and anonymity, participants were assigned a unique ID code during the study. Participants contact details and personal data were logged in a single, password-protected, Microsoft excel sheet stored in Cardiff University's secured and password protected online server and could not be accessed without verified credentials. BACKonLINE™ was completed online via www.onlinesurveys.ac.uk, and the completed questionnaires could only be accessed by the researcher. The validated questionnaires were kept in a locked locker in the School of Healthcare Sciences at Cardiff University. Interview transcripts were saved on a single, password-protected file on Cardiff University's secured and password protected online server.

For Phase 3, participants were only required to complete questionnaires which did not involve any foreseeable risk. Risk assessment was conducted by applying the School of Healthcare Studies research ethics handbook's recommended method of risk assessment (Likelihood: 1, Severity: 1). The possibility of injury in this study is slim to none. The researcher was aware of the on-site first aiders and was familiar with the venue and safety procedures in case any participants felt unwell.

9.4.3. Pilot Study

In order to ensure ease of access to BACKonLINE™, standardise the process, and assess the suitability of the venue, a pilot study with 2 people with a past history of LBP (not research participants) was conducted. The 2 individuals were invited to the venue, the whole process from the explanation, screening, completing BACKonLINE™, conducting an interview, completing the validated questionnaires (VAS, ODI, STarTBack, TSK, PASS 20) was piloted. The participants were then asked to complete both BACKonLINE™ and the validated paper-based questionnaires a week later from home.

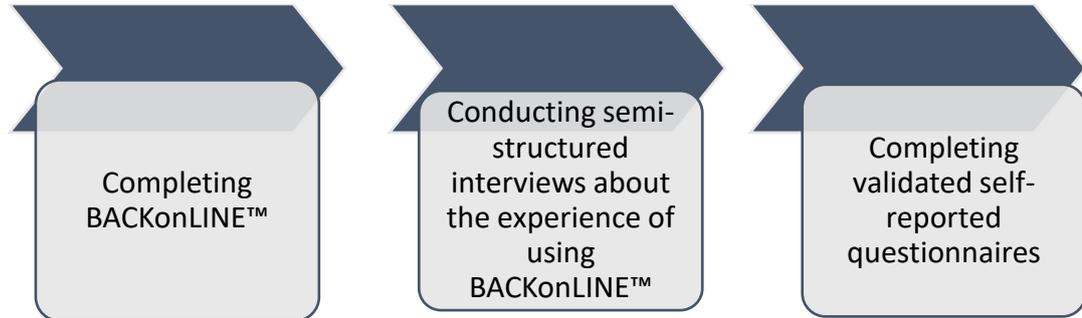
An average of 30 minutes was required to complete the process during Observation 1. Time of completion in Observation 2 could not be assessed due to the nature of the Observation (i.e. completed from home). However, both individuals did not report any difficulties completing the tools, accessing BACKonLINE™, or sending back the validated questionnaires via post. No issues were identified during the pilot study and no changes were made to the process.

9.5. Data Collection Procedure:

Data collection in the main study followed the procedure outlined in the pilot study. All participants were required to complete a battery of validated paper-based questionnaires (VAS, ODI, STarTBack, TSK, and PASS 20) and BACKonLINE™ on a computer on 2 occasions, 1 week apart.

For Observation 1, participants completed BACKonLINE™ on a prepared computer then they were interviewed (within a purpose-built sound-proof interview room located in School of Healthcare Sciences, Cardiff University) regarding their views on BACKonLINE™, and afterwards completed the validated paper-based questionnaires (Figure 12).

Figure 12 Phase 3, Observation 1 process



For Observation 2, the participants were asked to complete the same questionnaires at home, starting with BACKonLINE™ on a computer, then the validated paper-based questionnaires. Participants were encouraged to contact the researcher for any study-related questions and were provided with the researcher's full contact details.

For the current study, a 1 week interval was deemed appropriate between observations in order to avoid memory or learning effects (i.e. answering questions based on their answers in Observation 1) (Bolarinwa 2015). As all participants have CLBP, it was unlikely for their pain symptoms to be significantly different between Observation 1 and 2 (Andersson 1999, Costa, Maher et al. 2009, Balagué, Mannion et al. 2012). Table 28 details the data collection procedure.

Table 28 Phase 3 data collection procedure

Observation	Location/ status/ mode of communication	Procedure
Observation 1	School of Healthcare Sciences, Cardiff University, undergraduates laboratory interview room/ 1 st data collection point	<ol style="list-style-type: none"> 1. Participants were given the information sheet to read. The process of the research study participation explained, and participants were encouraged to take breaks at any point. Participants were screened for red flags before proceeding any further. 2. Participants signed the consent form 3. Participants completed BACKonLINE™ using a pre-set computer 4. An interview was conducted with participants regarding their experience with using BACKonLINE™ 5. Participants completed paper versions of ODI, VAS, STarTBack, TSK, and PASS 20 6. Participants provided with a paper version of ODI, VAS, STarTBack, TSK, and PASS 20 and a link to BACKonLINE™ and instructed not to complete them until they receive an e-mail 1 week later. Participants asked to return the completed questionnaires in the provided prepaid envelop.
Between Observation 1 and 2	E-mail/ telephone	A link of BACKonLINE™ was sent via email, and a reminder to complete and send back the questionnaires
Day 10 after Observation 1	E-mail/ telephone	Second reminder for non-responders
Observation 2	Home	Participants completed BACKonLINE™ and the validated questionnaires at home and sent them using the provided prepaid envelope

Key: ODI = Oswestry Disability Index, VAS = Visual Analogue Scale of pain, TSK = Tampa Scale of kinesiophobia, PASS 20 = Pain Anxiety Symptoms Scale short form 20

Semi-structured, face-to-face interviews were used to collect data on the user's experience after completing BACKonLINE™ during Observation 1. Interviews were chosen in favour of focus groups for several reasons: (1) participants needed 1 on 1 attention when completing BACKonLINE™ so logistically it was better to conduct an interview instead of organising a separate focus group, (2) participants unique experience with BACKonLINE™ was of interest which made interviews more suitable, (3) in order to give participants the freedom to convey their own experience without being influenced by other, more dominant voices (Lasch, Marquis et al. 2010). The interview questions were designed to capture the user's experience of completing BACKonLINE™, in terms of the process of completing it as well as expectations of self-management and mode of delivery (i.e. smartphone app, computer, or other modalities).

The questions were informed by the Technology Acceptance Model, which is a theory that explains how people accept and use a technology (Davis 1989, Lee, Kozar et al. 2003). The Technology Acceptance Model proposes that when presented with new technology, a number of factors influence the person's acceptance of it. These factors also tend to influence people's decision to use new technology. The most important factors involved in using an online tool are perceived usefulness, which is the extent to which a person believes that using the new tool improves their life, and perceived ease of use, which is the extent to which a person believes that using the new tool is effortless (Davis 1989). The main questions and their rationale are in Table 29. Interviews were conducted immediately after completing BACKonLINE™ during Observation 1 to ensure that the experience of using BACKonLINE™ is present in their memory, making answering interview questions easier.

Table 29 Interview guide for Phase 3

Topics	Rationale
1. Current experience of CLBP	Participants are encouraged to describe their pain in order to ease them into the interview process and to encourage them to do whatever they need to do during the interview to decrease their LBP (i.e. stretch, move about, stand up)
2. Impact of CLBP on daily life.	The purpose of this question was to further ease the participant into the interview process and in order to put them into the mindset of answering the next questions. Since BACKonLINE™ is envisioned as a self-assessment and self-management tool for people with CLBP, it would have to fit into their lifestyles.
3. BACKonLINE™ expectations regarding guided self-management	The purpose of this question is to explore the participants' understanding of the intent behind the tool and their expectations from such a tool
4. BACKonLINE™ delivery methods preferences	Since BACKonLINE™ is a self-assessment and self-management tool, it is essential to know the user's preference in the mode of delivery (i.e. smartphone app, computer, or other modalities)
5. Further comments regarding BACKonLINE™ or the study	This question was asked in order to ensure that all aspects of the user's experience were captured in case the participant had any other comments regarding

	<p>BACKonLINE™ and the study that they did not state previously including the ease of accessing and using BACKonLINE™.</p>
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9.5.1. Data Processing

9.5.1.1. BACKonLINE™ and the Validated Questionnaires

BACKonLINE™ data was directly exported from www.onlinesurveys.ac.uk into a Microsoft Excel spreadsheet and the validated questionnaires anonymised responses were manually entered into a Microsoft Excel spreadsheet and checked for entry error twice by the researcher.

9.5.1.2. Semi-Structured Interviews

The interviews were audio-recorded on a digital password-protected Dictaphone (ALON Dictaphone-Voice Recorder; ALON Software Ltd.). The audio files were transcribed by the researcher and sent for member checking to participants who agreed to receive transcripts in the consent form.

9.6. Data Analysis

The BACKonLINE™ and validated questionnaires data collected during Observation 1 and 2 were analysed using the Statistical Package for Social Sciences (SPSS) version 25 (SPSS Inc., Chicago, Illinois). Reliability of BACKonLINE™ was measured in terms of internal consistency and test retest reliability. Internal consistency was measured by calculating CA and item-total statistics for BACKonLINE™'s total and each domain separately for both Observation 1 and 2. Test retest reliability was assessed for the BACKonLINE™

overall score and for each domain within the scale by calculating the ICCs and CVs. Significance testing of the test retest ICCs were calculated by using a standard F-test. A composite score of the validated questionnaires was then calculated, and a paired samples T-test was performed.

The following sections detail the methods used for reliability and validity. Construct validity and concurrent validity (cut-off score) are presented. Qualitative data analysis methods used when analysing the interview transcripts are also presented.

9.6.1. BACKonLINE™ Reliability

9.6.1.1. BACKonLINE™ Reliability - Internal Consistency

Internal consistency, which measures correlations between different items within a tool or subscale of a tool (Streiner, Norman et al. 2015), was calculated for both Observation 1 and 2 using CA employing the matrix proposed by Ponterotto and Ruckdeschel (2007), which takes into consideration both the length of the developed tool (BACKonLINE™) and the size of the sample tested. Even though there is no standard for a good CA, most methodologists recommend a minimum CA ranking between 0.65 and 0.9, and a CA that falls under 0.5 is usually considered unsatisfactory (Charter and Feldt 2000, Kline 2000).

The internal consistency was calculated for both observations to check for any significant difference. However, Observation 2 data was used as the primary indication of internal consistency since Observation 2 was completed at home which is the intended medium for BACKonLINE™.

Item-total statistics for the entire BACKonLINE™ tool and each individual domain were calculated using 'Corrected Item-Total Correlation' and 'Cronbach's Alpha if Item

Deleted'. The 'Corrected Item-Total Correlation' is the correlation between each item and a total scale score excluding the item in focus (i.e. the scale uses all items but the one in focus). The 'Alpha if Item Deleted' for each item investigates the influence of individual items on CA if the item in focus was deleted. This statistic is used in order to check if any item is negatively affecting CA, thus decreasing internal consistency (Streiner, Norman et al. 2015). Since the CA was calculated for every domain and for the whole tool, item-total statistics were carried out for each domain and the whole tool to check item's influence on their respective domain and on BACKonLINE™.

9.6.1.2. BACKonLINE™ Reliability - Test Retest Reliability

BACKonLINE™'s test retest reliability was assessed using ICC variant (3,1) with absolute agreement, and the CVs were calculated using Observation 1 and 2 data (Shrout and Fleiss 1979). A mean CV is acquired by calculating the individual CV for each participant and then calculating the mean of the resulting CVs. A CV is the ratio of the SD of the sample to the mean of the sample (Brace, Snelgar et al. 2016).

The ICC variant (3,1) where model 3 is the 3rd model presented by Shrout and Fleiss (1979) and states that each participant is assessed by each rater (rater refers to the scale in this instance) and the raters are the only ones of interest. Form 1 in (3,1) means that reliability will be assessed on a single measure (Shrout and Fleiss 1979). BACKonLINE™ is a self-assessment measure which is intended to be completed once by participants in order to be directed to appropriate self-management advice. Therefore, form 1 was deemed appropriate in this study. The absolute agreement was calculated because the aim of the analysis is to assess how repeatable BACKonLINE™ is over a period of time.

The systematic variation between Observation 1 and 2 (e.g. if all scores increased by 1) does not affect ICCs for consistency but affects absolute agreement (Shrout and Fleiss 1979).

As a general rule, the closer the ICC value is to 1, the stronger the reliability of the scale, and an ICC > 0.6 is an acceptable score for an assessment tool used in clinical settings (Shoukri, Asyali et al. 2004, Portney and Watkins 2009). It is recommended that these values are taken as guidelines, and not as absolute values since the reliability of the examined tool might depend on its intended use (Portney and Watkins 2009).

In this study, an ICC value less than 0.60 is considered as low reliability, 0.60 to 0.80 as moderate reliability and above 0.80 as high reliability (Chinn 1990, Bruton, Conway et al. 2000).

According to McGraw and Wong (1996), researchers test the hypothesis that the ICC is greater than 0. However, non-zero correlations are expected in test retest reliability studies (McGraw and Wong 1996). Therefore, the significance of the acquired ICC should be tested (i.e. the likeliness that the acquired ICC occurred by chance) (McGraw and Wong 1996). In this study, significance testing of the acquired ICCs was done using a standard F-test in order to determine the effect size, which can be small, medium, and large (0.1, 0.3, and 0.5 respectively) (McGraw and Wong 1996, Field 2009).

9.6.1.3. Validated Questionnaires Composite Scores

In order to determine whether participants symptoms remained the same between Observation 1 and 2, a composite score, which is calculated from data from multiple variables, in this case of the validated questionnaires, was then measured and a paired

samples T-test was performed to determine the difference in the mean (Field 2009, Brace, Snelgar et al. 2016). The T-test is a robust inferential statistic. Therefore, even if the sample is approximately normally distributed, the T-test can still provide valuable information. A sample is considered to be approximately normally distributed for the purpose of using the T-test when the sample size consists of 30 people or more (Hinton 2014).

9.6.2. BACKonLINE™ Validity

9.6.2.1. Item-total Correlations with Other Domains Totals

Since factor analysis could not be performed on this sample due to the small sample size, correlations between each item and all 3 domains were assessed using Pearson’s r (Streiner, Norman et al. 2015). Correlations were assessed using Pearson’s r between items and each domain to explore whether each item belonged in the domain they’re in or if they belonged in another domain (Hinton 2014, Streiner, Norman et al. 2015).

9.6.2.2. Construct Validity

In this study, participants were required to complete several validated self-reported questionnaires relating to the different presentation of pain as described in pain and CLBP literature (i.e. the nomological network) (Bombardier and Heinemann 2000, Turk and Okifuji 2002, Dworkin, Turk et al. 2005). Table 30 summarises the validated, self-reported questionnaires used, their categories, and their cut-off points.

Table 30 Phase 3 validated self-reported pain and related symptoms assessment questionnaires

Questionnaire	Cut-off scores
Health-related quality of life and functional disability category	

Oswestry LBP Disability Index (ODI) (version 2) (Fairbank and Pynsent 2000, Mehra, Baker et al. 2008)	21-40 moderate disability 41-60 severe disability 61-80 crippled disability 81-100% bedbound or exaggerating
STarTBack (Hill, Dunn et al. 2008)	1=low risk 2=medium risk 3=high risk
Pain intensity category	
Visual analogue scale of pain (VAS) (Jensen, Chen et al. 2003)	No pain: 0-0.4 Mild pain: 0.5-4.4 Moderate pain: 4.5-7.4 Severe pain: 7.5-10
Kinesiophobia, anxiety and depression category	
Tampa Scale for Kinesiophobia (TSK) (Vlaeyen, Kole-Snijders et al. 1995)	The total score ranges between 17 and 68. A cut-off score of ≥ 37 indicates a high degree of kinesiophobia
Pain Anxiety Symptoms Scale short form (PASS 20) (Abrams, Carleton et al. 2007)	Cut-off score of 30 errs on the side of caution

Construct validity of BACKonLINE™ was assessed using data collected during Observation 1. Data from Observation 1 was chosen because it was collected in the laboratory where the researcher ensured that both BACKonLINE™ and the other questionnaires (VAS, ODI, STarTBack, TSK, and PASS 20) were completed at the same time, unlike Observation 2, where the participants completed BACKonLINE™ and the other validated questionnaires from home with possible, unreported time lapses between completion since symptoms could differ according to ADL or time of day (Cronbach and Meehl 1955, Portney and Watkins 2009). In addition, Observation 1 was chosen as opposed to Observation 2 in order to minimise learning effects since the participants have already completed the same process previously.

In the current study, it was hypothesised that BACKonLINE™ had moderate to strong convergent validity with the validated questionnaires since it is intended as a tool that measures CLBP under the umbrella of the biopsychosocial approach. It was also

hypothesised that the Pain behaviour domain has moderate to strong convergent validity with VAS, ODI, and STarTBack, all of which measure pain behaviour and physical symptoms. Additionally, it was hypothesised that the Impact of LBP on work and lifestyle domain would have moderate to strong convergent validity with STarTBack, TSK, and PASS 20. Finally, it was hypothesised that the Experience with LBP domain would have moderate to strong convergent validity with STarTBack, TSK, and PASS 20. It should be noted that STarTBack was hypothesised to have convergent validity with every domain because it is designed to check for biomedical, psychological, and social risk factors, all of which are included in BACKonLINE™'s 3 domains (Hay, Dunn et al. 2008, Hill, Dunn et al. 2008).

BACKonLINE™'s face and content validity were established in Phase 1 (the E-Delphi study). In order to assess construct validity using the validated questionnaires, convergent validity was explored. The correlation was calculated using Pearson's r in SPSS. A moderate to a high correlation between BACKonLINE™'s total and the validated questionnaires is desired without reaching the point of singularity. For the current study, an r value of < 0.30 is considered low, $r=0.30-0.70$ as moderate, $r > 0.70$ and <0.90 as strong, and an $r > 0.90$ as the point of singularity (Chiu, Hsueh et al. 2014, Streiner, Norman et al. 2015).

To the author's knowledge, no pain centralisation gold standard exists, instead, a comprehensive physiotherapy assessment identifying the cluster of symptoms that distinguish between different pain mechanisms has been used in literature as a reference standard to assess criterion validity (Saal 2002, Ford, Story et al. 2007, Smart,

Blake et al. 2012). However, due to the design of the current study criterion validity in the form of concurrent validity with STarTBACK was the chosen method.

9.6.2.3. BACKonLINE™ Cut-Off Scores

In order to determine the sensitivity and specificity of BACKonLINE™, the ROC curve was plotted using STarTBack as the reference standard (Kumar and Indrayan 2011). STarTBack was selected as a reference standard as opposed to the other questionnaires because it measures biomedical, psychological, and social risk factors, which are all theoretical constructs included in BACKonLINE™ (Hill, Dunn et al. 2008). The 9 item STarTBack tool has 3 outcomes: small, medium, and high risk; however, the STarTBack tool is calculated in 2 steps. The overall score stratifies the results into a low or high-risk group, and the sub score (items 5-9) further stratifies the high risk groups into medium and high (Hill, Dunn et al. 2008).

In the current study, sensitivity values (true positives) were plotted on the y-axis and 1-specificity values (true negatives) were plotted on the x-axis and the cut-off score was defined as the point closest to the upper left corner which would result in the smallest error rate (Streiner, Norman et al. 2015). The AUC with 95% CI was calculated to test the accuracy of BACKonLINE™ using STarTBack as a reference standard in order to signify the likelihood of correctly distinguishing between predominantly centrally sensitised LBP and predominantly peripherally sensitised LBP (Kumar and Indrayan 2011). Afterwards, post-hoc sample calculations were conducted in order to check the trustworthiness of the calculated cut-off score using nQuery, a sample size calculator software, which calculates the recommended sample size by using a reference standard

as a baseline (Hanley and McNeil 1982, Fawcett 2006). For the purpose of ROC curve analysis, nQuery was used to calculate the sample size required in order to reject the null hypothesis ($AUC_0=0.50$) in each arm of the population. ROC curve analysis is dichotomous in nature; therefore, the sample calculations result in 2 subgroups, a positive group sample, which is centrally sensitised LBP in this study (N+), and a negative group sample, which is peripherally sensitised LBP (N-).

Calculating the cut-off point of BACKonLINE™ and the AUC concluded the measurement properties part of Phase 3 of the study. The second part of the phase explored the participants' experience of BACKonLINE™ with data collected during Observation 1 of Phase 3.

9.6.3. Participants Experience of BACKonLINE™

All interviews were transcribed by the researcher and entered into a Microsoft Word document. Following the verification process (selected participants were given the transcripts to ensure correct account of their interviews), transcriptions were entered into NVivo 11 and inductive thematic analysis, detailed in Chapter 4, section 4.4.2.1.2, was performed in order to define and extract relevant themes for participant's expectations regarding guided self-management and their preferred BACKonLINE™ method of delivery (Braun and Clarke 2006, Fereday and Muir-Cochrane 2006, Joffe 2012).

BACKonLINE™ is a new tool and the patient experience of interacting with the tool is important for its further development. Phase 1, the E-Delphi study was theory-led; hence, it lends itself to deductive thematic analysis. Phase 3, however, is concerned with

patient experience and due to a lack of theory and the nascence of the tool, inductive thematic analysis was most appropriate.

In this inductive thematic analysis, participant's interview recordings were transcribed and coded for similar ideas or topics. Codes were then further organised into their representing themes (Braun and Clarke 2006). This process enabled a better understanding of the overall participants' experience of engaging with the tool and identified themes that help with the formulation of the self-management component in future research, outside the scope of this study.

9.7. Summary

In this chapter, the methods used in assessing measurement properties of BACKonLINE™ and patients experience with the tool was presented. The chapter started by displaying how BACKonLINE™ was scored and presenting both maximum and minimum achievable scores within the tool. Then, the study design, participants characteristics, and ethical considerations were outlined. This phase is divided into 2 parts. The first part assesses the measurement properties of BACKonLINE™ in terms of internal consistency, test retest reliability, construct validity, and preliminary establishment of cut-off scores. In order to collect data for the first part, 2 timepoints (Observation 1 and Observation 2) were established. In both Observations, participants were required to complete BACKonLINE™ and a battery of validated self-assessment questionnaires (VAS, ODI, STarTBack, TSK, PASS 20). The second part of this study explored participants experience with BACKonLINE™ using individual face to face interviews during Observation 1. The interviews examined participants expectations regarding self-management techniques

and their preferred mode of delivery for BACKonLINE™. This chapter also presented the data analysis procedures used in this phase. In the next chapter, the results of both parts of Phase 3 are presented.

Chapter 10. Phase 3 Results

10.1. Introduction

A total of 35 people with CLBP agreed to participate in this phase and data was collected during 2 observations conducted 1 week apart. This chapter presents the descriptive statistics of the sample and BACKonLINE™ data. The internal consistency and test retest reliability results followed by the validity results. The validity study results begin with reporting the item-total correlations for every domain in BACKonLINE™, followed by construct validity results when tested against the nomological network. The preliminary cut-off scores of BACKonLINE™ are then presented. Finally, the results from the inductive thematic analysis performed on the participants' interviews and their experience of BACKonLINE™ are reported.

10.2. Descriptive Statistics

10.2.1. Participants

Of the 78 potential participants, 5 (6%) declined, 12 (15%) did not have current CLBP, and 17 (22%) could not be reached resulting in a total of 44 (56%) eligible participants who agreed to participate in the study. Out of the 44 eligible participants, 35 (79.5%) attended Observation 1, and 9 (20%) did not respond to further communication. Out of the 35 participants who completed Observation 1, 2 participants did not complete Observation 2. During Observation 2, 32 participants completed both BACKonLINE™ and the validated questionnaires, 1 participant completed BACKonLINE™ only (without

sending back the validated questionnaires), and 2 participants did not complete either BACKonLINE™ or the validated questionnaires. During Observation 1, 15 males with an average age of 47 years (age range: 27-68) and 20 females with an average age of 44 years old (age range: 23-67) participated. In Observation 2, 14 males with an average age of 48 years old (age range: 27-68) and 18 females with an average age of 43 years old (age range: 23-67 years old) participated. The demographics of the participant is detailed in Table 31.

Table 31 Phase 3 demographic data summary

Demographic variable	Observation 1 (n=35)			Observation 2 (n=33)		
	Total	Age (years) (mean)	Age range (years)	Total	Average age (years)	Age range (years)
Male	15	47	27-68	14	48	27-68
Female	20	44	23-67	18	43	23-67

10.2.2. BACKonLINE™ tool

Descriptive statistics were calculated for each domain and the total of BACKonLINE™ (Table 32). The scores appear to be positively skewed for both the Pain behaviour domain and the Impact of LBP on work and lifestyle domain and BACKonLINE™’s total. However, the Experience with LBP domain was negatively skewed (Appendix 22). Overall, the average achieved score in this sample for each domain and the total average is low compared to the maximum achievable scores presented in the previous chapter. The average of the achieved score of the Pain behaviour domain was 29.40 and 29.15 (Observation 1 and Observation 2 respectively) out of a maximum score of 111. The average of the achieved score of the Impact of LBP on work and lifestyle was 4.97 and

4.85 (Observation 1 and Observation 2 respectively) out of a maximum score of 21. The average of the achieved score of the Experience with LBP domain was 8.71 and 8.24 (Observation 1 and Observation 2 respectively) out of a maximum score of 14. And the average total achieved score for the whole tool in this phase was 43.09 and 42.24 (Observation 1 and Observation 2, respectively) out of a maximum score of 146 (Table 32).

Table 32 Descriptive statistics for BACKonLINE™ for both Observation 1 and 2 in Phase 3

BACKonLINE™ domains	Maximum achievable score	Observation 1 (n=35)			Observation 2 (n=33)		
		Mean	SD	Range	Mean	SD	Range
1.Pain behaviour	111	29.40	10.44	10-62	29.15	12.21	11-75
2.Impact of low back pain on work and lifestyle	21	4.97	3.83	0-19	4.85	3.70	0-18
3.Experience of low back pain	14	8.71	2.81	3-14	8.24	3.71	1-13
BACKonLINE™ total	146	43.09	15.23	15-94	42.24	17.66	13-106

*Observation 1 and 2 data were used for the reliability study, and Observation 1 data was used for the validity study

10.3. BACKonLINE™ Reliability

10.3.1. BACKonLINE™ Reliability - Internal Consistency

In order to assess internal consistency for BACKonLINE™, CA was calculated for each domain in BACKonLINE™ and the whole tool for both Observation 1 and 2.

To evaluate the adequacy of the calculated CA, a matrix rating adequacy of internal consistency was used. BACKonLINE™'s total score achieved an excellent rating in both Observation 1 and 2 (CA=0.87 and 0.90 respectively), Pain behaviour domain increased from good in Observation 1 (CA=0.80) to excellent (CA=0.85) in Observation 2. The

Impact of LBP on work and lifestyle domain was rated as good in both Observation 1 and 2 (CA=0.77 and 0.75 respectively). The lowest scoring domain was Experience with LBP ranging between CA=0.56 in Observation 1 to CA=0.77 in Observation 2. Overall, the rating of CA within all the domains was higher in Observation 2 compared to Observation 1 (Table 33) and as a result of the analysis, null hypothesis 1 was rejected.

Table 33 Cronbach's Alpha for BACKonLINE™ in Observation 1 and 2 in Phase 3

Category	Observation 1 (n=35)		Observation 2 (n=33)	
	Cronbach's Alpha	Rating	Cronbach's Alpha	Rating*
Pain behaviour domain (no of items: 22)	0.80	Good	0.85	Excellent
Impact of low back pain on work and lifestyle domain (no of items: 10)	0.77	Good	0.75	Good
Experience with low back pain domain (no of items: 7)	0.56	Unsatisfactory	0.77	Good
BACKonLINE™ (no of items: 39)	0.87	Excellent	0.90	Excellent

*Cronbach's alpha's rating according to the matrix proposed by Ponterotto and Ruckdeschel (2007)

Item-total statistics were explored using 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' with the results presented in Table 34, 35, 36, and 37. For both Observations 1 and 2, most items seem to correlate well with the total score (Table 34). However, a few items seem to have a lower than average correlation. This means that the internal consistency of the tool would increase if those items were deleted. Table 34, 35, 36, and 37 highlights those items in red. Observation 2 scores were used for interpretation since BACKonLINE™ is intended to be used at home, unsupervised, and Observation 2 meets that criterion.

Table 34 Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (all items included)

Domain	Item	Observation 1 (CA=0.87)		Observation 2 (CA=0.90)	
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Pain behaviour	1	0.18	0.87	-0.05	0.91
	2	0.29	0.87	0.10	0.90
	3	0.56	0.86	0.61	0.89
	4	0.22	0.87	0.21	0.90
	5	0.43	0.87	0.32	0.90
	6	0.37	0.87	0.45	0.90
	7	0.37	0.87	0.66	0.89
	8	0.36	0.87	0.37	0.90
	9	0.54	0.86	0.75	0.89
	10	0.12	0.87	0.26	0.90
	11	0.37	0.87	0.44	0.90
	12	0.25	0.87	0.57	0.90
	13	0.35	0.87	0.46	0.90
	14	0.58	0.86	0.44	0.90
	15	0.40	0.87	0.48	0.90
	16	0.30	0.87	0.12	0.91
	17	0.35	0.87	0.58	0.90
	18	0.75	0.86	0.67	0.89
	19	0.43	0.87	0.55	0.90
	20	0.01	0.88	0.18	0.90
	21	0.56	0.86	0.59	0.90
	22	0.23	0.87	0.53	0.90
Impact of LBP on work and lifestyle	1	0.12	0.88	0.29	0.90
	2	0.31	0.87	0.30	0.90
	3	0.53	0.87	0.61	0.90
	4	0.56	0.87	0.63	0.90
	5	0.58	0.86	0.63	0.90
	6	0.56	0.87	0.63	0.90
	7	0.63	0.86	0.51	0.90
	8	0.69	0.86	0.62	0.90
	9	0.53	0.86	0.54	0.90
	10	0.37	0.87	0.36	0.90
Experience with LBP	1	0.43	0.87	0.51	0.90
	2	0.31	0.87	0.36	0.90
	3	0.32	0.87	0.36	0.90
	4	0.30	0.87	0.44	0.90
	5	0.47	0.86	0.57	0.90
	6	0.18	0.87	0.33	0.90
	7	0.21	0.87	0.46	0.90

Table 35 Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Pain behaviour domain items)

	Item	Observation 1 (CA=0.80)		Observation 2 (CA=0.85)	
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Pain behaviour domain	1	0.18	0.79	-0.05	0.86
	2	0.30	0.79	0.09	0.85
	3	0.54	0.78	0.66	0.83
	4	0.22	0.79	0.21	0.85
	5	0.47	0.78	0.29	0.85
	6	0.29	0.79	0.52	0.84
	7	0.43	0.78	0.65	0.83
	8	0.34	0.79	0.36	0.84
	9	0.42	0.79	0.68	0.83
	10	0.19	0.79	0.23	0.85
	11	0.29	0.79	0.40	0.84
	12	0.28	0.79	0.56	0.84
	13	0.38	0.79	0.50	0.84
	14	0.59	0.78	0.39	0.84
	15	0.35	0.79	0.44	0.84
	16	0.33	0.79	0.19	0.85
	17	0.38	0.79	0.58	0.84
	18	0.77	0.76	0.74	0.83
	19	0.41	0.79	0.60	0.84
	20	0.04	0.80	0.24	0.85
	21	0.54	0.78	0.55	0.84
	22	0.16	0.80	0.52	0.84

Table 36 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Impact of low back pain on work and lifestyle domain items)

	Item	Observation 1 (CA=0.77)		Observation 2 (CA=0.75)	
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Impact of low back pain on work and lifestyle domain	1	0.16	0.80	0.28	0.76
	2	0.37	0.76	0.43	0.73
	3	0.62	0.74	0.68	0.71
	4	0.57	0.75	0.57	0.73
	5	0.61	0.73	0.57	0.73
	6	0.57	0.75	0.57	0.73
	7	0.58	0.73	0.49	0.72

	8	0.66	0.71	0.48	0.72
	9	0.53	0.74	0.44	0.73
	10	0.22	0.78	0.22	0.76

Table 37 Phase 3 'Corrected Item-Total Correlations' and 'Cronbach's Alpha if Item Deleted' Item-total statistics for BACKonLINE™ (Experience with LBP domain items)

Experience with low back pain domain	Item	Observation 1 (CA=0.56)		Observation 2 (CA=0.77)	
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
	1	0.30	0.52	0.63	0.71
	2	0.27	0.53	0.37	0.77
	3	0.33	0.51	0.23	0.79
	4	0.18	0.56	0.62	0.72
	5	0.47	0.44	0.74	0.68
	6	0.29	0.52	0.34	0.78
	7	0.16	0.57	0.57	0.73

10.3.2. BACKonLINE™ Reliability - Test Retest Reliability

BACKonLINE™ test retest reliability between Observation 1 and Observation 2 (n=33) is presented in Table 38. In summary the ICC value (Model 3,1; absolute agreement) for BACKonLINE™ total score between Observation 1 and 2 had high reliability with score 0.92 (95% CI=0.83-0.95). Both Pain behaviour domain (ICC=0.91; CI=0.81-0.95) and Impact of LBP on work and lifestyle domain (ICC=0.92; CI=0.84-0.95) showed high reliability, while the Experience with LBP domain (ICC=0.71, CI=0.49-0.84) showed moderate reliability. The acquired CI indicated that it is safe to assume that BACKonLINE™'s ICC falls within a range of 0.83-0.95, indicating high test retest reliability.

In order to test the significance of the calculated test retest ICCs and their effect sizes, a standard F-test was performed. BACKonLINE™'s ICC value was found to significantly exceed 0.5 ($p < 0.001$ for BACKonLINE™ total, Pain behaviour domain, Impact of LBP on

work and lifestyle domain, and $p=0.02$ for the Experience with LBP domain). Although these values could have been assumed based on the 95% CIs reported in Table 38, significance testing using this method firmly establishes that, in this sample, the test retest ICC for BACKonLINE™ was of large effect size.

Test retests within subjects Coefficients of variance (CV) ranged between domains from 9-29%. The total BACKonLINE™ overall score was 10% which is considered good (i.e. indicating acceptable variance) (Table 38). As a result of the test retest analysis, null hypothesis 2 was rejected.

Table 38 Phase 3 test retest Reliability of BACKonLINE™

Category	ICC (95% CI)	Mean CV	CV range
Pain behaviour domain	0.91 (CI=0.81-0.95)	9%	0-25%
Impact of low back pain on work and lifestyle domain	0.92 (CI=0.84-0.95)	29%	0-141%
Experience with low back pain domain	0.71 (CI=0.49-0.84)	21%	0-79%
BACKonLINE™	0.92 (CI=0.83-0.95)	10%	0-27%

10.3.3. Validated Questionnaires Composite Scores

Composite scores for VAS, ODI, STarTBack, TSK, and Pass 20 were calculated for both Observations 1 and 2, and a paired T-test was performed. The T-test shows that the difference between Observation 1 and 2 was not significant ($t=0.09$, degrees of freedom (df)=31, $p=0.92$, 2-tailed) (Table 39).

Table 39 Paired samples T-test for composite scores for the validated questionnaires between Observation 1 and 2 in Phase 3

	Mean	t	degrees of freedom	Sig. (2-tailed)
Composite score for Observation 1 and 2	0.02	0.09	31	0.92

10.4. BACKonLINE™ validity

In this section, Item-total correlations of items with other domains totals and correlation of BACKonLINE™ with the nomological network were assessed. Afterwards, BACKonLINE™'s cut-off score was calculated.

Item-total correlations with other domains were assessed for both Observation 1 and 2 and construct validity of BACKonLINE™ was assessed for Observation 1 data. BACKonLINE™'s cut-off score was calculated by using ROC curve analysis and STarTBack as a reference standard.

10.4.1. Item-Total Correlations with Other Domains Totals

Every item was explored for 'fit' within each of the domains separately to examine whether an item better correlates with their assigned domain or another domain. Table 40 summarises the correlation of each item within each domain (Observation 1 and 2). Overall, most items best correlate with the domains that they were originally assigned to (e.g. PB17) with some exceptions. The items highlighted in green correlate more with a domain they are not originally assigned to which might indicate that they do not belong to their original domain.

Item PB2 (originally assigned to the Pain behaviour domain) seem to correlate more with the Impact of LBP on work and lifestyle domain in Observation 2. Items PB4 and PB11 (both originally assigned to the Pain behaviour domain) seem to correlate more with the Experience with LBP domain and the Impact of LBP on work and lifestyle domain in Observation 1 respectively but correlate with their assigned domain in Observation 2.

Some items appear to correlate with more than 1 domain significantly (e.g., PB18, WL7, P5) indicating the importance of those items. However, these results should be interpreted with caution due to the small sample size and the different venues. (Table 40).

Table 40 Comparison of Item-total correlations with each domain in Observation 1 and 2 in Phase 3

Item ID	Domain assigned	Observation 1 (n=35)			Observation 2 (n=33)		
		Pain Behaviour domain	Impact of low back pain on work and lifestyle domain	Experience with low back pain domain	Pain Behaviour domain	Impact of low back pain on work and lifestyle domain	Experience with low back pain domain
		Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>
PB1	Pain Behaviour domain	0.25	0.20	0.01	0.01	-0.06	-0.02
PB2		0.34*	0.26	0.07	0.13	0.16	0.00
PB3		0.62**	0.54**	0.30	0.72**	0.51**	0.28
PB4		0.31	0.04	0.32	0.28	0.18	0.13
PB5		0.57**	0.33	0.17	0.39*	0.29	0.28
PB6		0.39*	0.33	0.46**	0.57**	0.30	0.14
PB7		0.56**	0.21	0.14	0.73**	0.53**	0.47**
PB8		0.44**	0.20	0.41*	0.42*	0.36*	0.22
PB9		0.57**	0.51**	0.56**	0.77**	0.75**	0.53**
PB10		0.24	0.03	-0.09	0.27	0.30	0.20
PB11		0.33*	0.44**	0.31	0.44**	0.45**	0.34
PB12		0.34*	0.13	0.15	0.59**	0.47**	0.41*
PB13		0.44**	0.29	0.08	0.54**	0.30	0.24
PB14		0.63**	0.41*	0.40*	0.45**	0.46**	0.35*
PB15		0.43**	0.47**	0.17	0.52**	0.47**	0.37*
PB16		0.39*	0.20	0.15	0.25	0.02	-0.06
PB17		0.45**	0.18	0.22	0.63**	0.46**	0.36*
PB18		0.81**	0.64**	0.34*	0.78**	0.51**	0.28
PB19		0.56**	0.51**	0.11	0.70**	0.36*	0.32
PB20		0.09	-0.00	-0.08	0.29	0.23	-0.16
PB21		0.58**	0.42*	0.46**	0.59**	0.45**	0.55**
PB22		0.23	0.29	0.21	0.56**	0.50**	0.30
WL1	Impact of low back pain on work and	0.09	0.38*	0.07	0.22	0.49**	0.40*
WL2		0.26	0.53**	0.25	0.25	0.59**	0.20
WL3		0.49**	0.68**	0.21	0.60**	0.74**	0.28
WL4		0.54**	0.63**	0.26	0.67**	0.63**	0.23
WL5		0.56**	0.69**	0.23	0.67**	0.63**	0.23
WL6		0.54**	0.63**	0.26	0.67**	0.63**	0.23
WL7		0.55**	0.70**	0.55**	0.42*	0.65**	0.54**
WL8		0.60**	0.77**	0.63**	0.54**	0.65**	0.66**

Item ID	Domain assigned	Observation 1 (n=35)			Observation 2 (n=33)		
		Pain Behaviour domain	Impact of low back pain on work and lifestyle domain	Experience with low back pain domain	Pain Behaviour domain	Impact of low back pain on work and lifestyle domain	Experience with low back pain domain
		Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>	Pearson's <i>r</i>
WL9		0.46**	0.65**	0.47**	0.48**	0.59**	0.55**
WL10		0.34*	0.42*	0.40*	0.34	0.41*	0.39*
P1	Experience with low back pain domain	0.36*	0.47**	0.54**	0.40*	0.51**	0.77**
P2		0.27	0.29	0.54**	0.34	0.25	0.55**
P3		0.28	0.25	0.52**	0.32	0.42*	0.41*
P4		0.32	0.18	0.41*	0.33	0.43*	0.73**
P5		0.37*	0.52**	0.70**	0.40*	0.71**	0.84**
P6		0.14	0.12	0.55**	0.26	0.40*	0.53**
P7		0.15	0.31	0.38*	0.38*	0.40*	0.69**

Key: Green highlight indicates items correlating more with domains they are not assigned to. **: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed)

10.4.2. Construct Validity

BACKonLINE™'s total score and the score of each domain was correlated to the nomological network using Pearson's *r* (Table 41). BACKonLINE™ shows moderate correlation with VAS, ODI, STarTBack, TSK, and PASS 20 ($r=0.60, 0.70, 0.60, 0.42, 0.50$ respectively) (Table 41). The Pain behaviour domain shows moderate correlation with VAS, ODI, STarTBack, TSK, and PASS 20 ($r=0.60, 0.61, 0.50, 0.31, \text{ and } 0.40$ respectively). The Impact of LBP on work and lifestyle domain shows moderate correlation with the VAS, ODI, STarTBack, TSK, and PASS 20 ($r=0.31, 0.63, 0.50, 0.50, 0.60$ respectively). The Experience with LBP domain moderately correlated with all of the nomological network ($r=0.45, 0.51, 0.60, 0.50, 0.44$ against the VAS, ODI, STarTBack, TSK, and PASS 20 respectively) (Table 41). These results demonstrate that BACKonLINE™ and all the domains have convergent validity with the nomological network (Table 41). In summary, as a result of the construct validity analysis, null hypothesis 3,4,5, and 6 (listed in Chapter 8, section 8.9) were rejected.

Table 41 Correlations between BACKonLINE™ total and each domain with the nomological network in Observation 1 using Pearson’s correlation in Phase 3

Validated reference tools	BACKonLINE™ total	Pain behaviour domain	Impact of low back pain on work and lifestyle domain	Experience with low back pain domain
Visual analogue scale of pain (VAS)	0.60**	0.60**	0.31	0.45**
Oswestry LBP Disability Index (ODI)	0.70**	0.61**	0.63**	0.51**
STarTBack	0.60**	0.50**	0.50**	0.60**
Tampa Scale for Kinesiophobia (TSK)	0.42*	0.31	0.50**	0.50**
Pain Anxiety Symptoms Scale short form (PASS 20)	0.50**	0.40*	0.60**	0.44**

Key: **: Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

10.4.3. BACKonLINE™ Cut-Off Scores

In order to determine the sensitivity and specificity of BACKonLINE™, a ROC curve was plotted using STarTBack as the reference standard. Crosstabulations (Table 42) and subsequent sample size calculations were carried out in order to determine the minimum required sample size (Table 43).

Table 42 BACKonLINE™ and STarTBack Crosstabulation

BACKonLINE™'s score (Observation1)	STarTBack		Sample total (N)
	0	1	
15	1	0	1
17	1	0	1
20	1	0	1
27	0	1	1
29	1	0	1
30	1	0	1
31	1	0	1
34	2	0	2
36	2	0	2

BACKonLINE™'s score (Observation1)	STarTBack		Sample total (N)
	0	1	
37	2	0	2
40	2	1	3
41	1	0	1
42	0	2	2
43	3	0	3
44	1	0	1
46	0	1	1
47	1	0	1
51	0	1	1
53	0	1	1
54	1	0	1
55	0	1	1
59	2	0	2
62	0	1	1
63	0	1	1
64	0	1	1
94	0	1	1
Sample total (N)	23	12	35

Key: 0: predominantly peripherally sensitised low back pain group; 1: predominantly centrally sensitised low back pain group

Table 43 Phase 3 cut-off scores power calculations output from nQuery (sample size calculator software)

	1	2	3	4
Null hypothesis AUC (AUC0)	0.50	0.50	0.50	0.50
Alternative hypothesis AUC (AUC1)	0.79	0.79	0.75	0.70
Positive group sample size (N+)	25	20	35	58
Negative group sample size (N-)	13	11	19	31
Total sample (N)	38	31	54	89
Power (%)	91.09%	82.1%	90.5%	90.51%

Key: AUC: Area Under the Curve; N: sample number; Positive group sample size (N+): predominantly centrally sensitised sample; Negative group sample size (N-): predominantly peripherally sensitised sample. Test significance level, $\alpha=0.05$ (2-sided test)

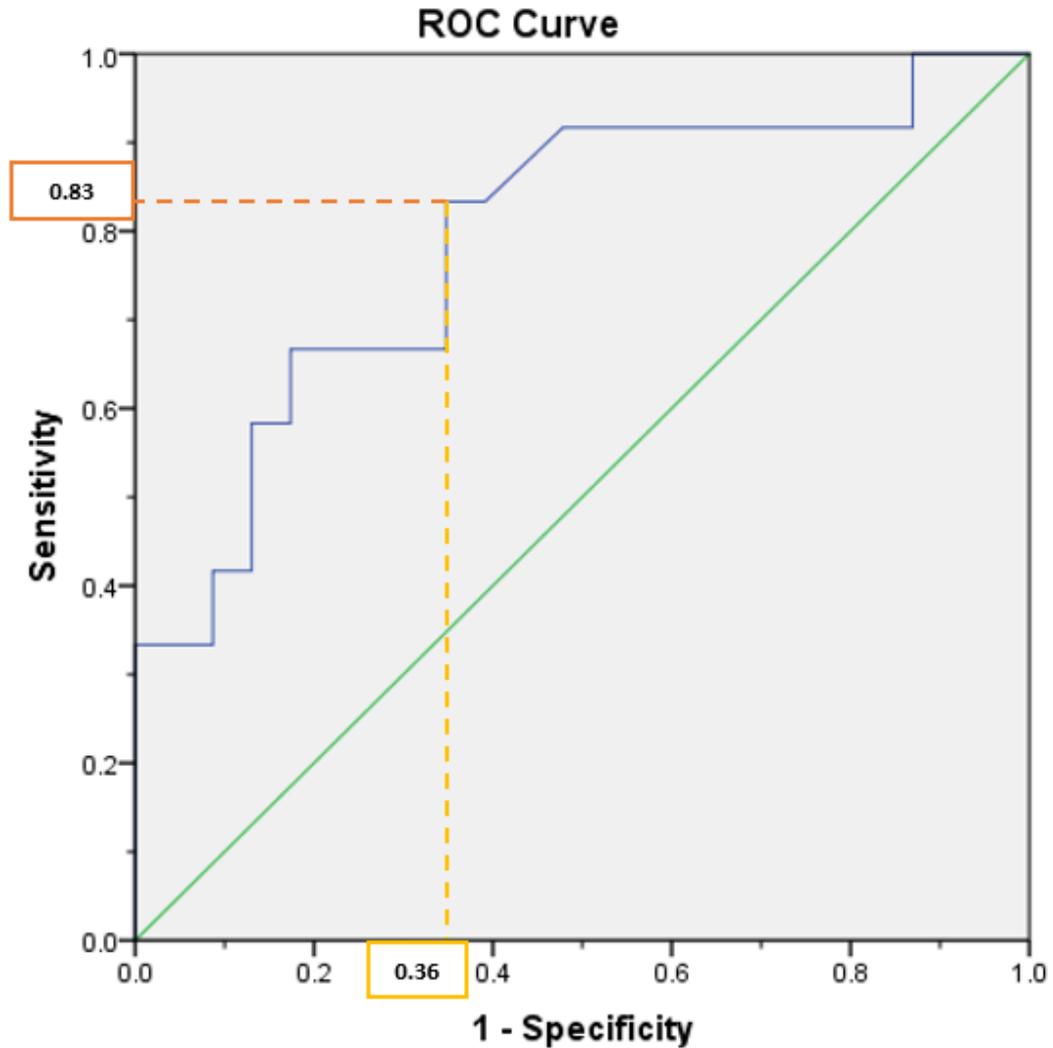
In a 2 sided test comparing the area under the ROC curve (AUC) to a reference value for continuous response data using a z-test approximation, a sample size of 20 from the predominantly centrally sensitised LBP group, the group under category N+, and a

sample size of 11 from the predominantly peripherally sensitised LBP group, the group under category N-, a total of 31, achieved 82.1% power at the 5% significance level when the AUC under the null hypothesis is 0.5, and the AUC under the alternative hypothesis is 0.79. Under the same circumstances, a sample size of 25 from the predominantly centrally sensitised LBP group, the group under category N+, and a sample size of 13 from the predominantly peripherally sensitised LBP group, the group under category N-, a total of 31, achieves 91.09% power (Table 43).

Variation in sample size for ROC curves is highly influenced by the AUC under the alternative hypothesis. Changing this to 0.75 increases the total sample size to 54, and to 0.7 increases it to 89 (both with powers at roughly 90%).

The AUC was calculated for BACKonLINE™ and it showed that BACKonLINE™ can moderately distinguish between people with predominantly centrally sensitised LBP and predominantly peripherally sensitised LBP (AUC=0.79) thus rejecting null hypothesis 7: BACKonLINE™'s ability to distinguish between people who have predominantly centrally sensitised LBP and people who have predominantly peripherally sensitised LBP is low (AUC < 0.70) (Figure 13).

Figure 13 Phase 3 ROC curve for BACKonLINE™ (Observation 1) using STarTBack as the reference standard



Diagonal segments are produced by ties.

The cut-off scores for BACKonLINE™ correlated with the point closest to the top left hand corner of the plotted graph (sensitivity=0.83, specificity-1=0.36) (Figure 13). After checking the coordinates of the established sensitivity and specificity, the closest point to the top left hand corner was identified (highlighted in green in Table 44) and it was decided that scores higher than 42 in BACKonLINE™ indicated predominantly centrally

sensitised LBP while scores equal to or lower than 42 indicated predominantly peripherally sensitised LBP (Table 44).

Table 44 Phase 3 BACKonLINE™ ROC Curve coordinates (Observation 1)

Positive if Greater Than or Equal To ^a	Sensitivity	1 - Specificity
14.00	1.00	1.00
16.00	1.00	0.95
18.50	1.00	0.91
23.50	1.00	0.87
28.00	0.91	0.87
29.50	0.91	0.82
30.50	0.91	0.78
32.50	0.91	0.73
35.00	0.91	0.65
36.50	0.91	0.56
38.50	0.91	0.47
40.50	0.83	0.39
41.50	0.83	0.34
42.50	0.66	0.34
43.50	0.66	0.21
45.00	0.66	0.17
46.50	0.58	0.17
49.00	0.58	0.13
52.00	0.50	0.13
53.50	0.41	0.13
54.50	0.41	0.08
57.00	0.33	0.08
60.50	0.33	0.00
62.50	0.25	0.00
63.50	0.16	0.00
79.00	0.08	0.00
95.00	0.00	0.00

Key: ^a The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of 2 consecutive ordered observed test values.

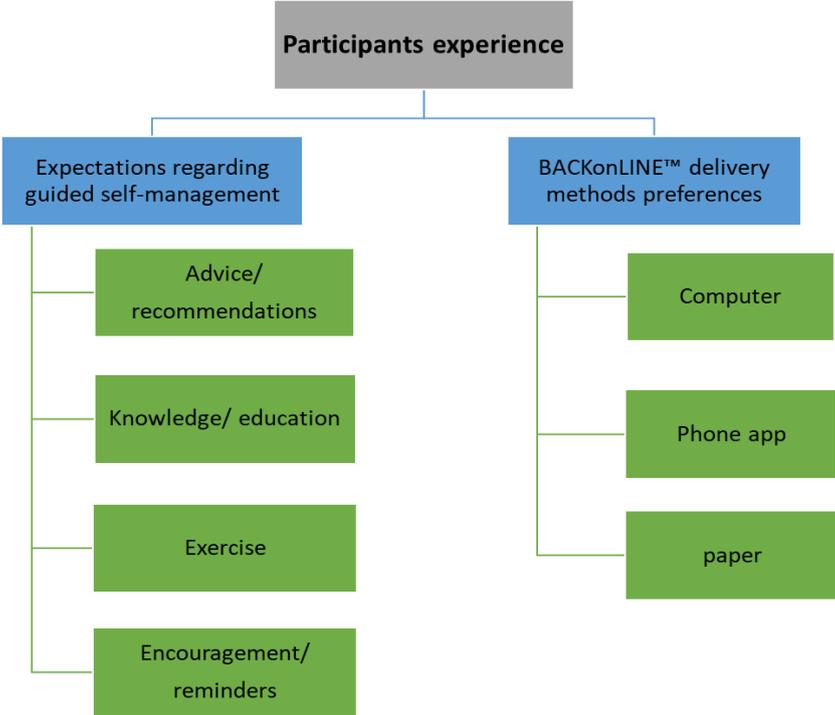
10.5. Participants Experience of BACKonLINE™

During Observation 1, semi-structured interviews were conducted to explore participants experience after using BACKonLINE™. The interviews were conducted individually and face to face with all participants in Observation 1 (n=35). Inductive thematic analysis was performed in order to extract relevant themes. Two main areas were explored: Expectations regarding self-management, and preferred mode of delivery of BACKonLINE™. The following sections present the results for both areas.

10.5.1. Expectations Regarding Self-Management in BACKonLINE™

When asked about their expectations regarding guided self-management, 4 main themes were identified: advice/recommendations, knowledge/education, exercise, encouragement/reminders. When asked about BACKonLINE™ delivery methods preferences, 3 themes were identified: Computer, smartphone app, paper (Figure 14).

Figure 14 Phase 3 themes of participants experience after using BACKonLINE™



When participants’ expectations regarding self-management were explored, various sub-themes were identified (Figure 15), and participants elaborated on what they would expect or want out of BACKonLINE™ (Table 45). As part of self-management in BACKonLINE™, participants have suggested advice on how to deal with the physical symptoms and how to mentally deal with their pain as noted from LBP15’s comment:

“Probably advice on how to address the symptoms that I was experiencing at that particular time. Also, maybe suggestions on how to mentally deal with the pain”

LBP15

Other participants expected a self-management that includes what is currently recommended for their pain LBP22:

“I would probably - I'd like to see, I suppose, what’s recommended, maybe, exercises”

LBP22

Gaining knowledge and education regarding their pain was also a common concept among participants. Participants have raised concerns about having their own misconceptions regarding their pain as can be seen from LBP27, LBP12, and LBP19's comments:

"Maybe a tiny bit - a paragraph of advice. I would love to know why I have it (back pain). I have my own suggestions in my mind. But no one - no health professional I've been to seems to be able to confirm or deny it"

LBP27

"I think any right education - I think the worst thing you can do is look on Google and not know, but I think the right education has to be led by the people with experience in that area, because otherwise, if you look at Google, I'd probably dead, because that's what Google says for everything"

LBP12

"I think psychologically it's quite nice to know that it's not something terrible or that it might go away, or what caused it. So, I think knowledge is quite useful in that respect"

LBP19

It can be deduced from the comments that evidence-based education is warranted in order to decrease symptoms of catastrophising and pain-related fear avoidance.

Exercise was another common suggestion by participants. The exercises suggested are related to the strengthening of their back, posture, yoga and stretches. Additionally, it can be inferred that convenience and regularity of doing these exercises are of certain importance since LBP52 expected "exercises to do every morning and night" and LBP62 expected exercises to be done "at home".

Getting encouragements and reminders through BACKonLINE™ was another recurring concept where participants expressed the need to be reminded and encouraged to move and to be reminded that pain does not equal harm which can be noted from participant LBP15, and LBP18's comments

"Encouragement to maybe not let it put you off doing things and how to not let it stress you out or get depressed about it. Maybe encouragement as well"

LBP15

"you need some reminders, maybe get some correct posture - walking, sitting".

LBP18

It could be inferred from participants comments that some of them know that movement would not harm them. However, they forget to move due to their busy days as can be seen from LBP60's comment:

"it's easy to, if you're embroiled in work, or whatever, to forget to stand up and walk around once an hour"

LBP60

Figure 15 Phase 3 participants expectations regarding self-management themes and sub-themes

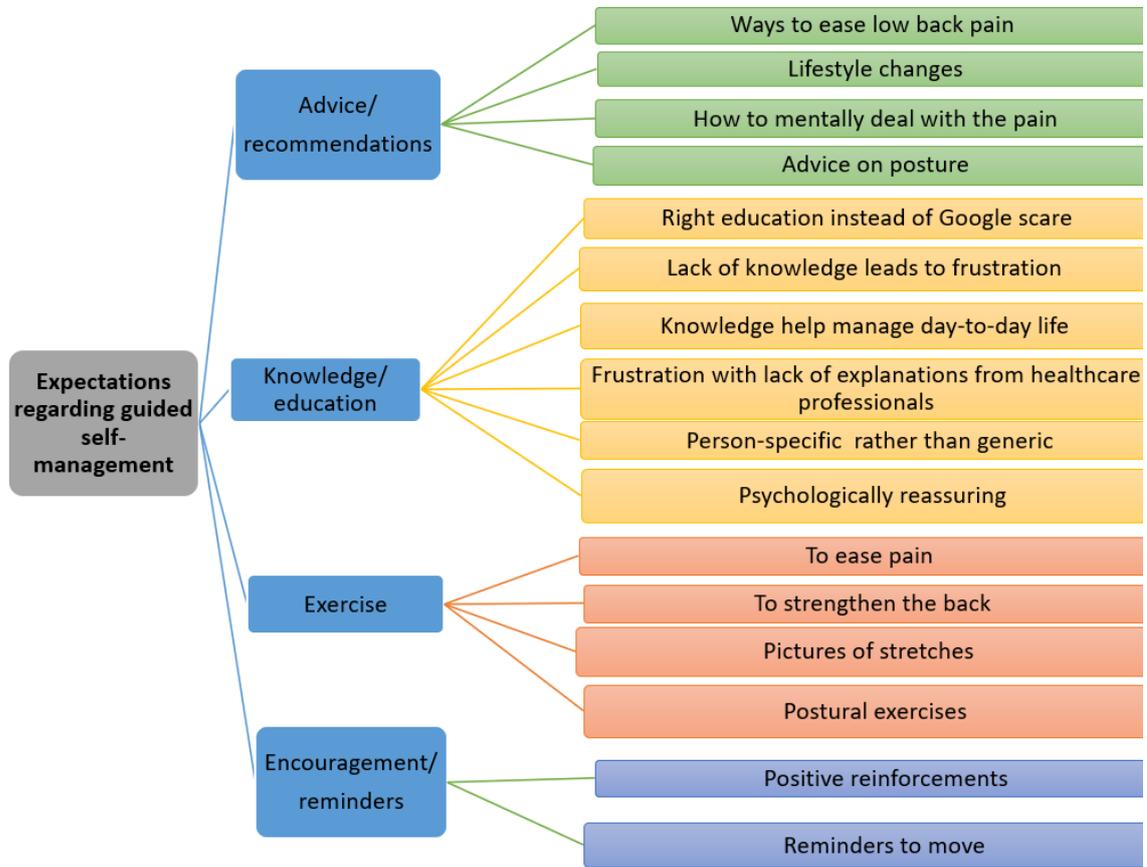


Table 45 Phase 3 participants' expectations regarding self-management main themes and examples

Category	Theme	Examples
Expectations regarding guided self-management	Advice/recommendations	<p>LBP15: "Probably advice on how to address the symptoms that I was experiencing at that particular time. Also maybe suggestions on how to mentally deal with the pain."</p> <p>LBP25: "some sort of guidance coming out of that would be useful. What would I best be doing to try and ease my back pain?"</p> <p>LBP12: "Maybe some lifestyle things of stuff which is known to help."</p> <p>LBP60: "I'm assuming that it will be some sort of advice on: posture; not remaining seated; standing up; taking rests from whatever activity you're doing, those sorts of things."</p>

Category	Theme	Examples
	Knowledge/ education	<p>LBP10: "I think knowing more about it could help you with how you do your day-to-day."</p> <p>LBP12: "I think any right education - I think the worst thing you can do is look on Google and not know, but I think the right education has to be led by the people with experience in that area, because otherwise, if you look at Google, I'd probably dead, because that's what Google says for everything."</p> <p>LBP20: "Absolutely in the beginning (would've liked to know more about back pain) because in that whole first year I really had no idea what to do. I had to figure it all out on my own and I became Doctor Google and that's not the best place to be in."</p> <p>LBP30: "the questions are good. Good for the people who don't understand it and haven't been through the cycle already. and probably what makes it worse and better. I think when you're reading you start to think that makes it worse, so maybe I should stop doing that. So, it triggers in your mind a little bit more."</p> <p>LBP19: "I think psychologically it's quite nice to know that it's not something terrible or that it might go away, or what caused it. So, I think knowledge is quite useful in that respect."</p>
	Exercise	<p>LBP52: "Probably exercises that I should probably do every morning and night to help my back, to strengthen my back."</p> <p>LBP27: "I might expect some pictures of yoga poses or an explanation of stretches or something."</p> <p>LBP55: "I suppose probably exercises and now I know tips on posture."</p> <p>LBP62: "I suppose to give you online exercise that you can do at home."</p>
	Encouragement/reminders	<p>LBP15: "Encouragement to maybe not let it put you off doing things and how to not let it stress you out or get depressed about it. Maybe encouragement as well."</p>

Category	Theme	Examples
		LBP60: "A reminder not to do the things that aggravate it. Which is all well and good, but it's easy to - if you're embroiled in work, or whatever, to forget to stand up and walk around once an hour. So, I suppose - I know my posture is poor, but it's easy to forget to sit properly and end up slouching and then it just drops. The other thing is, that I find the stretching - and I've found some yoga exercises that are helpful, but then I only think to do them when it's particularly bad and when it's normal low level pain, then I just slip back into not doing the exercises."

LBP: Low Back Pain (i.e. participant's ID)

10.5.2. Preferred Mode of Delivery of BACKonLINE™

When BACKonLINE™ delivery methods preferences were further explored, various sub-themes were identified (Figure 16), and participants elaborated on their choices (Table 46).

The 3 key modes of delivery according to participants are the computer, smartphone apps and paper. However, participants have noted advantages and disadvantages of each, except for smartphone apps. Participants pointed out that when using a computer, the tool can be accessed anywhere, easy to complete, and visually appealing. However, 1 participant, LBP52, preferred paper since a computer was something "wouldn't maybe go to look at it as often", an interesting comment considering that LBP52 is 23 years old and very comfortable with computers. Another participant who suggested paper-based was LBP41; however, they did not elaborate on their choice. It should be noted that LBP41 was not comfortable completing BACKonLINE™ in the laboratory. However, a detailed step-by-step explanation was provided by the researcher, and LBP41 was able to complete BACKonLINE™ during both Observations 1 and 2 without a problem. Having

BACKonLINE™ as a smartphone app was a popular concept among participants who thought that “you just switch it on” LBP25, “just easier on your phone” LBP24, and “you can do it wherever” LBP64.

Overall, there was no unanimous preference amongst participants. However, ease of access and ease of completion seem to be the main drivers for their choices. Comfort with technology seemed to be another driver for their choices.

Figure 16 BACKonLINE™ Phase 3 participants’ delivery methods preferences

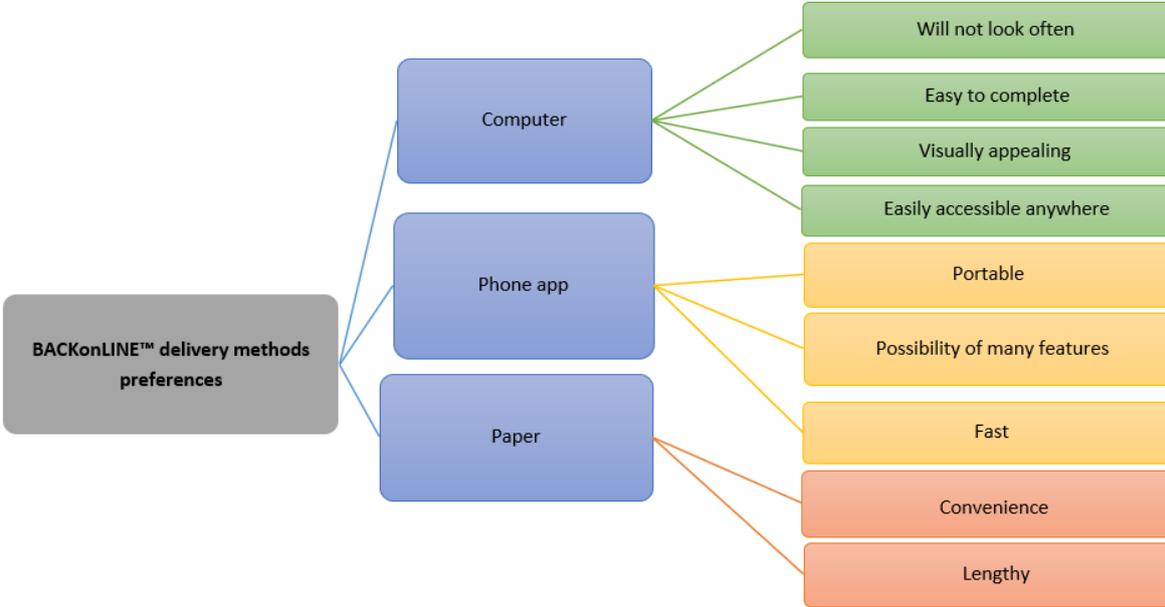


Table 46 Phase 3 BACKonLINE™ participants’ delivery methods preferences themes and examples

Category	Theme	Examples
BACKonLINE™ delivery methods preferences	Computer	<p>LBP16: “I think this online version is the best option. It's easy to complete. You can do it in your own time.”</p> <p>LBP35: “Website is quite easy because you can access it anywhere.”</p> <p>LBP31: “Well, I was quite happy with doing it on the computer. It's visual, you can see what is there, you just tick the boxes and that's fine.”</p>

Category	Theme	Examples
		<p>LBP62: "I think the computer's very good, actually, because it's nice and large and you can just click and whereas paper sometimes, it goes on and on and on."</p>
	Smartphone App	<p>LBP25: "Ideally, on a tablet or a mobile phone, Not on a computer, because I have to get that out, set it up. But on a tablet, you just switch it on and mobile phone"</p> <p>LBP13: "Okay, so I would suggest that it could be an app. I can already see features in there that if you haven't moved it would say you haven't moved, how's your back pain."</p> <p>LBP15: "I tend to use apps quite a bit, so I would say an app would probably be best. If it was a web page I probably wouldn't go and look up the web page and log on to it, but if it was an app and I had it on my phone then I might well use it."</p> <p>LBP64: "A phone app would be good, because that's much easier, isn't it? Because you can do it wherever."</p> <p>LBP24: "App would be a good idea. Yeah, and app where you can just press tick, tick, tick - be very fast. It's something - I mean sometimes when you've been working on a computer all day then the last thing you want to do is fire up your laptop or your computer when you get home - just easier on your phone, it's easy on an app."</p>
	Paper	<p>LBP52: "Maybe on a computer or just paper, something to read, to physically read, because then I think on a computer I could - I don't know, wouldn't maybe go to look at it as often, whereas if it was a piece of paper sat in my room by my bed, I would see it to think, oh, I need to read this or do my exercises."</p> <p>LBP41: "On the paper."</p>

10.6. Summary

BACKonLINE™ total score shows excellent test retest reliability (ICC=0.92, CI=0.83-0.95, CV=10%) and excellent internal consistency (Observation 1 CA=0.87, Observation 2 CA=0.90). While investigating the construct validity of BACKonLINE™, the total score showed high correlation with the nomological network without reaching the point of singularity. Sensitivity and specificity were plotted using the ROC curve and employing STarTBack as the reference standard. A BACKonLINE™ cut-off score of 42 was deemed appropriate in differentiating between centrally and peripherally sensitised LBP. An AUC was calculated and it was shown that BACKonLINE™ can moderately distinguish between predominantly centrally sensitised LBP and predominantly peripherally sensitised LBP (AUC=0.79).

When exploring participant experience of using BACKonLINE™ in terms of expected self-management and delivery methods, participants suggested advice, education, exercise, and encouragements as self-management options and computes, smartphone apps, and paper as potential modes of delivery. In the next chapter, the findings of Phase 3 are discussed.

Chapter 11. Phase 3 Discussion

11.1. Introduction

In Phase 3, the measurement properties and participants experience study, findings from the reliability and validity were analysed. In addition, participants experience with BACKonLINE™ was explored in terms of their expectations regarding self-management and their preferred mode of delivery of BACKonLINE™. This chapter discusses the findings of this study in regards to the sample and methodological considerations of testing measurement properties of patients reported measures.

11.2. Summary of Findings

Reliability, validity and patients experience of using BACKonLINE™ were assessed in Phase 3. Observation 2 results were used for internal consistency analysis and discussion. Internal consistency for BACKonLINE™ showed excellent rating (CA=0.90). The internal consistency rating of the Pain behaviour domain was excellent (CA=0.85), the Impact of LBP on work and lifestyle domain had good rating (CA=0.75), and the Experience with LBP domain had good rating (CA=0.77) (Ponterotto and Ruckdeschel 2007).

Item-total statistics were performed to check if CA was lowered by any item. Item-total statistics show that BACKonLINE™'s CA would increase to 0.91 if items PB1 and PB 16 were deleted. The CA of the Pain behaviour domain would increase to 0.86 if item PB1 was deleted, while the CA of the Impact of LBP on work and lifestyle domain would

increase to 0.76 if items WL1 and WL10 were deleted. The Experience with LBP's CA would increase to 0.79 if item P3 was deleted and the CA would increase to 0.78 if item P7 was deleted.

The test retest reliability of BACKonLINE™'s total was high (ICC=0.92, 95% CI=0.83-0.95). The test retest reliability of the Pain behaviour and Impact of LBP on work and lifestyle was high (0.91, 95% CI=0.81-0.95; and 0.92, 95% CI=0.84-0.95 respectively), and the Experience with LBP domain showed moderate reliability (ICC=0.71, CI=0.49-0.84). Composite scores for the validated questionnaires were computed, and a paired samples T-test was performed in order to confirm the stability of symptoms. The T-test shows an insignificant change in scores thus confirming the stability of symptoms (t=0.09, df=31, p=0.92, 2-tailed).

BACKonLINE™ items were correlated with their assigned domains and other domains in order to see if they fit into their assigned domains. Observation 2 was chosen for analysis and discussion. In Observation 2, Item PB2: what caused your low back pain? in the Pain behaviour domain has a higher correlation with the Impact of LBP on work and lifestyle domain and all other items seem to correlate with their assigned domain.

Construct validity of BACKonLINE™ was explored using the nomological network (VAS, ODI, STarTBack, TSK, PASS 20). BACKonLINE™ shows moderate correlation with VAS, ODI, STarTBack, TSK, and PASS 20 (r=0.60, 0.70, 0.60, 0.42, 0.50 respectively). The Pain behaviour domain shows moderate correlation with VAS, ODI, STarTBack, TSK, and PASS 20 (r=0.60, 0.61, 0.50, 0.31, and 0.40 respectively). The Impact of LBP on work and lifestyle domain shows moderate correlation with the VAS, ODI, STarTBack, TSK, and

PASS 20 ($r=0.31, 0.63, 0.50, 0.50, 0.60$ respectively). The Experience with LBP domain moderately correlated with the nomological network ($r=0.45, 0.51, 0.60, 0.50, 0.44$ against the VAS, ODI, STarTBack, TSK, and PASS 20 respectively).

In order to determine preliminary cut-off scores for BACKonLINE™ and investigate concurrent validity, ROC curve analysis was conducted using STarTBack as a reference standard. A BACKonLINE™ cut-off score of 42 was considered appropriate in differentiating between predominantly centrally sensitised LBP and predominantly peripherally sensitised LBP. The ROC curve analysis also showed that BACKonLINE™ is moderately able to differentiate between predominantly centrally sensitised LBP and predominantly peripherally sensitised LBP (AUC= 0.79).

Participants experience of using BACKonLINE™ was explored in terms of expected self-management techniques and preferred mode of delivery. Advice, education, exercise, and encouragements were suggested as self-management options in BACKonLINE™ and computers, smartphone apps, and paper were suggested as a mode of delivery. The next sections discuss the findings of Phase 3 in detail.

11.3. BACKonLINE™ Reliability

11.3.1. Internal Consistency

In order to evaluate the adequacy of the calculated Cronbach's Alpha (CA), the matrix proposed by Ponterotto and Ruckdeschel (2007), which takes into account both the length of the scale and the sample size, was used. Internal consistency for both Observation 1 and 2 was calculated in order to assess for major discrepancies, however, since BACKonLINE™ is intended to be used at home, data from Observation 2 were the

focus of interpretation and hypothesis testing. The high CA in both Observations (Observation 1=0.87, Observation 2=0.90) could be because of the relatively large number of self-assessment items in BACKonLINE™ (39 items in total) in proportion to the small sample size which could inflate CA (Tavakol and Dennick 2011).

Since BACKonLINE™ consists of multiple domains, CA was calculated for each domain separately. This method of analysis was suggested previously by Tavakol and Dennick (2011) to explore whether the total CA was a true reflection of BACKonLINE™'s internal consistency or whether it was artificially inflated given the number of items organised within the 3 domains. Overall, the rating of CA seems to have increased in Observation 2. Internal consistency of the Pain behaviour domain was the highest (CA=0.80 in Observation 1, 0.85 in Observation 2), followed by the Impact of LBP on work and lifestyle domain (CA=0.77 in Observation 1, 0.75 in Observation 2), while the Experience with LBP domain had the lowest internal consistency (CA=0.56 in Observation 1, 0.77 in Observation 2). The notably low CA of the Experience with LBP domain could be due to the fact that this particular domain has a low number of items (7 items in total compared to 22 in the Pain behaviour domain and 10 in the Impact of LBP on work and lifestyle) which affects CA (Ponterotto and Ruckdeschel 2007, Tavakol and Dennick 2011). It should be emphasised that CA assumes it measures the same construct in a scale, and this assumption would be compromised if the number of items is small (Graham 2006, Tavakol and Dennick 2011).

After calculating CA, item-total statistics of BACKonLINE™ were explored in order to detect if any item within BACKonLINE™ is negatively affecting the CA. Overall, item-total

statistics appear to be good except for a few items that seem to decrease the overall CA. It is apparent when looking at Observation 2 data that if items PB1 and PB16 were deleted, the CA of BACKonLINE™ would increase to 0.91. Deleting item PB1 would increase the Pain behaviour domain CA to 0.86 and deleting items WL1 and WL10 would increase the CA of the Impact of LBP on work and lifestyle domain to 0.76. With regard to the Experience with LBP domain, deleting item P3 would increase CA to 0.79 and deleting item P6 would increase CA to 0.78.

Item PB1 (Do you know what caused your current back pain?) in the Pain behaviour domain produced a negative CA value in Observation 2 (-0.05) which usually happens to reverse-scored questions. It should be noted that this item has 3 answer options: Yes, not sure, and no (scored 0, 1, and 2 respectively). Since no item was reversed in BACKonLINE™, a closer inspection was undertaken in order to explore the possible reasons for the negative result.

After examining the raw data, it was discovered that out of 33 participants who completed both Observations 1 and 2, 9 participants had the same answers and 13 changed their answer from either 'yes' or 'no' to 'not sure' or vice versa which could have caused the negative value. Having a middle option have been shown to negatively affect reliability due to the participant's tendency to choose the neutral option regarding it as the safe option (Weems and Onwuegbuzie 2001).

The ambiguity of questions or answers could also negatively affect the reliability of responses (Streiner, Norman et al. 2015). Sometimes, attaching a label to answer options might decrease ambiguity, but it might also contribute to it (Alwin and Krosnick

1991). When looking at the question at hand, even though it specifically asks what caused current back pain, responders might misunderstand the meaning of current. Some responders might understand it as pain this instant in Observation 1, but after a week, they might read the question again and understand current as pain in the past 2 weeks, hence changing their answers from yes/no to unsure and vice versa (Streiner, Norman et al. 2015). For future studies, it would be advisable to take a closer look at the answer options for this question. In retrospect, if the question is taken at face value, it is apparent why some people might be tempted to change to 'not sure' due to response bias and potential ambiguity, and it might be worth removing 'not sure' option and re-examining the quality of the question (Weems and Onwuegbuzie 2001).

It should be noted that Observation 1 was conducted in the laboratory, with a prepared computer, while Observation 2 was completed by participants from their own home, on their personal computer, which could have contributed to the notable improvement in internal consistency due to the influence of response bias (Peer and Gamliel 2011). Response bias is a participants' inclination to answer questions falsely; this type of bias is widespread in the research of self-assessment measures (Furnham 1986). Response bias results from the idea that human beings are dynamic and respond to situations by actively processing multiple sources of information in order to respond to any stimuli (Orne 1962).

Due to the nature of response bias, anything, from the behaviour of the researcher to participants desire to appear as good subjects, can influence the responses of participants (Nederhof 1985, Furnham 1986). Response bias can artificially inflate

internal consistency which might explain the overall high internal consistency of BACKonLINE™ in both Observation 1 and 2, however, several researchers have noted that the artificial inflation in internal consistency is more likely to happen with paper and pencil self-report tools rather than computerised tools (Mertler and Earley 2002, Mertler and Earley 2003, Peer and Gamliel 2011). With paper and pencil self-assessment measures, participants might change their answers in order to project a certain image of themselves or to convey certain beliefs they have about their back pain. For example, a participant could be positive in all domains (i.e. answering in a way indicating no influence on pain) except for the work and lifestyle domain in order to communicate their belief that their work caused their back pain completely masking other aspects of their pain symptoms.

BACKonLINE™ is an online tool where participants have no access to their answers after completion, which decreases the risk of internal consistency inflation (Peer and Gamliel 2011). The differences in Observation 1 and 2 could be attributed to the calculated CA occurring by chance due to the small sample size (Streiner, Norman et al. 2015). A small sample size might present a threat to internal consistency by inflating the CA of an item making it appear valuable when in actuality it could be insignificant when tested on another large sample size (DeVellis 2016). Additionally, a small sample size could have also affected the item-total statistics. Therefore, the results of this analysis should be interpreted with caution.

11.3.2. Test Retest Reliability

It is essential that the time period between observations in a test retest reliability study is long enough in order to decrease memory effects while ensuring the stability of the symptoms (Salek and Kamudoni 2013). In this study, a 1 week time period was deemed appropriate to meet the aforementioned required conditions. The average time period between observations for all participants was 10 days which was within the intended time period. During this time period, participants were encouraged to report any significant changes in their symptoms or pain intensity in the provided booklet. However, there were no reports of changes in symptoms or pain intensity. Additionally, a paired samples T-test for composite scores for the validated questionnaires (VAS, ODI, STarTBack, TSK, and PASS 20) confirmed the stability of symptoms by showing insignificant differences between the 2 Observations ($t=0.09$, degree of freedom=31, $p=0.92$, 2-tailed). This was expected since participants suffered from CLBP which is more likely to be more stable than acute LBP within the timeframe.

The ICC and the CV were calculated to test BACKonLINE™'s test retest reliability for the whole tool and each domain individually. ICC was high for BACKonLINE™'s total (ICC=0.92, CI=0.83-0.95) and both the Pain behaviour (ICC=0.91, CI=0.81-0.95) and Impact of LBP on work and lifestyle (ICC=0.92, CI=0.84-0.95) domains, and moderate for the Experience with LBP (ICC=0.71, CI=0.49-0.84) domain. The significance testing of the acquired ICCs was of large effect sizes (> 0.5) which indicated an extremely low possibility that the correlations between observations occurred by chance (Field 2009, McGraw and Wong 1996).

In regard to CV, it was observed that BACKonLINE™'s total and the Pain behaviour domain had acceptable variance (less than 12%) (Miller, Cohen et al. 2002, Wrosch, Miller et al. 2007, Streiner, Norman et al. 2015). However the average CV for the other 2 domains was higher than 12% (Impact of LBP on work and lifestyle and Experience with LBP domains, CV=29% and 21% respectively), this could be due to the relatively low number of items in each domain (10 and 7 items respectively) and small sample size (n=33) (Streiner, Norman et al. 2015).

Although both the total ICC and CV indicate excellent test retest reliability, the results should be treated with caution. The test retest study should be conducted on a larger sample where factor analysis could be conducted in order to ensure each item belongs in their assigned domain.

The internal consistency and test retest reliability of BACKonLINE™ appear to be comparative to the reliability studies done by Mayer, Neblett et al. (2012) and Smart, Curley et al. (2010) of the 2 other identified systems of distinguishing pain according to the mechanisms-based classification of pain where the CSI was reported to have a high test retest reliability and internal consistency (Pearson's correlation (r)=0.817; CA=0.879) and Smart, Curley et al. (2010) reported a substantial inter and intra-rater reliability by clinicians' mechanisms based classifications of LBP (\pm leg pain) (kappa=0.77; 95% CI: 0.57–0.96; % agreement=87.5 and kappa=0.96; 95% CI: 0.92–1.00; % agreement=92.5 respectively). When compared to STarTBack, a treatment stratification tool based on psychosocial risk factors (test retest reliability: Quadratic weighted kappa=0.73), BACKonLINE™ also appears to be comparative.

11.4. BACKonLINE™'s Validity

11.4.1. Item-Total Correlations with Other domains Totals

When each item in BACKonLINE™ was tested for fit in their domain (i.e. whether they correlate more with their assigned domain or other domains) some items seemed to correlate more to other domains (Items PB2, 4, 11). Even though some items correlated more with other domains than their own in both Observation 1 and 2, it was decided to leave each item in their respective domain due to the inconsistency of their domain correlation in Observation 1 and 2 and the small sample size.

It appeared that item PB18 (Other than your back pain, do you experience any of the following sensations?) in the Pain behaviour domain correlated well with both the Pain behaviour and Impact of LBP on work on lifestyle domains in both Observations. Interestingly, this item explored the presence of sensory dysfunctions other than pain and was the most highly ranked item in both Rounds of the E-Delphi study (Phase 1) (95% and 100% in the E-Delphi Round 1 and 2 respectively). Identification of sensory dysfunction and its location in the body has been stated as an essential component in differentiating between centrally sensitised and peripheral neuropathic pain.

Peripheral neuropathic pain is complex and can occur at the CNS or in the peripheral nerve plexus (Baron, Binder et al. 2010, Cohen and Mao 2014, Nijs, Torres-Cueco et al. 2014). Even though both centrally sensitised pain and peripheral neuropathic pain can be characterised by sensory dysfunction, they can be distinguished by the location of reported sensory dysfunction. In peripheral neuropathic pain, the location of the

sensory dysfunction should be segmentally logical and localized while being widespread and illogical in centrally sensitised pain (Baron, Binder et al. 2010, Nijs, Van Houdenhove et al. 2010, Cohen and Mao 2014, Nijs, Torres-Cueco et al. 2014). Additionally, items WL7: (I can't do my normal daily activities because of my back pain) and P5: (I have lost interest and/or pleasure in doing things because of my back pain) correlated highly with all 3 domains in both observations which might indicate their significance in BACKonLINE™.

11.4.2. Construct Validity

Overall the results indicate that BACKonLINE™'s total score displays moderate convergent validity with the validated questionnaires (i.e. nomological network) ($r=0.60, 0.70, 0.60, 0.42, 0.50$ with VAS, ODI, STarTBack, TSK, and PASS 20 respectively) and null hypothesis 3 (BACKonLINE™ does not have moderate to strong convergent validity with the nomological network) was rejected. These results seem comparative with the CSI which had convergent validity with VAS ($r=0.33$), ODI ($r=0.43$) and PASS 20 ($r=0.43$) (Choi 2014) which further confirms the association between central sensitisation mechanisms with pain intensity, anxiety, and decreased functional abilities.

The Pain behaviour domain appears to have moderate convergent validity with the nomological network ($r=0.60, 0.61, 0.50, 0.31, 0.40$ with VAS, ODI, STarTBack, TSK, and PASS 20 respectively) therefore, null hypothesis 4 (The Pain behaviour domain does not have moderate to strong convergent validity with VAS, ODI, and STarTBack) was rejected. The Impact of LBP on work and lifestyle domain appears to have moderate convergent validity with the nomological network ($r=0.31, 0.63, 0.50, 0.50, 0.60$ with

VAS, ODI, STarTBack, TSK, and PASS 20 respectively) rejecting null hypothesis 5 (The Impact of LBP on work and lifestyle domain does not have moderate to strong convergent validity with VAS, ODI, and STarTBack). The Experience with LBP domain seems to have moderate convergent validity with the nomological network ($r=0.45$, 0.51 , 0.60 , 0.50 , 0.44 against the VAS, ODI, STarTBack, TSK, and PASS 20 respectively) therefore rejecting null hypothesis 6 (The Experience with LBP domain does not have moderate to strong convergent validity with STarTBack, TSK, and PASS 20).

The domains within BACKonLINE™ had unpredicted correlations with some of the validated questionnaires. For instance, the Pain behaviour domain had unpredicted correlations with TSK and PASS 20, the Impact of LBP on work and lifestyle domain and VAS and ODI also had unpredicted correlations. Furthermore, unpredicted correlations between the Experience with LBP and both VAS and ODI was observed, and it is deemed that these correlations may substantiate the validity of BACKonLINE™. On hindsight, a scale with unrelated construct should have been administered and correlated with BACKonLINE™ to assess divergent validity in order to solidify the proof of validity. It should be noted, however, that this would have increased the burden on participants by making them complete an additional, non-LBP specific tool. Since this is a preliminary study with a small sample size, increasing the burden on participants seemed excessive. Furthermore, since factor analysis could not have been performed due to the small sample size, it is uncertain that BACKonLINE™ has 3 separate domains due to the lack of statistical confirmation. A study with a large sample size could identify different domains which then could lead to more rigorous validity studies.

11.4.3. BACKonLINE™ Cut-Off Scores

When using STarTBack as a reference standard to determine BACKonLINE™'s cut-off scores, it was determined that a score of higher than 42 indicted predominantly centrally sensitised LBP while a score of equal to or lower than 42 indicated predominantly peripherally sensitised LBP. In this sample, 12 participants appear to have predominantly centrally sensitised LBP while 23 participants appear to have predominantly peripherally sensitised LBP. A post-hoc analysis was conducted in order to test the trustworthiness of the acquired cut-off score and the adequacy of the sample size (Hanley and McNeil 1982, Fawcett 2006). The post-hoc sample analysis showed that in a sample of 31 participants with 20 of them categorised as having predominantly centrally sensitised LBP (or a sample of 38 people with 25 categorised as having predominantly centrally sensitised LBP) is needed in order to determine cut-off scores for BACKonLINE™. However, it should be noted that STarTBack stratifies people with LBP into high, medium, and low risk groups of having modifiable psychosocial factors, and thus, the results of the current study indicates that BACKonLINE™ is comparable to STarTBack in stratifying LBP patients into low and medium/high risk group in a small sample of 35 LBP patients. Even though the presentation of psychosocial factors is linked with central sensitisation of pain, it cannot be determined that BACKonLINE™ is capable of stratifying LBP into centrally sensitised and peripherally sensitised pain without conducting further studies with different methodologies (e.g. utilisation of a comprehensive physiotherapy assessment) and with larger samples.

Assessing and defining central sensitisation is not a foreign concept in pain literature which resulted into the development of 2 questionnaires aiming to define central

sensitisation (Ruscheweyh, Marziniak et al. 2009, Nijs, Torres-Cueco et al. 2014, Neblett, Hartzell et al. 2017). One such method is the Pain Sensitivity Questionnaire, which is a self-assessment questionnaire that measures pain intensity in imagined daily life situations and experimental pain testing in order to detect the presence of any heightened pain intensity perception (Ruscheweyh, Marziniak et al. 2009). The Pain Sensitivity Questionnaire is comprised of 17 questions that rate imagined painful situations (e.g.: Imagine you have a minor cut on your finger and inadvertently get lemon juice in the wound) on a 0 to 10 VAS and use the average acquired score to aid clinical judgement (Ruscheweyh, Marziniak et al. 2009).

Another available questionnaire is the Central Sensitisation Inventory (CSI), which is a self-assessment questionnaire designed to detect symptoms related to centrally sensitised pain. The CSI consists of 2 parts; part A includes 25 questions that are scored from 0-4, and part B explores the past history of a patient in order to aid clinical judgement. A patient is considered to have indications of centrally sensitised pain if they score > 40 in part A, while part B is not included in the scoring (Neblett, Hartzell et al. 2017). However, both questionnaires only explore certain aspects of centrally sensitised pain, and physical assessment and clinical judgement are needed for the complete picture of the presence and extent of centrally sensitised pain (Nijs, Torres-Cueco et al. 2014).

In the current study, preliminary cut-off scores were based on results calculated from a small sample and by using 1 corresponding self-assessment questionnaire (STarTBack), and even though tools measuring centrally sensitised pain, namely the CSI,

and the Pain Sensitivity Questionnaire, both of which need an accompanying clinical assessment, therefore, they were deemed inappropriate within the context of this study. The results of the current study should be treated with caution and future studies utilising clinical judgement, and larger sample sizes are required in order to determine a more precise cut-off score.

In order to assess the level of accuracy of BACKonLINE™ in distinguishing between predominantly centrally sensitised LBP and peripherally sensitised LBP, the AUC was plotted using STarTBack as a reference standard, with an AUC value of 0.79, it was concluded that BACKonLINE™ could moderately distinguish between predominantly centrally sensitised LBP and peripherally sensitised LBP which is a satisfactory result for self-assessment tools (Neblett, Cohen et al. 2013, Streiner, Norman et al. 2015).

11.5. Participants Experience of BACKonLINE™

During Observation 1, semi-structured interviews were conducted with all participants in order to explore their views on what constitutes self-management and what mode of delivery would they prefer for BACKonLINE™. The following sections discuss the findings from the acquired data.

11.5.1. Expectations Regarding Self-Management in BACKonLINE™

In the present study, advice/recommendations, knowledge/education, exercise, and encouragement/reminders were identified as themes derived from the semi-structured interviews with participants. Participants expected education about their LBP and

emphasised the impact of knowledge and education in lowering their fear and uncertainty about their condition. For example, LBP43 thought that:

“Definitely if it was more person-specific explanation because instead of being so generic”

LBP43

And LBP20 who emphasised the importance of person-specific knowledge:

“Absolutely in the beginning (would’ve liked to know more about back pain) because in that whole first year I really had no idea what to do. I had to figure it all out on my own and I became Doctor Google and that’s not the best place to be in.”

LBP20

These findings correspond with Fu, McNichol et al. (2016) qualitative systematic review which found that people with LBP seek information regarding their pain and how to manage it. Educating patients and increasing their knowledge about their condition has been shown to also improve their beliefs and decrease their fear avoidance (Burton, Waddell et al. 1999, Moore, Von Korff et al. 2000) and it also showed that it decreases other behaviours mainly prolonged absence from work (Symonds, Burton et al. 1995).

In another study, Coster and Norman (2009) reviewed 30 Cochrane reviews that focused on self-management of chronic conditions and found that providing knowledge to patients, and helping them acquire basic understanding of how to manage and cope with the pain would result in physical (e.g. increased self-efficacy) and psychological (e.g. decreased fear-avoidance beliefs) benefits and might decrease service use. Coster and Norman (2009)’s review of the psychological benefits of self-management, a concept also noted by participant LBP19 who linked knowledge to reassurance

“I think psychologically it's quite nice to know that it's not something terrible or that it might go away, or what caused it. So, I think knowledge is quite useful in that respect”

LBP19

BACKonLINE™ is based on the mechanisms-based classification of pain and embedded in the biopsychosocial approach in order to increase the specificity of the self-management, thus increasing its effectiveness. Contrastingly, the use of a theoretical model in the development of educational interventions for CLBP was noted to be lacking (Engers, Jellema et al. 2008). Engers, Jellema et al. (2008) emphasised the need to develop CLBP management techniques based on a theoretical model in order to enhance its effectiveness.

Coster and Norman (2009)'s review, for example, have excluded multi-dimensional and complex management packages that combined education with other management techniques such as behavioural therapy, social support, and psychotherapy which might have shed some light on other self-management approaches. This could be an issue since in a systematic review conducted by Verbeek, Sengers et al. (2004), it was highlighted that people with LBP wanted and expected clear explanation regarding their pain and guidance on how to manage it. The lack of multi-dimensional and complex management packages that combined education with other management techniques may not provide patients with LBP with sufficient explanation regarding their pain and self-management guidance. In this BACKonLINE™ study, this was avoided by the application of the biopsychosocial approach.

In a recent systematic review and meta-analysis of 8 RCTs (Wood and Hendrick 2019), PNE has shown to have a moderate short-term positive effect on CLBP and disability

when added to a physiotherapy intervention. However, this review included studies that used PNE together with other interventions such as manual therapy, exercise, and acupuncture. In addition, education was delivered in a variety of ways like group explanations, individual education, and via books and leaflets. The heterogeneity of the included studies might have affected the results of the review (Wood and Hendrick 2019).

In the current study, participants also emphasised their desire to learn exercises that could help them manage their pain:

“Maybe exercises I could do while I waited, so to maybe ease it”

LBP62

“I suppose to give you online exercise that you can do at home.”

LBP82

“Probably exercises that I should probably do every morning and night to help my back, to strengthen my back.”

LBP52

This is in line with the literature where exercise appears to be 1 of the main recommendations for CLBP (Searle, Spink et al. 2015).

In a Cochrane review investigating the effectiveness of exercise of non-specific CLBP, exercise has shown to be effective in pain reduction and physical function improvement (Hayden, Van Tulder et al. 2005). In addition, exercise has been shown to help improve mood and combat depression (Hoffman and Hoffman 2007). Also, exercise has been recommended in both national and international guidelines for the management of CLBP (NICE 2016, Oliveira, Maher et al. 2018). Implementation of these guidelines

appears to be challenging due to the notable diversity of types and durations of exercises in the available literature, which might lead to people with CLBP feeling frustrated and unsure of what exercise and duration are best for their condition (Searle, Spink et al. 2015). In a review and meta-analysis of 45 RCTs (Searle, Spink et al. 2015), exercise has been shown to significantly decrease CLBP. Searle, Spink et al. (2015) found that coordination, stabilisation, and strength exercises were effective in reducing CLBP, and cardiorespiratory exercise had no effect on CLBP (Searle, Spink et al. 2015). However, these results should be interpreted with caution due to the heterogeneity of the exercises in the included RCTs and the duration of interventions (1.5 weeks to 18 weeks). BACKonLINE™ is intended to provide targeted, person-specific self-management which will attempt to minimise the abundance of choice available online and guide people to self-management tailored to them without having to look through the plethora of exercises online that might not be relevant to them.

The third theme that was identified was the desire for encouragement and reminders that they (CLBP patients) are not hurting their back and to continue to be active:

“you need some reminders Maybe get some correct posture - walking, sitting.”

LBP18

“A reminder not to do the things that aggravate it. Which is all well and good, but it's easy to - if you're embroiled in work, or whatever, to forget to stand up and walk around once an hour

LBP60

“Encouragement to maybe not let it put you off doing things and how to not let it stress you out or get depressed about it. Maybe encouragement as well”

LBP15

Patient encouragement to avoid bed rest, to remain active and positive reinforcement has been advised by NICE 2016 as part of the management of CLBP (Foster, Anema et al. 2018). In a systematic review of 10 qualitative studies that explored the role of communication between LBP patients and healthcare professionals, positive reinforcement and encouragement were identified as 1 of the recurrent recommendations (Fu, McNichol et al. 2016). In this review, 2 methods of encouragement were identified: active listening (i.e. mindfully hearing and trying to comprehend words), and proactive contact from healthcare professionals (Fu, McNichol et al. 2016). It should be noted however that the Fu, McNichol et al. (2016) review only included 10 qualitative studies with small sample sizes ranging from 11-34 participants, thus compromising the generalisability of their results.

11.5.2. Preferred Mode of Delivery of BACKonLINE™

When asked about their preferred mode of delivery of BACKonLINE™, the majority of participants opted for a computer or a smartphone app due to their practicality and ease of access:

“Well, I was quite happy with doing it on the computer. It's visual, you can see what is there, you just tick the boxes and that's fine.”

LBP31

“I think this online version is the best option. It's easy to complete. You can do it in your own time.”

LBP16

“A phone app would be good, because that's much easier, isn't it? Because you can do it wherever.”

Interestingly, there was 1 participant (LBP41) who was uncomfortable using a computer unsupervised and requested direct supervision from the researcher. This participant received extra instructions on how to complete BACKonLINE™ from home and received a telephone call during the time of completion of Observation 2 in order to ensure completion and to avoid increasing the participant's aversion to technology due to frustration. It should be noted that all participants were offered assistance and supervision; however, they all felt comfortable with the prepared computer.

The National Telecommunications and Information Administration called for more computer education provision for people in this age of technology in order to ensure information access to all corners of society (Stanley 2003). Most health information and communications have gone digital, and interestingly, even with the small sample in this study, there was 1 participant who was uncomfortable with computers. In a cross-cultural study investigating computer use in China and the UK, it was found that Chinese participants were more confident and comfortable using computers than their UK counterparts (Li and Kirkup 2007). The same study concluded that male participants in both countries were more confident in their computer skills than female participants (Li and Kirkup 2007).

Willingness to use e-health technology has been associated with younger age, an education level beyond high school, computer literacy, and adequate health knowledge (Trubitt, Alozie et al. 2018, Holt, Karnoe et al. 2019). Healthcare professionals must take the time to ensure that their patients have adequate computer and condition specific

knowledge in order to be able to use the provided E-health pathway (Chuttur 2009, Holt, Karnoe et al. 2019). People might have different experiences with E-health that could stem from a variety of reasons including lack of motivation, lack of access to a computer, low socioeconomic status, and computer illiteracy (Chuttur 2009, Holt, Karnoe et al. 2019). This has been noticed in the current study where most participants were unsure of their ability to use a web-based tool until they got the chance to do it in front of the researcher who was there to answer any computer-related questions. This achieved level of comfort might have contributed to the high response rate (94%) in Observation 2 which was conducted from home, unsupervised. Therefore, when using BACKonLINE™, it is advisable that a step-by-step instruction manual is provided as an option for people who might need it.

11.5.3. Rigour of Phase 3 Interviews

In this section, the rigour of Phase 3 interviews is presented. The first element of assessing rigour in qualitative research is the truth value (credibility). During this phase, truth value was achieved by reiterating the participants' answers back to them right after the interview was done. As the interviews were short, the immediate reiteration process was feasible. Truth value was also confirmed by encouraging the participants to write comments in their provided booklets which they took home and kept for 7 days. This gave the participants enough time and freedom to reflect on their experience and add any additional views they wished to share (Sandelowski 1995).

The second element of rigour is applicability, which was achieved in this phase by the detailed presentation of the results including detailed demographics of the sample, and

direct quotations which would make it easier to use the results in similar contexts with similar demographics (Mayburg and Poggempoel 2007).

The third element of rigour is consistency which was achieved by providing a detailed account of the methods including the questions asked, the venue, and type of recording which would make it easier to replicate the study (Mayburg and Poggempoel 2007).

The final element of rigour is neutrality (i.e. acknowledgement of bias) (Sandelowski 1995). During this phase, the researcher introduced herself as a physiotherapist and PhD student which might have shifted the power dynamics where the participants could have been reluctant in providing self-management suggestions to a physiotherapist (Kuper, Lingard et al. 2008). To ensure as much neutrality as possible, participants were repeatedly reminded that there are no wrong answers and were given the opportunity to further comment privately in their provided booklet.

11.6. Strengths and Limitations of Phase 3

One of the main limitations of this phase is the small sample size which prevented the use of factor analysis, which in turn prevented the conceptualisation of data-driven domains (Field 2009, Hof 2012). However, this limitation was minimised by calculating item-total correlations with other domains totals which gave a statistical indication of item/domain fitness.

Another sample related limitation is the characteristics of the participants (Bland 2015) who were all recruited from a previous study contact list which limited the number of eligible participants in this phase.

A total of 35 people with current LBP participated in this study, 20 of which identified as female and 15 identified as male. The higher number of female participants could be due to the higher prevalence of CLBP among women (Macfarlane, Jones et al. 2006, Chenot, Becker et al. 2008). Furthermore, it has been reported that women seek medical help more than men which puts them in a prime position for research studies (Hunt, Adamson et al. 2011). However, in a review of 15 studies, inconsistent and weak evidence was found linking gender with seeking medical help (Hunt, Adamson et al. 2011). This inconsistent evidence could be due to women having greater loss of CLBP related function and other bodily pains requiring medical attention rather than purely gender (Chenot, Becker et al. 2008). Considering the small sample and the preliminary nature of this study, the differences in gender were deemed acceptable. However, gender differences should be assessed in future, bigger studies.

In addition, the reference standard for establishing validity comparator for LBP self-assessment tools is a comprehensive clinical assessment. Unfortunately, this was not possible in this study and validated LBP questionnaires, which are considered the next best option, were used instead (Kopec, Esdaile et al. 1995, Smart, Blake et al. 2012). Nevertheless, having a battery of validated questionnaires that covered different aspects of the pain experience is considered a strength in this phase.

Having 2 different venues for Observations 1 and 2 (the laboratory and home) could have affected test retest reliability, but it was considered a necessary limitation in order to decrease the burden on participants in this preliminary study. However, having the participants complete BACKonLINE™ from home in Observation 2 and assessing the

internal consistency of that Observation was considered a strength in order to evaluate the ability of participants to complete the tool unsupervised which was the ultimate goal of BACKonLINE™.

The involvement of the author in all aspects of the qualitative evaluation interviewing and data analysis part could have been viewed as a limitation. However, this involvement strengthened the consistency of data entry, recruitment, and interviewing. The involvement of only 1 researcher also helped with managing logistics in a timely manner in the relatively short period of time in the data collection phase. Another strength of this phase is having an interview aide-memoire for the researcher to follow during the interviewing process which increased consistency of the results.

11.7. Summary

In Phase 3, the measurement properties and participants experience study, BACKonLINE™ displayed excellent internal consistency (CA=0.90 in Observation 2), high test retest reliability (ICC=0.92, CI=0.83-0.95) and moderate to high construct validity (r=0.70, 0.60, 0.60, 0.42, 0.50 with ODI, VAS, STarTBack, TSK, and PASS 20 respectively). When assessing concurrent validity against STarTBack, BACKonLINE™ has shown to moderately distinguish between predominantly centrally sensitised and predominantly peripherally sensitised LBP (AUC=0.79) with a cut-off score of >42 indicating predominant central sensitisation of LBP. However, the results of the ROC curve analysis should be interpreted with caution due to the small sample size.

When exploring participant's expectations and experience with using BACKonLINE™ in this phase, 4 self-management expectation themes were identified

(advice/recommendation; knowledge/education; exercise; encouragement/reminders), and 3 preferred modes of delivery themes were identified (computer, smartphone app, paper-based) which seem to be in line with LBP and patient expectation literature.

To the author's knowledge, BACKonLINE™ is the first autonomous, self-assessment and self-management online tool conceptualised to guide LBP patients with their self-management by utilising patients' responses to determine the predominance of centrally sensitised LBP and peripherally sensitised LBP in order to design and guide self-management.

However, this is the first to date preliminary study designed to provide the first glimpse of the tool's reliability, validity and experience of patients using it. The sample size and lack of reference standard in the validation of self-assessment tools (i.e. physiotherapy assessment) are limitations. The qualitative evaluation was designed to obtain first experiences of people with LBP typically found in the community using BACKonLINE™ and getting views on the functionality of self-management. All of these were recommendations available in current literature which further strengthen their viability. Most participants were comfortable in having BACKonLINE™ electronically and were comfortable accessing the tool which supports the feasibility of having an online self-assessment and self-management tool for people with CLBP.

Chapter 12. Summary and Conclusion

The aim of the thesis was to develop a self-assessment and self-management online tool for people with CLBP (BACKonLINE™) to better target and support self-management. In order to achieve that aim, the study was conducted in 3 phases. Phase 1, the E-Delphi study, focused on developing the self-assessment items of BACKonLINE™ through achieving consensus from physiotherapy experts with the experts also providing some examples of what they consider relevant self-management advice. Phase 2 assessed the readability of the developed self-assessment items, while Phase 3 assessed the measurement properties and patients experience with using BACKonLINE™. The relevant literature for all phases, methods, results, and phase specific discussions were reported along with the strength and limitations of each phase. The aim of this chapter is to integrate the findings of the phases, relate them to relevant literature, and report the overall strengths and limitations of this study and discuss the clinical relevance of the study. This chapter ends with suggestions for future studies and a conclusion.

12.1. Summary of the Findings

12.1.1. Phase 1- The E-Delphi Study

Phase 1 started with a search of the available literature followed by a 2 Round E-Delphi study. In this study, the mechanisms-based classification of pain within a biopsychosocial approach was chosen as the basis of pain categorisation. The literature

search was conducted in order to identify symptoms linked to pain predominantly related to CLBP that exhibits features predominantly of central mechanisms and peripheral mechanisms, and to construct an initial item pool for the self-assessment part in BACKonLINE™ which would be included in the E-Delphi study. Using the available literature to predetermine items within a Delphi study is well established in the literature (Cook, Brismée et al. 2010, Rao, Anderson et al. 2010, Gobat, Kinnersley et al. 2015, Luedtke, Boissonnault et al. 2016, Ogden, Culp Jr et al. 2016). An initial 55 item pool was generated from the literature and divided into 3 domains: (1) Pain behaviour, (2) Impact of LBP on work and lifestyle, and (3) Perception of LBP domains thus forming version 1 of BACKonLINE™.

The expert panel for the E-Delphi study consisted of UK based and international physiotherapists. A total of 38 physiotherapists participated in Round 1, and 28 physiotherapists participated in Round 2 (response rate=74%). An agreed-upon minimum number of participants per Round to establish reliability of the responses does not exist in the literature (Wilhelm 2001). In this current study, both Round 1 and 2 included more than 20 participants (n=38 and 28 respectively), and this was deemed sufficient to ensure reliability of responses based on previous literature (Mullen 2003, Baker, Lovell et al. 2006).

Round 1 of the E-Delphi study resulted in 33 items reaching a $\geq 70\%$ consensus and 11 new items suggested by participants (BACKonLINE™ version 2). A total of 44 self-assessment items were sent back to the expert panel in Round 2, and as a result, 39 items reached $\geq 70\%$ and were included in the self-assessment part of BACKonLINE™

(BACKonLINE™ version 3). BACKonLINE™ appeared to have content validity since the self-assessment items were derived from currently available literature and rated by a group of experts who represented the area of knowledge (i.e. physiotherapy experts) (Keeney, Hasson et al. 2001).

When the physiotherapy experts were asked to suggest possible self-management techniques for BACKonLINE™ for predominantly centrally sensitised LBP, peripheral neuropathic LBP, and nociceptive LBP, pain education was identified as a theme for all 3 types of pain which is consistent with the NICE guidelines (NICE 2016) and current pain literature (Louw, Diener et al. 2011). Exercise was identified as a theme for predominantly peripherally sensitised (neuropathic) LBP and predominantly peripherally sensitised (nociceptive) LBP. In addition, sleep hygiene and mindfulness were identified as themes for predominantly centrally sensitised LBP, while medication was identified as a theme for predominantly peripherally sensitised (neuropathic) LBP.

The majority of chronic pain symptoms are maladaptive and do not follow the protective pattern of acute pain, which makes it more difficult to manage. The pain processes that drive chronic pain are more complex which makes them hard to identify in order to target them for treatment (Tracey, Woolf et al. 2019). This makes chronic pain a manifestation of the pathologic functions of the nervous system rather than a symptom of a specific disease. Therefore, treatment for chronic pain should target the underlying pathophysiological mechanisms instead of generally trying to suppress the sensation of pain (Tracey, Woolf et al. 2019).

The aim of BACKonLINE™ is to provide targeted self-management which could be detailed and simplified exercise, education and advice on the neurophysiologic types of pain.

Therefore, it was decided to focus the rest of the study on differentiating between predominantly centrally sensitised and predominantly peripherally sensitised LBP and measure the extent of LBP centralisation as a first step before differentiating between nociceptive and neuropathic LBP.

12.1.2. Phase 2- Readability of BACKonLINE™

The aim of this phase was to assess the readability of BACKonLINE™, and since no readability gold standard exists, it is recommended that it should be assessed using more than 1 method in order to ensure the reliability and validity of the content (Badarudeen and Sabharwal 2010). Therefore, the readability of BACKonLINE™ (version 3) was assessed in 3 stages using 3 different methods.

In stage 1, readability was assessed using FRE and achieved a total score of 92.2 (very easy to read), however, it was highlighted in the literature that quantitative reading formula such as the FRE are insufficient to assess readability of self-assessment tools due to the nature of the short sentences and 1 word answers in them which warranted further readability testing for BACKonLINE™ (Lenzner 2014).

In stage 2, BACKonLINE™ was sent to PEC to assess readability further, and a few minor changes were suggested and applied, resulting in BACKonLINE™ (version 4).

In stage 3, the readability of BACKonLINE™ was further explored utilising a focus group which consisted of volunteers with past or present history of CLBP. The importance of using the target population to assess readability and comprehension of a healthcare self-assessment tool has been emphasised in readability literature (Oakland and Lane 2004, Badarudeen and Sabharwal 2010). The amendments suggested by the focus group were applied, and an online version of BACKonLINE™ (version 5) was further assessed for readability and comprehension by individually interviewing 5 volunteers with CLBP. None of the volunteers reported any issues with the readability of BACKonLINE™ (version 5), therefore, the readability phase was concluded at this stage and BACKonLINE™ (version 5) was progressed into Phase 3, the measurement properties and participants experience.

12.1.3. Phase 3- BACKonLINE™ Measurement Properties and Participants' Experience

Phase 3 started by measuring the internal consistency and test retest reliability of BACKonLINE™ (version 5). BACKonLINE™'s total score showed excellent internal consistency rating (Observation 1 CA=0.87, Observation 2 CA=0.90). Both the Pain behaviour domain and the Impact of LBP on work and lifestyle domain had good internal consistency ratings in Observation 1 (CA=0.80 and 0.77 respectively) while the Experience with LBP domain had an unsatisfactory internal consistency rating (CA=0.56). During Observation 2, internal consistency of the Pain behaviour domain increased to an excellent rating (CA=0.85), the Impact of LBP on work and lifestyle domain maintained its good rating (CA=0.75), and the Experience with LBP domain achieved a good rating (CA=0.77). Internal consistency for Observation 2 was chosen for

interpretation since BACKonLINE™ was intended as an autonomous tool that can be used at home.

Afterwards, the test retest reliability of each domain and the whole tool was calculated and it was determined that BACKonLINE™'s total and both the Pain behaviour and Impact of LBP on work and lifestyle domains had high test retest reliability (ICC=0.92, 95% CI=0.83-0.95; 0.91, 95% CI=0.81-0.95; and 0.92, 95% CI=0.84-0.95 respectively), while the Experience with LBP domain showed moderate reliability (ICC=0.71, CI=0.49-0.84).

Then, the construct validity of BACKonLINE™ was explored using the nomological network (VAS, ODI, STarTBack, TSK, PASS 20). It was hypothesised that BACKonLINE™ would have moderate to strong convergent validity with the nomological network. Moderate convergent validity was qualified as a Pearson's correlation coefficient (r) between 0.30 and 0.70, and a strong correlation would be an r between 0.70 and 0.90 (Chiu, Hsueh et al. 2014). While the Pain behaviour domain would have moderate to strong convergent validity with VAS, ODI, and STarTBack and the Impact of LBP on work and lifestyle domain would have moderate to strong convergent validity with STarTBack, TSK, and PASS 20. And finally, the Experience with LBP domain would have moderate to strong convergent validity with STarTBack, TSK, and PASS 20. All null hypotheses were rejected. Additionally, ODI had convergent validity with both the Impact of LBP on work and lifestyle and Experience with LBP domains, while VAS had convergent validity with the Experience with LBP domain, all of which was not hypothesised.

In order to determine preliminary cut-off scores for BACKonLINE™, ROC curve analysis was conducted using STarTBack as a reference standard (Hill, Dunn et al. 2008). A BACKonLINE™ cut-off score of 42 was considered appropriate in differentiating between predominantly centrally sensitised and predominantly peripherally sensitised LBP. Additionally, within the ROC curve analysis, it was concluded that BACKonLINE™ can moderately distinguish between predominantly centrally sensitised and predominantly peripherally sensitised LBP groups (AUC=0.79) thus rejecting null hypothesis 7: BACKonLINE™'s ability to distinguish between people who have predominantly centrally sensitised LBP and people who have predominantly peripherally sensitised LBP is low (AUC < 0.70).

In addition to assessing the measurement properties of BACKonLINE™, participants experience of using the tool was explored in this phase. Participants suggested computers, smartphone apps, and paper as a mode of delivery and suggested advice, education, exercise, and encouragements as self-management options in BACKonLINE™. Further studies focusing on the self-management aspect of BACKonLINE™ should be conducted before drawing a conclusion on what should be included in the tool. Even though Phase 1 participants (physiotherapy experts) provided an idea on what self-management should be included in BACKonLINE™ and Phase 3 participants (people with CLBP) provided similar expectations from the tool, studies focusing on healthcare professionals, and patients' expectations should be aimed for. Other studies that measure the effect of self-management via BACKonLINE™ should also be conducted to

explore the tool's viability in providing helpful self-management for CLBP patients on physiotherapy waiting lists.

12.2. Comparisons of BACKonLINE™ with Current Management Pathways on Physiotherapy Waiting Lists

BACKonLINE™ is a comprehensive, autonomous self-assessment and self-management tool containing 39 self-assessment items which are meant to guide patients into individualised self-management and advice pathway while they wait for their physiotherapy appointment. Even though evidence shows that prompt access to physiotherapy services contribute to accelerated symptom relief, improved quality of life, and is more cost effective (Salisbury, Foster et al. 2009), timely physiotherapy access in the NHS is a widespread issue where patients have to wait for extended periods of time to receive physiotherapy treatment (Salisbury, Foster et al. 2013, Mant and Pape 2017). Additionally, early intervention has been linked to decreased chronicity (Clayson and Woolvine 2004).

In comparison to other aforementioned available pathways and online apps that was presented in Chapter 2, the literature review, BACKonLINE™ was developed as a standalone tool without the need for any contact with external resources including healthcare providers, and self-management is envisioned to be a visual, interactive advice that can be accessed anytime, anywhere without the need to visualise or memorise verbal advice. BACKonLINE™ could potentially provide an option for people on NHS waiting lists that does not require trained physiotherapists to administer. In addition, BACKonLINE™'s readability was tested in order to ensure the language and

comprehension is easily understandable and does not cause any confusion. And unlike some available apps, BACKonLINE™ is developed based on current peer-reviewed literature, and expert consensus and the development process of BACKonLINE™ is available and documented.

Moreover, BACKonLINE™ is intended to store subjective assessment answers that could help physiotherapists in their own assessment when the patient is off the waiting list, thus maximising physiotherapy effectiveness.

In this study, BACKonLINE™ was administered online, and even though some participants were hesitant at first, a short explanation on how to access and use the tool provided them with enough comfort and willingness to use it a second time from home, unsupervised. This observation, along with available literature, indicates that online tools are viable in this internet age. However, researchers and healthcare professionals should ensure that patients are able to use computers with ease and provide guidance to those who need it.

12.3. Comparisons of BACKonLINE™ with Current Chronic Low Back Pain Self-Assessment Tools

Available self-assessment tools either stratifies CLBP patients according to psychosocial risk factors (e.g: STarTBack, OMPQ), functional disability and ADL (e.g.: ODI, Roland-Morris Disability Questionnaire, Quebec Back Pain Disability Scale, Waddell Disability Index, Million Visual Analogue Scale, Low Back Pain Rating Scale, Resumption of Activities of Daily Living Scale, Back Pain Function Scale, Low Back Outcome Score, Clinical Back Pain Questionnaire), or fear-avoidance beliefs (Fear-Avoidance Beliefs

Questionnaire). These tools are intended to help healthcare professionals determine the best course of action to take with patients. BACKonLINE™, on the other hand, is intended to be utilised by the patients without external interference in order to discriminate between different LBP mechanisms to determine the content and focus of self-management. For example, exercise could be a subset of all LBP mechanisms presentations. However it could be less structured in the centrally sensitised LBP and more focused on pacing and relaxation (Nijs, Kosek et al. 2012, Lumley and Schubiner 2019). On the other hand, exercise could be more structured and targeted towards the mechanical element in nociceptive pain disorders (O’Sullivan 2005), and inflammations in peripheral neuropathic pain disorders (Kuphal, Fibuch et al. 2007).

BACKonLINE™ is an online tool that is meant to be accessed by CLBP patients anywhere in order to gain immediate access to relevant advice and guidance, whereas all the aforementioned tools are paper-based, and need to be scored by a healthcare professional in order to refer patients to appropriate management pathways. Given the NHS shortage in resources, most patients then wait for management for an extended period of time (Salisbury, Foster et al. 2013, Mant and Pape 2017). However, BACKonLINE™ is patient-centered and is intended to be used by patients whenever it is convenient and important for them in order to give them immediate and relevant advice and guidance to adopt behaviours and practices to begin to manage their LBP at the point of completing the BACKonLINE™ self-assessment part without having to wait for referrals.

12.4. Clinical Implications

BACKonLINE™ is a self-assessment and self-management online tool for CLBP, and even though other means exist for assessing and/or managing back pain conditions, they lack the autonomy and specificity that BACKonLINE™ offers. Additionally, this study has shown that there is a readiness both in the physiotherapy field and by LBP patients for such a tool evidenced by the high response rate between Round 1 and 2 in the Delphi study, the supplementary comments in Round 1 and LBP patients willingness to participate in Phases 2 and 3 of the study.

Another interesting finding is the similarity between the perceived meaning of self-management by LBP patients and the recommended self-management by physiotherapy experts. This similarity indicates the feasibility of having such a tool before an LBP patient enters a primary care setting or while waiting for a physiotherapy appointment. BACKonLINE™ could potentially be the first step of therapy by supporting patients until their appointment and could lower the assessment time in physiotherapy by providing therapists with the subjective data gathered by the tool thus increasing actual management time during physiotherapy. Moreover, BACKonLINE™ could also improve adherence to exercises by alerting and reminding individuals (Hamine, Gerth-Guyette et al. 2015).

12.5. Strengths and Limitations

This 3-phased study should be interpreted while considering a number of methodological limitations. In Phase 1, physiotherapists were the only healthcare professionals that were included in the E-Delphi study, which may have decreased the

generalisability of the findings. This limitation was reduced by including an international panel of physiotherapists in order to get a broader sample. Furthermore, using a modified, literature-based Delphi study as a consensus gathering approach may have limited elaborations from participants and may have caused some items to be unintentionally omitted. However, this limitation has been reduced by providing free text boxes next to each item and after each domain in order to give participants a chance to elaborate and suggest new items. Additionally, the incorporation of neurophysiological mechanisms of pain in physiotherapists clinical reasoning is uncommon and usually requires post-graduate education (Smart and Doody 2006). This limitation was minimised by providing an introductory explanation of these mechanisms in the 1st Round of the E-Delphi study.

Another limitation could be the merging of peripheral neuropathic LBP and nociceptive LBP into 1 category after the conclusion of Phase 1, the E-Delphi study. However, it was decided that assessing the degree of pain centralisation is an important first step to achieve before differentiating between neuropathic and nociceptive LBP.

In Phase 3, the measurement study, construct validity was measured by correlating BACKonLINE™ with a number of other self-administered tools encapsulating the multi-dimensionality of LBP. However, the lack of objective measures and relying solely on subjective self-reported measures is considered a limitation in this phase, which could not have been avoided due to logistical and methodological reasons. Future studies employing a complete physiotherapy assessment (current reference standard) with larger samples should be conducted to test the validity of BACKonLINE™ further.

12.6. Future Recommendations and Vision

This is a preliminary study which endeavoured to present a self-contained online tool for CLBP. However, future studies should be conducted in order to examine the viability of such tool further. In a future study, criterion validity should be assessed using the current best reference standard (i.e. physiotherapy assessment). Furthermore, studies with larger sample sizes should be conducted in order to assess the feasibility, acceptability, and usability of BACKonLINE™. Large sample analysis will lend itself to investigating the comparative weighing of self-assessment items in terms of accurately distinguishing between the chronic pain subsets (centrally sensitised pain, peripheral neuropathic pain and nociceptive pain). Within this study, the self-management component was not fully defined. Therefore, future studies must be conducted in order to define viable self-management options and their effectiveness in decreasing symptoms should be tested. It is envisioned that self-management would be available within BACKonLINE™'s platform in the form of targeted audio-visual material and text-based material without the need for users to be redirected to outside sources. The intended self-management packages would be based on the decision BACKonLINE™ makes on the underlying predominance of pain mechanisms. Subsequent studies should also explore the viability of separating the self-management part of peripheral neuropathic LBP and nociceptive LBP using other methodologies.

Biopsychosocial based management approaches are recommended in order to tackle the plethora of symptoms associated with CLBP (NICE 2016). However, it is imperative to tailor this management advice to the individual patient in order to achieve desired outcomes (NICE 2016). Following further measurement properties studies,

BACKonLINE™ could potentially be used clinically to identify subgroups of patients with centrally sensitised LBP, peripheral neuropathic LBP, and nociceptive LBP presentations and to facilitate the implementation of targeted management. In the future, BACKonLINE™ could be available in primary care following a GP screening, in order to reach patients before they spiral into chronicity. Furthermore, BACKonLINE™ could be used in intermediate care to provide support for people with LBP while they wait for their physiotherapy appointments. Having BACKonLINE™ in intermediate care is not meant to replace secondary care but support it by providing LBP patients with tools that help them manage pain while they wait for their appointments. BACKonLINE™ could also be utilised in secondary care to support treatment strategies provided by physiotherapists. In addition, BACKonLINE™ could be used in the workplace and in occupational health, provided that screening for red flags is included in the tool.

12.7. Conclusion

This study aimed to develop a new, stand-alone, online self-assessment and self-management tool for CLBP (BACKonLINE™). It is proposed in the future that the tool would provide targeted and individualised treatment for people with CLBP while they wait for their physiotherapy appointments. The planned tool was meant to assess pain based on a neurophysiological pain mechanisms-based approach and use the biopsychosocial approach as a theoretical framework. To the author's knowledge, this is the first conceptualisation of this autonomous BACKonLINE™ CLBP tool.

The self-assessment items were first extracted from available literature then gained consensus in a 2 Round E-Delphi study utilising international physiotherapy experts. The

literature search and subsequent E-Delphi Rounds resulted in 39 items covering 3 main domains (Pain behaviour, Impact of LBP on work and lifestyle, and Experience with LBP). This study has introduced BACKonLINE™ and assessed its readability and measurement properties. BACKonLINE™ has shown preliminary reliability and validity, and cut-off scores were calculated. It was established that scores higher than 42 indicated predominantly centrally sensitised LBP. Further measurement properties studies with larger sample sizes will add to the robustness and confirm these results. The concept of self-management was also explored in this study with both physiotherapists and patients. Both therapists and patients seemed to agree that pain education and exercise should be the main focus in the self-management component of the tool. Following the previously mentioned recommendations, BACKonLINE™ could be a cost effective, and practical tool used for people with CLBP.

The original contribution of this thesis is the conceptualisation of BACKonLINE™ as an autonomous and practical tool for patient self-assessment and self-management. This study was focussed on the development of BACKonLINE™, which should be further researched alongside the development of the self-management component of the tool.

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Appendix 1. NHS Apps library Categories

Figure: NHS Apps library categories

The screenshot shows the NHS Apps Library website. At the top, there is a blue navigation bar with the NHS logo on the left and a search bar on the right. Below the navigation bar, there are links for 'Home', 'Health A-Z', 'Live Well', 'Care and support', 'Health news', and 'Services near you'. The main content area has a heading 'NHS Apps Library' and a sub-heading 'Find digital tools to help you manage and improve your health'. Below this is a search bar for apps. The 'Filter apps' section is expanded, showing a 'By category' filter. Under 'By category', there are 16 checkboxes for various health categories: Cancer, Child health, Dental, Diabetes, First aid, Healthy living, Learning disabilities, Memory and communication, Mental health, NHS services, Online community, Pregnancy and baby, Respiratory, Sleep, Social care, and Body areas. At the bottom of the filter section is a green 'Apply filters' button.

https://www.nhs.uk/apps-library/

NHS Search

Health A-Z Live Well Care and support Health news Services near you

[Home](#)

NHS Apps Library

Find digital tools to help you manage and improve your health

Search apps

Filter apps

By category

<input type="checkbox"/> Cancer	<input type="checkbox"/> First aid	<input type="checkbox"/> Mental health	<input type="checkbox"/> Respiratory
<input type="checkbox"/> Child health	<input type="checkbox"/> Healthy living	<input type="checkbox"/> NHS services	<input type="checkbox"/> Sleep
<input type="checkbox"/> Dental	<input type="checkbox"/> Learning disabilities	<input type="checkbox"/> Online community	<input type="checkbox"/> Social care
<input type="checkbox"/> Diabetes	<input type="checkbox"/> Memory and communication	<input type="checkbox"/> Pregnancy and baby	<input type="checkbox"/> Body areas

By price

Apply filters

Appendix 2. Ethical Approval Letter for Phase 1: The E-Delphi study

School of Healthcare Sciences
Head of School and Dean Professor Heather
Waterman

Ysgol Gwyddorau Gofal Iechyd
Pennaeth yr Ysgol a Deon Yr Athrawes Heather Waterman



17 June 2016

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Dalal Alothman
Cardiff University
School of Healthcare Sciences

Dear Ms Alothman

**Patient self-assessment and self-management online classification tool (MY
BACK SELF-CST**

The School's Research Governance and Ethics Committee Chair has considered your request in relation to the above Ethics application. The decision is that your work should:

Pass – PHASE 1 only

This will enable you undertake Delphi study with physiotherapy 'experts'

Please be sure to address the concerns identified previously in regard to issues in the application and Participation Information Sheet prior to the information being given to physiotherapists and certainly before submission to HRA for NHS approval of phases 2 and 3

Please note that if there are any subsequent major amendments to the project made following this approval you will be required to submit a revised proposal form. You are advised to contact me if this situation arises. In addition, in line with the University requirements, the project will be monitored on an annual basis by the Committee and an annual monitoring form will be despatched to you in approximately 11 months' time. If the project is completed before this time you should contact me to obtain a form for completion.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Mrs Liz Harmer – Griebel
Research Administration Manager

Cardiff University is a registered charity, no. 1136855
Mae Prifysgol Caerdydd yn elusen gofrestredig, rhif 1136855

Appendix 3. Phase 1 Participants Information Sheet



PARTICIPANTS INFORMATION SHEET

Part1:

Study Title: Patient self-assessment and self-management online tool (BACKonLINE™)

Invitation:

The researcher for this study is a qualified and experienced physiotherapist and is currently working on her PhD at Cardiff University. She would like to invite you to participate in her research study. Before deciding to participate or not, please take time to read the following information.

What is the purpose of the study?

The purpose of this study is to develop a self-assessment and self-management online tool (BACKonLINE™) for people with low back pain (LBP) and test its acceptability and feasibility.

The proposed mixed methods study will attempt to answer the following questions (1) Can people with LBP effectively self-assess their LBP disorder? (2) Is there an agreement between clinician- and patient-assessment outcome (3) Is patient-assessment using an online platform acceptable and feasible and does it have a potential to bring to the patients and the health service?

Phase 1 will develop BACKonLINE™ for the self-assessment and self-management of LBP based on a consensus from clinical/research experts using a 2 round Delphi study. **Phase 2** will test BACKonLINE™ against a gold standard clinician examination to assess the construct validity. **Phase 3** will assess the feasibility and acceptability of BACKonLINE™ with LBP patients and evaluate the potential of the tool in bringing clinical benefits to people with LBP.

Why have I been invited to participate?

This study will develop BACKonLINE™ based on centralisation and peripheralisation of pain disorders. It will evaluate the feasibility of people with LBP self-assessing and managing their back pain using BACKonLINE™. You have been invited to participate in this study because you have been identified as a physiotherapist/researcher with experience in dealing with patients with LBP.

Do I have to take part?

Your participation in this study is completely voluntary, and you may withdraw from the study at any point without any negative consequences.

Version 3
30th November, 2016

What will happen to me if I take part?

If you decide to take part in the study, you will be given access to the online survey powered by Bristol online (BoS).

What will I have to do?

You will be asked to participate in a two round Delphi study where you will receive an electronic Bristol online survey via e-mail. **In round I**, you will rank each statement within BACKonLINE™ on its relevance and importance for self-assessment. This tool will be developed from existing evidence based research literature of classification of back pain. A 7-point Likert scale will be used to rate statements as “not at all important” to “extremely important” at either end of the scale to discern more accurately between different levels of perceived importance. A box for further comments will be included to allow you to express your views not necessarily captured within the items. You will also be asked to indicate your view on patients self-assessing their back pain in terms of potential benefits, enabling factors and barriers. After completing the survey, the researcher will gather all the information from all participants and will adjust BACKonLINE™ accordingly.

In **Round II of the Delphi**, you will receive the adjusted BACKonLINE™ and will be presented in 3 sections: (1) Feedback from round 1 will be presented in a narrative summary of the sections and items that had reached higher and lower consensus. (2) Experts will be asked to feedback on those items (i) with the lower consensus feedback in a narrative form (ii) terminology used within the lower scoring domains and (iii) additional items from free text boxes identified in round I. You will be asked to rate the items again on a seven-point response scale between “strongly disagree” and “strongly agree” statements. An item would be included in BACKonLINE™ if at least 70% of the expert panel agreed on it.

What is the device/procedure being tested?

A self-assessment and self-management online tool (BACKonLINE™) will be tested in this study.

What are the possible disadvantages and risks of taking part?

There are no foreseeable risks or disadvantages in taking part in this study.

What are the possible benefits of taking part?

There is no direct benefit in participating in the study, however, your opinion will be utilised to assist in the development of BACKonLINE™. If this tool demonstrates to have validity and reliability, then it will be used by LBP patients thus decreasing the assessment time for healthcare professionals and if the management part of the tool is effective, it may potentially decrease the patient load in physiotherapy clinics.



Will my taking part in the study remain confidential?

Your participation will remain confidential and your personal information will not be shared with any third party. Anonymous data may be shared with external collaborators but your personal information will **NOT** be shared with them. All personal information will be stored on a single encrypted USB device and kept in a locked cabinet on Cardiff University premises and accessible only to the researcher (DA). You will have a unique code and your identity will be anonymised and only the researcher (DA) will have access to the information. All collected data will be encrypted on a password-protected USB storage drive in compliance with the Data protection act (1998). The USB drive and any other additional hard copies will be locked in a cabinet only accessible by the researcher (DA). All data will be destroyed two years after completion of the study.

Part 2

What if relevant new information becomes available?

If any new, relevant information becomes available you will be updated immediately.

What will happen if I don't want to carry on with the study?

If you decide to withdraw from the study, you can do that without any prejudice.

What if there is a problem?

The researcher will provide you with her contact information in case you have any problems relating to the study.

What if I have a complaint?

If you have any complaints, please contact Dr. Kate Button, Director of Research Governance, School of Healthcare Sciences at buttonk@cardiff.ac.uk

Will my taking part in this study be kept confidential?

Your participation will be kept confidential. All gathered data will be encrypted on an encrypted USB storage device. This device as well as any additional hard copies will be kept in a locked cabinet, only accessible by the researcher.

What will happen to the results of the research study?

The results of the study will be part of a thesis required to complete a PhD. Your participation will remain completely anonymous and confidential. If you wish to be kept informed about the results of the study, you may contact the researcher.



Who is organising and funding the research?

The study is part of a PhD thesis funded by the researchers' sponsors.

Who has reviewed the study?

The Delphi study was reviewed and approved by Cardiff University's Research Governance and Ethics Committee.

For further information, please contact:

Name: Dalal Alothman

E-mail: AlothmanDD@cardiff.ac.uk

Thank you for your participation.

Version 3
30th November, 2016

Appendix 4. Phase 1: The E-
Delphi Study Round 1
(BACKonLINE™ Version 2)



BACKonLINE™ Round 1

Page 1: Introduction

Thank you for participating in this study. This survey is a first of a 2 Round Delphi study and is part of a PhD project. The study is designed to gather your expert opinion to develop a new online low back pain (LBP) self-assessment and self-management tool (BACKonLINE™) that aims to provide early individualised LBP management advice to patients on physiotherapy waiting lists.

The tool asks patients a series of questions about their pain characteristics, behaviour and its impact on their lives **in order to discern between pain predominantly driven by the central nervous system (centrally driven pain) or peripheral nervous system (peripherally driven pain)**. Patients' responses will trigger access to early LBP management advice, resources and other information specifically targeting factors predominantly associated with central or the peripheral pain presentation.

For the purposes of this study, we are using the following descriptors of pain characteristics:

Centrally driven pain: musculoskeletal pain characterised by dysfunction in the central nervous system (e.g.: central sensitisation/hyper-excitability) which can be due to sensitivity to cognitive and psychosocial stimuli such as thoughts and feelings.

Peripherally driven pain: can be nociceptive or neuropathic.

Nociceptive pain: pain from tissues at neuron ends, where nerve endings are excited by mechanical or chemical processes originating from tissues in which nerve endings are embedded.

Neuropathic pain: caused by dysfunction in the peripheral nervous system characterised by abnormal impulse generation, electrical hyper-excitability, and mechanical, chemical, and thermal sensitivity (Butler 2000, Smart et al. 2010).

This survey is divided into four parts:

1. Assessment of pain characteristics and behaviour.
2. Assessment of impact of pain on a person's life.
3. Assessment of patients perceptions regarding their pain
3. Management targeting centrally driven and peripherally driven back pain.

What you need to do

You will be asked for your opinion in relation to the questions within the tool. Please answer all questions, you will then have a chance to revise your answers in the second round of the survey. Where appropriate, a "further comments" box is available in case you wish to provide further comments or opinions on a specific question.

How long it will take

There are 3 sections that will together take up roughly 30 minutes of your time in total.

You may take breaks from the survey at any time, and return to pick up where you left off. Please click '**Finish later**' button at the end of each page to save your work. You may log out of the survey and log in at a later time using your personal link to finish it.

What will happen to the data you provide

All information you provide will be anonymous and viewable only by the research team (Dalal Alothman, Dr. Valerie Sparkes, Dr. Liba Sheeran). All collected data will be encrypted and stored at Cardiff University, and will only be used for the purposes of this study. All collected data will be destroyed after 10 years following the completion of the study.

Page 2: Consent to participate in the study

1. Participation checklist: Please read each statement carefully and select one answer per statement *Required

Please don't select more than 1 answer(s) per row.

Please select at least 1 answer(s).

	I accept	I decline
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without any negative consequences and without legal rights being affected	<input type="checkbox"/>	<input type="checkbox"/>
I understand that all information about me will be kept in a confidential way and destroyed once the study is completed.	<input type="checkbox"/>	<input type="checkbox"/>
I agree to my anonymised responses to be used during the Delphi study	<input type="checkbox"/>	<input type="checkbox"/>
I agree to the anonymised data I provide may be used in any publications or presentation of the research.	<input type="checkbox"/>	<input type="checkbox"/>
I agree to my anonymised responses to be accessed by members of the research team. And I understand that my name will not be linked with the research materials, and I will not be identifiable during the Delphi survey or in the reports that result from the research. And if I do not wish to answer any particular question or questions, I am free to decline.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that anonymous research data may be shared with external collaborators, and I understand that personal information will NOT be shared with anyone	<input type="checkbox"/>	<input type="checkbox"/>
I agree to take part in this study.	<input type="checkbox"/>	<input type="checkbox"/>

This section explores the characteristics and behaviour of a person's pain. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'. Please use the 'further comments' box for any suggestions.

2. How important is each question?

	* Required							Further comments <i>Optional</i>
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)	
Do you know what caused your low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
If yes, what caused your low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
When did you have your first episode of low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Have you ever received treatment for low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
If you have been treated for low back pain, were you satisfied with the treatment you received?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Are you currently on any medication for your low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
What medication do you take to manage your low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

How often do you take your medication?	<input type="radio"/>								
How effective is the medication in reducing your low back pain?	<input type="radio"/>								
Where is your pain located? Please tick all body regions that apply: Neck -Shoulder - Arm -Upper back -Lower back -Leg - Other	<input type="radio"/>								
Are you experiencing any other types of sensations (such as pins and needles, numbness) beside pain?	<input type="radio"/>								
What type of sensation is it?	<input type="radio"/>								
Please tick all the regions where you experience this type of sensation: Neck - Shoulder - Arm -Upper back -Lower back -Leg - Other	<input type="radio"/>								
On average, how many hours do you sleep?	<input type="radio"/>								
Does your low back pain wake you up at night?	<input type="radio"/>								

<p>If your sleep is disrupted because of low back pain, are you able to get back to sleep?</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						
<p>If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain right now</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						
<p>If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your typical or average low back pain</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						
<p>If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its best (How close to "0" does your pain get at its best?)</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						
<p>If 0 (zero) is no pain at all, and 10 is the worst imaginable pain, please rate your low back pain level at its worst (How close to "10" does your pain get at its worst?)</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						
<p>Is your pain constant?</p>	<input type="radio"/>	<input type="text"/> <input type="text"/>						

Are you able to ease your low back pain?	<input type="radio"/>							
How do you ease your low back pain?	<input type="radio"/>							
How much time on average does it take for your pain to go away?	<input type="radio"/>							
From the list below, please tick all the activities that trigger or increase your pain: Slouched Sitting- Sitting up straight- Standing up straight- Walking- Fast walking- Lying on your side curled up- Running- Lifting- Forward bending (stooping)- Cycling- Overhead reaching- Everything I do aggravates my pain	<input type="radio"/>							
Do you agree with this statement: "My pain is there no matter what I do"	<input type="radio"/>							

From the list below, please tick all the activities that stop or decrease your pain:								
Slouched								
Sitting								
Sitting up straight								
Standing up straight								
Walking								
Fast walking								
Lying on your side								
curled up								
Running								
Lifting								
forward bending								
(stooping)								
Cycling								
Overhead reaching								
Nothing I do relieves my pain								
Painkillers								

3. Are there any other questions you think should be included in the pain characteristics and behaviour section? please comment below

Optional

Page 4: Domain 2: Impact of pain on work and lifestyle

This section explores the impact of LBP on a person's life and is divided into 2 sections: Impact of back pain on work, and impact of back pain on lifestyle

Impact of back pain on work:

This part focuses on the effect of LBP on work. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'. Please use the 'further comments' box for any suggestions.

4. How important is each question?

	* Required							Further comments <i>Optional</i>
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)	
What is your current work status?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
What is your occupation?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
How satisfied are you with your job?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"I believe that my work is significantly contributing to my low back pain" how strongly do you agree with this statement?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Have you ever had time off work because of low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Are you off work right now because of your low back pain?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
If you answered yes to the previous question, how long have you been off work?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Is your employer understanding when it comes to your low back pain?	<input type="radio"/>							
How likely it is that you would return to work within 6 months?	<input type="radio"/>							

5. Are there any other questions you think should be included in the impact of back pain on work section? please comment below
Optional

Impact of back pain on lifestyle:

This part focuses on the effect of LBP on a person's lifestyle. In this part, the person will be given several statements and will be asked if they agree with each statement or not. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'. Please use the 'further comments' box for any suggestions.

6. How important is each statement?

	* Required							Further comments <i>Optional</i>
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important nor unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)	
"I am unable to do my normal daily activities because of my low back pain."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"My low back pain is decreasing my overall daily productivity"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"I am unable to perform my daily activities without external help."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

"My low back pain is negatively affecting my social life"	<input type="radio"/>	<input type="text"/>						
"My low back pain is affecting my relationship with my significant other"	<input type="radio"/>	<input type="text"/>						

7. Are there any other questions you think should be included in the LBP and lifestyle part? please comment below: *Optional*

Page 5: Domain 3: Perception of back pain

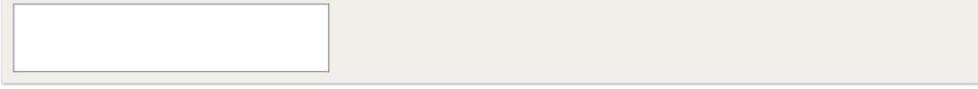
This part covers individual awareness and perception of a person's own LBP. In this part, the person will be given several statements and will be asked if they agree with each statement or not. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where **1 is 'not at all important' and 7 is 'extremely important'**. Please use the 'further comments' box for any suggestions.

8. How important is each statement?

	* Required							Further comments <i>Optional</i>
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important nor unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)	
"Because of my low back pain, I feel stressed/ anxious all the time."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"Feeling stressed increases my low back pain"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"Physical activity will increase my low back pain"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"I believe that my low back pain should go away completely before I can move on with my life."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"I seem to be more sensitive to things like loud noises, bright light, and odours."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
"Since my low back pain started, I seem to feel more tired."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

"Since my low back pain started, I seem to have problems remembering things."	<input type="radio"/>								
"Since my low back pain started, I seem to be moody."	<input type="radio"/>								
"I believe that what I do on a daily basis is significantly contributing to my low back pain"	<input type="radio"/>								
"I have no interest or pleasure in doing things anymore because of my low back pain"	<input type="radio"/>								
"I don't think my family and friends understand what I'm going through in relation to my low back pain"	<input type="radio"/>								
"My back is weak and fragile"	<input type="radio"/>								
"My low back pain will only improve with an intervention from a healthcare professional"	<input type="radio"/>								
"I do not think my low back pain will ever recover"	<input type="radio"/>								

9. Are there any other questions you think should be included in the perception of LBP domain? please comment below: *Optional*



Page 6: Part2: Management targeting centrally driven and peripherally driven back pain

In this section we want your opinion on what would be the most appropriate initial piece of advice to give to people with characteristics of predominantly centrally or peripherally driven LBP.

If you have any helpful resources (e.g.: online resources, help books) for people with characteristics of predominantly centrally or peripherally driven LBP, please include them with your advice

NOTE: The advice you provide does not have to be exclusive to each section below. You may use the same advice in one or more of the sections.

10. If a person has predominant characteristics of **centrally driven LBP**, please write the best 3 to 5 top tips in the box below * *Required*

11. If a person has predominant characteristics of **peripherally (nociceptive) driven LBP**, please write the best 3 to 5 top tips in the box below * *Required*

12. If a person has predominant characteristics of **peripherally (neuropathic) driven LBP**, please write the best 3 to 5 top tips in the box below * *Required*

Page 7: Your comments on the survey

13. Do you have any other comments regarding the objectives of this study aiming to discern between people with characteristics of **predominantly centrally or peripherally driven LBP**? Please comment below: *Optional*

Page 8: Conclusion

This concludes the first round of the Delphi study. If you have any questions regarding the survey, please contact Dalal Alothman at AlothmanDD@cardiff.ac.uk

Thank you

Appendix 5. Phase 1: The E-Delphi Study Round 1 and 2 Invitation and Reminder Emails

BACKonLINE™ Delphi study- invitation to round 1



Dalal Alothman



Reply all | v

Sent Items



Hello,

Thank you for agreeing to participate in this Delphi study aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™). Please note that this is an online study and no travel will be required, as participants do not have to meet physically at any time during the study.

The first round of the study will close on the **8th of April, 2017**. And you may receive **reminders** to complete the survey should you need prompting to do so.

Please read the attached information sheet for further details, and if you have any further inquiries, please do not hesitate to contact me.

To start round 1 of the survey, please follow this link <https://cardiff.onlinesurveys.ac.uk/backonline>

Your assistance is highly appreciated.

Thank you

Kind regards,

Dalal Alothman

PhD student

Cardiff University

Survey completion reminder: BACKonLINE™ Delphi study- round 1

 Dalal Alothman    Reply all | 

Sent items

Hello,

Hope you all had wonderful holidays, and in light of the holidays we are extending the deadline for submitting your response for the BACKonLINE™ survey until the 28th of February, 2017. If you have already completed and submitted the survey, thank you for your valuable input.

You can complete your survey at <https://cardiff.onlinesurveys.ac.uk/backonline>



BACKonLINE™
cardiff.onlinesurveys.ac.uk
Online survey BOS

Thank you once again for your ongoing help in developing BACKonLINE™. If you have any questions, please don't hesitate to contact me.
Your assistance is highly appreciated.
Thank you

Kind regards,
Dalal Alothman
PhD student
Cardiff University
School of Healthcare Sciences
AlothmanDD@cardiff.ac.uk

Final Reminder: BACKonLINE™ Delphi study- round 1

DA

Dalal Allothman

📧 📧 📧 Reply all | ▾

Sent items

📧 | Action items

Hello,

On the 1st of December, 2016, you were sent an invitation to participate in round 1 of a Delphi study aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™). If you have already completed and submitted the survey, thank you for your valuable input. If not, please complete your survey at <https://cardiff.onlinesurveys.ac.uk/backonline>, and submit your responses by the **28th of February, 2017**. Your responses are much appreciated as they will help us develop BACKonLINE™. If you have any questions, please don't hesitate to contact me.



BACKonLINE™

cardiff.onlinesurveys.ac.uk

Online survey BOS

Your assistance is highly appreciated.
Thank you

Kind regards,
Dalal Allothman
PhD student
Cardiff University
School of Healthcare Sciences
AllothmanDD@cardiff.ac.uk

BACKonLINE™ Delphi study- invitation to round 2 (FINAL round)



Dalal Alothman
Tue 02/05/2017, 15:05

Reply all | v

Sent items

Dear participant,

Thank you for your ongoing participation in this study aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™) that can be used by patients with low back pain (LBP) on physiotherapy waiting lists to provide them with early advice to manage their condition. The purpose of this 2nd round is to reach a consensus on the final BACKonLINE™ tool as based on the responses from Round 1 where a 70% agreement was sought. As in Round 1 you will be asked to what extent you agree with the statements within the tool. This final round of the study will close on the **3rd of July 2017**. You may receive reminders to complete the survey. If you have any further inquiries, please do not hesitate to contact me using the email below.

To start round 2 of the survey, please follow this link:
<https://cardiff.onlinesurveys.ac.uk/backonline-r2>

I would like to take this opportunity to thank you for your continuing help in this study.

Kind regards,
Dalal Alothman
PhD student
Cardiff University
School of Healthcare Sciences
AlothmanDD@cardiff.ac.uk

Reminder: BACKonLINE™ Delphi study- round 2 (FINAL round)



Dalal Alothman
Wed 31/05/2017, 09:27

Reply all | v

Hello,

On the 2nd of May 2017, you were sent an invitation to participate in round 2 of a Delphi study (final round) aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™). If you have already completed and submitted the survey, thank you for your valuable input. If not, please complete your survey at <https://cardiff.onlinesurveys.ac.uk/backonline-r2>, and submit your responses by the **3rd of July 2017**. Your responses are much appreciated as they will help us develop BACKonLINE™. If you have any questions, please don't hesitate to contact me.

Your assistance is highly appreciated.
Thank you

Kind regards,
Dalal Alothman
PhD student
Cardiff University
School of Healthcare Sciences
AlothmanDD@cardiff.ac.uk

Second Reminder: BACKonLINE™ Delphi study- round 2 (FINAL round)



Dalal Allothman
Thu 15/06/2017, 15:06

📧 Reply all | ▼

[Redacted]

Sent Items

This message was sent with high importance.

Hello,

On the 2nd of May 2017, you were sent an invitation to participate in round 2 of a Delphi study (final round) aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™). If you have already completed and submitted the survey, thank you for your valuable input. If not, please complete your survey at <https://cardiff.onlinesurveys.ac.uk/backonline-r2>, and submit your responses by the 3rd of July 2017. Your responses are much appreciated as they will help us develop BACKonLINE™. If you have any questions, please don't hesitate to contact me.



BACKonLINE™ Round 2

cardiff.onlinesurveys.ac.uk

Online survey BOS

Your assistance is highly appreciated.
Thank you

Kind regards,
Dalal Allothman
PhD student
Cardiff University
School of Healthcare Sciences
AllothmanDD@cardiff.ac.uk

Final Reminder: BACKonLINE™ Delphi study- round 2 (FINAL round) Closing on the 3rd of July 2017



Dalal Allothman
Fri 30/06/2017, 16:35

📧 Reply all



Sent items: inbox

This message was sent with high importance.

Dear Participant

On the 2nd of May 2017, you were sent an invitation to participate in round 2 of a Delphi study (final round) aiming to develop a patient self-assessment and self-management online tool (BACKonLINE™). If you have already completed and submitted the survey, thank you for your valuable input. If not, please complete your survey at <https://cardiff.onlinesurveys.ac.uk/backonline-r2>, and submit your responses by the end of the 3



BACKonLINE™ Round 2

cardiff.onlinesurveys.ac.uk

Online survey: BOS

rd of July 2017. Your responses are much appreciated as they will help us develop BACKonLINE™. If you have any questions, please don't hesitate to contact me.

Your assistance is highly appreciated.

Thank you

Kind regards,
Dalal Allothman
PhD student
Cardiff University
School of Healthcare Sciences
AllothmanDD@cardiff.ac.uk

Appendix 6. Phase 1: The E-
Delphi study Round 2
(BACKonLINE™ Version 3)



BACKonLINE™ Round 2

Page 1: Introduction:

Thank you for participating in this study. This is the 2nd and final Round of a Delphi study and is part of a PhD project developing a patient self-assessment and self-management online tool (BACKonLINE™).

This Delphi study is designed to gather your expert opinion to develop a new online low back pain tool (BACKonLINE™), that can be used by patients with low back pain (LBP) on physiotherapy waiting lists to provide them with early advice to manage their condition. **BACKonLINE™ aims to discern between people with characteristics of predominantly centrally or peripherally driven LBP** and provide individualised advice accordingly.

Summary from Round 1:

The results from Round 1 have been used to calculate the extent to which all the participants thought that each question should be included in the final version of BACKonLINE™. **Questions that received $\geq 70\%$ consensus have been included in this round and each question has the percentage score it received in Round 1 next to it.** Additional questions that have been suggested by participants in round 1 have been integrated within this round and defined as New Item (N.I.).

What you need to do:

You will be asked to rate each question as to **whether questions should be included in the BACKonLINE™ tool to discern between people with characteristics of predominantly centrally or peripheral driven LBP.**

How long it will take:

There are 3 domains that will together take up about 20-30 minutes of your time.

You may take breaks from the survey at any time, and return to pick up where you left off. Please click '**Finish later**' button at the end of each page to save your work. You may log out of the survey and log in at a later time using your personal link to finish it.

What will happen to the data you provide:

All information you will provide will be anonymous and viewable only by the research team. All collected data will be encrypted and stored at Cardiff University, and will only be used for the purposes of this study.

Page 2: Personal details:

1. **Full name:** * Required

2. **E-mail:** * Required

Please enter a valid email address.

Page 3: Domain 1: Pain behaviour:

This domain explores the behaviour of a person's pain. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'

Key:

Percentage (%): Refers to level of consensus achieved in round 1

N.I.: New Item

3. How important is each question?

	* Required					
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)
Do you know what caused your low back pain? (73.6%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If yes, choose the most appropriate cause from the list below: (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If you have been treated for low back pain, were you satisfied with the treatment you received? (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Are you currently on any medication for your low back pain? (71.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
What medication do you take to manage your low back pain? Paracetamol/Ibuprofen codeine/diazepam/Amitriptyline/duloxetine/Gabapentin/Opioids/Other (71.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How effective is the medication in reducing your low back pain? (76.2%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Where is your pain located? Please tick all body regions that apply (body chart will be included in the final version): Neck /Shoulder /Arm/Upper back /Lower back/Leg/Other (92.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Are you experiencing any other types of sensations (such as pins and needles, numbness, tingling, burning, stinging, pressure-like) beside pain? (89.5%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
What type of sensation is it? pins and needles/numbness/tingling/burning/stinging/pressure-like (86.9%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
please tick all the regions where you experience this type of sensation body chart will be included in the final version): Neck /Shoulder/Arm/Upper back/Lower back/Leg/Other (94.7%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
On average, how many hours do you sleep? (73.6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does your low back pain wake you up at night? (79%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If your sleep is disrupted because of low back pain, are you able to get back to sleep? (71%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is this the first time you experience this type of pain? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If you answered no to the previous question, how did you relieve the pain previously? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is your pain there all the time? (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you have less pain in the morning or at the end of the day? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
What type of pain is it? Deep/nagging/dull/sharp/shooting/dull ache/bright/lightning like/burning/pressure like/stinging/aching/throbbing/diffused (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Are you able to ease your low back pain? (84.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

How do you ease your low back pain? (84.2%)	<input type="radio"/>					
In general, is your back pain getting better/staying the same/ getting worse? (N.I.)	<input type="radio"/>					
What have you been previously told about why you have low back pain? (N.I.)	<input type="radio"/>					
From the list below, please tick all the activities that trigger or increase your pain: Slouched Sitting/Sitting up straight/Standing up straight/Walking/Fast walking/Lying on your side curled up/Running/Lifting/Forward bending (stooping)/Cycling/Overhead reaching/Working on a computer /Hoovering/Shopping/Gardening/Everything I do aggravates my pain (84.2%)	<input type="radio"/>					
From the list below, please tick all the activities that stop or decrease your pain: Slouched Sitting/Erect sitting- sitting up straight/Erect Standing-standing up straight/Walking/Fast walking/Lying on your side curled up/Running/Lifting/Forward bending (stooping)/Cycling/Overhead reaching/Nothing I do relieves my pain/Painkillers (81.6%)	<input type="radio"/>					

Page 4: Domain 2: Impact of pain on work and lifestyle

This domain explores the impact of LBP on a person's life and is divided into 2 sections.

Section 1: Impact of back pain on work

This section focuses on the effect of LBP on work. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'.

Key:

Percentage (%): Refers to level of consensus achieved in round 1

N.I.: New Item

4. How important is each question?

	* Required						
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)
"I believe that my work caused /contributed to my low back pain" how strongly do you agree with this statement? (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Are there other people in your occupation who have had similar issues? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How is your relationship with your supervisor/line manager/ boss? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you feel supported by your boss and/or co-workers? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How is your back pain affecting your work? (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Are you off work right now because of your low back pain? (73.7%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If you answered yes to the previous question, how long have you been off work? (79%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
How likely it is that you would return to work within 6 months? (71.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 2: impact of back pain on lifestyle

This section focuses on the effect of LBP on a person's lifestyle. In this section, the person will be given several statements and will be asked if they agree with each statement or not. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'.

Key:

Percentage (%): Refers to level of consensus achieved in round 1

N.I.: New Item

5. How important is each statement?

	* Required						
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)
"I am unable to do my normal daily activities because of my low back pain. " (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"My low back pain is negatively affecting my social life" (76.3%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"My low back pain is affecting my relationship with my significant other" (73.7%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"I don't know what aggravates or eases my low back pain and it seems to vary greatly" (N.I.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Perception of Back pain

This section covers individual awareness and perception of a person's own LBP. In this section, the person will be given several statements and will be asked if they agree with each statement or not. We want your opinion on how important the questions are in **discerning between people with characteristics of predominantly centrally or peripherally driven LBP**. Please rate each question on the level of its importance in differentiating the aforementioned characteristics where 1 is 'not at all important' and 7 is 'extremely important'.

Key:

Percentage (%): Refers to level of consensus achieved in round 1

N.I.: New Item

6. How important is each statement?

	* Required						
	1 (Not at all important)	2 (Moderately unimportant)	3 (Slightly unimportant)	4 (Neither important or unimportant)	5 (Slightly important)	6 (Moderately important)	7 (Extremely important)
"Because of my low back pain, I feel stressed/ anxious all the time." (79%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Feeling stressed increases my low back pain" (79%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Physical activity will increase my low back pain" (79%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"I seem to be more sensitive to things like loud noises, bright light, and smells." (71.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Since my low back pain started, I seem to feel more tired." (71%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"I have no interest or pleasure in doing things anymore because of my low back pain" (73.7%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"I don't think my family and friends understand what I'm going through in relation to my low back pain" (73.7%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"I do not think my low back pain will ever recover" (71.1%)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. Do you wish to be informed of the results of this Delphi study? * Required

Yes

No

Page 6: Conclusion:

This concludes the 2nd and final round of the Delphi study. If you have any questions regarding the survey, please contact Dalal Alothman at AlothmanDD@cardiff.ac.uk.

Thank you for your participation

Appendix 7. Ethical Approval Letter for Phase 2: The Readability Study

School of Healthcare Sciences
Head of School and Dean Professor Heather Waterman

Ysgol Gwyddorau Gofal Iechyd
Pennaeth yr Ysgol a Deon Yr Athrawes Heather Waterman



11 September 2019

Ms Dalal Alothman
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Newport Rd, Cardiff CF24 0AB

Cardiff University
Ty Dewi Sant
Heath Park
Cardiff CF14 4XN

Tel Ffôn +44(0)29 20687552
E-mail E-bost harmerl@cf.ac.uk

Prifysgol Caerdydd
Ty Dewi Sant
Mynydd Bychan
Caerdydd CF14 4XN

Dear Ms Alothman

Development of a patient self-assessment and self-management online tool (BACKonLINE)

I am writing to inform you that the Chair of the Research Ethics Committee has, following consultation, **approved** your revised research proposal. The Committee will ratify this decision at its meeting on **16th January 2018**.

Please note that if there are any major amendments to the project you will be required to submit a revised proposal form. You are advised to contact me if this situation arises. In addition, in line with the University requirements, the project will be monitored on an annual basis by the Committee and an annual monitoring form will be despatched to you in approximately 11 months' time. If the project is completed before this time you should contact me to obtain a form for completion.

Please do not hesitate to contact me if you have any questions.

Yours sincerely

Liz

Mrs Liz Harmer Griebel
Research Administration Manager

Cardiff University is a registered charity, no. 1136855
Mae Prifysgol Caerdydd yn elusen gofrestredig, rhif 1136855

Appendix 8. Phase 2 Participants Information Sheet



PARTICIPANTS INFORMATION SHEET

Part1:

Study Title: Development of a patient self-assessment and self-management online tool (BACKonLINE™)

Invitation:

The researcher for this study is a qualified and experienced physiotherapist and is currently working on her PhD at Cardiff University. She would like to invite you to participate in her research study. Before deciding to participate or not, please take time to read the following information.

What is the purpose of the study?

The purpose of this study is to develop an online self-assessment and management tool for low back pain (LBP) patients and test its acceptability and feasibility. This study aims to reduce chronicity of LBP through involving and engaging people with LBP in the screening and assessment process of their condition and allowing them greater autonomy by giving them the chance to self-manage their condition. In order to achieve that, an online self-assessment and management tool of LBP was developed.

Why have I been invited to participate?

This study will evaluate the feasibility of people with LBP self-assess and manage their own condition using an online self-assessment and management tool. In order to be sure that the wording of the tool is easy to understand, you have been invited to participate in this study because you are an adult with a current or past history of LBP and you would help us determine the level of readability of the tool

Do I have to take part?

Your participation in this study is completely voluntary, and you may withdraw from the study at any point without any negative consequences.

What will happen to me if I take part?

If you decide to take part in the study, you will be asked to sign a consent form.

Expenses and Payment

Your participation will be voluntary and greatly appreciated and any travel expense will be covered by the researcher.

What will I have to do?

You will be given the questionnaire with multiple choice questions focusing on low back pain and you will be asked to read and assess the language and readability of the questionnaire. You will discuss these questions by taking part in a focus group/telephone interview led by the researcher. During the focus group/telephone interview, you will be asked about the questions and whether they were clear and easy to understand or not. The focus group/telephone interview will be audio recorded to ensure that all the comments and suggestions have been addressed. After the conclusion of the focus group/telephone interview, the audio recordings will be written down and sent back to you for verification. Your feedback will be used to further develop the language of the questions in order to construct a low back pain self-assessment and management tool.

What is the device/procedure being tested?

A patient self-assessment and self-management online tool (BACKonLINE™) will be tested in this study.

What are the possible disadvantages and risks of taking part?

There are no foreseeable risks or disadvantages in taking part in this study.

What are the possible benefits of taking part?

As a result of participating, there is a possibility that you may know more about chronic low back pain.

Will my taking part in the study remain confidential?

Your participation will remain confidential and your information will not be shared with any third party.

Part 2

What if relevant new information becomes available?

If any new, relevant information becomes available, like a change of venue, procedure, or time, you will be updated immediately.

What will happen if I don't want to carry on with the study?

If you decide to withdraw from the study, you can do that without any negative consequences.

What if there is a problem?

The researcher will provide you with her contact information in case you have any problems or questions relating to the study.

What if I have a complaint?

Phase2 volunteer information Sheet (readability part)
Version2: 29/07/2017



If you have any complaints, please contact Dr. Kate Button, Director of Research Governance, School of Healthcare Sciences, at buttonk@cardiff.ac.uk

Will my taking part in this study be kept confidential?

Your participation will remain confidential and your personal information will not be shared with any third party. Anonymous data may be shared with external collaborators but your personal information will **NOT** be shared with them. All personal information will be stored on a single encrypted USB device and kept in a locked cabinet on Cardiff University premises and accessible only to the researcher. You will have a unique code and your identity will be anonymised and only the researcher will have access to the information.

What will happen to the results of the research study?

The results of the study will be part of a thesis required to complete a PhD degree. Your participation will remain completely anonymous and confidential. If you wish to be kept informed about the results of the study, you may contact the researcher.

Who is organizing and funding the research?

The study is part of a PhD thesis funded by the researchers' sponsors.

Who has reviewed the study?

The study was reviewed by Cardiff University's Research Governance and Ethics Committee, Cardiff and Vale research and development committee, and the NHS Research Ethics Committee (NHS RECs).

For further information, please contact:

Name: Dalal Alothman

E-mail: AlothmanDD@cardiff.ac.uk

Phone: +44 7562839353

Thank you for your participation.

Phase2 volunteer information Sheet (readability part)
Version2: 29/07/2017

Appendix 9. Phase 2 Participants Consent Form



PARTICIPANT CONSENT FORM

Title of study: Development of a patient self-assessment and self-management online tool (BACKonLINE™)

Name of Researcher: Dalal Alothman

Please Initial Box

I confirm I have read and understood the information sheet, dated 04/08/2017 Version 1 for the above study and have had the opportunity to consider the information, to ask questions and to have had these answered.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.

I understand that all information about me will be kept in a confidential way and destroyed once the study is completed.

I agree to the focus group/telephone interview being audio recorded

I agree to the use of anonymised quotes in publications

I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers.

I agree to take part in this study.

Name of Participant Date Signature

Name of Person Date Signature
taking consent

When completed, 1 for participant, 1 for researcher site file
Participant consent form
Version2: 29/07/2017

Appendix 10. Phase 2: Stage 3 - Part A: Focus Group Instructions Manual

Readability focus group participants instruction manual

Name:

Age:

Gender:

Occupation:

First language:

Second language (if applicable):

Location of the focus group:

Ty Dewi Sant Building, Heath Park, Cardiff, CF14 4XN



For more information, or any questions, please contact Dalal Alothman

Phone call, text, or whatsapp on: 07935422528

Or Email at AlothmanDD@cardiff.ac.uk

Focus group participants instruction manual

Thank you for participating in this part of the study. Please take a few minutes to read the instructions carefully before looking at the attached self-assessment and self-management online tool (BACKonLINE™):

- In this booklet, you will find a paper version of BACKonLINE™, opposite to each page of the tool, you will have a blank page for your notes should you feel the need to take some.
- Please be sure to read the booklet before attending the focus group. And please know that there are no such things as wrong answers.
- Please read each question in turn and ask yourself; do I understand the question? If you do not understand then please make a note of what you do not understand about it. Consider the following while reading each question:
 - ✚ The wording
 - ✚ Style, and size of the typeface used
 - ✚ Spacing between questions
- After reading all questions within BACKonLINE™, please ask yourself the following questions:
 - ✚ Do I have any suggestions regarding the tool that might improve its clarity and readability?
 - ✚ Do I have any other comments regarding the tool and its readability and clarity?

Important note: Please bring the booklet with you when attending the focus group and note that all booklets will be collected after the conclusion of the focus group to ensure that all comments and suggestions are addressed.

Thank you and talk to you soon!



BACKonLINE™

Please turn the page to start the questionnaire

BACKonLINE™

A: Pain behaviour

01. Do you know what caused your current back pain?

- Yes
- No
- Not sure

02. If yes, choose an option from the list below:

- Car accident
- Sport injury
- Lifting/bending accident
- Falling down
- Other trauma
- Work related
- Other
- Nothing specific

03. What do you think is wrong with your back? Please tick **all** options that apply

- Wear and tear
- Arthritis
- Osteoporosis
- Bad posture
- Weak core muscles
- Muscle/ligament problem
- Disc problem
- Not sure

04. If you have been treated for back pain, were you satisfied with your treatment?

- Yes, I was satisfied with the treatment
- I was neither satisfied nor dissatisfied with the treatment
- No, I was not satisfied with the treatment
- I was never treated for back pain

05. What medication do you take to manage your back pain? Please tick **all** options that apply

- Paracetamol
- Ibuprofen
- Codeine
- Diazepam
- Amitriptyline
- Duloxetine/Cymbalta
- Gabapentin
- Tramadol
- Hydrocodone
- Cortisone
- Acetaminophen
- Glucosamine
- Valium
- Naproxen
- Other
- I don't take any medication for my back pain

06. How effective is the medication in reducing your back pain?

- Effective
- Not sure
- Ineffective

07. Where is your pain? Please tick **all** body areas that apply

- Neck
- Right shoulder
- Left shoulder
- Right arm
- Left arm
- Upper back
- Lower back
- Right buttock
- Left buttock
- Right hip
- Left hip
- Right leg
- Left leg

08. Is your pain there all the time?

- My pain is there all the time
- My pain comes and goes
- Not sure

09. What type of pain is it? Please tick **all** options that apply

- Deep
- Nagging
- Dull
- Sharp
- Shooting
- Dull ache
- Like lightning
- Burning
- Pressure

- Stinging
- Aching
- Throbbing
- Spread over a wide area

10. When is your pain at its worst?

- in the morning
- at the end of the day
- My pain is there all day long

11. Can you ease your back pain?

- Yes
- Sometimes
- No

12. How do you ease your back pain? Please tick **all** options that apply

- Medication/pain killers
- Rest
- Walking
- Standing
- Sitting
- Exercise
- Massage
- Hot pack
- Cold pack
- Other
- I am unable to ease my back pain

13. In general, is your back pain getting better, staying the same or getting worse?

- My pain is getting better
- My pain has stayed the same
- My pain is getting worse

14. From the list below, please tick **all** the activities that make your pain worse.

- Sitting relaxed
- Sustained sitting
- Sitting up straight
- Standing
- Sustained standing
- Walking
- Fast walking
- Lying on your side curled up
- Running
- Lifting
- Forward bending (stooping)
- Cycling
- Overhead reaching
- Working on a computer
- Hoovering
- Shopping
- Gardening
- Any activity that I do for a long period of time increases my back pain

- Everything I do causes me pain

15. From the list below, please tick **all** the activities that stop or decrease your pain.

- Walking
- Lying on your side curled up
- Running
- Cycling
- Changing positions
- Sitting down
- Avoiding activities that causes me pain
- Stretching exercises (for example: bending forward, bending backwards, reaching upwards)
- Moving about
- Painkillers
- Nothing I do stops my pain

16. Is this the first time you have experienced this type of pain?

- Yes
- No
- Not sure

17. If you had a previous episode of back pain, what helped in making your pain better? Please tick **all** options that apply

- Medication/ pain killers
- Rest
- Walking
- Standing
- Sitting
- Exercise
- Heat pack
- Cold pack
- massage

- Other
- Nothing helped
- I can't remember

18. Other than your back pain, do you experience any of the following? Please tick **all** options that apply

- Pins and needles
- Numbness
- Tingling
- Burning
- Stinging
- Pressure
- None of the above
- Other

19. Please tick **all** the areas where you experience this feeling:

- Neck
- Right shoulder
- Left shoulder
- Right arm
- Left arm
- Upper back
- Lower back
- Right buttock
- Left buttock
- Right hip
- Left hip
- Right leg
- Left leg

20. On average, how many hours do you sleep?

hours	minutes

21. Does your back pain wake you up at night?

-Yes

-Sometimes

-No

22. If you wake up with back pain, can you get back to sleep?

-Yes

-Sometimes

-No

B: Low back pain and work:

23. how strongly do you agree with this statement: 'I believe that my job caused /contributed to my back pain'

- Agree
- Neither agree nor disagree
- Disagree

24. Do you feel supported by your boss and/or co-workers?

- Yes
- No
- I don't know
- Not applicable

25. How is your back pain affecting your work?

- Not at all
- Sometimes
- Frequently
- I am unable to work because of my back pain

26. Are you off work right now because of your back pain?

- Yes
- No
- I don't work

27. How long have you been off work?

- Less than 3 months
- Between 1 to 6 months
- More than 6 months

28. How likely it is that you would return to work within six months?

- Likely
- Not sure
- Unlikely

C: Low back pain and lifestyle:

Do you agree with the following statements?

29. 'I can't do my normal daily activities because of my back pain'

- agree
- neither agree nor disagree
- disagree

30. 'My back pain is negatively affecting my social life'

- agree
- neither agree nor disagree
- disagree

31. 'My back pain is affecting my relationship with my significant other'

- agree
- neither agree nor disagree
- disagree

32. 'I don't know what makes my back pain worse or what eases it '

- agree
- neither agree nor disagree
- disagree

D: Perception of low back pain:

Do you agree with the following statements?

33. 'My back pain makes me feel stressed/anxious'

- agree
- neither agree nor disagree
- disagree

34. 'Stress increases my back pain'

- agree
- neither agree nor disagree
- disagree

35. 'Physical activity increases my back pain'

- agree
- neither agree nor disagree
- disagree

36. 'Since my back pain started, I feel more tired'

- agree
- neither agree nor disagree
- disagree

37. 'I have lost interest and/or pleasure in doing things because of my back pain'

- agree
- neither agree nor disagree
- disagree

38. 'I don't think my family and friends understand what I'm going through with my back pain.'

- agree
- neither agree nor disagree
- disagree

39. 'I don't think my back pain will ever go away.'

- agree
- neither agree nor disagree
- disagree

End of questionnaire

Appendix 11. BACKonLINE™ (Version 5)

BACKonLINE™

A: Pain behaviour

01. Do you know what caused your current back pain?

- Yes
- No
- Not sure

02. If yes, choose an option from the list below:

- Car accident
- Sport injury
- Lifting/bending accident
- Falling down
- Other trauma
- Work related
- Other
- Nothing specific

03. What do you think is wrong with your back? Please tick **all** options that apply

- Wear and tear
- Arthritis
- Osteoporosis
- Bad posture
- Weak core muscles

BACKonLINE™-Version 5

-Muscle/ligament problem

-Disc problem

-Not sure

04. If you have been treated for back pain, were you satisfied with your treatment?

-Yes, I was satisfied with the treatment

-I was neither satisfied nor dissatisfied with the treatment

-No, I was not satisfied with the treatment

-I was never treated for back pain

05. What medication do you take to manage your back pain?
Please tick **all** options that apply

-Paracetamol

-Ibuprofen

-Codeine

-Diazepam

-Amitriptyline

-Duloxetine/Cymbalta

-Gabapentin

-Tramadol

-Hydrocodone

-Cortisone

-Acetaminophen

-Glucosamine

-Valium

- Naproxen
- Other
- I don't take any medication for my back pain

06. How effective is the medication in reducing your back pain?

- Effective
- Not sure
- Ineffective

07. Where is your pain? Please tick **all** body areas that apply

- Neck
- Right shoulder
- Left shoulder
- Right arm
- Left arm
- Upper back
- Lower back
- Right buttock
- Left buttock
- Right hip
- Left hip
- Right leg
- Left leg

BACKonLINE™-Version 5

08. Is your pain there all the time?

- My pain is there all the time
- My pain comes and goes
- Not sure

09. What type of pain is it? Please tick **all** options that apply

- Deep
- Nagging
- Dull
- Sharp
- Shooting
- Dull ache
- Like lightning
- Burning
- Pressure
- Stinging
- Aching
- Throbbing
- Spread over a wide area

10. When is your pain at its worst?

- in the morning
- at the end of the day
- My pain is there all day long

11. Can you ease your back pain?

- Yes
- Sometimes
- No

12. How do you ease your back pain? Please tick **all** options that apply

- Medication/pain killers
- Rest
- Walking
- Standing
- Sitting
- Exercise
- Massage
- Hot pack
- Cold pack
- Other
- I am unable to ease my back pain

13. In general, is your back pain getting better, staying the same or getting worse?

- My pain is getting better
- My pain has stayed the same
- My pain is getting worse

14. From the list below, please tick **all** the activities that make your pain worse.

- Sitting relaxed
- Sustained sitting
- Sitting up straight
- Standing
- Sustained standing
- Walking
- Fast walking
- Lying on your side curled up
- Running
- Lifting
- Forward bending (stooping)
- Cycling
- Overhead reaching
- Working on a computer
- Hoovering
- Shopping
- Gardening
- Any activity that I do for a long period of time increases my back pain
- Everything I do causes me pain

15. From the list below, please tick **all** the activities that stop or decrease your pain.

- Walking
- Lying on your side curled up
- Running
- Cycling
- Changing positions
- Sitting down
- Avoiding activities that causes me pain
- Stretching exercises (for example: bending forward, bending backwards, reaching upwards)
- Moving about
- Painkillers
- Nothing I do stops my pain

16. Is this the first time you have experienced this type of pain?

- Yes
- No
- Not sure

17. If you had a previous episode of back pain, what helped in making your pain better? Please tick **all** options that apply

- Medication/ pain killers
- Rest
- Walking
- Standing

BACKonLINE™-Version 5

- Sitting
- Exercise
- Heat pack
- Cold pack
- massage
- Other
- Nothing helped
- I can't remember

18. Other than your back pain, do you experience any of the following? Please tick **all** options that apply

- Pins and needles
- Numbness
- Tingling
- Burning
- Stinging
- Pressure
- None of the above
- Other

19. Please tick **all** the areas where you experience this feeling:

- Neck
- Right shoulder
- Left shoulder
- Right arm

- Left arm
- Upper back
- Lower back
- Right buttock
- Left buttock
- Right hip
- Left hip
- Right leg
- Left leg

20. On average, how many hours do you sleep?

hours	minutes

21. Does your back pain wake you up at night?

- Yes
- Sometimes
- No

22. If you wake up with back pain, can you get back to sleep?

- Yes
- Sometimes
- No

BACKonLINE™-Version 5

B: Low back pain and work:

23. how strongly do you agree with this statement: 'I believe that my job caused /contributed to my back pain'

- Agree
- Neither agree nor disagree
- Disagree

24. Do you feel supported by your boss and/or co-workers?

- Yes
- No
- I don't know
- Not applicable

25. How is your back pain affecting your work?

- Not at all
- Sometimes
- Frequently
- I am unable to work because of my back pain

26. Are you off work right now because of your back pain?

- Yes
- No
- I don't work

27. How long have you been off work?

- Less than 3 months
- Between 1 to 6 months
- More than 6 months

28. How likely it is that you would return to work within six months?

- Likely
- Not sure
- Unlikely

C: Low back pain and lifestyle:

Do you agree with the following statements?

29. 'I can't do my normal daily activities because of my back pain'

- agree
- neither agree nor disagree
- disagree

30. 'My back pain is negatively affecting my social life'

- agree
- neither agree nor disagree
- disagree

31. 'My back pain is affecting my relationship with my significant other'

- agree
- neither agree nor disagree
- disagree

32. 'I don't know what makes my back pain worse or what eases it'

- agree
- neither agree nor disagree
- disagree

D: Experience with low back pain:

Do you agree with the following statements?

33. 'My back pain makes me feel stressed/anxious'

- agree
- neither agree nor disagree
- disagree

34. 'Stress increases my back pain'

- agree
- neither agree nor disagree
- disagree

35. 'Physical activity increases my back pain'

- agree
- neither agree nor disagree
- disagree

36. 'Since my back pain started, I feel more tired'

- agree
- neither agree nor disagree
- disagree

BACKonLINE™-Version 5

37. 'I have lost interest and/or pleasure in doing things because of my back pain'

- agree
- neither agree nor disagree
- disagree

38. 'I don't think my family and friends understand what I'm going through with my back pain.'

- agree
- neither agree nor disagree
- disagree

39. 'I don't think my back pain will ever go away.'

- agree
- neither agree nor disagree
- disagree

End of questionnaire

Appendix 12. Oswestry Disability Index (ODI)

Oswestry Low Back Pain Disability Questionnaire

Sources: Fairbank JCT & Pynsent, PB (2000) The Oswestry Disability Index. *Spine*, 25(22):2940-2953.

Davidson M & Keating J (2001) A comparison of five low back disability questionnaires: reliability and responsiveness. *Physical Therapy* 2002;82:8-24.

The Oswestry Disability Index (also known as the Oswestry Low Back Pain Disability Questionnaire) is an extremely important tool that researchers and disability evaluators use to measure a patient's permanent functional disability. The test is considered the 'gold standard' of low back functional outcome tools [1].

Scoring instructions

For each section the total possible score is 5: if the first statement is marked the section score = 0; if the last statement is marked, it = 5. If all 10 sections are completed the score is calculated as follows:

Example: 16 (total scored)
 50 (total possible score) x 100 = 32%

If one section is missed or not applicable the score is calculated:

 16 (total scored)
 45 (total possible score) x 100 = 35.5%

Minimum detectable change (90% confidence): 10% points (change of less than this may be attributable to error in the measurement)

Interpretation of scores

0% to 20%: minimal disability:	The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.
21%-40%: moderate disability:	The patient experiences more pain and difficulty with sitting, lifting and standing. Travel and social life are more difficult and they may be disabled from work. Personal care, sexual activity and sleeping are not grossly affected and the patient can usually be managed by conservative means.
41%-60%: severe disability:	Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.
61%-80%: crippled:	Back pain impinges on all aspects of the patient's life. Positive intervention is required.
81%-100%:	These patients are either bed-bound or exaggerating their symptoms.

Oswestry Low Back Pain Disability Questionnaire

Instructions

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking ONE box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

Section 1 – Pain intensity

- I have no pain at the moment
- The pain is very mild at the moment
- The pain is moderate at the moment
- The pain is fairly severe at the moment
- The pain is very severe at the moment
- The pain is the worst imaginable at the moment

Section 2 – Personal care (washing, dressing etc)

- I can look after myself normally without causing extra pain
- I can look after myself normally but it causes extra pain
- It is painful to look after myself and I am slow and careful
- I need some help but manage most of my personal care
- I need help every day in most aspects of self-care
- I do not get dressed, I wash with difficulty and stay in bed

Section 3 – Lifting

- I can lift heavy weights without extra pain
- I can lift heavy weights but it gives extra pain
- Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently placed eg. on a table
- Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- I can lift very light weights
- I cannot lift or carry anything at all

Section 4 – Walking*

- Pain does not prevent me walking any distance
- Pain prevents me from walking more than 30m
- Pain prevents me from walking more than 100m
- Pain prevents me from walking more than 200m
- I can only walk using a stick or crutches
- I am in bed most of the time

Section 5 – Sitting

- I can sit in any chair as long as I like
- I can only sit in my favourite chair as long as I like
- Pain prevents me sitting more than one hour
- Pain prevents me from sitting more than 30 minutes
- Pain prevents me from sitting more than 10 minutes
- Pain prevents me from sitting at all

Section 6 – Standing

- I can stand as long as I want without extra pain
- I can stand as long as I want but it gives me extra pain
- Pain prevents me from standing for more than 1 hour
- Pain prevents me from standing for more than 30 minutes
- Pain prevents me from standing for more than 10 minutes
- Pain prevents me from standing at all

Section 7 – Sleeping

- My sleep is never disturbed by pain
- My sleep is occasionally disturbed by pain
- Because of pain I have less than 6 hours sleep
- Because of pain I have less than 4 hours sleep
- Because of pain I have less than 2 hours sleep
- Pain prevents me from sleeping at all

Section 8 – Sex life (if applicable)

- My sex life is normal and causes no extra pain
- My sex life is normal but causes some extra pain
- My sex life is nearly normal but is very painful
- My sex life is severely restricted by pain
- My sex life is nearly absent because of pain
- Pain prevents any sex life at all

Section 9 – Social life

- My social life is normal and gives me no extra pain
- My social life is normal but increases the degree of pain
- Pain has no significant effect on my social life apart from limiting my more energetic interests eg, sport
- Pain has restricted my social life and I do not go out as often
- Pain has restricted my social life to my home
- I have no social life because of pain

Section 10 – Travelling

- I can travel anywhere without pain
- I can travel anywhere but it gives me extra pain
- Pain is bad but I manage journeys over two hours
- Pain restricts me to journeys of less than one hour
- Pain restricts me to short necessary journeys under 30 minutes
- Pain prevents me from travelling except to receive treatment

References

1. Fairbank JC, Pynsent PB. The Oswestry Disability Index. Spine 2000 Nov 15;25(22):2940-52; discussion 52.

Appendix 13. Keele STarTBack Tool

Pt name: DOB: Trial No: Physio: Date:

STarT Back: For these questions, please think about your back pain over the last few days.

1. How **bothersome** has **pain spreading down your legs from your back** been in the **last few days**?

Not at all	Slightly	Moderately	Very much	Extremely
<input type="text"/>				
0	1	2	3	4

2. How **bothersome** has pain in your **shoulder or neck** been in the **last few days**?

Not at all	Slightly	Moderately	Very much	Extremely
<input type="text"/>				
0	1	2	3	4

For each of the following, please cross one box to show how much you agree or disagree with the statement, thinking about the **last few days**.

3. In the last **few days**, I have **dressed more slowly** than usual because of my back pain.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

4. In the last **few days**, I have only **walked short distances** because of my back pain.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

5. It's **really not safe** for a person with a condition like mine to be **physically active**.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

6. **Worrying thoughts** have been going through my mind a lot of the time in the last **few days**.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

7. I feel that **my back pain is terrible** and that **it is never going to get any better**.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

8. In general, in the last **few days**, I have **not enjoyed** all the things I used to enjoy.

Completely disagree											Strongly agree
0	1	2	3	4	5	6	7	8	9	10	

9. Overall, how **bothersome** has your **back pain** been in the **last few days**?

Not at all	Slightly	Moderately	Very much	Extremely
<input type="text"/>				
0	1	2	3	4

1st Time Score	2nd Time Score	Change score

Appendix 14. Visual Analog Scale of Pain Questionnaire (VAS)

Visual Analog Scale of Pain Questionnaire (VAS)

Instructions: **Put a mark on the line at the point that best represents your pain**

1 – What is your pain **RIGHT NOW**?

No pain _____ Worst possible pain
0 10

2 – What is your **TYPICAL** or **AVERAGE** pain?

No pain _____ Worst possible pain
0 10

3 – What is your pain level **AT ITS BEST** (How close to “0” does your pain get at its best)?

No pain _____ Worst possible pain
0 10

4 – What is your pain level **AT ITS WORST** (How close to “10” does your pain get at its worst)?

No pain _____ Worst possible pain
0 10

OTHER COMMENTS:

Reprinted from *Spine*, 18, Von Korff M, Deyo RA, Cherkin D, Barlow SF, Back pain in primary care: Outcomes at 1 year, 855-862, 1993, with permission from Elsevier Science.

Appendix 15. Tampa Scale for Kinesiophobia (TSK)

Tampa Scale for Kinesiophobia
(Miller , Kori and Todd 1991)

1 = strongly disagree
2 = disagree
3 = agree
4 = strongly agree

1. I'm afraid that I might injury myself if I exercise	1	2	3	4
2. If I were to try to overcome it, my pain would increase	1	2	3	4
3. My body is telling me I have something dangerously wrong	1	2	3	4
4. My pain would probably be relieved if I were to exercise	1	2	3	4
5. People aren't taking my medical condition seriously enough	1	2	3	4
6. My accident has put my body at risk for the rest of my life	1	2	3	4
7. Pain always means I have injured my body	1	2	3	4
8. Just because something aggravates my pain does not mean it is dangerous	1	2	3	4
9. I am afraid that I might injure myself accidentally	1	2	3	4
10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening	1	2	3	4
11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body	1	2	3	4
12. Although my condition is painful, I would be better off if I were physically active	1	2	3	4
13. Pain lets me know when to stop exercising so that I don't injure myself	1	2	3	4
14. It's really not safe for a person with a condition like mine to be physically active	1	2	3	4
15. I can't do all the things normal people do because it's too easy for me to get injured	1	2	3	4
16. Even though something is causing me a lot of pain, I don't think it's actually dangerous	1	2	3	4
17. No one should have to exercise when he/she is in pain	1	2	3	4

Reprinted from:
Pain, Fear of movement/(re) injury in chronic low back pain and its relation to behavioral performance, 62, Vlaeyen, J., Kole-Snijders A., Boeren R., van Eek H., 371.
Copyright (1995) with permission from International Association for the Study of Pain.

Scoring Information
Tampa Scale for Kinesiophobia
(Miller et al 1991)

A total score is calculated after inversion of the individual scores of items 4, 8, 12 and 16.

Reprinted from:
Pain, Fear of movement/(re) injury in chronic low back pain and its relation to behavioral performance, 62, Vlaeyen, J., Kole-Snijders A., Boeren R., van Eek H., 371.
Copyright (1995) with permission from International Association for the Study of Pain.

Appendix 16. Pain Anxiety
Symptoms Scale short form 20
(PASS 20)

Pain Anxiety Symptom Scale Short Form 20

Please rate each item in terms of frequency, from 0 (Never) to 5 (Always).

Item Numbers	Never	Always
1. I can't think straight when in pain	0	5
2. During painful episodes it is difficult for me to think of anything besides the pain	0	5
3. When I hurt I think about pain constantly	0	5
4. I find it hard to concentrate when I hurt	0	5
5. I worry when I am in pain	0	5
6. I go immediately to bed when I feel severe pain	0	5
7. I will stop any activity as soon as I sense pain coming on	0	5
8. As soon as pain comes on I take medication to reduce it	0	5
9. I avoid important activities when I hurt	0	5
10. I try to avoid activities that cause pain	0	5
11. I think that if my pain gets too severe it will never decrease	0	5
12. When I feel pain I am afraid that something terrible will happen	0	5
13. When I feel pain I think I might be seriously ill	0	5
14. Pain sensations are terrifying	0	5
15. When pain comes on strong I think that I might become paralyzed or more disabled	0	5
16. I begin trembling when engaged in activity that increases pain	0	5
17. Pain seems to cause my heart to pound or race	0	5
18. When I sense pain I feel dizzy or faint	0	5
19. Pain makes me nauseous	0	5
20. I find it difficult to calm my body down after periods of pain	0	5

Total Score _____

Cont'd ►

Pain Anxiety Symptom Scale Short Form 20 *(cont'd)*

Means and standard deviations for the revised, shortened Pain Anxiety Symptoms Scale subscales and the total score (N=282 patients with chronic pain)

Subscale	Mean	SD
Cognitive (items 1 to 5)	12.27	6.73
Escape/avoidance (items 6 to 10)	12.84	6.11
Fear (items 11 to 15)	7.37	6.38
Physiological anxiety (items 16 to 20)	6.15	5.69
Total	38.62	20.38

McCracken LM, Dhingra L. A short version of the Pain Anxiety Symptoms Scale (PASS-20): preliminary development and validity. *Pain Res Manag.* 2002;7(1):45-50.

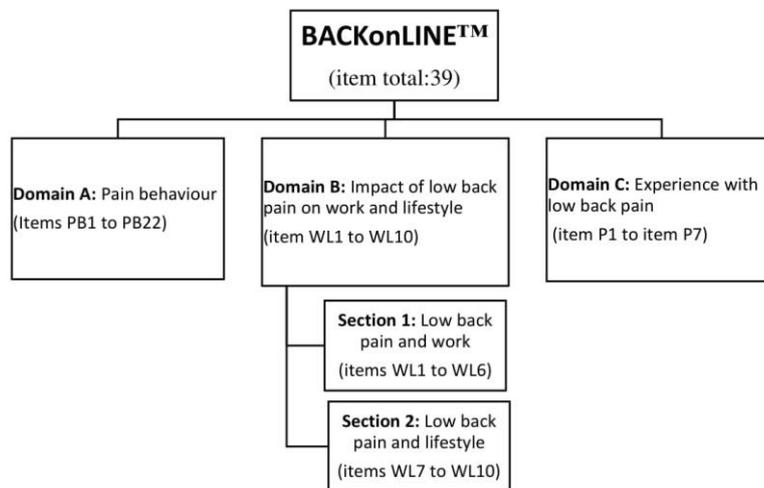
Appendix 17. BACKonLINE™ (Version 5) with scores

BACKonLINE™

Domains of BACKonLINE™:

- **Domain A:** Pain behaviour domain: Items PB1 to PB22
- **Domain B:** Impact of low back pain on work and lifestyle: this domain has 10 items (item WL1 to WL10) and there are two sections within this domain (please note that this domain is analysed as one without separating the sections):
 1. **Section 1:** Low back pain and work: this section is represented by items WL1 to WL6
 2. **Section 2:** Low back pain and lifestyle: this section is represented by items WL7 to WL10
- **Domain C:** Experience with low back pain domain previously known as perception of back pain domain): this domain has 7 items (item P1 to item P7) (Figure 1)

Figure 1 BACKonLINE™ layout



BACKonLINE™

Domain A: Pain behaviour

PB1. Do you know what caused your current back pain?

0-Yes

2-No

1-Not sure

PB2. If yes, choose an option from the list below:

1-Car accident

0-Sport injury

0-Lifting/bending accident

0-Falling down

0-Other trauma

1-Work related

0-Other

1-Nothing specific

1- I don't know

PB3. What do you think is wrong with your back? Please tick **all** options that apply

- 1 -Wear and tear
- 1 -Arthritis
- 1 -Osteoporosis
- 1 -Bad posture
- 1 -Weak core muscles
- 1 -Muscle/ligament problem
- 1 -Disc problem
- 0 -Not sure

PB4. If you have been treated for back pain, were you satisfied with your treatment?

- 1-Yes, I was satisfied with the treatment
- 2-I was neither satisfied nor dissatisfied with the treatment
- 3-No, I was not satisfied with the treatment
- 0 -I was never treated for back pain

PB5. What medication do you take to manage your back pain?
Please tick **all** options that apply

- 1-Paracetamol
- 1-Ibuprofen
- 1-Codeine
- 1-Diazepam
- 2-Amitriptyline
- 2-Duloxetine/Cymbalta
- 2-Gabapentin
- 1-Tramadol
- 1-Hydrocodone
- 1-Cortisone
- 1-Acetaminophen
- 1-Glucosamine
- 1-Valium
- 1-Naproxen
- 1-Other
- 0-I don't take any medication for my back pain

PB6. How effective is the medication in reducing your back pain?

- 0-Effective
- 1-Not sure
- 2-Ineffective
- 0- I don't take any medication for my back pain

PB7. Where is your pain? Please tick **all** body areas that apply

- 1-Neck
- 1-Right shoulder
- 1-Left shoulder
- 1-Right arm
- 1-Left arm
- 1-Upper back
- 1-Lower back
- 1-Right buttock
- 1-Left buttock
- 1-Right hip
- 1-Left hip
- 1-Right leg
- 1-Left leg

PB8. Is your pain there all the time?

- 2-My pain is there all the time
- 0-My pain comes and goes
- 1-Not sure

PB9. What type of pain is it? Please tick **all** options that apply

- 1-Deep
- 1-Nagging
- 1-Dull
- 1-Sharp
- 1-Shooting
- 1-Dull ache
- 1-Like lightning
- 1-Burning
- 1-Pressure
- 1-Stinging
- 1-Aching
- 1-Throbbing
- 2-Spread over a wide area

PB10. When is your pain at its worst?

- 1- in the morning
- 1- at the end of the day
- 2-My pain is there all day long

PB11. Can you ease your back pain?

- 0-Yes
- 1-Sometimes
- 2-No

PB12. How do you ease your back pain? Please tick **all** options that apply

- 0-Medication/pain killers
- 0-Rest
- 0-Walking
- 0-Standing
- 0-Sitting
- 0-Exercise
- 0-Massage
- 0-Hot pack
- 0-Cold pack
- 0-Other
- 2-I am unable to ease my back pain

PB13. In general, is your back pain getting better, staying the same or getting worse?

- 0-My pain is getting better
- 1-My pain has stayed the same
- 2-My pain is getting worse

PB.14. From the list below, please tick **all** the activities that make your pain worse.

- 0-Sitting relaxed
- 0-Sustained sitting
- 0-Sitting up straight
- 0-Standing
- 0-Sustained standing
- 0-Walking
- 0-Fast walking
- 0-Lying on your side curled up
- 0-Running
- 0-Lifting
- 0-Forward bending (stooping)
- 0-Cycling
- 0-Overhead reaching
- 0-Working on a computer
- 0-Hoovering
- 0-Shopping
- 0-Gardening
- 1-Any activity that I do for a long period of time increases my back pain
- 2-Everything I do causes me pain

PB15. From the list below, please tick **all** the activities that stop or decrease your pain.

0-Walking

0-Lying on your side curled up

0-Running

0-Cycling

0-Changing positions

0-Sitting down

2-Avoiding activities that causes me pain

0-Stretching exercises (for example: bending forward, bending backwards, reaching upwards)

0-Moving about

1-Painkillers

2-Nothing I do stops my pain

PB16. Is this the first time you have experienced this type of pain?

0-Yes

2-No

1-Not sure

PB17. If you had a previous episode of back pain, what helped in making your pain better? Please tick **all** options that apply

1-Medication/ painkillers

1-Rest

0-Walking

0-Standing

0-Sitting

0-Exercise

0-Heat pack

0-Cold pack

1-massage

0-Other

2-Nothing helped

1-I can't remember

PB18. Other than your back pain, do you experience any of the following? Please tick **all** options that apply

1-Pins and needles

1-Numbness

1-Tingling

1-Burning

1-Stinging

1-Pressure

0-None of the above

PB19. Please tick **all** the areas where you experience this feeling:

- 1-Neck
- 1-Right shoulder
- 1-Left shoulder
- 1-Right arm
- 1-Left arm
- 1-Upper back
- 1-Lower back
- 1-Right buttock
- 1-Left buttock
- 1-Right hip
- 1-Left hip
- 1-Right leg
- 1-Left leg
- 0- Not applicable

PB20. On average, how many hours do you sleep?

hours	minutes

Number of hours	score
<5	2
5-7	1
8+	0

**Score for P.B.20*

PB21. Does your back pain wake you up at night?

- 2-Yes
- 1-Sometimes
- 0-No

PB22. If you wake up with back pain, can you get back to sleep?

0-Yes

1-Sometimes

2-No

Domain B: Impact of low back pain on work and lifestyle:

Section 1: Low back pain and work:

WL1. how strongly do you agree with this statement: 'I believe that my job caused /contributed to my back pain'

2-Agree

1-Neither agree nor disagree

0-Disagree

0-Not applicable

WL2. Do you feel supported by your boss and/or co-workers?

0-Yes

2-No

1-I don't know

0-Not applicable

WL3. How is your back pain affecting your work?

0-Not at all

0-Sometimes

1-Frequently

2-I am unable to work because of my back pain

0-Not applicable

WL4. Are you off work right now because of your back pain?

2-Yes

0-No

0-Not applicable

WL5. How long have you been off work?

1-Less than 3 months

2-Between 1 to 6 months

3-More than 6 months

0 -Not applicable

WL6. How likely it is that you would return to work within six months?

0-Likely

1-Not sure

2-Unlikely

0 -Not applicable

Section 2: Low back pain and lifestyle:

Do you agree with the following statements?

WL7. 'I can't do my normal daily activities because of my back pain'

2- agree

1- neither agree nor disagree

0- disagree

WL8. 'My back pain is negatively affecting my social life'

2- agree

1- neither agree nor disagree

0- disagree

WL9. 'My back pain is affecting my relationship with my significant other'

2- agree

1- neither agree nor disagree

0- disagree

WL10. 'I don't know what makes my back pain worse or what eases it '

2- agree

1- neither agree nor disagree

0- disagree

Domain C: Experience with low back pain:

Do you agree with the following statements?

P1. 'My back pain makes me feel stressed/anxious'

2- agree

1- neither agree nor disagree

0- disagree

P2. 'Stress increases my back pain'

2- agree

1- neither agree nor disagree

0- disagree

P3. 'Physical activity increases my back pain'

2- agree

1- neither agree nor disagree

0- disagree

P4. 'Since my back pain started, I feel more tired'

2- agree

1- neither agree nor disagree

0- disagree

P5. 'I have lost interest and/or pleasure in doing things because of my back pain'

2- agree

1- neither agree nor disagree

0- disagree

P6. 'I don't think my family and friends understand what I'm going through with my back pain.'

2- agree

1- neither agree nor disagree

0- disagree

P7. 'I don't think my back pain will ever go away.'

2- agree

1- neither agree nor disagree

0- disagree

End of BACKonLINE™ Version 5

Appendix 18. Ethical Approval
Letter for Phase 3: Measurement
Properties and Participants
Experience of BACKonLINE™



GIG NHS | Bwrdd Iechyd Prifysgol
Caerdydd a'r Fro
Cardiff and Vale
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From: Professor C Fegan
R&D Director
R&D Office, 2nd Floor TB2
University Hospital of Wales
Cardiff
CF14 4XW

01 December 2017

Mr Tim Matthews
Orthopaedic Consultant
Cardiff & Vale University Health Board
CAVOC Research Office
Llandough Hospital
Llandough
CF64 3XX

Dear Mr Matthews,

Study title	Opinions about management of musculoskeletal disorders: Qualitative analysis of patient and clinician opinion
Cardiff and Vale UHB reference	17/JUN/6961
IRAS reference	51853

The above project was forwarded to Cardiff and Vale University Health Board R&D Office by the Health and Care Research Wales Permissions Service. A Governance Review has now been completed.

I am pleased to inform you that based on the review of the documents submitted to the Health and Care Research Wales Permissions Service, the UHB has no objection to your proposal.

You have informed us that Cardiff University is willing to act as Sponsor under the Research Governance Framework for Health and Social Care. Please accept this letter as confirmation of permission for the project to begin within this UHB.

In order to comply with Health and Care Research Wales reporting requirements, you must inform the R&D Office of the following dates:

- **The date which this site opens to recruitment,**

Bwrdd Iechyd Prifysgol Caerdydd a'r Fro yw enw gweithredol Bwrdd Iechyd Lleol Prifysgol Caerdydd a'r Fro
Cardiff and Vale University Health Board is the operational name of Cardiff and Vale University Local Health Board



- the date that the first patient is recruited at this site,
- The expected date that recruitment will end at this site.

Please email this information to CAV research.development@wales.nhs.uk.

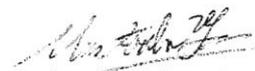
If your study is adopted onto the Health and Care Research Wales Clinical research Portfolio, it will be a condition of this NHS research permission that you will be required to upload recruitment data onto the portfolio database, or forward recruitment data to the Chief Investigator to be uploaded. Please also note that, for studies with a recruitment target of more than one participant per month, the first participant should be recruited within 30 calendar days of the date of R&D approval/site initiation (whichever is latest).

During recruitment to portfolio adopted studies accrual data will need to be submitted on a monthly basis to the CPMS database. Failure to do so may result in the withdrawal of R&D approval. Systems have been set up to streamline and make this process as automated as possible. Details on how to upload accrual data are available at <http://www.crn.nihr.ac.uk/can-help/funders-academics/nihr-crmp-portfolio/portfolio-user-guides/>. Please contact portfolio@Wales.nhs.uk if help is required.

May I take this opportunity to wish you success with the project and remind you that as Chief / Principal Investigator you are required to:

- Inform the Health and Care Research Wales Permissions Service and the UHB R&D Office if any external or additional funding is awarded for this project in the future
- Ensure that all study amendments are submitted to the Health and Care Research Wales Permissions Service
- Ensure the Health and Care Research Wales Permissions Service is notified of the study's closure
- Ensure that the study is conducted in accordance with all relevant policies, procedures and legislation
- Provide information on the project to the UHB R&D Office as requested from time to time.

Yours sincerely,



Professor Christopher Fegan
R&D Director / Chair of the Cardiff and Vale Research Review Service (CaRRS)

CC Deputy R&D Lead, Mr Paul Hodgson
CC Chief Investigator: Professor Bruce Caterson
CC Sponsor contact, Cardiff University
CC Centre Research manager, Cheryl Cleary
CC CVUHB Finance

Arthritis Research UK Biomechanics and Bioengineering Centre

**Centre Research Protocol
(Ethical Approval Document)**

Sponsors: Cardiff University

Version 12

30th November 2017

Contents Page

1.1 Background

1.2 Overall Aims and Objectives

1.3 The following described the different routes of recruitment which applies to all protocols

1.3.1 Recruiting through clinics

1.3.2 Recruiting through clinic and treatment waiting list

1.3.3 Post-treatment patients

1.3.4 Volunteers

1.3.5 Recruitment through participation of other Centre protocols

2. Protocol One - Assessment of joint function in healthy and pathological subjects using motion analysis techniques.

2.1 Background and Objective

2.2 The overarching hypothesis

2.2.1 Protocol specific Primary Aim

2.2.2 Protocol specific Secondary Aim

2.2.3 The specific objectives of the studies that involve this protocol

2.3 Anticipated joint pathologies

2.4 Inclusion and Exclusion Criteria

2.4.1 Patient inclusion Criteria

2.4.2 Patient exclusion Criteria

2.4.3 Healthy volunteer inclusion criteria

2.4.4 Healthy volunteer exclusion criteria

2.5 Sample Size Estimation

2.6 Timescale

2.7 Patient Selection

2.8 Method / Study Design

2.8.1 Laboratory and clinical movement analysis assessment Day

2.9 Ethical consideration

2.10 Longitudinal Studies

2.11 Payment of travel expenses

2.12 Statistics and data analysis

2.13 Data storage and encryption

2.14 Data Storage and Data Sharing

2.15 Disseminations

2.16 Information Sheets & Consent Forms Protocol One

3 Protocol Two - Fluoroscopic imaging

3.1 Fluoroscopy Studies at Cardiff

3.2 Protocol specific aims, objectives and overarching hypothesis

3.2.1 The overarching hypothesis

3.2.2 Primary Aim

3.2.3 Secondary Aim

3.2.4 The specific objectives of the studies that involve this protocol

3.2.5 The objective of this protocol

3.3 Anticipated joint pathologies

3.4.1 Patient volunteer inclusion Criteria

3.4.2 Patient volunteer exclusion Criteria

3.4.3 Healthy volunteer inclusion Criteria

3.4.4 Healthy volunteer exclusion criteria

3.5 Sample Size Estimation

3.6 Timescale

3.7 Method / Study Design

3.7.1 Patient Selection

3.7.2 Fluoroscopy Assessment Day

3.8 Ethical considerations

3.9 Longitudinal Studies

3.10 Payment of travel expenses

3.11 Statistics and data analysis

3.12 Data storage and encryption

3.13 Data Storage and Data Sharing

3.14 Disseminations

3.15 Information Sheets & Consent Forms Protocol Two

4. Protocol Three - MRI imaging for the joint “Joint imaging in patients with musculoskeletal disease and healthy people”

4.1 Background

4.2 Protocol specific aims, objectives and overarching hypothesis

- 4.2.1 The overarching hypothesis is
- 4.2.2 Protocol specific Primary Aim
- 4.2.3 Protocol specific Secondary Aim
- 4.2.4 The specific objectives of the studies that involve this protocol
- 4.3 Anticipated joint pathologies
- 4.4 Inclusion and Exclusion Criteria
 - 4.4.1 Patient volunteer inclusion Criteria
 - 4.4.2 Patient volunteer exclusion Criteria
 - 4.4.3 Healthy volunteer inclusion criteria
 - 4.4.4 Healthy volunteer exclusion criteria
- 4.5 Sample Size Estimation
- 4.6 Timescale
- 4.7 Patient Selection
- 4.8 Method / Study Design
 - 4.8.1 Laboratory assessment day
- 4.9 Ethical Considerations
- 4.10 Longitudinal Studies
- 4.11 Payment of travel expenses
- 4.12 Statistics and data analysis
- 4.13 Data storage and encryption
- 4.14 Data Storage and Data Sharing
- 4.15 Disseminations
- 5. Protocol Four - The analysis of human samples to study the structure, function, metabolism in joints and identify biomarkers in joint pathology**
- 5.1 Background
- 5.2 Protocol specific aims, objectives and overarching hypothesis
 - 5.2.1 The overarching hypothesis is
 - 5.2.2 Protocol specific Primary Aim
 - 5.2.3 Protocol specific Secondary Aim
 - 5.2.4 The specific objectives of the studies linked to this protocol
- 5.3 Centre specific projects will be conducted in ARUKBBC to address these aims and objectives

- 5.4 Anticipated joint pathologies
- 5.5 Inclusion and Exclusion Criteria
 - 5.5.1 Patient inclusion Criteria
 - 5.5.2 Patient exclusion Criteria
 - 5.5.3 Healthy volunteer inclusion criteria
 - 5.5.4 Healthy volunteer exclusion criteria
- 5.6 Sample Size Estimation
- 5.7 Timescale
- 5.8 Patient Selection
- 5.9 Method and study design
 - 5.9.1 Clinical waste samples during routine clinical procedures
 - 5.9.2 Blood and Urine samples
 - 5.9.3 Points of entry into the protocol (collection of non-clinical waste synovial fluid)
- 5.10 Consent Procedure
- 5.11 Enduring Consent
- 5.12 Procedure for sample collection and transport
- 5.13 Sample Processing
- 5.14 The storage of human samples
- 5.15 Procedure for usage and disposal of sample collection
- 5.16 Analyses to be undertaken
- 5.17 Questionnaires
- 5.18 Ethical Considerations
 - 5.18.1 Sample collection: Blood/Urine
 - 5.18.2 Clinical waste samples
 - 5.18.3 Sample collection: non-clinical waste
 - 5.18.4 Sample Storage - Confidentially
- 5.19 Longitudinal Studies
- 5.20 Payment of travel expenses
- 5.21 Statistics and data analysis
- 5.22 Data Storage and Anonymity

5.23 Future use

5.24 Disseminations

6. Protocol Five Qualitative analysis of patient and clinician opinion

6.1 Background

6.2 Planned investigation

6.3 Protocol specific aims and objectives

6.4 Anticipated joint pathologies

6.5 Inclusion / Exclusion criteria

6.6 Sample size estimation

6.7 Timescale

6.8 Participant recruitment

6.9 Method / Study design

6.10 Consent Process

6.11 Interviews / Focus Groups

6.12 PROMs

6.13 Ethical considerations

6.14 Longitudinal studies

6.15 Payment of travel expenses

7. PROJECT MANAGEMENT

8. REFERENCES

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Abbreviations

2D – two dimensional
3D – Three dimensional
ACL – Anterior Cruciate Ligament
ADAMTS - A Disintegrin And Metalloproteinase with Thrombospondin Motifs
AMPA - α -amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptor
ARUK – Arthritis Research UK
ARUKBBC – Arthritis Research UK Biomechanics and Bioengineering Centre
BOLD - Blood oxygen level dependent
CAD – Computer Aided Design
CAVOC – Cardiff and Vale Orthopaedic Centre
CBT – Cognitive behavioural therapy
CI – Chief Investigator
CNMP – Chronic non-malignant pain
CT scan - Computerized axial Tomography scan
CUBRIC - Cardiff University Brain Research Imaging Centre
DBS – Disclosure Barring Service
DEXA - Dual energy X-ray absorptiometry
DOB – Date of Birth
DST – Dempster-Shafer Theory of Evidence
EEG – Electroencephalogram
ECG – Electrocardiography
ELISA – Enzyme-linked immunosorbent assays
EMG – Electromyography
ERP – Event related potential
FA – Fractional anisotropy
fMRI – Functional Magnetic Resonance Imaging
GCP – Good Clinical Practice
GluR – Glutamate Receptors
GP – General Practitioner
HCARE – School of Healthcare Sciences
HOOS – Hip injury and Osteoarthritis Outcome Score
HPLC - High Performance Liquid Chromatography
HTO – High tibial osteotomy
IAB – International Advisory Board
IL-1 β - Interleukin 1 beta
IL-6 – Interleukin 6
ISB – International Society for Biomechanics
IR(ME)R – Ionising Radiation (Medical Exposure) Regulations
KOOS – Knee injury and Osteoarthritis Outcome Score
LDA – Linear discriminate analysis
miRNA – microRNA / microRibonucleic Acid
MMP - matrix metalloproteinases
MOCAP – Motion Capture Analysis
MRI – Magnetic resonance imaging
MRS – Magnetic resonance spectroscopy
MT – Management Team

NHS – National Health Service
NMR - Nuclear Magnetic Resonance
NSAIDS – Non Steroidal Anti Inflammatory Drugs
OA – Osteoarthritis
OARSI – Osteoarthritis Research Society International
PCA – Principle Component Analysis
PMP – Pain management programme
PPI – Patient and Public Involvement
R&D – Research and Development
RA – Rheumatoid arthritis
RC – Research Committee
RCCK – Research Centre for Clinical Kinaesiology
REC – Research Ethics Committee
ROM – Range of Motion
RPA – Radiation Protection Advisor
SF – Synovial Fluid
sMRI – structural Magnetic resonance imaging
SOP – Standard Operating Procedure
THR – Total Hip Replacement
TKR – Total knee replacement
TNF- α – Tumour Necrosis Factor – alpha
UHB – University Health Board
UHW – University of Hospital Wales
uSv – Microsievert
WOMAC – Western Ontario and McMaster Universities Arthritis Index

Section One

1.1 Background

Cardiff University was chosen by Arthritis Research UK in 2009 to be the UK centre of excellence in Biomechanics and Bioengineering to research the causes, prevention and treatment of joint diseases. This prestigious award was further enhanced with funding from Cardiff University, meaning that £10 million over 10 years will be invested at Cardiff University to investigate joint pathologies. The Arthritis Research UK Biomechanics and Bioengineering Centre (ARUKBBC) is a multidisciplinary Centre with members from 6 University Schools and a number of Welsh Health Boards but principally the Cardiff and Vale Orthopaedic Centre (CAVOC). The Centre's interdisciplinary studies involve biochemists, cell biologists, geneticists, engineers, pharmacologists, physiotherapists, rheumatologists and orthopaedic surgeons. The Centre has recently been reviewed by Arthritis Research UK and has been awarded a further 5 years (£2M) funding until December 31st 2020.

The Centre will drive interdisciplinary studies across a team of internationally recognised researchers and clinicians to improve patient care. The team will apply a 'molecule to man' approach to investigate normal joint biomechanics and determine how this is influenced by pathology to inform clinical intervention and rehabilitation in musculoskeletal disorders. The centre is applying the expertise, experience and established collaborations within Cardiff University in biomechanics, bioengineering, mechanotransduction, pain and inflammation to define, identify and target mechanical pathways underlying arthritis pathology. The centre is also supported by a wide range of clinicians based in local NHS hospitals in all disciplines of orthopaedics and rheumatology providing us with easy access to patients and tissues from pathological joints during surgical procedures.

The research being conducted within the Centre is particularly interested in the arthritic condition osteoarthritis (OA). OA affects over 8 million people in the UK and is a degenerative joint disease leading to loss of articular cartilage that causes joint stiffness and pain. Major risk factors (obesity, occupations involving increased bending, sports participation and injury) demonstrate that mechanical loading influences onset and progression of OA [1, 2]. Cartilage degeneration in OA occurs due to activities of degradative enzymes (e.g. matrix metalloproteinases (MMPs), aggrecanases, ADAMTSs) driven by inflammatory cytokines [3, 4].

There are no specific, disease-modifying agents for OA, with joint replacement the only option for severe OA. Pain, the major burden to patients with arthritis, determines timing of joint replacement, but self-reported pain scores are notoriously variable and do not correlate with extent of joint damage. There is an urgent clinical requirement for objective functional and biological measures for use in early diagnosis of joint degeneration and assessment of treatment efficacy.

The Centre is also researching into Rheumatoid arthritis (RA). RA affects 1% of adults and arises due to autoimmune responses that cause inflammation and bone and cartilage erosion, dramatically altering loading through the joint. Cytokines such as IL-6, TNF α and IL-1 β are pivotal in RA pathogenesis. Thus joint biomechanics and the local effects of destructive cytokines and enzymes drive joint degeneration in both OA and RA.

Current treatment for RA modulate cytokines indirectly, using disease modifying agents (methotrexate, leflunomide), or directly, by targeting cytokines/cytokine receptors such as TNF or TNF receptor (etanercept, adalimumab and infliximab). Anti-TNF therapy has significantly advanced RA treatment, but unresponsive patients and concerns over long-term side effects necessitate new therapeutic targets [5, 6].

1.2 Overall Aims and Objectives

The Centre is addressing a number of objectives which is coordinating bioengineering, biomechanical, biologically and imaging-based studies to enhance the understanding of joint disorders and applying basic scientific and translational studies into clinical practice.

The vision for the Centre is to deliver on the following major clinically relevant questions:

1. Can we slow, stop or reverse degenerative joint diseases by altering joint biomechanics?
2. Can we identify specific indicators of rapid onset of degenerative joint disease after acute injury and develop interventions to prevent OA development and progression?
3. Can we develop multivariate interdisciplinary tools to predict TKR outcomes and better direct appropriate interventions?

To address these research questions, the Centre have set the following aims and objectives Define how human joint function changes with age, exercise, disease and physiotherapy.

- Quantify forces within normal and diseased human joints.
- Provide clinical tools to quantify changes in human joint function for diagnosis and treatment.
- Identify mechanically regulated biomarkers of joint degeneration and repair.
- Identify mechanically regulated therapeutic targets for arthritis and osteoporosis.
- Identify pain indicators that correspond to joint loading.
- Identify therapies that target pain, pathology and inflammation in arthritis.
- Model the processes that cause cements to crack and prostheses to fail.
- Improve cements and coatings to resist failure, enhance osseointegration and reduce infection.
- Identify factors that influence recovery and dysfunction to inform rehabilitation.

The Centre has developed a unique platform of skills and facilities a “step-change” in treatment and understanding of arthritis. Our programme has evolved to focus on core areas that provide demonstrable results through clinical translation and/or commercial development. Centre funding supports projects requiring long-term, longitudinal collection of patient data and the development of new, challenging, interdisciplinary, experimental pipelines correlating biomechanics and biology. Implementation requires a dedicated infrastructure to coordinate patients, measurements and samples and to ensure regulatory compliance.

To address these research goals a number of protocols need to be carried out many of which interlink. The projects are: 1. Motion Capture analysis (MOCAP); 2. Fluoroscopy; 3 Magnetic Resonance Imaging (MRI) of the joint and 4. Human Samples (please see Diagram 1). Detailed information about each of the protocols and what is required of the participants can be found in Section 2. A longitudinal research design will be used to collect data over the course of the joint disorder or problem; an example of the “patient journey” and the Centre’ longitudinal, interlinking research approach is illustrated in Diagram 2.

The research protocol have been developed through collaboration of individuals from the orthopaedic, rheumatology, physiotherapy departments (Cardiff and Vale University and Cwm Taf NHS Health Boards) and Cardiff University (including the Schools of Biosciences, Medicine, Engineering, Dentistry, Healthcare Sciences, Pharmacy and Pharmaceutical Sciences and the Cardiff University Brain Research Imaging Centre). The proposal and protocols outlined within this Protocol document have been internationally scientifically critiqued. Patients may be asked if they would like to participate in one of more of the Centre protocols outlined above and this is explained in the relevant patient information sheets and consent forms, pending suitability.

Diagram 1: Interlinking nature of the Centre's research

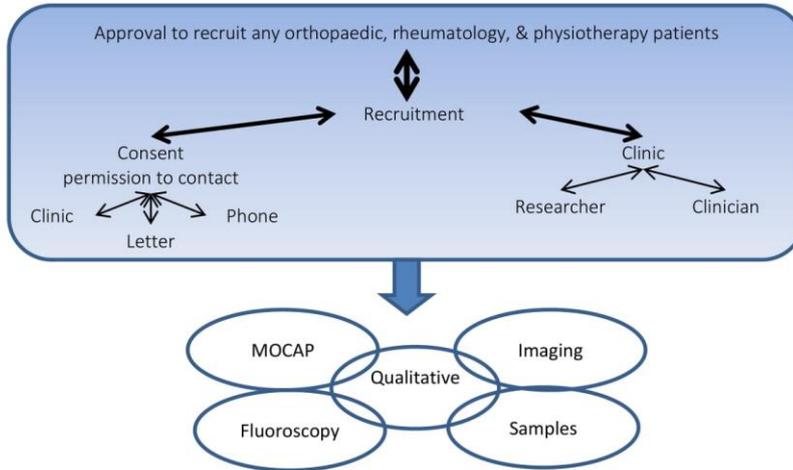
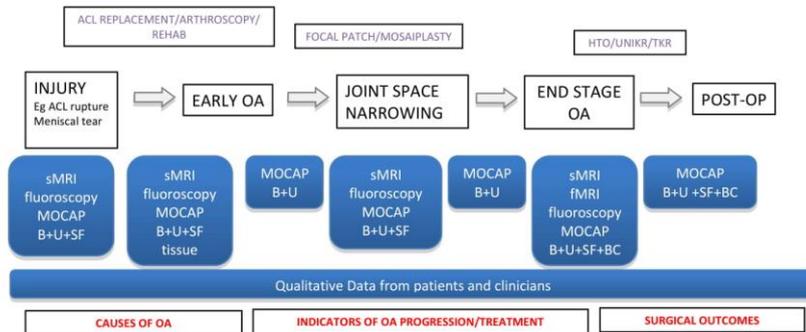


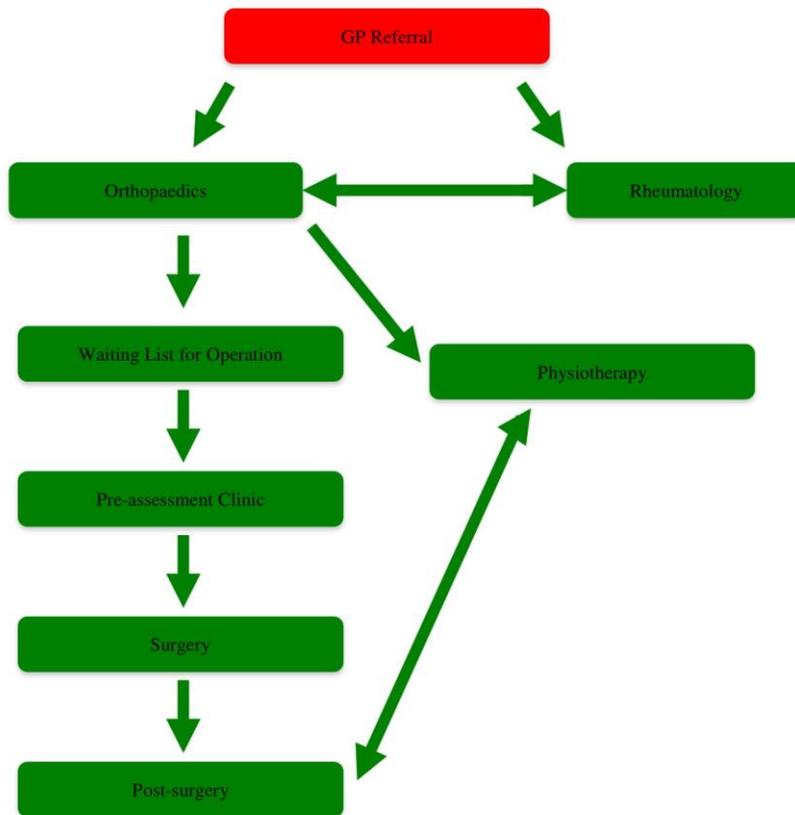
Diagram 2: Example of the “patient journey” and the ARUKBBC longitudinal, interlinking research approach



Key: B = Blood; U = Urine; SF = Synovial Fluid, BC = Bone Cores (HTO only)

Diagram 3: Patient Recruitment and Points of Entry into the Study

We intend to patients through different routes of the patient care pathway as highlighted in Diagram 3 below:



Points of entry and potential stages of participation in the research studies highlighted in green

1.3 The following described the different routes of recruitment which applies to all protocols.

1.3.1 Recruiting through clinics

1a) Patients present to participating NHS Health Board orthopaedic/rheumatology consultants or physiotherapists with joint pathology or injury and are provided with a "permission to contact" form. Included in this form is a request for permission to access relevant medical information from their treating clinician. It is stated on the form that this information is required to determine their suitability to take part in the study and that this will be carried out by a treating clinician and researchers from the Centre who will be in possession of a valid Research Passport/letter of access or an Honorary NHS contract issued by the appropriate NHS Health Board. Patients will be given the choice to complete at clinic or take the form away to complete in their own time. The form will take approximately 10 minutes to complete. They may also be provided with questionnaires to help decide their suitability. Patients again will be given the choice to complete at clinic or take the form away to complete in their own time.

1b) Patients may also be asked if they are willing to provide verbal permission (to a member of their clinical team) for a researcher from the Centre to talk to them about the research studies while they are at the clinic. If they are interested in taking part they will be provided with information about the relevant study.

2) Patients will be clinically assessed by members of the clinical team to determine suitability to take part in the research study. Suitability may also be carried out by researchers with Research Passport/ Honorary NHS contract (following permission to contact and access to relevant medical information is obtained from the patient in accordance with the data protection act).

3) Participants deemed suitable will be contacted by Arthritis Research UK Biomechanics and Bioengineering Centre researchers at Cardiff University for further assessment for the purposes of the research study and participants will also be sent appropriate questionnaires, based on the joint, pathology and protocol. Where possible, patients will be given at least 24 hours to decide whether or not they wish to take part in the research protocol(s) before full informed written consent is requested.

1.3.2 Recruiting through clinic and treatment waiting list

The treating clinician can also contact suitable patients on the waiting list for treatment via letter. The identification of the patients is carried out by physiotherapists, orthopaedic surgeons or rheumatologists or suitable delegate who work at the hospital setting and can therefore search the service database and hospital medical records. The clinicians or delegates identifying the patients will also be collaborators with our research centre. Once suitable patients are identified, a contact letter is sent from the clinician inviting them to participate in the research study. An information sheet of the study will also be sent out with the letter. At least a week after the letter and information sheet(s) have been sent, the patient will be contacted by the clinician / delegate or a Cardiff University researcher for the Arthritis Research UK Biomechanics and Bioengineering Centre with a research passport / letter of access for the relevant healthboard. This is to further determine suitability and to find out if the patient is interested in taking part in the relevant protocol. If so, arrangements will be made for the patient to take part. We will only carry out the study once the patient understands what is involved in the protocol and is willing to sign the corresponding consent form. Personal details of the patient will be stored on the Centre's secure, robust and password protected database which only persons with a research passport and letter of access or an NHS contract will have access to.

1.3.3 Post-treatment patients

The Centre will extract information for epidemiology/linkage purposes to determine clinical outcomes and further treatment following joint surgery for the treatment for musculoskeletal disease. This will involve screening present and past patient groups that have been previously been consented and taken part in this study. This will be carried out by clinical members of staff at the relevant Health Board (through funded clinical fellowships or as part of their research sessions as a UHB orthopaedic research fellows) to gain relevant information to determine the effectiveness of current or past treatments as well as determine any potential correlations in developing additional health problems due to the treatment. In the first instance, the Centre will determine the potential development of additional pathologies following joint replacement surgery and the insertion of orthopaedic devices. This will be carried out by clinical members of staff obtaining lists of patients who have had joint replacement in Cardiff and Vale Health Board over the last 10 years. The list will be obtained by searching through service databases, past operating lists and operation implant books which are filed away and stored securely on Health Board premises. This may also use the service of NHS Wales approved patient databases (such as the Patient Episode Database for Wales) to extract the information required (i.e. patients who have had certain joint replacements carried out within Cardiff and Vale Health Board over the last 10 years) and provided with correlating patient NHS numbers as the identifier. In addition, only clinical members of staff associated with the Centre's research will have access to these NHS patient numbers which will be stored on a secure password protected database. To determine the potential linkage between joint replacement surgery and the development of additional health problems this again will involve clinical medical staff searching Cardiff and Vale NHS service databases and medical notes to identify the development of specific pathologies that we are interested in following the joint replacement surgery. Centre-associated clinical members of staff may also screen the medical notes and service database of patients who have undergone joint replacement surgery to determine any correlations. All NHS numbers will be seen and handled by Centre-associated clinical members of staff only and stored on password protected database. Other data and findings generated from such studies which contain no patient personal information will be available to relevant research staff and statisticians for analysis. In addition, any form disseminations will include no patient personal information.

1.3.4 Volunteers

Pathological volunteers and age and gender matched healthy volunteers may also be recruited by expression of interest after gaining information on the Centre's/Cardiff University website. . The relevant ARUKBBC researchers will determine the volunteer's suitability via the inclusion and exclusion criteria. Pathological volunteers and age and gender matched healthy volunteers may also be recruited by expression of interest after gaining information on the Centre's/Cardiff University website. The relevant ARUKBBC researchers will determine the volunteer's suitability via the inclusion and exclusion criteria. If deemed suitable, the volunteer will be sent a volunteer information sheet about the study. Consent forms will also be sent so that the volunteer are made aware of what they may be asked to consent to should they wish to attend a data collection session. A minimum of 24-hour notice will always be given for the volunteer to decide whether they would like to participate in the study. It will be made clear to volunteer when they are first recruited that they will be free to withdraw from of the research at any. Willing participants will be contacted to arrange a convenient time for them to attend the research laboratories to conduct the assessment. Clear instructions on how to get to the place of assessment will be given.

1.3.5 Recruitment through participation of other Centre protocols

Participants may also be identified and recruited through their involvement with one or more of the Centre studies. participates deemed suitable who have provided permission to be contacted will be contacted by Arthritis Research UK BBC researchers at Cardiff University for further assessment for the purposes of each specific research study,

Letters and forms linked to Section 1

1. Permission to contact form:

2. Approved example recruitment letter:
3. Consent form: Payment of travel expenses for Arthritis Research UK Biomechanics and Bioengineering Centre volunteers

2. Protocol One - Assessment of joint function in healthy and pathological subjects using motion analysis techniques.

2.1 Background and Objective

The protocol is designed to investigate the differences in the motion and loading patterns in the joints of healthy subjects and those who have joint trauma or pathology that affect either their knees, hips, ankles, shoulders, elbow, wrists, hands or spine. This will include assessing patients pre- and post-operatively where appropriate. This will contribute to the development of non-invasive tools to aid orthopaedic consultants and physiotherapists in clinical diagnosis, prognosis of pathologies and to assess functional outcomes of different treatment models. In addition it will provide information on joint function and loading that can be related to other Centre protocols.

Joint replacements and joint-preserving surgery (such as osteotomies, where the bone is broken and re-aligned) have been designed by Biomechanical Engineers and Orthopaedic Consultant Surgeons in order to produce comfortable joints which move and function normally, such as for the knee, hip, shoulder, ankle, elbow and wrist, as well as for smaller joints of the hands and feet. It is the job of research Engineers, Orthopaedic and Physiotherapy experts to investigate the ways in which these types of devices work and to improve existing designs for the benefit of the patient. It is only through gaining a thorough understanding of the detailed way in which peoples' joints work in health and disease, as well as following treatment, that new and improved tools to aid orthopaedic consultants can be developed.

For some common activities, motion analysis methodology is well established in the literature. This includes quantitative clinical gait and motion analysis techniques used in the measurements of pre- and post-operative functional ability of total knee replacement patients and high tibial osteotomy patients [7, 8]. The motion analysis laboratory equipment comprises of multiple infra-red, digital cameras and video cameras, force plates, built into the floor of a specifically designed walkway (these detect forces in the floor but do not move and are level with the floor, so they do not alter gait and do not represent a risk of tripping), a number of electromyography sensors for measuring muscle activity, and also small movement sensors. Computer controls enable the simultaneous synchronous measurement of 3-dimensional movement, ground reaction forces and physiological measurements of the motion of points on the body (the movement kinematics). When combined with anthropometric measurements and force plate data, it can accurately calculate the centres of rotation and range of motion (ROM), and calculate the external forces and movement at the joint such as the ankle, knee, hip and shoulder (the movement kinetics). The force plates can also be used to measure the position of the centre of pressure, in order to assess the response to imbalances of the body's centre of gravity, and hence the patients' postural stability.

Research Team: Research undertaken in the Cardiff University Musculoskeletal Biomechanics Research Facility (formerly, the Motion Analysis Laboratory at the School of Engineering, 1996 – 2015), and the Research Centre for Clinical Kinesiology RCKK at the School of Healthcare Sciences, has been mainly in the field of motion capture and analysis technology applied to musculoskeletal biomechanics. This includes investigating the motion analysis, joint function and forces and muscle responses of children and adults with musculoskeletal and neuromuscular diseases and disorders, for example, osteoarthritis, cerebral palsy, joint trauma, and those undergoing surgical and non-surgical interventions, including users of wheelchair and other assistive devices. The laboratory staff and Centre members associated with these studies include Professor Cathy Holt, (BEng, PhD CEng FIMechE), the laboratory manager who is an experienced mechanical engineer with substantial experience of motion analysis with particular reference to orthopaedics and Dr Gemma Whatling, a Senior Lecturer (and, formerly a Cardiff Academic Fellow for the Centre), who also has extensive experience of motion analysis and conducted her PhD studies in the area of motion analysis in orthopaedics. Mr Chris Wilson (Consultant in Trauma and Orthopaedic Surgery and Honorary Professor at the School of Engineering) is also associated with these studies and involved in the design and development of the methodology. Professor Robert

Van Deursen (Director of the Research Centre for Clinical Kinesiology RCCK) and Dr Valerie Sparkes (Reader) have expertise in the field of lower limb complications and spine disorders and Clinical Specialist Physiotherapist, specialises in knee injury. Dr Liba Sheeran, Lecturer and clinical expert in back pain classification. Dr Rebecca Hemming specialises in Spinal pain and classification and Dr Jennifer Davies specialises in movement analysis.

The proposed protocol is to be carried out as part of a long-term research strategy to build up a sound research base in the field of 3D kinematics and kinetics of human joints (such as the knee, hip, ankle, shoulder and spine) for healthy function and ability with the aim to develop non-invasive tools to aid orthopaedic surgeons, physiotherapists and occupational therapists. The work will be carried out by laboratory staff associated with the Centre, under the supervision of the Laboratory Managers for the Schools of Engineering and Healthcare Sciences.

2.2 The overarching hypothesis is:

Assessment of joint function in healthy and pathological subjects using three dimensional motion analysis techniques (MOCAP) can elucidate biomechanical changes in patients with osteoarthritis to understand the disease mechanisms, targeted interventions, their efficacy and outcomes.

2.2.1 Protocol specific Primary Aim

Contribute to the development of non-invasive tools to aid orthopaedic consultants, physiotherapists, occupational therapists and medical device research and developers in clinical diagnosis, prognosis of pathologies and to assess functional outcomes of different treatment models, devices and interventions.

2.2.2 Protocol specific Secondary Aim

Provide information on joint function and loading that can be related to the other relevant Centre protocols.

2.2.3 The specific objectives of the studies that involve this protocol, taken from section 1.2 are to:

- Define how human joint function changes with age, exercise, disease and physiotherapy.
- Quantify forces within normal and diseased human joints.
- Provide clinical tools to quantify changes in human joint function for diagnosis and treatment.
- Identify therapies that target underlying causes of pain, pathology and inflammation in arthritis and other musculoskeletal conditions such as back pain and ACL rupture.
- Identify factors that influence recovery and dysfunction to inform rehabilitation.

2.3 Anticipated joint pathologies

The Centre's research remit will cover a number of joint and bone diseases that present at the orthopaedic, rheumatology and related physiotherapy clinics within the hospitals we have R&D approval for; these include the following:

Degenerative joint disease

OA
Chronic or non-specific spinal/back pain
Non-specific knee pain

Joint trauma/Injury

Anterior cruciate ligament damage/rupture/reconstruction
Meniscal tears
Cartilage fractures, cartilage/bone fractures
Soft tissue injuries

2.4 Inclusion and Exclusion Criteria

2.4.1 Patient inclusion Criteria

- Recruitment will target those attending orthopaedic clinics, rheumatology clinics and related physiotherapy clinics.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

2.4.2 Patient exclusion Criteria

- Inability to provide written informed consent.
- Patients that have any previous injury to the joint under investigation that that the treating clinician deems unsuitable.
- Other pathologies e.g. neurological or visual conditions which might affect the way they move

2.4.3 Healthy volunteer inclusion criteria

- Will be recruited into the protocol from the general public.
- Only those with no history of joint (under investigation) pathology or instability will be included.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

2.4.4 Healthy volunteer exclusion criteria

- Inability to provide written informed consent.
- History of pathology or instability of the joint under examination.
- Other pathologies e.g. musculoskeletal, neurological or visual conditions which might affect the way they move.

2.5 Sample Size Estimation

The protocol outlined in this document is designed for exploratory studies and therefore sample size estimation for patients with knee and spine pathologies is 400 over a 5 year period. This is based on the number of patients that have been involved in the last five years of the study including patient volunteers with knee and spine pathologies and healthy volunteers.

2.6 Timescale

The project has recently an additional £2M from ARUK over 5 years (1st Jan 2016-Dec 2020). The findings will be used to develop received appropriate testing for different pathologies, suitable techniques of statistical analysis will also be determined. The remainder of the time will be spent collecting data for the development of the diagnostic tool, as described below.

2.7 Patient Selection

Participant selection will be carried out as described previously in Section 1.3. Willing participants will be contacted to arrange a convenient time for them to attend the research laboratories to conduct the assessment. Clear instructions on how to get to the place of assessment will be given. Travel costs will be reimbursed to all participants.

2.8 Method / Study Design

Participants will be assessed either in the Cardiff University Musculoskeletal Biomechanics Research Facility (formerly, the Motion Analysis Laboratory at the School of Engineering, 1996 – 2015), or in the Cardiff University School of Health Care Sciences (HCARE) Research Centre for

Clinical Kinesiology (RCCK) or in the relevant clinical settings. This will be done once pre-treatment and up to six times post-treatment (where appropriate), at varying time intervals depending on the joint and/or injury. These sessions will normally last a maximum of three hours, including consent and explanation of the laboratory. With some pathology subgroups, two sessions each of two hours may suffice.

2.8.1 Laboratory and clinical movement analysis assessment Day

On the day of assessment the willing participants will be greeted and escorted by a member of staff at all times whilst on University premises. There will be six main tasks the participants will be asked to carry out-

1. Consenting to taking part
2. Complete relevant questionnaires
3. Change into appropriate garments for the assessment
4. Anthropometrical measurements taken (such as weight, height, length, knee width, thigh girth and circumferences of the trunk and upper extremities)
5. Assessment preparation - Marker placement (individual markers attached using wig tape and marker clusters attached using Coban tape). Possibly EMG surface electrode and inertial sensor placement, which may involve shaving and exfoliating the skin in preparation. Identifiable birthmarks and tattoos visible to the video camera will be covered with Tubigrip, if possible (if this is not possible these will be digitally masked during video editing). While participants faces will be visible during video recording, all participants identifiers (birth marks, tattoos, faces) will be digitally masked for research dissemination.
6. Carry out the assessment - (including different styles of level, incline, stair and treadmill gait, along with various activities such as sit to stand and passive range of motion).

There is lift access to all laboratories and toilets

1. Consent Process

Once patient eligibility has been determined, the patient will be contacted by a suitable Centre researcher (whom will have a research passport/letter of access or honorary NHS contract), who will provide the patient with further information. Upon arrival at the School of Engineering laboratories, RCCK or clinical setting patients will have the entire assessment explained again to them and have health and safety aspects of the laboratory or clinic. For NHS participants, it will be made clear that they are free to withdraw from the study at any time and that their participation in the research will not affect their relationship with the NHS in any way. Once patients/volunteers are satisfied and wish to participate in the study, if they wish to still take part, informed written consent will be obtained. Copies of the consent forms will be stored in a secure lockable filing cabinet and in a lockable room that only researchers with an NHS research passport or NHS honorary contract has access to. Information about the completed consent form will also be stored on the ARUKBBC secure and robust database.

2. Questionnaires and patient information pack

We plan to examine the loading and movement patterns of participants who have joint trauma or pathology affecting their knees, hips, ankles, shoulders, elbow, wrists, hands or spine as well as age, sex, weight and height matched "normal" controls. Willing participants will be asked to complete appropriate pain, quality of life and Activities of Daily Living questionnaires, which will be sent out in their information pack, prior to laboratory attendance. The questionnaires used will be pathology and joint specific as described previously, therefore note not all the questionnaires will need to be completed by each patient / volunteer).

Knee osteoarthritis (early and pre-operative) and knee pain patients
VAS pain score [7]

EQ5D [8]
KOOS (has an integrated WOMAC) [9]
The Oxford Knee Score [10]
Expectancy questionnaires [11]

Knee instability patients (i.e. ligament injury/reconstruction patients)

VAS pain score [7]
EQ5D [8]
Expectancy questionnaires [11]

Hip osteoarthritis and hip pain patients

VAS pain score [7]
EQ5D [8]
HOOS (has an integrated WOMAC) [9]
The Oxford Hip Score [10]
Expectancy questionnaires [11]

Back pain patients

VAS pain score [7]
EQ5D [8]
Oswestry Disability Questionnaire
Pain Catastrophizing scale (PCS)
Coping strategies questionnaire (CSQ)
Pain anxiety symptoms score (PASS-20)
StartBack
Roland and Morris Disability Questionnaire [14]
Distress Risk assessment Method [15]
Örebro Musculoskeletal Screening questionnaire [16]
Expectancy questionnaires [11]

Shoulder osteoarthritis/pain patients

VAS pain score [7]
EQ5D [8]
The Oxford Shoulder Score [17]
Expectancy questionnaires [11]
Patient screening questionnaire (Centre specific)
Patient expectation questionnaire (Centre specific – Based on Mannion et al, 2009¹ and MODEMS prognosis questions²)

Shoulder instability patients

VAS pain score [7]
EQ5D [8]
The Oxford Shoulder Instability Score [18]
Expectancy questionnaires [11]
SF-12³ (scored using the SF-6D, is a classification for describing health derived from a selection of SF-36 items. It is composed of six multi-level dimensions. Any patient who completes the SF-

¹ Mannion AF, Junge A, Elfering A, Dvorak J, Porchet F, Grob D. (2009) Great expectations: really the novel predictor of outcome after spinal surgery? Spine 34:1590-9

² Henn RF 3rd, Kang L, Tashjian RZ, Green A (2007) Patients' preoperative expectations predict the outcome of rotator cuff repair. J Bone Joint Surg Am.89:1913-9

³ <http://www.sf-36.org/tools/sf12.shtml>

36 or the SF-12 can be uniquely classified according to the SF-6D. The SF-6D describes 18,000 health states in total⁴).

Ankle patients (all ankle OA patients including pre/post-operative)

VAS for pain [7]

EQ5D [8]

Foot function index [19]

American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score (filled in by researcher)

Expectancy questionnaires [11]

Healthy Volunteers

VAS pain score [7]

EQ5D [8]

KOOS (has an integrated WOMAC) [9]

Expectancy questionnaires [11]

Wrist patients

DASH Outcome Measure (20)

QuickDASH (21)

Patient Rated Wrist/Hand Evaluation (22)

3. Change of clothing

Following the completion of the relevant questionnaires, participants will be asked to wear or bring clothing appropriate to the joint being examined (e.g. shorts for knee, well-fitting vest, sports bra or swimming costume for shoulder and spine, etc; female shoulder patients will be given a special apron to wear that leave their shoulders visible, but covers their chest). Participants will be asked to change clothing prior to the start of the assessment, this process will be conducted with the upmost professionalism to maintain comfortable environments for all parties and a screened off area will be provided for changing. During laboratory sessions, access to the laboratory is limited and a sign is placed on the door advising other staff not to enter whilst the research is in progress.

4. Anthropometrical measurements

The participants weight, height, thigh girth, medial-lateral and anterior-posterior knee widths measurements will be taken and recorded. The lengths and circumferences of the trunk and upper extremities (upper arm, forearm and hand) will also be measured and recorded during upper limb studies.

5. Pre-assessment preparations

During the session, participants will have a number of very light passive, retro-reflective markers (polystyrene or cork round markers) attached to the skin over bony landmarks and other areas of the head, trunk and limbs using double sided hypoallergenic tape or medical grade silicon based adhesive. This is to allow the calculation of segment and joint rotations using the recommended standards of the International Society of Biomechanics (23, 24). The locations of the passive, retro-reflective markers will be dependent on the joint type under examination.

6. Assessment

Range of Motion (ROM) of the joint may be quantified and the participants will be instructed to perform activities of daily living (such as walking with and without walking aids, running, standing, climbing stairs, wheelchair use, lower limb prosthesis use, combing hair or taking hand to mouth).

A series of recordings will be made using motion capture cameras and/or digital video cameras and/or inertial sensors allowing quantification of the 3D location of the reflective markers

⁴ <http://www.shef.ac.uk/scharr/sections/heds/mvh/sf-6d>
Version 12 – 30th November 2017

positioned on the body, attached to the skin and 2D analysis of joint motion. Audiovisual files will be digitally stored on password protected Cardiff University computer drives. Specific consent will have been obtained for the use and storage of video data. Data storage methods will be followed as per the guidelines below.

When appropriate to the joint under study, muscle activity and joint strength may also be determined during these sessions. This will involve placement of EMG electrodes onto the surface of the skin to record muscle activity during the motion measurement. The locations of the electrodes will be dependent on the muscle groups under examination and can be defined based on standard EMG techniques. A small (4x4cm) patch of hair may need to be shaved if this is done on hairy skin. An abrasive gel such as Nu-Prep (Weaver and Company, USA), may also be used to improve conductivity of the skin.

If the assessment is carried out in RCCK, participants may be asked to use the Motek V-Gait system, which consists of a treadmill, and screen for display of virtual reality scenes. The treadmill can move in an upward/downward pitch direction, a sideways sway or a perturbation (wobble). There will be a 180° semi-circular virtual reality screen,; motion analysis system, video cameras and/or sensors. in front of the participant that can display a variety of images to give the impression of walking on a forest path or kicking a ball, for example. This system will be used with the same marker sets and cameras as in the other motion analysis studies but participants will carry out the exercises on the treadmill. Participants will be required to wear a special harness whilst on the treadmill to prevent injury if they lose footing. There are safety procedures in place to limit the speed and movement of the treadmill and to abort the research if necessary.

Alternatively, if the assessment is carried out at the School of Engineering laboratory, study participants may be asked to use a dual-belt Bertec treadmill with an incline feature. Participants will be required to wear a safety harness whilst on the treadmill to prevent injury if they lose footing. Hand rails will be provided as additional support.

For upper limb ROM, the passive markers may also be combined with electromagnetic tracking device and a tracking device and a scapula locator (a three pointed rigid device used to palpate the bony landmarks of the scapula) to determine the orientation of one bone segment relative to another. Participants may also be asked to use a supporting brace which minimises rotation of the forearm by holding the elbow fixed at 90 degrees. The brace will be secured to the elbow using Velcro.

For back pain, patients will be asked to perform sitting and standing repositioning tasks, sitting on different types of chairs and seating devices whilst performing a desk based writing or attention task (typing, writing, using mobile phone), lifting, bending tasks, squats, sit to stand, gait on treadmill at different speeds and inclinations. Patients may be asked to perform these tasks with feedback that specifically targets their movement or motor control impairment to correct exercise technique. Functional tasks such as bending, stretching, lifting a cup from a table. Spinal movement (angular movement), together with gait parameters such as velocity, will be assessed whilst walking on a treadmill at different speeds and different inclinations. Patients may be asked to perform these tasks with feedback that specifically targets their movement or motor control impairment to correct exercise technique. The effect of specific motor control intervention for specific motor control deficits will be assessed compared to generic advice and self-management.

Patients will be assessed once pre-surgery/intervention and up to 6 times post-surgery/intervention over a 5 year period dependant on the cohort. Data will be kept securely for a minimum of 15 years from the end of the study in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance to the Data Protection Act 1998.

2.9 Ethical consideration

The worst outcome of participating in this research for the patient would be increase pain in their affected joint. The risk of this happening will be minimised by only allowing patients to perform activities that are considered bearable by the individual. The participant will be informed that regular breaks can be taken when needed. If the individual finds anything too painful they will have the right to terminate the assessment at any point. Where possible, different data collection sessions will be scheduled on the same day to minimise the inconvenience to patients. Patients will be given contact details of the research member to contact if symptoms persist.

2.10 Longitudinal Studies

As outlined in this document involve longitudinal studies, which will include contacting the participant in the future to invite them to take part in further studies. Before contacting the individual we plan to contact their GP to ensure they have not suffered any adverse health problem or have passed away. We aim to contact the GP approximately one month before inviting them to take part in further studies. We will ask each participant to consent to us contacting his or her GP via the consent form.

2.11 Payment of travel expenses

We will offer research participants reimbursement them for any travel expenses for undertaking any research activities that are not linked to their normal clinical care. We will use the current travel expenses consent form to allow their personal details (i.e. name, address and vehicle registration number) to be passed on to Cardiff University finance department.

2.12 Statistics and data analysis

Cross sectional studies are typically analysed using ANOVA with between and within group factors; normality and equal variance/sphericity assumptions are checked first; post hoc analysis is carried out using Bonferroni correction of the significance threshold.

Longitudinal studies are typically analysed using a repeated measures ANOVA; a polynomial contrast may be used. Otherwise linear regression analysis/stepwise regression is used to explore relations between predictor and dependent variables. Part of this analysis will always be the use of descriptive statistics and exploration of correlations; in part to achieve data reduction for the analysis mentioned above.

The salient characteristics of each pathology/injury will be examined. Age matched controls will also be examined and recruited as previously described. These volunteers will be consented and treated in exactly the same manner as patients. Standard clinical gait analysis techniques will be used to assess lower limbs. For all joints under study, kinematic and kinetic waveforms will also be analysed using Principal Component Analysis to reduce the multidimensional data sets whilst retaining temporal information about the function being analysed.

The resulting output variables will be combined for use in the development of an objective Dempster-Shafer classifier, similar to that used by Jones *et al* 2006 [25] which uses a number of input variables that are found to be salient to the joint and pathology or condition under study to classify healthy and pathological joint function.

For the spine, variables for different back pain subgroups will be input to the classifier. Appropriate statistical tests will be carried out determined by the type of data collected and number of comparisons being made. Being able to monitor normal, pathological and surgically altered joints whilst undergoing activities of daily living will allow us to monitor the effectiveness of joint

replacements, joint preserving surgery, rehabilitation and assistive device interventions, and further classify joint function.

Close work between orthopaedic surgeons, physiotherapists, scientists and engineers is improving the tools available for volunteer assessment and diagnosis and volunteers can clearly benefit from better diagnosis, thus promoting increased confidence in their medical care.

The motion analysis data (3D marker positions, muscle activity and inertial sensor measurements) will also be used as input to optimised musculoskeletal models of the patient. This will enable the engineers to develop patient specific models of the joints under investigation where temporal changes in joint loading and movement are quantified and then input to finite element analyses to determine the changes in the stresses acting across the articulating supporting tissues and bones.

2.13 Data storage and encryption

One of the important aspects of research into joint diseases, that this project will enable us to deliver, is the longitudinal study of patients, following a patient throughout multiple treatment cycles and methods, for as long as that patient is happy to participate.

It is essential that we maintain each patient's confidentiality, whilst being able to track a patient through the different treatment arms of the project. Once patients have entered our system they will be assigned a unique identifier which will follow them through the multiple arms of the study. This will be linked to their hospital patient number on a secure database, which only researchers in possession of a valid research passport and letter of access or a NHS honorary contract will have password protected access to. Other data, such as age, gender and aspects of medical history will be freely available to all researchers who need to have access to this data. All data will be held on encrypted university servers and password protected. Paper copies of consent forms and other relevant paperwork will be stored in a locked filing cabinet.

2.14 Data Storage and Data Sharing

Data will be kept securely for a minimum of 15 years in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance to the Data Protection Act 1998. We may wish to share fully anonymised study findings and related anonymised cohort information to research collaborators. Anonymised patient details we may like to share include patient age, gender and appropriate medical information (such as previous orthopaedic problems etc. and orthopaedic-related test results). The sharing of anonymised findings with collaborators with expertise in the related field will enhance our research results with the ultimate aim to improve patient benefit.

2.15 Disseminations

No video or photographic material that could identify a participant will be used in the dissemination of the results (publications, conference presentations), the patients/volunteers face will be masked and/or blurred (subject to the consent of the patient/volunteer) for any dissemination or presentation outside of the Arthritis Research UK Biomechanics and Bioengineering Centre.

2.16 Information Sheets & Consent Forms Protocol One

1. Patient information sheet & consent form: "Assessment of joint function in patients with joint problems using three dimensional motion analysis techniques" part 1 and part 2 / Consent form
2. Volunteer information sheet & consent form: "Assessment of joint function in healthy volunteers using three dimensional motion analysis techniques" part 1 and 2/ consent form

3. Protocol 2 - Fluoroscopic imaging

3.1 Fluoroscopy Studies at Cardiff

A previous pilot study carried out by Cardiff School of Engineering and local orthopaedic surgeon used dynamic fluoroscopy to examine knee and shoulder pathologies [26, 27]. The Arthritis Research UK BBC, now aims to continue with these studies by improving the accuracy and repeatability of the techniques currently in place and then to apply these methods to an increased subject. Dynamic fluoroscopy is used to analyse the movement of a joint and involves extremely low radiation exposure to the patient. Previous knee and shoulder studies have sought X-ray exposure data from the Radiation Protection Advisor (RPA) from Velindre NHS Trust prior to application for ethical approval for this protocol. The ARUKBBC, now aims to continue with these studies by improving the accuracy and repeatability of the techniques currently in place and then to apply these methods to an increased number of subjects, ultimately to quantify the differences of the kinematics and response to loading for healthy subjects and for patients with knee OA and/or knee interventions, e.g., knee replacement, knee realignment through surgical and non-surgical devices or rehabilitation.

During the patient assessment, two-dimensional (2D), fluoroscopic images are recorded over a short period of time whilst the patient performs a specific activity, e.g., knee flexion during step up, or arm elevations. During this time several frames are recorded where the adjacent, articulating bones or implant components are imaged to be moving relative to each other. Where patients to be studied are having joint replacement surgery, 3D, computer aided design models of the specific implanted components will be used to match with these 2D fluoroscopic images and these will be provided through the R&D departments of the companies that manufacture the implants. Where fluoroscopy is used to record the 2D movement of either patients' or healthy volunteers' bones, it is required to create 3D models of the bones under study for image registration techniques. In this case volunteers who have agreed to take part in Protocol 3 would have their knees MRI scanned. This provides data that can then be used to create 3D models of the bones. The 3D implant or bone models are then matched to the 2D fluoroscopic images, frame-by-frame, to quantify 3D kinematics of the joints using a process called 2D-to-3D image registration (using JointTrack software). Combined with a post-processing software (JointView), this tool can generate 3D knee kinematic data (such as joint angles and translations), identify knee centres of rotation, and contact points of the femur and tibia during the exercises. Kinematic outputs of the image registration method will be compared to other studies using the standard 3D marker or sensor based motion analysis techniques, for collecting such data. This type of work will contribute to development of non-invasive clinical tools for assessment of joint function in patients.

The results from this protocol can be used as inputs to studies that quantify joint loading and tissue response and can also be correlated with results from biological marker (biomarker) and motion analysis studies to further strengthen classification of subjects as healthy/osteoarthritic, and assess intervention outcomes.

In addition to recording Fluoroscopy images the volunteers may, in some cases, also have markers or sensors placed on their body as described in Protocol 1 (MOCAP). This is because our current system allows simultaneous capture of fluoroscopy images, human movement, ground reaction forces and electromyography. Using simultaneous marker or sensor based motion capture allows us to quantify errors and the gross kinematics of the lower limbs plus the internal knee kinematics combined with loading and muscle motor control. This allows us to collect a larger raft of data for the volunteer in one session with the addition of only 20 mins of time to apply the movement markers or sensors.

3.2 Protocol specific aims, objectives and overarching hypothesis

3.2.1 The overarching hypothesis is:

Assessment of joint kinematics and response to loading in healthy and pathological subjects using fluoroscopy can elucidate changes in joint and tissue response in patients with osteoarthritis, to understand the disease mechanisms, targeted interventions, their efficacy and outcomes.

3.2.2 Primary Aim

To develop the use of fluoroscopic imaging combined with image registration techniques to quantify in-vivo joint kinematics and response to loading. To correlate findings generated for patients that have also undergone any of the additional protocols. This aims to contribute to the development of non-invasive tools to aid orthopaedic consultants, physiotherapists, occupational therapists and medical device research and developers in clinical diagnosis, prognosis of pathologies and to assess functional and structural outcomes of different treatment models, devices and interventions.

3.2.3 Secondary Aim

Determine whether errors associated with marker or sensor based motion analysis can be calibrated using fluoroscopy to improve research into the development of clinical diagnostic tools. Correlate findings generated for patients that have also undergone any of additional Centre protocols.

3.2.4 The specific objectives of the studies that involve this protocol

Define how human joint function changes with age, exercise, disease and physiotherapy.

- Provide clinical tools to quantify changes in human joint function for diagnosis and treatment.
- Identify mechanically regulated biomarkers of joint degeneration and repair.
- Identify therapies that target pain, pathology and inflammation in arthritis.
- Identify factors that influence recovery and dysfunction to inform rehabilitation.

3.2.5 The objective of this protocol is to enhance current image based motion analysis techniques that have been developed at Cardiff University, to study the knee and ultimately to use the outputs to more accurately quantify the motion of the knee before and after joint replacement or remedial surgery/rehabilitation.

3.3 Anticipated joint pathologies:

The Centre's research remit will cover a number of joint and bone diseases that present at the orthopaedic, rheumatology and related physiotherapy clinics within the hospitals we have R&D approval for; these include the following:

Degenerative joint disease

OA
Non-specific knee pain

Joint trauma/Injury

Anterior cruciate ligament damage/rupture/reconstruction
Meniscal tears
Cartilage fractures, cartilage/bone fractures
Soft tissue injuries

3.4.1 Patient volunteer inclusion Criteria

- Recruitment will target those attending orthopaedic clinics, rheumatology clinics and related physiotherapy clinics.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

3.4.2 Patient volunteer exclusion Criteria

- Inability to provide written informed consent.
- Patients that have any previous injury to the joint under investigation that that the treating clinician deems unsuitable.
- Other pathologies e.g. neurological or visual conditions which might affect the way they move.
- If they are pregnant

3.4.3 Healthy volunteer inclusion Criteria

- Will be recruited into the protocol from the general public.
- Only those with no history of joint (under investigation) pathology or instability will be included.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

3.4.4 Healthy volunteer exclusion criteria

- Inability to provide written informed consent.
- History of pathology or instability of the joint under examination.
- Other pathologies e.g. neurological or visual conditions which might affect the way they move.
- If they are pregnant

Note: If there is any chance that they could be pregnant, the radiation exposure will not take place. We include this question in the Protocol 2 Healthy or Patient Volunteer Information Sheet and Consent Form, and if they answer they are pregnant they are excluded from the protocol. Advice from the RPS at UHW has suggested that they use a simple yes/no form, and if the Patient (in their case), states they are not pregnant they must sign the form along with a signature from the operator and the examination may safely proceed (Cardiff University – fluoroscopy screening form for low-dose procedures form). If the Patient (in their case), suspects that she may be pregnant, the examination must not proceed until pregnancy status is established. However, in the case of this Protocol, this is not applicable as the Protocol excludes all pregnant volunteers. Therefore the radiation exposure will not take place.

3.5 Sample Size Estimation

The protocol outlined in this document is designed for exploratory studies and therefore sample size estimation for patients with knee pathologies is 100 over a 5 year period. This is based on the number that have been involved in the last five years of the study including patient participants with knee pathologies and healthy participants.

3.6 Timescale

The project has recently an additional £2M from ARUK over 5 years (1st Jan 2016-Dec 2020). The findings will be used to develop received appropriate testing for different pathologies, suitable

techniques of statistical analysis will also be determined. The remainder of the time will be spent collecting data for the development of the diagnostic tool, as described below.

3.7 Method / Study Design

3.7.1 Patient Selection

Patient and healthy volunteer selection will be carried out as described previously in Section 1.3. Willing participants will be contacted to arrange a convenient time for them to attend and conduct the assessment. Clear instructions on how to get to the place of assessment will be given. Travel costs will be reimbursed to all participants.

Participants will be assessed at either in the new Cardiff University Musculoskeletal Biomechanics Research Facility (formerly, the Motion Analysis Laboratory at the School of Engineering, 1996 – 2015), or at Llandough Hospital. The assessment will be done once pre-treatment and up to 3 times post-intervention (where appropriate), at varying time intervals depending on the joint and/or pathology. Each session will last approximately 2 hours which will include a briefing session, the completion of questionnaires, measurements and preparation for the X-ray and the actual X-ray measurements which will take no more than 5 minutes.

3.7.2 Fluoroscopy Assessment Day

Since all previous studies and thus the Protocol have involved the NHS sites, this will continue to be the preferred site for participant assessment. Over the next 12 months, new Fluoroscopy facilities are being established in the School of Engineering, Cardiff University, and while this is happening the preferred site will be Llandough Hospital, however initial pilot studies to standardise the protocol will be undertaken in the new facilities. Once the new Fluoroscopy facilities have been commissioned and IRMER documentation and Local rules are in place patients will then be recruited to this new site only.

On arrival at the X-ray department, Llandough Hospital or School of Engineering, participants will have the entire assessment explained to them again. On the day of assessment the participants will be greeted and escorted by a member of staff at all times whilst on Llandough Hospital premises or School of Engineering premises. It will be made clear that they are free to withdraw from the research at any time and that their participation in the trial will not affect their relationship with the NHS in any way. Once participants are satisfied and wish to participate in the study, informed consent will be obtained.

Important note: All researchers involved in this protocol have gone through Radiation Protection Supervisor Training, Laboratory Health and Safety induction, GCP and Consent Training

There will be 5 main tasks the participant will be asked to carry out:

1. Consent to taking part
2. Pre-assessment screening
3. Questionnaires
4. Change of clothing
4. Anthropometrical measurements taken (such as weight, height, length, knee width, thigh girth and circumferences of the trunk and upper extremities).
5. Carry out the assessment

1. Consent Process

Once patient eligibility has been determined, the patient will be contacted by a suitable Centre researcher (whom will have a research passport/letter of access or honorary NHS contract), who will provide the patient with further information. Upon arrival the participant will have the entire assessment explained again to them and have health and safety aspects described. For NHS participants, it will be made clear that they are free to withdraw from the study at any time and that

their participation in the research will not affect their relationship with the NHS in any way. Once patients/participants are satisfied and wish to participate in the study, if they wish to still take part, informed written consent will be obtained. Copies of the consent forms will be stored in a secure lockable filing cabinet and in a lockable room that only researchers with an NHS research passport or NHS honorary contract has access to. Information about the completed consent form will also be stored on the ARUKBBC secure and robust database.

2. Pre-assessment screening

As per the Ionising Radiation (Medical Exposure) Regulations (IR(ME)R) documentation approved by the Velindre RPA and Cardiff University RPA, participants will be screened before further assessment. The screening form untitled "Cardiff University – Fluoroscopy Screening Form for Low-Dose Procedures" This form has two sections:

Participant Identification

It is the policy of the School of Engineering that the participant must be correctly identified (i.e. the person attending must be asked for their name, date of birth and their address as a minimum). It is the responsibility of the IR(ME)R operator to positively identify (check all participants details against the recruitment list) each participant. The IR(ME)R operator will ask the participant for their name, full address and DOB which the participant must provide without prompting from any member of staff, prior to exposure. These details are checked by another operator. If there are any discrepancies between the answers supplied by the participant and the information within the participant database (Arthritis Research UK Subject Database) and these can be satisfactorily explained by the participant then the examination may proceed. Such discrepancies may involve a recent change of address or the use of a single initial when the participant has more than one forename. If the participant cannot be positively identified, the examination must not proceed.

Adult females of a childbearing age

For females of childbearing age it is the policy of the School of Engineering and to check with all females aged 18-55 years as to whether they are pregnant or not prior to exposure. Participants will have already been provided with the criteria for being considered "not pregnant" within the Patient Information Sheet, and will have already confirmed they are not pregnant within the Consent Form. The Fluoroscopy Screening Form acts as an additional check that the participant meets the criteria, and ensures that during follow-up visits the participant is reminded of the criteria in case their circumstances have changed.

3. Questionnaires

We plan to examine participants who have joint trauma or pathology affecting their knees as well as age, sex, weight and height matched "normal" controls. Willing, consented participants will be asked to complete appropriate pain, disability, quality of life and function related questionnaires on the day of their first visit. These questionnaires will also be sent through the post prior to any subsequent visits. The questionnaires used will be pathology and joint specific and therefore note not all the questionnaires will need to be completed by each patient / participant):

Knee osteoarthritis (early and pre-operative) and knee pain patients

VAS pain score

EQ5D

KOOS (has an integrated WOMAC)

The Oxford Knee Score

Expectancy questionnaires

Knee instability patients (i.e. ligament injury/reconstruction patients)

VAS pain score

EQ5D

Expectancy questionnaires

Healthy Volunteers
VAS pain score
EQ5D
KOOS (has an integrated WOMAC)
Expectancy questionnaires

4. Change of clothing

Following the completion of the relevant questionnaires, participants will be asked to wear or bring clothing appropriate to the joint being examined (e.g. shorts for knee or well-fitting vest). There are appropriate changing facilities for all participants. Researchers are required to hold valid research passports, which require a DBS check as part of the application. Participants will be asked to change clothing prior to the start of the assessment, this process will be conducted with the upmost professionalism to maintain comfortable environments for all parties and a screened off area will be provided for changing. During laboratory sessions, access to the laboratory is limited and a sign is placed on the door advising other staff not to enter whilst the research is in progress.

5. Anthropometrical measurements

The participants weight, height, thigh girth, medial-lateral and anterior-posterior knee widths measurements will be taken and recorded. The lengths and circumferences of the trunk and upper extremities (upper arm, forearm and hand) will also be measured and recorded during upper limb studies.

6. Carrying out the assessment

Non-radiolucent markers will be placed on the joint being examined and held in place using Tubigrip™ or Coban™ self-adherent wrap. Passive retro-reflective markers will also be attached to the relevant bony landmarks and the patient / volunteer will also be asked to stand still for short periods of time (1 second), whilst a maximum of measurements is recorded using a palpator to indicate the positions of bony landmarks that cannot be identified by directly placing a marker over the landmark. These measurements will be recorded using motion capture cameras for approximately 5 minutes. This allows calibration for the individual participate and establishes both technical and anatomical 3D coordinate axes of the joint. The position information is processed later using specially designed computer software to relate anatomical axes to technical axes using transformation matrices, a neutral, quiet joint position is established. Small, lightweight inertial sensors may also be attached to the skin to record body movements. These will be located at similar locations to the markers, in order to measure gross movement of joints.

The participant will then be asked to perform a number of set joint movements whilst being recorded by both the motion capture cameras and the fluoroscope. These actions will be directed by either the researcher who is present and who is an IR(ME)R approved operator or by a trained radiographer at either the Hospital site or School of Engineering.. This will take approximately 20 minutes where the X-ray exposure will amount to a maximum of 5 minutes. Typical examples of tasks to be studied are, stepping up onto a 16 cm step to study knee function under loading or walking on a treadmill. These are representative of activities of daily living.

Participants will also be recorded using audiovisual cameras during the sessions. This is to allow re-assessment of results as a quality assurance measure. All data files and audiovisual files will be digitally stored on password protected Cardiff University computer drives. Participants anonymity will be ensured in any video content being presented / published using digital masking methods. Consent will be obtained for the use and storage of video data.

3.8 Ethical considerations

The use of X-rays raises ethical concerns. In this protocol we plan to analysis the knee

For the knee, the maximum effective radiation dosage has been approved by the Radiation Protection Service, Velindre NHS Trust, and is estimated to be 8.5 uSv (microSieverts), corresponds to approximately 28 hours of natural background radiation, to which we are all exposed continuously. In comparison a chest x-ray is considerably higher, equivalent to 10 days background radiation, and an oral dental x-ray has a similar dose to the intended maximum exposure. A 300 second exposure to the knee might correspond to a risk of lifetime induction of malignancy of one in 2.5 million. This places this imaging investigation within the level of risk graded as Category I – Trivial, defined in ICRP publication 62 "Radiological Protection in Biomedical Research". The X-rays will be recorded for an estimated maximum time of 300 seconds.

Please refer to the updated reports from the Radiation Protection Service, Velindre NHS Trust (22nd. June 2016), for further details of the calculated summary provide to the REC

3.9 Longitudinal Studies

As outlined in this document involve longitudinal studies, which will include contacting the participant in the future to invite them to take part in further studies. Before contacting the individual we plan to contact their GP to ensure they have not suffered any adverse health problem or have passed away. We aim to contact the GP approximately one month before inviting them to take part in further studies. We will ask each participant to consent to us contacting his or her GP via the consent form.

3.10 Payment of travel expenses

We will offer research participants reimbursement for any travel expenses for undertaking any research activities that are not linked to their normal clinical care. We will use the current travel expenses consent form to allow their personal details (i.e. name, address and vehicle registration number) to be passed on to Cardiff University finance department.

3.11 Statistics and data analysis

The fluoroscopic data will be saved during the patient/volunteer visit along with the motion capture coordinate data. The data will later be converted using Digital Imaging software to a file format compatible with image analysis. These files can then be used to shape match with CAD (Computer Aided Design) models of the implant and superimpose them onto the fluoroscopic images. 3D axes can then be established on the components and produce graphs of the range of motion of the study joint.

These axes will be compared to the motion capture files for the same set of measurements to quantify the difference between the two ranges of motion in order to quantify and calibrate the errors associated with skin movement artefact observed when using skin mounted markers. Body segment and joint coordinate systems will be established and joint and segment rotations calculated according to the recommendations of the International Society of Biomechanics [28, 29]. This data will also be used to develop patient specific musculoskeletal models that are optimised to quantify muscle and joint loading.

3.12 Data storage and encryption

One of the important aspects of research into joint diseases, that this project will enable us to deliver, is the longitudinal study of patients, following a patient throughout multiple treatment cycles and methods, for as long as that patient is happy to participate.

It is essential that we maintain each patient's confidentiality, whilst being able to track a patient through the different treatment arms of the project. Once patients have entered our system they

will be assigned a unique identifier which will follow them through the multiple arms of the study. This will be linked to their hospital patient number on a secure database, which only researchers in possession of a valid research passport and letter of access or a NHS honorary contract will have password protected access to. Other data, such as age, gender and aspects of medical history will be freely available to all researchers who need to have access to this data. All data collected during a patient session are stored on local hard drives on the Research Computers and archived on encrypted external hard drives. Paper copies of consent forms and other relevant paperwork will be stored in a locked filing cabinet.

3.13 Data Storage and Data Sharing

Data will be kept securely for a minimum of 15 years from the end of the study in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance to the Data Protection Act 1998. We may share fully anonymised study findings and related anonymised cohort information to research collaborators. Anonymised patient details we may like to share include patient age, gender and appropriate medical information (such as previous orthopaedic problems etc. and orthopaedic-related test results). The sharing of anonymised findings with collaborators with expertise in the related field will enhance our research results with the ultimate aim to improve patient benefit.

3.14 Disseminations

No video or photographic material that could identify a participant will be used in the dissemination of the results (publications, conference presentations), the patients/volunteers face will be masked and/or blurred (subject to the consent of the patient/volunteer) for any dissemination or presentation outside of the Arthritis Research UK Biomechanics and Bioengineering Centre.

3.15 Information Sheets & Consent Forms Protocol Two

1. Patient Information Sheet & consent form: "Assessment of joint function using fluoroscopic imaging techniques" part one and two/ consent form
2. Volunteer Information Sheet and consent form: "Assessment of joint function in healthy volunteers using fluoroscopic imaging techniques" part 1 and part 2/consent form

Other documents related to this protocol:

New knee radiation report dated 22/06/2016

Cardiff University – Fluoroscopy form for low-dose procedures

4. Protocol Three - MRI imaging for the joint “Joint imaging in patients with musculoskeletal disease and healthy people”

4.1 Background

Magnetic resonance imaging (MRI) is a well-established technique for imaging the body and brain using strong magnetic fields and low energy radio waves to make pictures of the inside of the human body non-invasively. MRI is routinely used in hospitals for diagnosis and identification of a range of musculoskeletal pathologies. In many instances, the extent of damage in the knee is hard to determine without invasive procedures such as arthroscopic surgery. Structural MRI can generate high resolution images of tissues in the knee, which when combined with a 3-D image data visualisation, analysis and model generation software, allows researchers to generate accurate computer-aided-design (CAD) models. Also, when combined with multiple lower resolution long-leg scans, computational models for the whole leg (top of the femur to the ankle) can be created.

In a process called 2D-to-3D image registration (using JointTrack software), 3D computational models generated from MR scan data can be shape matched to 2D fluoroscopy (video x-ray) images of patients' knees, while they are performing common daily activities such as a step-up, step-down exercise. Combined with a post-processing software (JointView), this tool can generate 3D knee kinematic data (such as joint angles and translations), identify knee centres of rotation, and contact points of the femur and tibia during the exercises. Kinematic outputs of the image registration method will be compared to other studies using the standard 3D marker based motion analysis techniques, for collecting such data. This type of work will contribute to development of non-invasive clinical tools for assessment of joint function in patients.

CAD models extracted from high resolution MR scan images of cartilage, bone and menisci can be used to generate quantitative data for regions of interest. For menisci and cartilage, deformation (change of shape) can be measured before and during joint loading. This will be achieved by subjecting patients or healthy volunteers to normal, everyday joint loads (20kg) within the MRI scanner, using a wooden rig with a weighted foot platform. Knee CAD models will also be used to measure cartilage thickness in diseased knees, pre- and post-surgical intervention to determine the longitudinal effect of the intervention on restoring cartilage back to a healthy state. 3D models can also be imported into finite element analysis software which allows simulation of patient specific models under load to calculate engineering principles such as strain and stress. The results from this protocol can be correlated with results from biological marker (biomarker) and motion analysis studies to further strengthen classification of subjects as healthy/osteoarthritic, and assess intervention outcomes.

2-Dimensional MRI sequences will also be used to generate high-resolution scans in a single plane, for qualitative assessment of structure and composition of knee tissues. Scoring systems including the 'MRI Osteoarthritis Knee Score' (MOAKS), 'Whole Organ Magnetic Resonance Imaging Score' (WORMS) and the 'Boston Leeds Osteoarthritis Knee Score' (BLOKS) are common practice in orthopaedic clinics, and will can be utilized in a research environment to qualitatively assess bone and soft tissue imaging markers of osteoarthritis, such as focal cartilage damage and the presence of bone marrow lesions. These assessments will provide information for tracking progression or regression of the disease to correlate with biomechanics and biomarkers of OA in response to interventions, to further elucidate their efficacy and outcomes.

4.2 Protocol specific aims, objectives and overarching hypothesis

4.2.1 The overarching hypothesis is:

Assessment of joint structure and composition and response to loading in healthy and pathological subjects using MRI can elucidate changes in tissue structure and composition in patients with

osteoarthritis to understand the disease mechanisms, targeted interventions, their efficacy and outcomes.

4.2.2 Protocol specific Primary Aim

To use MRI for non-invasive imaging tool applied to musculoskeletal tissues of the lower limb. This aims to contribute to the development of non-invasive tools to aid orthopaedic consultants, physiotherapists, occupational therapists and medical device research and developers in clinical diagnosis, prognosis of pathologies and to assess functional and structural outcomes of different pathologies, treatment models, devices and interventions.

4.2.3 Protocol specific Secondary Aim

Provide information on joint structure and response to loading that can correlate with findings with standard 3-D marker based motion analysis techniques, and biological indicators of disease in human samples (tissues, synovial fluid, blood and urine), to contribute to the development of prognostic and diagnostic clinical tools.

4.2.4 The specific objectives of the studies that involve this protocol, taken from section 1.2 are to:

- Define how human joint function changes with age, exercise, disease and physiotherapy.
- Provide clinical tools to quantify changes in human joint function for diagnosis and treatment.
- Identify mechanically regulated biomarkers of joint degeneration and repair.
- Identify therapies that target pain, pathology and inflammation in arthritis.
- Identify factors that influence recovery and dysfunction to inform rehabilitation.

4.3 Anticipated joint pathologies:

The Centre's research remit will cover a number of joint and bone diseases that present at the orthopaedic, rheumatology and related physiotherapy clinics within the hospitals we have R&D approval for; these include the following:

Degenerative joint disease

- OA
- Chronic or non-specific spinal/back pain
- Non-specific knee pain

Joint trauma/Injury

- Anterior cruciate ligament damage/rupture/reconstruction
- Meniscal tears
- Cartilage fractures, cartilage/bone fractures
- Soft tissue injuries

4.4 Inclusion and Exclusion Criteria

4.4.1 Patient volunteer inclusion Criteria

- Will be recruited into the protocol from the general public.
- Recruitment will target those attending orthopaedic clinics, rheumatology clinics and related physiotherapy clinics.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

4.4.2 Patient volunteer exclusion Criteria

2. Inability to provide written informed consent.
3. Patients that have any previous injury to the joint under investigation that that the treating clinician deems unsuitable.

4. Other pathologies e.g. neurological or visual conditions which might affect the way they move
5. Fitted with any electrical magnetic or mechanical implanted device (e.g. pacemaker, cochlear implant, artificial heart valve).
6. Further generic MRI exclusions as listed in the CUBRIC MRI initial screening form

4.4.3 Healthy volunteer inclusion criteria

- Will be recruited into the protocol from the general public.
- Only those with no history of joint (under investigation) pathology or instability will be included.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

4.4.4 Healthy volunteer exclusion criteria

- Inability to provide written informed consent.
- History of pathology or instability of the joint under examination.
- Other pathologies e.g. neurological or visual conditions which might affect the way they move.
- Fitted with any electrical magnetic or mechanical implanted device (e.g. pacemaker, cochlear implant, artificial heart valve).
- Further generic MRI exclusions as listed in the CUBRIC MRI initial screening form

4.5 Sample Size Estimation

The protocol outlined in this document is designed for exploratory studies and therefore sample size estimation for patients with knee and spine pathologies is 100 over a 5 year period. This is based on the number that have been involved in the last five years of the study including patient volunteers with knee and spine pathologies and healthy volunteers.

4.6 Timescale

The project has recently an additional £2M from ARUK over 5 years (1st Jan 2016-Dec 2020). The findings will be used to develop received appropriate testing for different pathologies, suitable techniques of statistical analysis will also be determined. The remainder of the time will be spent collecting data for the development of the diagnostic tool, as described below.

4.7 Patient Selection

Patient and healthy volunteer selection will be carried out as described previously in Section 1.3. Willing participants will be contacted to arrange a convenient time for them to attend and conduct the assessment. Clear instructions on how to get to the place of assessment will be given. Travel costs will be reimbursed to all participants.

4.8 Method / Study Design

Once participants have been identified as suitable and are willing to take part, Information packs will be given to the potential participant. MRI. A minimum of 24 hour notice would always be given for the patient to decide whether they would like to take part in the study. It will be made clear to patients when they are first recruited that they will be free to withdraw from of the research at any time. A CUBRIC, Cardiff University – MRI Unit Initial Screening Form may be given to participants alongside the information sheet so that suitability can be assessed. Participants will be assessed at Cardiff University Brain Research and Imaging Centre (CUBRIC). This will be done once pre-treatment and up to four times post treatment (where appropriate), at varying times intervals depending on the joint and/or pathology. Members listed research staff will conduct the assessment.

4.8.1 Laboratory assessment day:

On the day of assessment patients / volunteers will be greeted and escorted by a member of staff at all times when on University premises. Patients / volunteers will be asked to carry out five tasks which would normally last up to 1.5 hours in total:

1. Provide consent
2. Questionnaires
3. Assessment preparation
4. Screening
5. Assessment

There is lift access to the laboratories and toilets if required.

1. Consent process

Once patient eligibility has been determined, the patient will be contacted by a suitable Centre researcher (whom will have a research passport/letter of access or honorary NHS contract), who will provide the patient with further information. Upon arrival at CUBRIC building, patients will have the assessment fully explained to them and have the health and safety aspects described. For NHS participants, it will be made clear that they are free to withdraw from the study at any time and that their participation in the research will not affect their relationship with the NHS in any way. Once patients/volunteers are satisfied and wish to participate in the study, if they wish to still take part, informed written consent will be obtained. Copies of the consent forms will be stored in a secure lockable filing cabinet and in a lockable room that only researchers with an NHS research passport or NHS honorary contract has access to. Information about the completed consent form will also be stored on the ARUKBBC secure and robust database.

2. Questionnaires

We plan to examine the loading and movement patterns of participants who have joint trauma or pathology affecting their knees or spine as well as age, sex, weight and height matched "normal" controls. Willing, consented participants will be asked to complete appropriate pain, disability, quality of life and function related questionnaires which will be sent out in their information pack, prior to data collection visit. The questionnaires used will be pathology and joint specific as described previously in section 1.6 (therefore note not all the questionnaires will need to be completed by each patient / volunteer):

Knee osteoarthritis (early and pre-operative) and knee pain patients

VAS pain score
EQ5D
KOOS (has an integrated WOMAC)
The Oxford Knee Score
Expectancy questionnaires

Knee instability patients (i.e. ligament injury/reconstruction patients)

VAS pain score
EQ5D
Expectancy questionnaires

Back pain patients

VAS pain score
EQ5D
Oswestry Disability Questionnaire
Pain Catastrophizing scale (PCS)
Coping strategies questionnaire (CSQ)

Pain anxiety symptoms score (PASS-20)
StartBack
Roland and Morris Disability Questionnaire
Distress Risk assessment Method
Örebro Musculoskeletal Screening questionnaire
Expectancy questionnaires

3. Assessment Preparation

Participants will be directed to the changing rooms, and asked to get changed into shorts. They will also be asked to ensure there are no metal objects, jewellery or anything that may harm the patient or affect the scanner (listed on the CUBRIC screening form) in their presence. Two short and two long plastic marker holders (used for image matching post scan) will be attached to various places on the examined leg using hypoallergenic double-sided tape. Tubigrip™ will also be used to hold the marker holders securely on the leg. Height and weight will be measured with equipment in the pre-MRI scan room and recorded on the screening form.

4. Screening

The participants will be asked to fill out a CUBRIC initial and second screening form to ensure they are medically suitable for the protocol, and that they do not carry any particular risks into the scanner such as metal objects or jewellery (the second screening form lists these risks in detail). The screening forms will be checked by the researcher and then passed onto the CUBRIC MRI radiographer for approval, prior to entering the MRI room.

5. Assessment

Participants will be guided into the MRI scanner room and asked to lay down on either the scanner platform for the non-loaded scans, or the padded wooden platform (loading rig) for the loaded, and will be asked to adjust themselves until comfortable. They are also provided with a cushion and quilt for comfort and warmth. The researcher or radiographer will loosely wrap a limb coil around the knee for higher resolution scanning. There also may be adjustments to positioning made by the radiographer to ensure the participant is correctly lying for entry into the scanner bore. The participants will also be given soft ear plugs to help mitigate the loud noises given off by the scanner when in use.

For participants to be scanned under loaded conditions, the researcher or radiographer will manipulate the position of the knee to the relevant position (flexed, internally or externally rotated) before entry, and support the leg with foam wedges and padding. Once the initial scout scan is carried out, 20kg sandbags are gently placed into the loading rig to generate a gradual load on the joint and prevent sudden loading. The load generated by the 20kg sandbags are normally equivalent to much less than body weight and therefore should not feel uncomfortable, however in every occasion the participant is asked to confirm they are comfortable with the load and are not experiencing any pain.

The participant will be asked to remain as still as possible throughout the entirety of the scans, each of which usually last 6-10 minutes depending on the scan sequence used, with a maximum total scanning time of 60 minutes.

Scan sequences may differ from participant to participant and from lower to upper limb joints, depending on height (normally 3 but may be 4 in the case of tall participants). There are 2 sets of scans for each subject being imaged, for example, when imaging the knee:

- Full lower leg imaging in three to four sections depending on height of patient (around the hip, around the knee and around the ankle with overlap between the two neighbouring images).

- High resolution imaging around the knee at full extension neutral position, or flexed at normally 45° (depending on the height of the patient).

Full lower limb imaging involves the following scanning:

- 5-10 second scout scan
- Spoiled Gradient Recalled Acquisition sequence (8 minute acquisition time). Centred on the approximate joint centre, the scan consists of an echo time of 1.32ms, repeat time 3.8s and section thickness of 10mm; 256x256 matrix.

High resolution knee imaging involves the following scanning:

- 5-10 second scout scan
- 6 to10 minute scans involving a section thickness of 0.5 to 3 mm and a 256x256 matrix. This can involve several scanning options including Three-dimensional (3D) constructive interference in steady state (CISS3D), Proton density Turbo Spin Echo Two Dimensional (PD-TSE 2D), Three-dimensional Double Echo Steady Date (DESS), T1 Mapping Anatomical Scans and Steady State Free Precession Imaging (TruFISP).
- .

These allow for sufficient resolution images to enable segmentation and creation of bone and soft tissue structures for modelling and image registration and identification of tissue features that can be correlated with metabolic changes due to osteoarthritis and trauma to the joint.

Participants who find it problematic lying down in a scanner for the full scan time will be offered rest periods, however the overall time of the study will be extended.

4.9 Ethical Considerations

MRI involve minimal risk. No serious side effects of being in an MRI scanner have been reported despite millions of scans having been worldwide. Although the possibility of long-term effects cannot be completely ruled out, the weight of experience and opinion is against this.

Some people find being inside an MRI scanner claustrophobic although this is less so with the more compact systems like those used in CUBRIC. The scanner also makes quite loud noises for which we provide ear plugs. The radiofrequency waves we use to create the MR scans and profiles can cause your head and body to warm up slightly. This is not a problem, and the volunteer usually won't notice it, as their blood flow will increase slightly to take the heat away; the scanner room is kept quite cool so that the volunteer always remains comfortable.

A few people have reported minor side effects including dizziness, mild nausea, a metallic taste in the mouth, and the sensation of seeing flashing lights. These side effects, if experienced, go away as soon as the volunteer leaves the magnet.

If the subject finds the experience in the scanner unpleasant, they are asked to squeeze the emergency stop button, which alerts the researcher and actions can be taken to and take the subject out of the scanner.

Patients / volunteers who may find it problematic lying down in a scanner for the full scan time will be offered rest periods, however the full study time will be extended. The worst outcome of participating in this research for the subject would be loose magnetic objects within the MRI scan room causing an injury, or a vital internal device such as a pacemaker being affected by the magnet within the scanner. The risk of this happening is minimised by the researcher explaining the risks and dangers of being in the presence of an MRI scanner before entry, and a two stage screening process requiring subjects to clearly mark their understanding of each of these risks and sign underneath.

The Patient and Healthy Volunteer Information Sheets state that “Patients will be advised that they should not take part if they:

- have now or have had in the past cardiac (heart), vascular (blood vessel) or respiratory/pulmonary (breathing/lung) conditions, including high blood pressure
- have now or have had in the past a neurological (brain or nerve) disease
- experience dizziness or fainting
- have a pacemaker
- suffer from either asthma or diabetes mellitus
- are pregnant or have given birth in the last 6 weeks
- have a history of drug dependency
- have taken illicit drugs in the last 4 weeks
- have been involved in any drug trials (scientific studies involving you taking a drug) in the last 4 weeks”

Participants will be informed that they have the right to withdraw at any time without the need to provide a reason and that it will not affect the provision of or standard of their future care. Participants have the right to be treated justly and therefore, putting the participants first, considering the issues involved in the research and providing clear and accurate information from invitation to learn more about the study through to providing debriefing information serves to deliver justice.

Participants who find it problematic lying down in a scanner for the full scan time will be offered rest periods, however the overall time of the study will be extended.

4.10 Longitudinal Studies

As outlined in this document involve longitudinal studies, which will include contacting the participant in the future to invite them to take part in further studies. Before contacting the individual, we plan to contact their GP to ensure they have not suffered any adverse health problem or have passed away. We aim to contact the GP approximately one month before inviting them to take part in further studies. We will ask each participant to consent to us contacting his or her GP via the consent form.

4.11 Payment of travel expenses

The Centre will offer research participants reimbursement for any travel expenses for undertaking any research activities that are not linked to their normal clinical care. We will use the current travel expenses consent form to allow their personal details (i.e. name, address and vehicle registration number) to be passed on to Cardiff University finance department.

4.12 Statistics and data analysis

Kinematic measurements including internal and external rotation of the tibia relative to the femur, joint translations, and knee joint angles during activities of daily living can potentially be more accurately measured using 2D to 3D image registration techniques compared to 3D marker-based motion capture. Therefore, a direct comparison of data from both techniques can be made to determine these differences, and validate motion capture methods. Centres of rotation for the knee can also be extracted using both techniques, and as a critical factor in collecting accurate data, is important for comparison between the two.

In our longitudinal studies, cartilage thickness measurements will be compared with kinematic outputs from image registration or 3D motion analysis techniques, pre-surgery and post-surgically up to 5 years. Statistical analysis can then determine what effect the destruction or repair of cartilage

has on joint biomechanics (kinetics and kinematics). Similarly, cartilage thickness will also be compared to concentrations of biomarkers or metabolomic patterns representing disease in human samples (tissue, synovial fluid, blood and urine), to determine how cartilage thickness affects the biological environment of the knee.

Kinematic waveforms will be analysed using standard clinical motion analysis techniques such as parameterisation i.e. calculating maximum and minimum values for specific phases of the activity. These waveforms will also be analysed using Principal Component Analysis, an objective method of reducing temporal information into far fewer discrete variables, while still representing the majority of the variance between the subjects.

In addition to standard statistical techniques, an objective data classification technique will be utilised. The classification tool developed at Cardiff University, based on Dempster-Shafer theory and described by Jones *et al* 2006 [33], uses a number of input variables from a training body of healthy and pathological subjects in order to classify joint function. This tool allows the objective consolidation of the large wealth of data which can be obtained within this protocol. By consolidating this information, it is possible to monitor normal, pathological and surgically altered joints to monitor the effectiveness of joint replacements or joint preserving surgery, and further classify joint function. It will also be possible to compare the classified joint function with the aforementioned biomarkers, and patient reported outcome measures.

Qualitative bone and soft tissue assessments using the 2D MRI scan sequence will be carried out following the 'MRI Osteoarthritis Knee Score' (MOAKS), 'Whole Organ Magnetic Resonance Imaging Score' (WORMS) and the 'Boston Leeds Osteoarthritis Knee Score' (BLOKS) protocols. The assessments will lead to scores, which can be tracked longitudinally for looking at changes in tissue structure and composition, and directly correlated to biomechanics and biomarkers of OA in response to interventions, to track progression or regression of the disease, and to further elucidate their efficacy and outcomes.

4.13 Data storage and encryption

One of the important aspects of research into joint diseases, that this project will enable us to deliver, is the longitudinal study of patients, following a patient throughout multiple treatment cycles and methods, for as long as that patient is happy to participate.

It is essential that we maintain each patient's confidentiality, whilst being able to track a patient through the different treatment arms of the project. Once patients have entered our system they will be assigned a unique identifier which will follow them through the multiple arms of the study. This will be linked to their hospital patient number on a secure database, which only researchers in possession of a valid research passport and letter of access or a NHS honorary contract will have password protected access to. Other data, such as age, gender and aspects of medical history will be freely available to all researchers who need to have access to this data. All data collected during a patient session are stored on local hard drives on the Research Computers and archived on encrypted external hard drives. Paper copies of consent forms and other relevant paperwork will be stored in a locked filing cabinet.

4.14 Data Storage and Data Sharing

Data will be kept securely for a minimum of 15 years from the end of the study in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance to the Data Protection Act 1998. We may share fully anonymised study findings and related anonymised cohort information to research collaborators. Anonymised patient details we may like to share include patient age, gender and appropriate medical information (such as previous orthopaedic problems etc. and orthopaedic-related test results). The sharing of anonymised

findings with collaborators with expertise in the related field will enhance our research results with the ultimate aim to improve patient benefit.

4.15 Disseminations

Any data presented (e.g. journal articles, conferences, Centre's website) will not contain any participants personal information.

Information Sheets & Consent Forms - Protocol Three (section 2.3.2)

1. Patient info Sheet & consent form: "Assessment if joint structure and response to loading in patient volunteers using Magnetic Resonance Imaging" part 1 and part 2/consent form
2. Healthy Volunteer information sheet and consent form: "Assessment if joint structure and response to loading in healthy volunteers using Magnetic Resonance Imaging" part 1 and part 2/consent form

Other supporting documents for this protocol:

CUBRIC Initial Screening form

CUBRIC Second Screening form

CUBRIC visitor screening form – access to the outer controlled area

Protocol Four - The analysis of human samples to study the structure, function, metabolism in joints and identify biomarkers in joint pathology

5.1 Background

This protocol will focus on protocol number four; Samples (The analysis of human samples to study the structure, function, metabolism in joints and identify biomarkers in joint pathology).

The Samples protocol will be used to understand how mechanical loading activates signals in joint tissues, leading to OA onset and progression. Revealing biological effects of altered joint biomechanics from injury or surgery will inform clinicians about surgery/rehabilitation efficacy, identify new drug targets to prevent OA progression and reveal new diagnostic and prognostic biomarkers. No therapeutic options directly target the biological effects of mechanical loading in arthritis and no studies have translated such findings from basic science to human intervention trials. Our loading models and longitudinal data matching biomechanics to biology in humans address this knowledge gap.

5.2 Protocol specific aims, objectives and overarching hypothesis

5.2.1 The overarching hypothesis is:

Biological mechanisms underlying pathological changes in degenerative musculoskeletal diseases will reveal new interventions or diagnostic/prognostic tools for arthritis.

5.2.2 Protocol specific Primary Aim

To provide evidence of biomechanically regulated biomarkers and pathways linked to the development of joint pathology, inflammation, pain and to develop diagnostic and therapeutic targets.

5.2.3 Protocol specific Secondary Aim

Provide information on joint function and loading that can be related to the other relevant protocols.

5.2.4 The specific objectives of the studies linked to this protocol from the overarching objectives of the ARUKBBC are to:

- Identify mechanically regulated biomarkers of joint degeneration and repair.
- Identify mechanically regulated therapeutic targets for arthritis
- Identify pain indicators that correspond to joint loading.
- Identify therapies that target pain, pathology and inflammation in arthritis.

5.3 Centre specific projects will be conducted in ARUKBBC to address these aims and objectives. Examples of these projects are:

Biomechanics and biology in HTO patients.

Longitudinal assessment of HTO patients to determine how altered joint biomechanics influences signals in the bone, joint fluids/blood/urine that cause pain, inflammation and pathology.

Approach: Quantify mRNA expression from HTO bone cores pre/post-surgery, using established assays and relate to associated structural, clinical and motion analysis data. Analyse fluids pre/post-surgery for markers of bone remodelling and global/targeted biomarkers.

Numbers of tests to be undertaken on each participant: Bone cores and synovial fluid at surgery and plate removal. Blood and urine pre, and 3/6/12 months post-surgery (some will have some/all ENGIN analyses).

Analysis plans: multivariate analysis of gene expression changes (bone) and biomarker changes (joint fluids and urine) related to clinical and physical data.

Glutamate receptor antagonists in joint injury

Determine if ACL/meniscal injury increases synovial fluid glutamate concentrations to activate GluRs, which may be therapeutically targeted after injury to protect against OA.

Approach: Determining how mechanical loading of bone influences glutamate concentrations to cause joint degeneration, and which GluRs mediate these responses in vitro and in vivo. GluR antagonists (patent filed) are ideal candidates for treatment and/or prevention of early onset OA following ACL/meniscus injury. Measurement of glutamate concentrations in human synovial fluid following ACL/meniscus injury will inform treatment regime for this work.

Numbers of tests to be undertaken on each participant: blood and synovial fluid close to time of injury and at surgery/arthroscopy. Waste tissue (ligament/meniscus) from surgery will be taken if possible. TKR waste tissue is used to observe expression of specific glutamate receptors.

Analysis plans: glutamate concentrations (ELISA, Novus, sensitivity 0.3-60µg/ml) will be measured to indicate range and related to other pro-inflammatory markers (IL-6, TNF) to inform drug concentrations required for future intervention trials.

NBQX percutaneous delivery

To determine if GluR antagonists such as NBQX are suitable for percutaneous delivery in arthritis treatment.

Approach: NBQX, or other AMPA/Kainate glutamate receptor antagonists may be amenable to percutaneous penetration as a unionised molecule or a co-drug with an ibuprofen analogue. Physico-chemical parameters will be assessed and efficacy of penetration tested in porcine skin and bovine joint models to assess percutaneous and synovial fluid drug delivery, respectively. Measurement of glutamate concentrations in human synovial fluid following ACL/meniscus injury will inform treatment regime for this work.

Mechanically regulated biomarkers in injury-induced OA

To determine if mechanically regulated biomarkers identified from rodent ACL rupture model will reflect longitudinal changes in joint fluid/blood/urine from ACL rupture patients ND reveal diagnostic, prognostic and treatment efficacy tools.

Approach: The ACL-rupture model will identify targeted (neurotransmitter/inflammatory/bone) and global (NMR) biomarkers associated with disease progression. Biomarkers will be validated against longitudinal human blood/urine/joint fluid samples taken after ACL injury.

Analysis plans: multivariate analysis (e.g. PCA and LDA) of various global biomarkers developed by Centre staff (e.g. NMR, microparticles) or targeted analyses of single biomarkers (e.g. transglutaminase, glutamate, adenosine, miRNAs). Longitudinal analysis allows within patient variation to be assessed and increases power over cross sectional analysis. Biomarkers will be correlated to clinical scores of pain/function, functional motion analysis data and used to reveal biomarker patterns and patient classification.

Bone model for drug screening

Investigate if human osteocyte and osteocyte/osteoblast models, incorporating physiological loading and genetic mutations in multi-well plate format will reveal disease mechanisms to provide new drug screening tools for osteoporosis and osteoarthritis.

Approach: The Centre will combine our osteocyte mono- and co-culture models and adapt our loading plate to a high throughput model, where effects of loading (experienced in human bone)

and genotype can be assessed. This project needs waste joint tissue for cell culture. Numbers of tests to be undertaken on each participant: Waste tissue from surgery will be taken. Analysis plans: Cells grown from the tissue are used in various bone cell assays including proliferation, differentiation, gene/protein expression, mineralization and biomarker release. The effect of mechanical loading, and other treatments (transfection, drugs etc.) will be analysed using standard approaches (e.g. ANOVA and Fishers post hoc tests for parametric data).

Adenosine in bone and cartilage responses to mechanical loading
Investigate adenosine signalling in the response of bone and cartilage to mechanical loading will reveal new disease mechanisms leading to novel targets for preventative and/or treatment. Approach: Use human 3D culture methods for osteocytes and chondrocytes to measure adenosine release, and investigate adenosine receptor signalling response to loading and cross-talk between osteocytes/osteoblasts and osteocytes/chondrocytes. This project will need waste joint tissue for cell culture.

Biochemical markers that predict joint degeneration following injury
Conduct longitudinal assessment of biomarkers following ACL/meniscal injury to determine predictors of early OA. Approach: Collection of joint fluid/urine/blood after ACL/meniscal injury. Retrospective analysis of longitudinally collected samples to identify/verify biomarker patterns at the onset of disease along with controls. These data will be compared with OARSI biomarkers, and our novel global/targeted biomarkers.

Biomarkers in low back pain.
To identify biomarkers at early and late stage presentation of non-specific low back pain. This together with patient reported outcomes will inform the development of chronic pain syndromes and will link clinical outcomes to loading and pain. Inflammatory biomarkers in the acute stage will inform targeted treatment in order to reduce chronicity.
Approach: Collection of blood and urine at presentation of acute onset and presentation at physiotherapy clinics. Analysis may be associated with radiology results if any are available as requested by the GP. Number of tests: 4 in total, (onset of disorder and 3, 6, 12 month follow up)

5.4 Anticipated joint pathologies:

Degenerative joint disease

- OA
- Chronic or non-specific spinal/back pain
- Non-specific knee pain

Joint trauma/Injury

- Anterior cruciate ligament damage/rupture/reconstruction
- Meniscal tears
- Cartilage fractures, cartilage/bone fractures
- Soft tissue injuries

Inflammatory arthropathies

- RA
- Psoriatic arthritis
- Gout

Disorders of bone remodelling and inflammation

- Osteoporosis
- Osteolysis

5.5 Inclusion and Exclusion Criteria

5.5.1 Patient inclusion Criteria

- Recruitment will target those attending orthopaedic clinics, rheumatology clinics and related physiotherapy clinics.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

5.5.2 Patient exclusion Criteria

7. Inability to provide written informed consent.
8. Other pathologies e.g. neurological or visual conditions which might affect the way they move
9. Known infectious pathologies (such as Hep-B)

5.5.3 Healthy volunteer inclusion criteria

- Will be recruited into the protocol from the general public.
- Only those with no history of joint (under investigation) pathology or instability will be included.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

5.5.4 Healthy volunteer exclusion criteria

- Inability to provide written informed consent.
- History of pathology or instability of the joint under examination.
- Other pathologies e.g. musculoskeletal, neurological or visual conditions which might affect the way they move.
- Known infectious pathologies (such as Hep-B)

5.6 Sample Size Estimation

The protocol outlined in this document are exploratory studies and therefore sample size estimation is difficult to obtain. However, based on the last 5 year recruitment rate and needs of the projects, the estimated sample sizes are:

HTO patients – 50 patients over the 5 year period

Total knee replacement patients - 150 over a 5 year period.

ACL injury patients – 100 over a 5 year period

MT patients – 100 over a 5 year period

5.7 Timescale

The project has recently been awarded an additional £2M from ARUK over 5 years from 1st Jan 2016 to Dec 2020. This time will be spent collecting samples and data for the development of the diagnostic and treatment tools for testing in

5.8 Patient Selection

Patient and healthy volunteer selection will be carried out as described previously in Section 1.3. Willing participants will be contacted to arrange a convenient time for them to attend and conduct

the assessment. Clear instructions on how to get to the place of assessment will be given. Travel costs will be reimbursed to all participants.

5.9 Method and study design

Patients will be recruited through various means as previously described. . Before samples are taken, patients must have at least 24h to read the relevant Patient Information Sheet (PIS), had the opportunity to discuss the study, ask any questions and willingly sign an informed consent form. Copies of the completed consent forms will be stored in a secure lockable filing cabinet and in a lockable room that only researchers with an NHS research passport or NHS honorary contract have access to. Information about the completed consent form will also be stored on the ARUKBBC secure and robust database with only researcher with an NHS research passport or an NHS honorary contract.

The Centre is interested in collecting and analysing a number of different biological samples which include 1. Clinical waste samples collected during routine clinical procedures; 2. Blood and Urine samples, 3. Joint fluid not taken as part of a routine clinical procedure and 4. Bone Cores taken during HTO procedure and HTO plate removal.

5.9.1 Clinical waste samples during routine clinical procedures

The Centre will collect patient's clinical waste samples from consented patients during a routine orthopaedic or rheumatology clinical procedure (that is normally incinerated as waste). These samples include:

- Synovium, joint capsule, ligaments, tendons, cartilage, meniscus, fat pad from joint replacement surgery and any attached bone.
- Waste bone, associated bone marrow and other tissue obtained from other orthopaedic surgeries.
- Musculoskeletal soft tissues; tendon and associated sheaths, ligaments, joint capsule and any attached bone from shoulder, elbow, wrist, hand, hip, knee or ankle/foot reconstruction.
- Intervertebral disc tissues and spinal ligaments, cartilage endplate, facet joint, synovial fluid and attached bone obtained at spinal surgery.
- Synovial fluid taken from synovial joints prior to lavages, joint replacement surgery, HTO, arthroscopy.

Participants can be recruited at any point prior to surgery as previously described. Willing patients will be consented before any procedure at least 24 hours after receiving information sheets about the study. Where appropriate, participants may also be recruited through their involvement with one of more of the other Centre protocols. Following consent, researchers will communicate with the patient's consultant about the date and time of the patient's procedure to arrange sample collection. Following the clinical procedure, the sample waste will either be stored at 4°C or in a liquid nitrogen cooled dry shipper (approximately -150°C) located near theatre/clinic with identification/permission access only dependant on the sample. Researchers with appropriate research passports and letter of access or honorary NHS contracts will either collect and transport the sample to Cardiff University or arrange for collection with through an agreement with a local taxi company (Dragon Taxis). The samples will be given a unique identification code and stored appropriately.

Number of times samples will be collected: for the collection of clinical waste, this is dependent on the pathology and the number of times the patient has an operation in relation to their pathology. Clinical Waste will only be collected during surgery where there is clinical waste which normally be destroyed after the operation.

5.9.2 Blood and Urine samples

The Centre will obtain blood, urine and synovial fluid samples from patients, and healthy volunteers (following consent) to identify biomarkers of disease. The objective is to investigate the cellular and biochemical constituents of blood and synovial fluid, as well as catabolites found in urine, in healthy subjects and those who have joint trauma or pathology affecting synovial joints (knees, hips, ankles, shoulders, elbow, wrists, and hands) or spine. Our aim is to identify changes in the pattern of these constituents by following individual patients over time (longitudinally) and also comparing patients to healthy individuals and various other control groups (cross-section). This will contribute to the development of non-invasive tools to aid orthopaedic and rheumatology consultants as well as physiotherapists in clinical diagnosis, prognosis of pathologies and to assess functional outcomes of different treatment modes. In addition, this will add to our understanding of the normal and pathological processes that are involved in degenerative joint disease and the factors that influence progression and recovery (the state of immune system, joint loading, etc.). These samples will be obtained with the volunteers/patients prior written and signed consent and knowledge of what these samples will be used for.

5.9.3 Joint fluid from non-clinical procedure

Patients will be identified as the same for the collection of blood and urine and asked by their treating clinician whether they would consider having synovial fluid aspirated from their joint so research studies can be conducted on the sample(s). It will be emphasised that the procedure to obtain the sample will be for research reasons only and that it is not part of their routine clinical care. If the patient expresses an interest they will be asked to sign the "permission to contact form" and provided with a patient information sheet. It will be emphasised that by expressing an interest this does not mean they have to take part and they have the right to pull out at any point. The patients will be given at least 24h to read the information sheet before they are contacted and will be have the opportunity to discuss any concerns and ask questions etc. Where possible, the collection of their fluid will be taken when the patients is visiting clinic as part of their routine care. Collection of fluid will only be taken once the patient has been consented and is fully happy with the process. Where appropriate, participants may be recruited through their involvement with one of the other ARUKBBC protocols. The Centre will not obtain fluid from the joint without at least a 6 months gap from the previous fluid collection. The methods used to assess the biomarkers will be the same ones as outlined in the assessment for "clinical waste" synovial fluid.

This protocol involves following individual patients throughout multiple treatment cycles for as long as that person is happy to participate. The Centre will carry out analysis of multiple samples from individual patients/volunteers. This will enable disease/biomarker patterns to be (i) identified, (ii) related to clinical outcome (i.e. disease progression/recovery), (iii) compared in different treatment regimes (e.g. medications/physiotherapy/surgery) and (iv) integrated with the findings of other associated studies (e.g. motion, loading, and pain analysis).

5.9.4 Bone Cores from High Tibial Osteotomy (HTO) Surgery

Patients having a HTO will be approached to consent for the collection of bone cores during their HTO surgery and again during plate removal (approximately one year after HTO). 4 small (2ml) cores of bone from the operation site will be removed.

5.9.3 Points of entry into the protocol (collection of non-clinical waste synovial fluid)

Patients will be identified as the same for the collection of blood and urine and asked by their treating clinician whether they would consider having synovial fluid aspirated from their joint so research studies can be conducted on the sample(s). It will be emphasised that the procedure to obtain the sample will be for research reasons only and that it is not part of their routine clinical care. If the patient expresses an interest they will be asked to sign the "permission to contact form" and provided with a patient information sheet. It will be emphasised that by expressing an interest this does not mean they have to take part and they have the right to pull out at any point. The patients will be given at least 24h to read the information sheet before they are contacted and will be have the opportunity to discuss any concerns and ask questions etc. Where possible, the collection of their fluid will be taken when the patients is visiting clinic as part of their routine care. Collection of fluid will only be taken once the patient has been consented and is fully happy with the process.

5.10 Consent Procedure

Consenting of participants must be carried out in accordance to the most up to date Standard Operating Procedure (SOP) for consent within the ARUKBBC. All members undertaking consent must be trained on the protocol and consent procedures as per ARUKBBC SOP's.

5.11 Enduring Consent

Participants will be asked to provide consent for the collection of subsequent additional samples that are specific to the information sheet/consent form that has been provided (e.g. additional blood/urine will only be collected on the blood/urine form and additional synovial fluid will only be collected on the synovial fluid form). The initial consent will endure for 2 years and it is anticipated that participants will be asked to donate additional samples up to 10 times over the course of the 5 years. The date and all the consent details will be stored on the secure Centre database. Following the initial consent, each time a participant is asked to provide samples, the researcher will check prior to sample collection to determine if the participant needs to be consented again (i.e. whether or not the consent is within in the 2 year valid period). If the consent time period falls outside of 2 years then the participant will be kindly asked to re-consent and the details of the new signed consent form will be added to the Centre secure database. It will always be made clear that there is no obligation to provide these additional samples and consent can be withdrawn at any time. If the participant withdraws consent, their sample(s) will not be used in any subsequent studies and will be destroyed according to local practices. Any sample(s) already distributed for use in research prior to the withdrawal of consent will continue to be used in that study and any sample(s) remaining at the end of the study will be destroyed.

5.12 Procedure for sample collection and transport

The collection and transport of samples must abide by the most up to date SOP for sample collection and transport with the ARUKBBC members. The purpose of this Standard Operating Procedure (SOP) is to ensure that staff involved in ARUKBBC understand the procedure and mechanisms for the collection and transportation of human samples. All members involved in sample collection and transport must be trained on the protocol as per the SOP.

5.13 Sample Processing

Sample processing will be carried as per "sample processing" protocol attached with this document.

5.14 The storage of human samples

Version 12 – 30th November 2017

Page 53 of 71

Samples will be stored according to the Cardiff University Code of Practice for Human Tissue Research. At the end of the project, any materials left will be stored under Cardiff University Human Tissue Authority licences. These licences are granted under Section 16(2) (e) (ii) of the Human Tissue Act 2004 and authorises the storage of relevant human material which has come from a human body for the use in research such as proposed in this application. The maintenance and management of sample storage will be carried out by the Centre's Research Manager and Centre Administrator and overseen by the Centre's Director, Professor Bruce Caterson. In addition, samples may also be used for future, related studies under the discretion and agreement of the Centre CI as well as the Centre Management Team. Participants are asked in the consent form if they are willing to agree to this. Of note, all the mechanism of sample storage will abide by the SOP for the storage of human samples within ARUKBBC. The purpose of this Standard Operating Procedure (SOP) is to ensure that staff involved in research within the Arthritis Research UK BBC understand the procedure and mechanisms for the storage of human samples.

5.15 Procedure for usage and disposal of sample collection

Members of staff involved in the usage and disposal of samples must abide by the most up to date SOP for usage and disposal of sample collection within the ARUKBBC. The purpose of this Standard Operating Procedure (SOP) is to ensure that staff involved in research within the Arthritis Research UK BBC understand the procedure and mechanisms for the usage and disposal of human samples. All members involved in sample collection and transport must be trained on the protocol as per the SOP.

5.16 Analyses to be undertaken

- Explant cultures: individual tissue or morphologically distinct components of a tissue will be subjected to *in vitro* explant culture to determine the metabolic state and responses of the tissue.
- Isolation of cells for *in vitro* culture relevant to musculoskeletal cell culture systems and further analyses e.g. flow cytometry, immunohistochemical characterisation.
- Patient's tissues and/or cells WILL NOT be used in any *in vivo* studies, e.g. allograft/zenograft procedures.
- Extraction and subsequent biochemical and immunochemical analyses of connective tissue cell and matrix macromolecules, e.g. tissue extraction with guanidine hydrochloride followed by isolation and purification of connective tissue matrix components.
- Extraction of RNA and analysis of gene expression profiles.
- Extraction of DNA and analysis for gene mutations that may cause musculoskeletal diseases.
- Histological and immunohistological analyses by microscopy techniques e.g. light, confocal and electron microscopy.
- Biomechanical testing, e.g. the resistance of cartilage, bone, meniscus, etc., to various loads.
- Biochemical analysis of sample composition using spectroscopic (nuclear magnetic resonance [NMR], magnetic resonance spectroscopy [MRS]) and proteomic approaches (high performance liquid chromatography [HPLC], gel electrophoresis, mass spectrometry, etc.).

5.17 Questionnaires

Willing, consented participants will be asked to complete appropriate questionnaires which will be pathology and joint specific (therefore not all the questionnaires will need to be completed by each patient / volunteer):

Knee osteoarthritis (early and pre-operative) and knee pain patients

VAS pain score
EQ5D
KOOS (has an integrated WOMAC)
The Oxford Knee Score

Knee instability patients (i.e. ligament injury/reconstruction patients)
VAS pain score
EQ5D

Hip osteoarthritis and hip pain patients
VAS pain score
EQ5D
HOOS (has an integrated WOMAC)
The Oxford Hip Score

Back pain patients
VAS pain score
EQ5D

Shoulder osteoarthritis/pain patients
VAS pain score
EQ5D
The Oxford Shoulder Score

Shoulder instability patients
VAS pain score
EQ5D
The Oxford Shoulder Instability Score

Ankle patients (all ankle OA patients including pre/post operative)
VAS for pain
EQ5D
Foot function index
American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score (filled in by researcher)

Healthy Volunteers
VAS pain score
EQ5D
Knee - KOOS (has an integrated WOMAC)
Expectancy questionnaires
The Oxford Knee Score
Hip - HOOS (has an integrated WOMAC)
The Oxford Hip Score
The Oxford Shoulder Score
The Oxford Shoulder Instability Score
Ankle - Foot function index
American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score (filled in by researcher)

5.18 Ethical Considerations

5.18.1 Sample collection: Blood/Urine

For patients, urine and blood will be collected on the same day as a clinical procedure, visit or data collection. Venepuncture may be associated with some minor discomfort. Participants will be made

as comfortable as possible during blood collection. Pressure will be applied immediately afterwards to minimise bleeding and subsequent bruising. The procedure is minimally invasive. Predicted procedures per participant are between 1-10 and the average time taken 5mins. Up to 40ml of venous blood will be taken per visit (for serum and whole blood/plasma). This will be performed by qualified personnel. Collection of urine may cause mild inconvenience, correct facilities will be provided for privacy and comfort. The collection of urine is non-invasive and has no associated pain. Predicted procedures per participant is between 1 and 10.

5.18.2 Clinical waste samples will be collected as part of routine clinical procedures. Only tissue that is deemed as clinical waste during the procedure will be collected for research purposes.

5.18.3 Sample collection: non-clinical waste

The procedure of Joint fluid aspiration is performed using a sterile needle to draw joint fluid from a joint; it is also known as arthrocentesis. The skin is sterilised in the area which will be punctured with the needle and a local anaesthetic is used to minimise discomfort as much as possible. The aspiration is done with a larger needle than routinely used for the collection of blood and may also cause some pain. The procedure usually lasts less than a minute. The risks associated with this procedure are very rare. Uncommon risks that can potentially occur include infection of the joint, which is more commonly associated with repeated aspirations within a short period of time which we would not ask the patient to undertake. Another rare risk is bleeding into the joint space. The information sheet will highlight the potential risks of having this procedure and the patient will be given time to discuss this with their clinician. There will be an opportunity to discuss this procedure and any concerns with their treating clinician during the clinic visit. However, there will also be opportunities for the potential participants to discuss any further concerns with the clinician through facilitation with the ARUKBBC. There is contact details for the Arthritis Research UK Biomechanics and Bioengineering Centre research staff on the patient information sheet.

5.18.4 Collection of Bone Cores for HTO patients

The procedure is carried during the HTO procedure and again during plate removal approximately 12 months after first procedure if the patient consents to do so. Four small (2ml) cores are taken from the operation site using a sterile bone needle. The collection of these cores causes no morbidity for the patient.

5.18.5 Sample Storage - Confidentially

One main ethical consideration for the storage of human samples is confidentiality, identification and tracking of the samples. Long-term, samples will be stored in a lockable -80°C freezer and contain identifiable codes. The temperature of all our storage systems are monitored remotely by Tutela System Monitoring who have a current list of contacts when the temperature goes outside the pre-set limits. If a Unit fails, then spare storage capacity is available within the Centre but also as a backup within the School of Biosciences and the School of Dentistry where our samples are held. No patient personal details will be visible on the sample containers. Patient's personal details will be stored on a Centre database that is password protected and only researchers with NHS research passports and letter of access or NHS honorary contracts will have access to the Centre database. It is important to note that details of the patient's identity and other personal and private information do not need to be known by most of the basic (non-clinical) scientists involved in these studies and this information will not be provided in any subsequent scientific, clinical or lay publication or presentation of this research. All that needs to be known by these researchers is patient age, gender, clinical diagnosis and relevant clinical and medication history taken prior to surgery. The clinical consultants associated with these studies will maintain patient confidentiality but facilitate in the interpretation of data arising from this research. All researchers who may have

access to further patient details will hold a Research Passport and Letter of Access or Honorary Contract from the NHS Health Boards from which they receive volunteer samples.

5.19 Longitudinal Studies

As outlined in this document, most patients are involved in longitudinal studies which will include contacting the participant in the future to invite them to take part in further studies. Before contacting the individual we plan to contact their GP to ensure they have not suffered any adverse health problem or have passed away. We aim to contact the GP approximately one month before inviting them to take part in further studies. We will ask each participant to consent to us contacting his or her GP via the consent form.

5.20 Payment of travel expenses

Research participants will be reimbursed any travel expenses for any research activities that are not linked to their normal clinical care. We will use a consent form to allow their personal details (i.e. name, address and vehicle registration number) to be passed on to Cardiff University finance department.

5.21 Statistics and data analysis

Data will be tested for normality (Anderson-Darling) and equal variance prior to parametric analyses using the statistical software Minitab. A Student's two sample T-test will be used to compare two independent sample groups i.e. OA versus healthy. A multivariate ANOVA will be used to analyse multiple comparisons within an experimental group i.e. comparing the effects on different tissue types. Multivariate analyses such as principal components analysis will be used to investigate pattern of data sets. Where data is not normal and/or is unequal, log transformations will be attempted prior to statistical analysis. If data cannot be normalised by transformation, non-parametric tests will be performed such as Mann-Whitney or the Sheirer-Hay test. Differences will be considered significant at $p < 0.05$.

5.22 Data Storage and Anonymity

Once patients are enrolled, they will be assigned a reference number which will be used as their identifier throughout the research and for purposes of data analyses. A master copy of the patient information and relevant reference numbers will be stored on password protected Cardiff University computers to allow future contact with patients. Printed data will be stored in locked filing cabinets in Cardiff University. Appropriate encryption software will be used for data storage purposes. Only researchers in possession of an NHS research passport and letter of access or honorary contract will have access to the patient's personal and medical information.

It is important to note that not all researchers conducting this protocol will need to know the patient's identity and other personal and private information. This knowledge will not be needed by most of the basic (non-clinical) scientists involved in these studies. In addition, this information will not be provided in any subsequent scientific, clinical or lay publication or presentation of this research. All that needs to be known by these researchers is patient age, gender, clinical diagnosis and relevant clinical and medication history taken prior to surgery. The clinical consultants associated with these studies will maintain patient confidentiality but facilitate in the interpretation of data arising from this research. Data will be kept securely for a minimum of 15 years in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance to the Data Protection Act 1998.

We may share fully anonymised study findings and related anonymised cohort information to research collaborators. Anonymised patient details we like to share include patient age, gender and appropriate medical information (such as previous orthopaedic problems etc. and orthopaedic-related test results). The sharing of anonymised findings with collaborators with expertise in the related field will enhance our research results with the ultimate aim to improve patient benefit.

5.23 Future use

Consent is obtained from willing participants to share anonymised samples with collaborators from other institutions for research purposes, both academic and commercial, in the UK and abroad under the terms of the Centre's ethics.

5.24 Disseminations

Any data presented (e.g. journal articles, conferences, Centre's website) will not contain any participants personal information.

5.25 Information Sheets & Consent Forms - Protocol Four

1. Patient Information Sheet & consent form : "The collection, storage and analysis of clinical waste, blood & urine samples"

2. Volunteer Information Sheet & consent form: "The collection, storage and analysis of blood and urine samples"
3. Patient Information Sheet & consent form: "The collection of synovial fluid from joints"

Other supporting documents for this protocol:

Sample processing document

6. Protocol Five - Qualitative analysis of patient and clinician opinion

6.1 Background

This protocol will focus on protocol number five, Qualitative data collection. We aim to record and evaluate patient and clinician experiences, attitudes and satisfaction via interviews and focus groups.

6.2 PLANNED INVESTIGATION

The protocol is designed to investigate patient and clinician attitudes, experiences and satisfaction in areas related to their current condition treatment (patients) .use of new technology to deliver treatments (clinicians) It will also explore patient/clinician opinion on possible future treatments and location of delivery of treatment. The protocol will address the following aims:

1. Describe the impact that living with OA has on the every day lives of patients
2. Evaluate patient and clinician opinion regarding the choice and effectiveness of treatment
3. Evaluate patient /clinician opinion regarding use of new technology delivering treatment advice
4. Evaluate patient /clinical opinion regarding location of delivery of treatment

6.3 Protocol specific aims, objectives

Protocol specific Primary Aim

This research will investigate patient and clinician experiences with respect to management of musculoskeletal disorders. To make the project deliverable we will take a defined approach and concentrate on patients with and clinicians treating degenerative joint disease including spinal pain and/or joint trauma/acute injury.

Protocol specific Secondary Aim??

Investigate patient and clinician opinion of use of new technologies to deliver treatment advice for example Apps and what they are willing to receive (in the form of future therapies)- drug delivery for example.

6.4 Anticipated joint pathologies:

The Centre's research remit will cover a number of joint and bone diseases that present at the orthopaedic, rheumatology and related physiotherapy clinics within the hospitals we have R&D approval for; these include the following:

6.4.1 Degenerative joint disease

OA
Acute & Chronic or non-specific spinal pain
Non-specific knee pain

6.4.2 Joint trauma/Injury

Anterior cruciate ligament damage/rupture/reconstruction
Meniscal tears
Cartilage fractures, cartilage/bone fractures
Soft tissue injuries

6.5 Inclusion and Exclusion Criteria

Patient inclusion Criteria

- Patients that fall in to the 'anticipated joint pathologies in section 3.3
- Recruitment will target those attending orthopaedic clinics, rheumatology clinics and related physiotherapy clinics.
- Will be recruited within the age range from 18-80.
- Can be recruited if they are participating in another Centre study.

Patient exclusion Criteria

- Inability to provide written informed consent.
- Patients that have any previous injury to the joint under investigation that the treating clinician deems unsuitable.

Clinician inclusion criteria

- Clinicians treating musculoskeletal disorders

Clinician exclusion criteria

- Not giving informed consent

6.6 Sample Size Estimation

In most qualitative approaches numbers needed are determined when 'saturation' point is reached i.e. no further themes or new data is emerging. (Green & Thorogood 2014)

6.7 Timescale

The Arthritis Research UK Biomechanics and Bioengineering Centre has recently been awarded an additional £2M from Arthritis Research UK over 5 years (1st Jan 2016-Dec 2020). The remainder of the time will be spent collecting data to inform the management of musculoskeletal conditions.

6.8 Participant Recruitment

Patients may be recruited through various routes as follows:

Recruiting through clinics

1a) Patients present to participating NHS Health Board orthopaedic/rheumatology consultants or physiotherapists with joint pathology or injury and are provided with a "permission to contact" form. Included in this form is a request for permission to access relevant medical information from their treating clinician. It is stated on the form that this information is required to determine their suitability to take part in the study and that this will be carried out by a treating clinician and researchers from the Centre. Patients will be given the choice to complete at clinic or take the form away to complete in their own time. The form will take approximately 10 minutes to complete.

1b) Patients may also be asked if they are willing to provide verbal permission (to a member of their clinical team) for a researcher from the Centre to talk to them about the research studies while they are at the clinic. If they are interested in taking part they will be provided with information about the study.

2) Participants deemed suitable and who have signed a permission to contact form will be contacted by Arthritis Research UK Biomechanics and Bioengineering Centre researchers at Cardiff University for further assessment for the purposes of the research study and participants will be provided with an information sheet about the study. All volunteers will be given a minimum of 24 hours to decide

whether they wish to take part in the research study before full informed written consent is requested.

Post-treatment patients

Centre-associated clinical members of staff may also screen the medical notes and service database of patients who have undergone joint replacement surgery to determine any correlations. All NHS numbers will be seen and handled by Centre-associated clinical members of staff only and stored on password protected database. Other data and findings generated from such studies which contain no patient personal information will be available to relevant research staff and statisticians for analysis. In addition, any form disseminations will include no patient personal information.

Healthy and Pathological Volunteers

Pathological volunteers and age and gender matched healthy volunteers may also be recruited in order to gain general public opinion on delivery of treatments / services, by expression of interest after gaining information on the Centre's/Cardiff University website or response to posters displayed in appropriate sites. The relevant ARUKBBC researchers will determine the volunteer's suitability via the inclusion and exclusion criteria. If deemed suitable, the volunteer will be sent a volunteer information sheet about the study. Consent forms will also be sent so that the volunteers are made aware of what they may be asked to consent to should they wish to be included in the research.. A minimum of 24-hour notice will always be given for the volunteer to decide whether they would like to be interviewed. It will be made clear to the volunteer when they are first recruited that they will be free to withdraw from of the research at any time. Willing participants will be contacted to arrange a convenient time for them to attend the research facilities in Cardiff university or healthboard clinic for the interview to take place. . Clear instructions on how to get to the research facilities will be given.

Clinicians

Clinicians who are currently treating musculoskeletal disorders will be approached in the clinic setting. They will be given an information sheet to read and consider and have at least 24 hours before being approached for consent and to arrange the interview. Interviews will take place on healthboard premises or at one of our research facilities within Cardiff University. .

6.9 METHOD / STUDY DESIGN

The Arthritis Research UK Biomechanics and Bioengineering Centre Research Committee meets once per month and consists of project leaders, principal investigators, clinicians and representatives from the Research Committee's sub groups; Clinical Interaction, Patient Translation and Patient & Public Involvement. Within the appropriate research sub groups the specific interview / question schedule will be determined according to the cohort of patients. We will use serial semi structures interviews/focus groups as appropriate. Interviews/focus groups will be carried out as appropriate: this may include once pre-treatment and up to four times post-treatment (where appropriate), at varying time intervals depending on the joint and/or injury. Clinician interviews/focus groups will take place at an appropriate time with respect to their availability.

The types of questions asked will include the following:

Patients and Pathological Volunteers:

- A description of the patients condition
- The impact of their condition on their every day life
- How they have managed their condition so far
- What sources of information have they accessed so far about their condition

- Expectations of treatment they will receive
- Opinions about using and usefulness of technology for advice about their condition
- Experiences of previous treatments/interventions
- Opinions about accessing health care using electronic resources
- Opinions about self-management of musculoskeletal disorders
- Opinions about involvement in choice of treatments for a musculoskeletal disorder
- Opinions about use of technology in supporting delivery of care
- Opinions about location of delivery of care
- Opinions about newly developed questionnaires (paper and electronic versions)

Patients - Post Treatment Interviews:

- An update of the condition
- An update on the impact of their condition in every day life
- What care and treatment have they received since the pre treatment interview
- Opinions about choice of care and treatment
- Opinions about treatment meeting their needs and its effectiveness
- Opinions about involvement in management of their condition
- Opinions about location of delivery of care
- Expectations regarding recovery
- Opinions about usefulness of technology supporting management of their condition

Clinicians:

- Opinions about choice of treatments for patients
- Opinions about and acceptability of technology and biomechanics feedback. How would this information alter their decision making on treatment selection
- Opinions about location of delivery of care

Healthy Volunteers:

- Opinions about accessing health care using electronic resources
- Opinions about self-management of musculoskeletal disorders
- Opinions about involvement in choice of treatments for a musculoskeletal disorder
- Opinions about preferences for treatment
- Opinions about use of technology in supporting delivery of care
- Opinions about location of delivery of care

The Arthritis Research UK Biomechanics and Bioengineering Centre Research Committee will also evaluate interview/focus group data in order to ensure that the correct questions are being asked in order to gain relevant data from the interviews.

6.10 Consent Process

Once patient eligibility has been determined, the patient will be contacted by a suitable Centre researcher (whom will have a research passport/letter of access or honorary NHS contract), who will provide the patient with further information. They will be invited to take part in a qualitative interview at one of the centre's research facilities or in a clinic setting in the healthboard. Upon arrival at the School of Engineering laboratories, School of Healthcare Sciences Research facilities or clinical setting patients/volunteers will have the interview/focus group process explained to them. It will be made clear that they are free to withdraw from the study at any time and that their participation in the research will not affect their relationship with the NHS in any way. Once

patients/volunteers are satisfied and wish to participate in the interview, if they wish to still take part, informed written consent will be obtained.

Consenting of participants must be carried out in accordance to the most up to date Standard Operating Procedure (SOP) for Obtained Informed Consent within the Arthritis Research UK Biomechanics and Bioengineering Centre. All members undertaking consent must be trained on the protocol and consent procedures as per Arthritis Research UK Biomechanics and Bioengineering Centre SOP's.

6.11 Interviews/Focus groups

Interviews will be conducted by a member of the research team. Research staff conducting the interviews will be fully trained on the protocol and interview schedule, have current GCP training and competent in carrying face to face interviews with patients. The interviews will normally take up to between 30 minutes and 1 hour depending on the nature of the questions and exploration of the responses to the questions. which will include explanation of the study and consent.

On the day of interview/focus group the willing participants will be greeted and escorted by a member of staff at all times whilst on University and clinical premises as appropriate. The researcher will carry out the informed consent process with the patient. The researcher will then conduct the interview/focus group with the patient and the interview will be audio recorded. The interview may be audio -recorded (with appropriate consent obtained). A note taker will be present to take 'field notes' to support the data collection.

A transcript of the conversation, once transcribed, will be sent to the participants for transparency to ensure that the transcription reflects an accurate record of the conversation.

6.12 PROMs

In addition patients/Pathological volunteers may be asked to complete validated Patient Reported Outcome Measures questionnaires (PROMs). Only questionnaires that are relevant to their condition and relevant to the study will be completed.

Knee osteoarthritis (early and pre-operative) and knee pain patients

VAS pain score [7]

EQ5D [8]

KOOS (has an integrated WOMAC) [9]

The Oxford Knee Score [10]

Expectancy questionnaires [11]

Knee instability patients (i.e. ligament injury/reconstruction patients)

VAS pain score [7]

EQ5D [8]

Expectancy questionnaires [11]

Hip osteoarthritis and hip pain patients

VAS pain score [7]

EQ5D [8]

HOOS (has an integrated WOMAC) [9]

The Oxford Hip Score [10]

Expectancy questionnaires [11]

Back pain patients

VAS pain score [7]

EQ5D [8]

Oswestry Disability Questionnaire
Pain Catastrophizing scale (PCS)
Coping strategies questionnaire (CSQ)
Pain anxiety symptoms score (PASS-20)
StartBack
Roland and Morris Disability Questionnaire [14]
Distress Risk assessment Method [15]
Örebro Musculoskeletal Screening questionnaire [16]
Expectancy questionnaires [11]
BACKonLINE™ non validated questionnaire

Shoulder osteoarthritis/pain patients

VAS pain score [7]
EQ5D [8]
The Oxford Shoulder Score [17]
Expectancy questionnaires [11]
Patient screening questionnaire (Centre specific)
Patient expectation questionnaire (Centre specific – Based on Mannion et al, 2009 and MODEMS prognosis questions)

Shoulder instability patients

VAS pain score [7]
EQ5D [8]
The Oxford Shoulder Instability Score [18]
Expectancy questionnaires [11]
SF-12 (scored using the SF-6D, is a classification for describing health derived from a selection of SF-36 items. It is composed of six multi-level dimensions. Any patient who completes the SF-36 or the SF-12 can be uniquely classified according to the SF-6D. The SF-6D describes 18,000 health states in total).

Ankle patients (all ankle OA patients including pre/post operative)

VAS for pain [7]
EQ5D [8]
Foot function index [19]
American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Score (filled in by researcher)
Expectancy questionnaires [11]

Healthy Volunteers

VAS pain score [7]
EQ5D [8]
KOOS (has an integrated WOMAC) [9]
Expectancy questionnaires [11]

Wrist patients

DASH Outcome Measure (22)
QuickDASH (23)
Patient Rated Wrist/Hand Evaluation (24)

6.13 Ethical considerations

Participants may be discussing sensitive and personal information relating to their condition, treatment, working environment and this may make them feel uncomfortable. In order to minimise this it will be made clear that participants need only answer questions to which they feel

comfortable doing so and will be informed before the interview begins that they may stop the interview should they not wish to proceed any further.

6.14 Longitudinal Studies

As outlined in this document this research can involve longitudinal studies, which will include contacting the participant in the future to invite them to take part in further studies. Before contacting the individual we plan to contact their GP to ensure they have not suffered any adverse health problem or have passed away. We aim to contact the GP approximately one month before inviting them to take part in further studies. We will ask each participant to consent to us contacting his or her GP via the consent form.

6.15 Payment of travel expenses

We will offer research participants reimbursement for any travel expenses for undertaking any research activities. We will use a travel expenses consent form to allow their personal details (i.e. name, address and vehicle registration number) to be passed on to Cardiff University finance department.

Protocols Removed from last approved protocol

- Implementation and delivery of different rehabilitation interventions for management of patients with joint problems: Views of experts, managers, clinicians and patients.
- Anonymised Datasets
- Shoulder fluoroscopy
- Ankle fluoroscopy
- Diagnostic ultrasound scanning of the shoulder
- Imaging neural - MRI imaging of the brain – "Imaging and measuring metabolite levels of neural responses to anticipated and actual pain stimuli in patients with musculoskeletal disease and healthy people"
- Static imaging
- Research clinic
- Patient and Public Involvement (PPI) research advisory Panel

7. PROJECT MANAGEMENT

Staff

All Arthritis Research UK Biomechanics and Bioengineering Centre staff and students taking part in studies that involve this protocol will have undertaken appropriate training and will have research passports, honorary contracts or NHS contracts from the appropriate NHS Health Board. Specifically for the motion analysis techniques protocol, training to use the required software and hardware will be provided as part of laboratory induction and risk assessment. The competencies are audited and recorded in the laboratory health and safety documentation. Once training has been completed staff and students are deemed competent to work in the laboratory and listed as an approved laboratory user. Quality control is ensured for all staff and students via regular ad-hoc checks on data collection, data processing and analysis within the research team.

ARUKBBC Management and Staffing Structure

All studies conducted within the Centre will be overseen by the CI and the Centre Director, Professor Bruce Caterson. However, there will be specific project individuals managing and/or conducting this research study

ARUKBBC Management Team and Research Committee

The Centre is managed by a Management Team (MT), chaired by the Director, meet every 2 weeks and who are responsible for the day-to-day running of the Centre. It is supported by a Research Committee (RC), which includes some of the co-investigators who are responsible for recommendations based on the research needs, which is fed back to the MT. The members include a multidisciplinary team of clinicians and researchers who have considerable expertise in all aspects of design, running, quality assurance and analysis of the study. The RC team will meet monthly to assess the study progress. A Centre Research Manager oversees the Research Management and the Centre administrator supports Centre activities and provides web and other support.

Funding Management

The ARUK funding is to primarily provide a platform for future research, the majority of which will be funded from other sources. It will support an infrastructure for recruitment and retention of patients and technical support for biomechanical measurements. Centre funding supports projects requiring long-term, longitudinal collection of patient data and the development of new, challenging, interdisciplinary, experimental pipelines correlating biomechanics and biology. Implementation requires a dedicated infrastructure to coordinate patients, measurements and samples and to ensure regulatory compliance. Staff and facility infrastructure will underpin the entire proposed scientific projects core to this study. However, to allow the Centre to achieve all the aims and objectives, additional funding from other external sources will be essential and ARUK are fully aware of this. To allow the Centre to manage this and to ensure all additional funding and centre staff are addressing the Centre objectives, milestones and deliverable – proposed grant applications will go through the Centre RC for approval. The contribution of the Centre's infrastructure costs will be clearly outlined.

ARUKBBC International Advisory Board

The Arthritis Research UK Biomechanics and Bioengineering Centre has previously appointed an International Advisory Board (IAB). The Board is chaired by **Prof Al Grodzinsky**, Director, Centre for Biomedical Engineering, Massachusetts Institute of Technology, Boston, USA and has met approximately every 12-18 months.

The remit of the advisory board is to:

1. Review the progress of the Centre's work towards its overall objectives
2. Discuss and advise of future work priorities to achieve the milestones and deliverables
3. Inform the funding body on the progress of ARUKBBC.

Protocol training

All researchers will be required to undergo the relevant training by the managers of this protocol, read the protocol and related ARUKBBC SOP's and sign to agree that they understand the documents and that they will adhere to them. The ARUKBBC Centre administrator will store records of these declarations. Each researcher working on this project will also be required to complete and sign the relevant study log form and again, the Centre administrator will store a record of this.

The ARUKBBC management team (headed by the Centre Director) together with sponsors (Cardiff University) of this research investigation will be responsible for monitoring this study. The duties include production and maintenance of complete, legible, well-organised and easily retrievable data. In addition, assuring that the researchers and study managers understand their responsibilities in accordance to the protocol and abide by GCP, confidentiality and data protection principles. Approaches to monitoring include both remote and on-site visits as appropriate and the rationale and frequency for monitoring will be at the Sponsor's discretion.

Data Monitoring and Management

Personal data collected during the study will be handled and stored in accordance with the 1998 Data Protection Act. All patient details and relevant data will be stored on the secured ARUKBBC database.

All of the data collected in this trial will be entered into a secure trial database held at the secured Cardiff University server which is password protected. The database has two different levels of access – level 1 allows access to patient details in accordance to having a research and/or honorary contract of the relevant health board/trust add about level 2 which is no patient's details can be seen. Paper forms with patient-identifiable information will be held in secure, locked filing cabinets within a restricted area.

All participants given a unique study number, which will be generated using the ARUKBBC database. Identifiable paper participant data will be held in a locked filing cabinet and coded with a study participant number to tag identifiable data to the outcome data. Participant details will also be added to the ARUKBBC secure database whereby only level 1 access researchers will be able retrieve.

Quality assurance checks will be undertaken by study management team to ensure integrity of study entry procedures and data collection. ARUKBBC has a quality assurance personals via the Centre manager and administrator who will monitor this trial by conducting regular (yearly or more if deemed necessary) inspections of the ARUKBBC Master File. Furthermore, the processes of consent taking, provision of information and data collection will be monitored. Written reports will be produced for the ARUKBBC management team, informing them if any corrective action is required.

Archiving Plans

Study documentation and data will be archived at the ARUKBBC site for 15 years after completion of the trial in accordance with Cardiff University archiving SOPs.

GCP Compliance

The study will be conducted in accordance with the principles of Good Clinical Practice (GCP) and guidelines, ARUKBBC SOPs, relevant UK legislation and the Protocol. GCP-trained personnel will

conduct the trial. Copies of the researcher's GCP are kept centrally in the master file and managed by the Centre Research Manager.

Funder Review Committee

The ARUKBBC is required to provide reports to ARUK on the progress of the Centre's research. This also coincides with a review from the internationally advisory board. The identification for additional funding will be identified through the ARUKBBC RC

Ethical and R&D Amendments Procedure

Requests for amendments to the ethical and R&D protocol(s) will be made via the ethics/R&D amendment form. The completed form will be reviewed via the Centre's MT and Cardiff University governance team for approval. Only requests that have been approved can proceed through the normal REC/R&D amendments route via IRAS/NISCHR PCU, respectively.

Insurance and Indemnity Arrangements

As the Sponsor of the ARUK-BBC studies, Cardiff University has in place insurance to cover negligent harm resulting from the design and/or management of the studies (as described in the protocols) and the conduct of the study by Cardiff University employees. With regards to the conduct of the study, NHS indemnity will apply where NHS Health Boards have a duty of care to participants recruited to the study and where NHS staff are conducting the study on behalf of the University.

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Ymchwil Iechyd
a Gofal Cymru
Health and Care
Research Wales

Gwasanaeth Moeseg Ymchwil
Research Ethics Service



Ariennir gan
Lywodraeth Cymru
Funded by
Welsh Government

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Health and Care Research Wales Castlebridge 4
15 – 19 Cowbridge Road East
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Website : www.hra.nhs.uk

20 December 2017

Professor Bruce Caterson
Cardiff School of Biosciences
Cardiff University
Cardiff CF10 3AX

Dear Professor Caterson

Study title: Arthritis Research UK Biomechanics and Bioengineering Centre
Multi-Project Ethical Submission
REC reference: 10/MRE09/28
Protocol number: n/a
EudraCT number: n/a
Amendment number: ARUKBBC2017.02
Amendment date: 12 December 2017
IRAS project ID: 51853

The above amendment was reviewed by the Sub-Committee in correspondence.

The members of the Committee taking part in the review gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Document	Version	Date
Non-validated questionnaire [BACKonLINE Questionnaire]	5	22 November 2017
Notice of Substantial Amendment (non-CTIMP)	ARUKBBC20 17.02	12 December 2017
Research protocol or project proposal [ARUKBBC REC protocol]	12 (clean)	30 November 2017
Research protocol or project proposal [ARUKBBC REC protocol]	12 (tracked)	30 November 2017

Membership of the Committee

The members of the Committee who took part in the review are listed on the attached sheet.

Working with NHS Care Organisations

Sponsors should ensure that they notify the R&D office for the relevant NHS care organisation of this amendment in line with the terms detailed in the categorisation email issued by the lead nation for the study.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

We are pleased to welcome researchers and R & D staff at our Research Ethics Committee members' training days – see details at <http://www.hra.nhs.uk/hra-training/>

10/MRE09/28: Please quote this number on all correspondence

Yours sincerely



Dr. Corinne Scott
Senior Ethics Service Manager
Health and Care Research Wales

pp **Mrs. Monika Hare**
Vice Chair

E-mail: corinne.scott@wales.nhs.uk

Enclosures: List of names and professions of members who took part in the review

Copy to: Mr Stephen Jones, Cardiff and Vale UHB
Cheryl Cleary

Wales REC 3
Attendance at Sub-Committee of the REC meeting on 20 December 2017

Written comments received from:

Name	Position
Ms Donna Duncan	Professional Head of Nutrition and Dietetics (MH and LD)
Mrs Monika Hare	Researcher
Dr Andrea Longman	Researcher

Also in attendance:

Name	Position (or reason for attending)
Dr Corinne Scott	Senior Ethics Service Manager (Minutes)
Mrs Helen Williams	REC Coordinator

Appendix 19. Research Passport



GIG
CYMRU
NHS
WALES

Bwrdd Iechyd Prifysgol
Caerdydd a'r Fro
Cardiff and Vale
University Health Board

Ysbyty Athrofaol Cymru
University Hospital of Wales

Heath Park,
Cardiff, CF14 4XW
Phone 029 2074 7747
Fax 029 2074 3838
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CAV_research.development@wales.nhs.uk

From: R&D Office, 2nd Floor TB2
University Hospital of Wales
Cardiff
CF14 4XW

01 December 2017

Ms Dalal Alothman
Post graduate student
Eastgate house
Newport Road
Cardiff
CF24 0AB

Dear Ms Alothman,

Letter of access for research issued by Cardiff and Vale University Health Board

Title of Agreed Research Project: Opinions about management of musculoskeletal disorders: Qualitative analysis of patient and clinician opinion
R&D Reference: 17/JUN/6961
IRAS Reference: 51853

Agreed Duties to be Undertaken: Recruitment and data collection.

In accepting this letter, each participating organisation confirms your right of access to conduct research through their organisation for the purpose and on the terms and conditions set out below. This right of access commences on **01 December 2017** and ends on **31 October 2019 (your Cardiff University contract end date)** unless terminated earlier in accordance with the clauses below.

You have a right of access to conduct such research as confirmed in writing in the letter of permission for research from Cardiff and Vale UHB. Please note that you cannot start the research until the Principal Investigator for the research project has received a letter from us giving confirmation from the individual organisation(s) of their agreement to conduct the research.

The information supplied about your role in research at Cardiff and Vale University Health Board has been reviewed and you do not require an honorary research contract with this NHS organisation. We are satisfied that such pre-engagement checks as we consider necessary have been carried out.

You are considered to be a legal visitor to Cardiff and Vale University Health Board premises. You are not entitled to any form of payment or access to other benefits provided by this NHS organisation to employees and this letter does not give rise to any other relationship between you

Bwrdd Iechyd Prifysgol Caerdydd a'r Fro yw enw gweithredol Bwrdd Iechyd Lloed Prifysgol Caerdydd a'r Fro
Cardiff and Vale University Health Board is the operational name of Cardiff and Vale University Local Health Board



LoA for university researchers, v2.3

and this NHS organisation, in particular that of an employee.

While undertaking research through Cardiff and Vale University Health Board, you will remain accountable to your academic, **Cardiff University** but you are required to follow the reasonable instructions of **Mr Alun Morgan** in this NHS organisation or those given on his behalf in relation to the terms of this right of access.

Where any third party claim is made, whether or not legal proceedings are issued, arising out of or in connection with your right of access, you are required to co-operate fully with any investigation by this NHS organisation in connection with any such claim and to give all such assistance as may reasonably be required regarding the conduct of any legal proceedings.

You must act in accordance with Cardiff and Vale University Health Board policies and procedures, which are available to you upon request, and the Research Governance Framework.

You are required to co-operate with Cardiff and Vale University Health Board in discharging its duties under the Health and Safety at Work etc Act 1974 and other health and safety legislation and to take reasonable care for the health and safety of yourself and others while on Cardiff and Vale University Health Board premises. You must observe the same standards of care and propriety in dealing with patients, staff, visitors, equipment and premises as is expected of any other contract holder and you must act appropriately, responsibly and professionally at all times.

If you have a physical or mental health condition or disability which may affect your research role and which might require special adjustments to your role, if you have not already done so, you must notify your employer and Cardiff and Vale University Health Board Research and Development Office prior to commencing your research role at the Health Board.

You are required to ensure that all information regarding patients or staff remains secure and *strictly confidential* at all times. You must ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice and the Data Protection Act 1998. Furthermore you should be aware that under the Act, unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

You should ensure that, where you are issued with an identity or security card, a bleep number, email or library account, keys or protective clothing, these are returned upon termination of this arrangement. Please also ensure that while on the premises you wear your ID badge at all times, or are able to prove your identity if challenged. Please note that this NHS organisation accepts no responsibility for damage to or loss of personal property.

This organisation may revoke this letter and any organisation(s) may terminate your right to attend at any time either by giving seven days' written notice to you or immediately without any notice if you are in breach of any of the terms or conditions described in this letter or if you commit any act that we reasonably consider to amount to serious misconduct or to be disruptive and/or prejudicial to the interests and/or business of the organisation(s) or if you are convicted of any criminal offence. You must not undertake regulated activity if you are barred from such work. If you are barred from working with adults or children this letter of access is immediately terminated. Your employer will immediately withdraw you from undertaking this or any other regulated activity and you **MUST** stop undertaking any regulated activity immediately.

Your substantive employer is responsible for your conduct during this research project and may in the circumstances described above instigate disciplinary action against you.

Cardiff and Vale University Health Board will not indemnify you against any liability incurred as a result of any breach of confidentiality or breach of the Data Protection Act 1998. Any breach of the Data Protection Act 1998 may result in legal action against you and/or your substantive employer.

If your current role or involvement in research changes, or any of the information provided in your Research Passport changes, you must inform your employer through their normal procedures. You must also inform your nominated manager in this NHS organisation.

Yours sincerely



Mrs Lee Hathaway/Mrs Catrin Vaughan
Registration and Permissions Improvement Manager
On behalf of Cardiff and Vale University Health Board

cc: HR department of the substantive employer
Manager at Cardiff and Vale UHB

Appendix 20. Phase 3 Participants Information Sheet

Prof Bruce Caterson
Director
Cardiff School of Bioscience
Cardiff University
Cardiff
CF10 3AX
Tel: 029 2087 5419



PATIENT INFORMATION SHEET

Qualitative analysis of patient and clinician opinion on experiences, opinions and satisfaction on current and proposed methods of care and treatment

Part one

You are being invited to take part in a research study with Cardiff University's Arthritis Research UK Biomechanics and Bioengineering Centre (ARUKBBC). Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. One of our team will go through the information sheet with you. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to participate. Part 1 tells you about the purpose of this study and what will happen to you if you take part. Part 2 gives you more detailed information about the conduct of the study.

What is the purpose of this research?

This research is part of a series of studies being conducted by the Arthritis Research UK Biomechanics and Bioengineering Centre, which uses an interlinking approach to investigate the effects of disease, injury and/or any related treatment on the biomechanics of the joint compared to healthy joints.

The aim of this study is to obtain views of patients with musculoskeletal disorders, via interviews about their experiences, opinions and satisfaction on current and proposed methods of care and treatment.

Why have I been asked to take part in this study?

You have been asked to take part in this study as you have a joint problem that we are interested in. It will allow us to gain your opinion via a recorded interview on the use of new technologies, treatments and advice such as the use of phone apps.

Do I have to take part?

It is up to you to whether or not to take part. If you do decide to take part you will be given this information sheet to keep and after you have had enough time to read through it, be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time, without giving a reason. However, any data that we may have collected up to the point of withdrawal will be kept for analysis. If you decide not to take part we will remove your data / contact details from our database and it will not affect your care or treatment in the NHS.

What will happen to me if I take part?

If you wish to take part you will be invited to attend one of our research centres in Cardiff University or in a clinic setting in the hospital where you are being treated.

You will be interviewed by a Cardiff university researcher. The types of questions asked during interview will include the following:

Interviews conducted before treatment is undertaken for your condition:

- A description of your condition
- The impact of the condition on your every day life
- How you have managed your condition so far
- What sources of information have you accessed so far about your condition
- Expectations of treatment you will receive
- Opinions about using and usefulness of technology for advice about your condition
- Experiences of previous treatments/interventions
- Opinions about accessing health care using electronic resources
- Opinions about self-management of musculoskeletal disorders
- Opinions about involvement in choice of treatments for a musculoskeletal disorder
- Opinions about use of technology in supporting delivery of care
- Opinions about location of delivery of care

If you have received treatment for your condition you may be asked to attend a further interview and will asked questions that include the following:

- An update of your condition
- An update on the impact of your condition in every day life
- What care and treatment have you received since the pre treatment interview
- Opinions about choice of care and treatment
- Opinions about treatment meeting your needs and its effectiveness
- Opinions about involvement in management of your condition
- Opinions about location of delivery of care
- Expectations regarding recovery
- Opinions about usefulness of technology supporting management of your condition

Interviews should take no longer than 30 / 45 minutes, in most cases it will take less time.

The interviews will be recorded on a tape recorder. After the interview the interview will be transcribed and you will receive a copy of this transcription if you wish to have a copy.

During interview(s) you may also be asked to complete some paper based questionnaires called PROMs (Patient Reported Outcome Measure's). This will take around ten minutes to complete.

Will the information I provide be kept confidential?

Your data and interview details / transcription will be kept securely for a minimum of 15 years from the end of the study in accordance with good research practice and data protection regulations imposed by Cardiff University in accordance with the Data Protection Act 1998. All data obtained during the study will remain confidential. Access to data will only be available to the investigators attached to the Arthritis Research UK Biomechanics and Bioengineering Centre at Cardiff University. If new information becomes available, we may invite you to take part in a follow-up study in the future, please indicate on the consent sheet if you do not mind us contacting you. With your permission and consent, we may also invite you to take part in other interlinking studies associated with our research. However, you are under no obligation to take in any other or future studies.

Are there any risks in participating in this research?

We do not anticipate any risks for taking part in interviews.

Are there any benefits in participating in this research?

Being part of this research project is of no added benefit to you directly. However, the information we collect may help improve care for others in the future.

Are there any disadvantages in participating in this research?

The only disadvantage would be the time taken to take part in the interview(s).

If the information in Part 1 has interested you and you are considering participation, please read the additional information in Part 2 before making a decision.

PATIENT INFORMATION SHEET

Qualitative analysis of patient and clinician opinion on experiences, opinions and satisfaction on current and proposed methods of care and treatment

Part Two

What will happen if I do not want to carry on with the study?

If you decide you would like to withdraw from the study, we will erase all identifiable material. However, any information collected up to that point will be kept and used unless you tell us that you would like your information removed from the project.

What if something goes wrong?

In the rare circumstance that you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact a member of our team the details of which are in the "What if I wish to lodge a complaint?" section below.

Will my taking part in this study be kept confidential?

Once you have consented to take part in the study, you will be assigned a unique identifier which will be linked to your details and will also allow us to track you through the study. All information which is collected about you during the course of the research will be kept strictly confidential. We may share the data we collect with researchers at other institutions including Universities and commercial research organisations, in the UK and abroad. However, any information that leaves the Centre will be anonymous. It will have your name and address removed so that you cannot be recognised from it. In any sort of report we might publish, we will not include information that will make it possible for other people to know your name or identify you in any way. You will simply be referred to by your gender, age and your condition.

Will my GP be informed of my involvement in the study?

We do not routinely send a letter to the GP to inform them of your participation in this research.

What will happen to the results of the research study?

We may wish publish the results of this study in a scientific journal. We may also present the results at a scientific conference or a seminar in a university. We may also publish results on our website. We would be happy to discuss the results of the study

with you and send you a copy of the published results. It will not be possible to identify you in any report or publication.

Who is organising and funding the research?

Research staff at the Arthritis Research UK Biomechanics and Bioengineering Centre at Cardiff University and Consultant Orthopaedic Surgeons at the University Hospital of Wales are carrying out the study. The study is part of the Arthritis Research UK Biomechanics and Bioengineering Centre at Cardiff University; it is not funded by commercial sources and runs alongside research in the Cardiff University School of Engineering motion analysis laboratories and Research Centre for Clinical Kinesiology at Cardiff University School of Healthcare Sciences. Occasionally work associated with these studies may also be supported by commercial companies, we will inform you by sending you a letter when this is the case.

Who has reviewed the study?

This study has been reviewed by Wales Research Ethics Committee 3 (REC 3).

What if I wish to lodge a complaint?

If you wish to make a complaint regarding the way you were approached or treated during the recruitment and/or interviews, please contact the Arthritis Research UK Biomechanics and Bioengineering Centre on Telephone: 029 2087 5417 or 029 2087 4986 Email: ArthritisCentre@cardiff.ac.uk.

If you feel your complaint is not adequately addressed then you may escalate your complaint by writing to the School Manager of the host school for the Centre: The School Manager, School of Biosciences, Museum Avenue, Cardiff, CF10 3AX. Please ensure you include details of any complaint made so far and correspondence you have so far received.

Contact for further information

ARUKBBC Administrator
Arthritis Research UK Biomechanics and Bioengineering Centre
Cardiff School of Biosciences
Cardiff University
Cardiff
CF10 3AX
Tel: 029 2087 5419 or 029 2087 4986
Email: ArthritisCentre@cardiff.ac.uk

This completes Part 2. Thank you for reading this information sheet.

If you agree to take part in this study then you will be given a copy of the information sheet and a signed consent form to keep.

PATIENT CONSENT FORM

Qualitative analysis of patient and clinician opinion on experiences, opinions and satisfaction on current and proposed methods of care and treatment

Study Number

Patient Identification Number for this research:

You DO NOT have to sign this document. Please DO NOT sign this document unless you fully understand it. If there is ANYTHING which you do not understand please do not hesitate to ask for a full explanation.

To confirm agreement with each of the statements below, please initial each box and delete where applicable:

1. I confirm that I have read and understand the information sheet dated 14 April 2017 (Version 1) for the above study and have had the opportunity to ask questions.
2. I understand that my participation in the interviews is voluntary and that I am free to withdraw at any time, without giving any reason, and without my medical care or legal rights being affected but any data collected up to the point of my withdrawal will be kept.
3. I understand that my details will be linked to a unique identifier to allow you to follow me through course of the study
4. You may / may not (please delete as appropriate) contact me in the future to ask if I would be interested in participating in a future research project/survey
5. I do / do not (please delete as appropriate) agree for you to share my anonymised data with external collaborators in the UK and abroad, including commercial companies
6. I agree for you to record my interviews on tape recorder and that the interview will be transcribed. I would / would not (please delete as appropriate) like to receive a copy of the transcription.

7. I agree to take part in the above study.

Name of Patient: _____
(Please print)

Signature: _____ Date: _____

I confirm that I have fully explained the experimental protocol and purpose of the study

Name of Researcher: _____

Signature: _____ Date: _____

Name of person taking consent: _____
(If different from researcher)

Signature: _____ Date: _____

*Original Centre file, 1 copy for the patient; 1 copy for the patient notes (if applicable),
1 copy researcher*

Appendix 21. Phase 3 Participants Consent Form

PATIENT CONSENT FORM

Qualitative analysis of patient and clinician opinion on experiences, opinions and satisfaction on current and proposed methods of care and treatment

Study Number

Patient Identification Number for this research:

You DO NOT have to sign this document. Please DO NOT sign this document unless you fully understand it. If there is ANYTHING which you do not understand please do not hesitate to ask for a full explanation.

To confirm agreement with each of the statements below, please initial each box and delete where applicable:

1. I confirm that I have read and understand the information sheet dated 14 April 2017 (Version 1) for the above study and have had the opportunity to ask questions.
2. I understand that my participation in the interviews is voluntary and that I am free to withdraw at any time, without giving any reason, and without my medical care or legal rights being affected but any data collected up to the point of my withdrawal will be kept.
3. I understand that my details will be linked to a unique identifier to allow you to follow me through course of the study
4. You may / may not (please delete as appropriate) contact me in the future to ask if I would be interested in participating in a future research project/survey
5. I do / do not (please delete as appropriate) agree for you to share my anonymised data with external collaborators in the UK and abroad, including commercial companies
6. I agree for you to record my interviews on tape recorder and that the interview will be transcribed. I would / would not (please delete as appropriate) like to receive a copy of the transcription.

7. I agree to take part in the above study.

Name of Patient: _____
(Please print)

Signature: _____ Date: _____

I confirm that I have fully explained the experimental protocol and purpose of the study

Name of Researcher: _____

Signature: _____ Date: _____

Name of person taking consent: _____
(If different from researcher)

Signature: _____ Date: _____

*Original Centre file, 1 copy for the patient; 1 copy for the patient notes (if applicable),
1 copy researcher*

Appendix 22. Phase 3
BACKonLINE™ Total and Each
Domain Normal Distribution
Assessment

Descriptive statistics: Phase 3 BACKonLINE™ total and each domain normal distribution assessment

A: Skew

Distribution is positively skewed when more data is on the right side of the distribution and negatively skewed when most data are on the left side of distribution.

Interpretation of skewness:

- If skewness is < -1 or > 1 , the distribution is highly skewed.
- If skewness is -1 to -0.5 or 0.5 to 1 , the distribution is moderately skewed.
- If skewness is between -0.5 to 0.5 , the distribution is approximately symmetric (i.e. basically normal).

In the current study, data was either moderately or highly skewed, Table 47 presents the skewness results for each Observation while figures 17, 18, 19, 20, 21, 22, 23, and 24 represent visual results of the skewness in the form of histograms.

Table 47: BACKonLINE™ total and each individual domain skewness and kurtosis in Phase 3 for both Observations 1 and 2

	N	Skewness			Kurtosis	
		Statistic	Std. Error	Interpretation	Statistic	Std. Error
BACKonLINE™ Observation 1 total score	35	0.904	0.398	Moderately skewed	2.531	0.778
BACKonLINE™ Observation 2 total score	33	1.365	0.409	Highly skewed	4.071	0.798
Pain behaviour domain total (Observation1)	35	0.815	0.398	Moderately skewed	1.387	0.778
Pain behaviour domain total (Observation2)	33	1.639	0.409	Highly skewed	4.954	0.798
Impact of LBP on work and lifestyle domain total (Observation1)	35	1.439	0.398	Highly skewed	4.076	0.778
Impact of LBP on work and lifestyle domain total (Observation2)	33	1.486	0.409	Highly skewed	3.825	0.798
Experience with LBP domain total (Observation1)	35	-0.144	0.398	Moderately skewed	-0.422	0.778
Experience with LBP domain total (Observation2)	33	-0.176	0.409	Highly skewed	-1.234	0.798

Figure 17 BACKonLINE™ Observation 1 total score

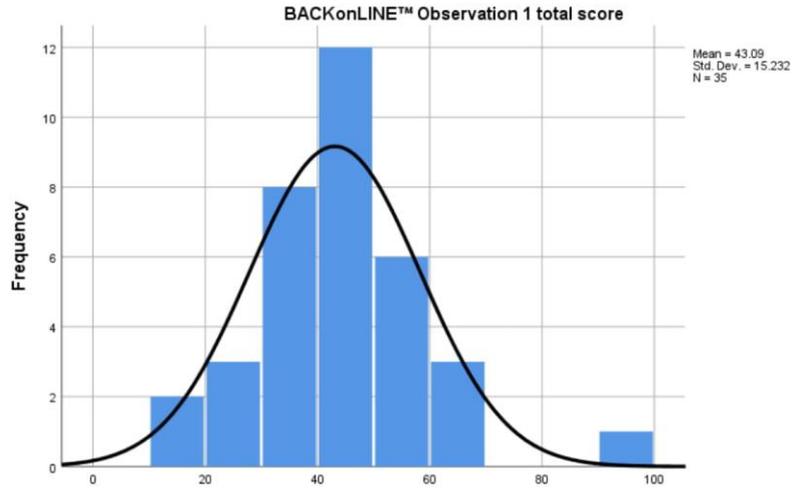


Figure 18 BACKonLINE™ Observation 2 total score

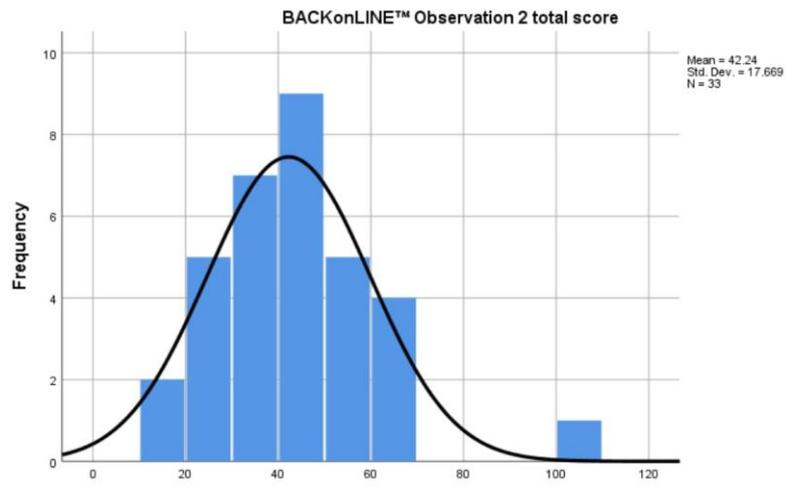


Figure 19 Pain behaviour domain total (Observation1)

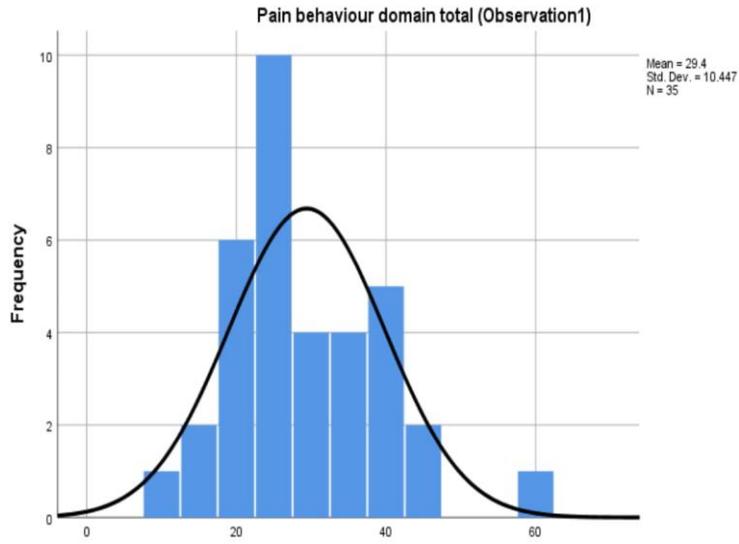


Figure 20 Pain behaviour domain total (Observation2)

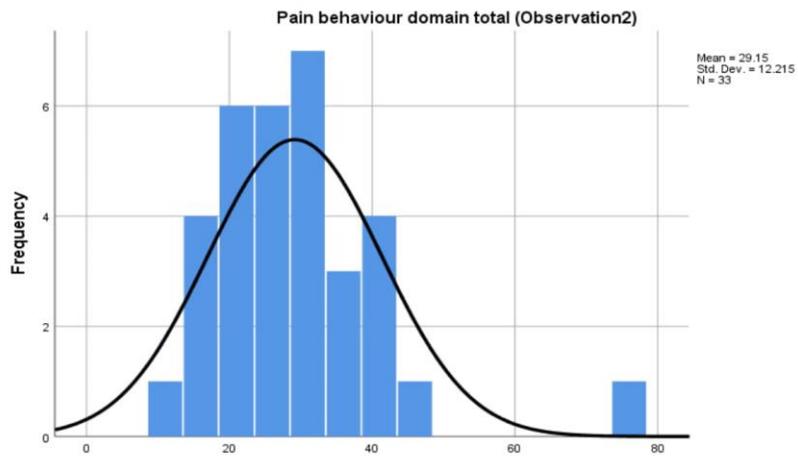


Figure 21 Impact of LBP on work and lifestyle domain total (Observation1)

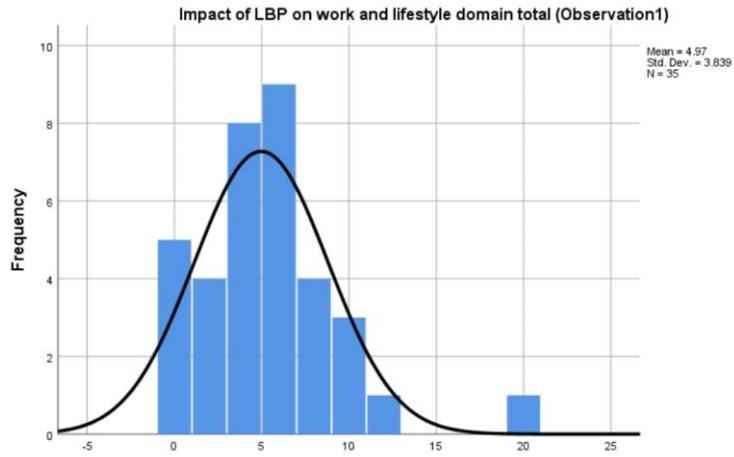


Figure 22 Impact of LBP on work and lifestyle domain total (Observation2)

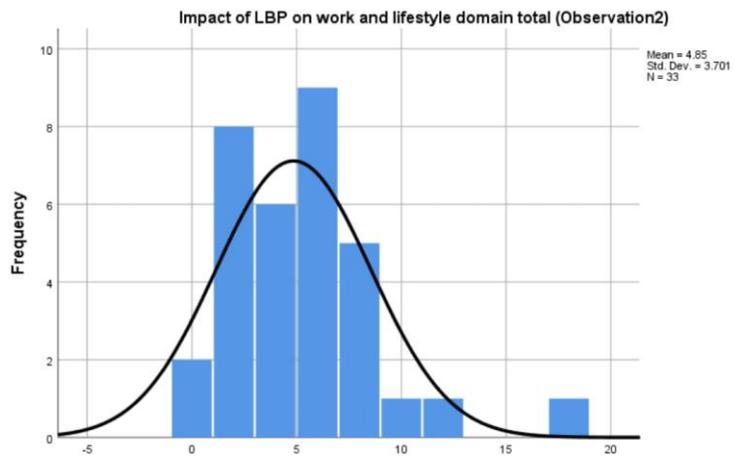


Figure 23 Experience with LBP domain total (Observation 1)

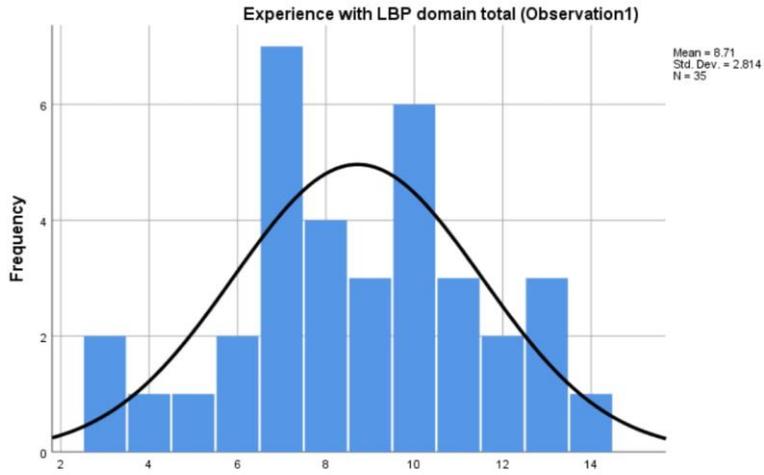
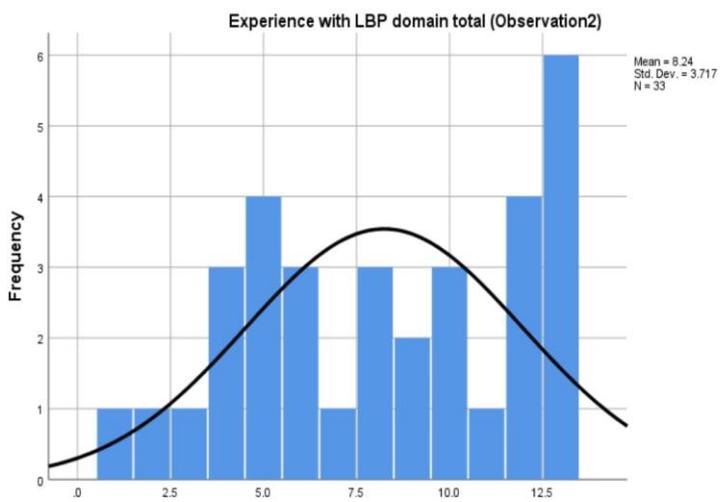


Figure 24 Experience with LBP domain total (Observation 2)



B: Numeral tests of normality

Table 48 presents the results from two tests of normality, the Kolmogorov-Smirnov Test and the Shapiro-Wilk Test. The Shapiro-Wilk Test is more appropriate for smaller sample sizes ($N < 50$ samples), therefore, the Shapiro-Wilk test was used as the numerical means of assessing normality in Phase 3. When checking for normality using the Shapiro-Wilk Test, if the significance is greater than 0.05, then the data is normal. If the significance is below 0.05, the data significantly deviate from a normal distribution (Gissane 2016). It should be noted that in small sample sizes, normality tests have little power to reject the null hypothesis and therefore small samples most often pass normality tests (Ghasemi and Zahediasl 2012).

In the current study, according to the Shapiro-Wilk Test, BACKonLINE™ Observation 1 total score, Pain behaviour domain total (Observation1), and Experience with LBP domain total (Observation1) are normally distributed while BACKonLINE™ Observation 2 total score, Pain behaviour domain total (Observation2), Impact of LBP on work and lifestyle domain total (Observation 1 and 2), and Experience with LBP domain total (Observation2) are not normally distributed. Figures 25,26,27,28,29,30,31, and 32 provide a visual representation of the test of normality using Q-Q plots.

Table 48 tests of normality for BACKonLINE™ total and each domain for Observation 1 and 2

	Tests of Normality					
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BACKonLINE™ Observation 1 total score	0.141	33	0.093	0.943	33	0.082
BACKonLINE™ Observation 2 total score	0.127	33	0.193	0.910	33	0.010
Pain behaviour domain total (Observation1)	0.134	33	0.137	0.949	33	0.124
Pain behaviour domain total (Observation2)	0.107	33	0.200 [*]	0.884	33	0.002
Impact of LBP on work and lifestyle domain total (Observation1)	0.154	33	0.047	0.875	33	0.001
Impact of LBP on work and lifestyle domain total (Observation2)	0.135	33	0.131	0.888	33	0.003
Experience with LBP domain total(Observation1)	0.107	33	0.200 [*]	0.969	33	0.446
Experience with LBP domain total(Observation2)	0.147	33	0.068	0.924	33	0.023
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

C: Visual tests of normality (Normal Q-Q plots):

Figure 25 BACKonLINE™ Observation 1 total score

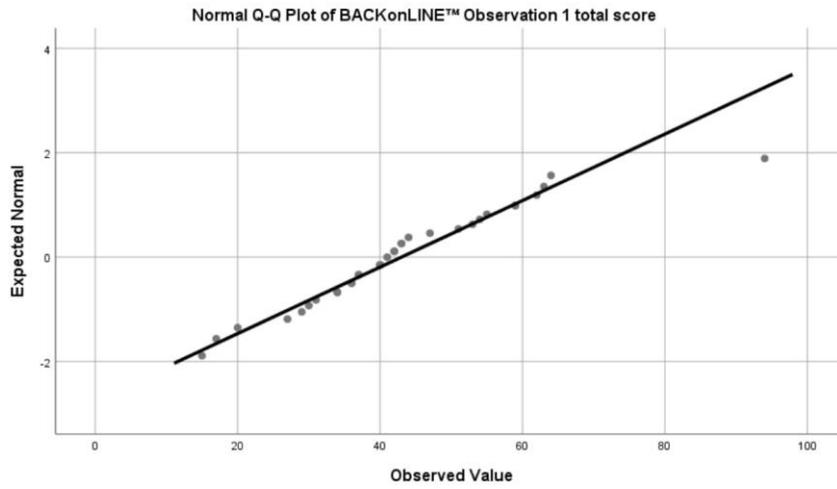


Figure 26 BACKonLINE™ Observation 2 total score

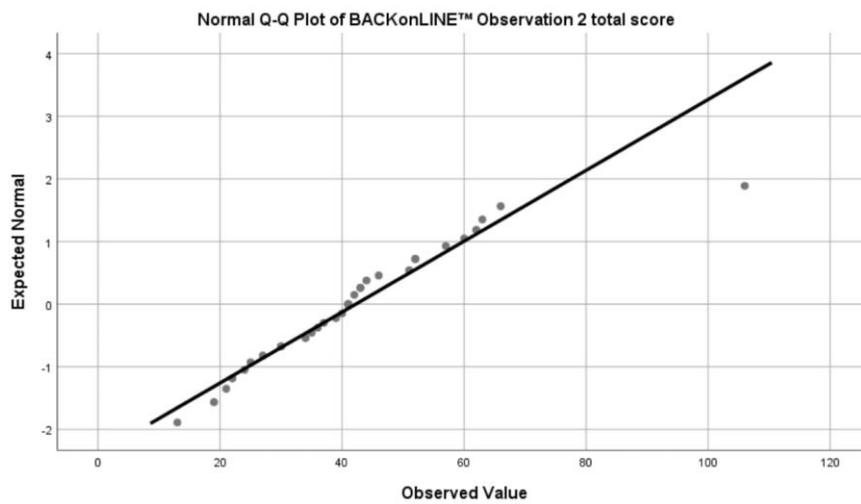


Figure 27 Pain behaviour domain total (Observation1)

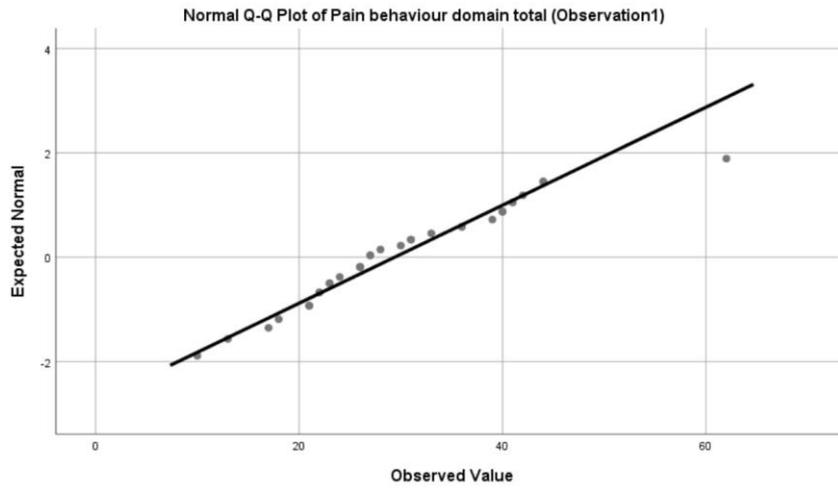


Figure 28 Pain behaviour domain total (Observation2)

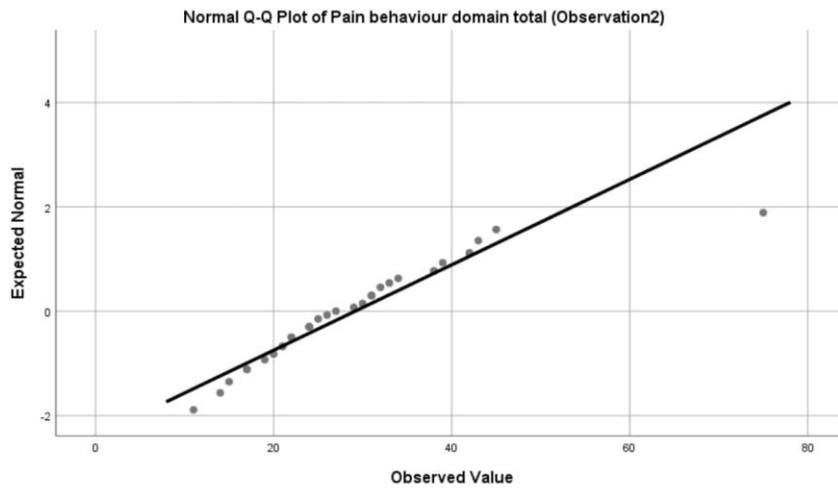


Figure 29 Impact of LBP on work and lifestyle domain total (Observation1)

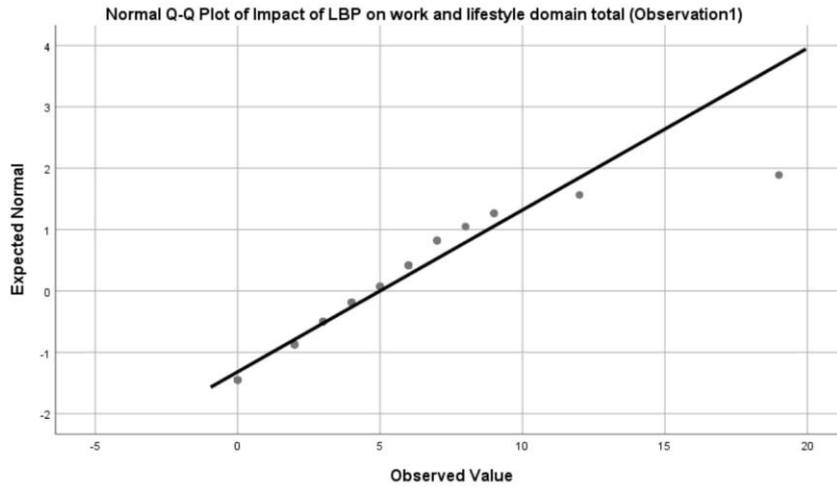


Figure 30 Impact of LBP on work and lifestyle domain total (Observation2)

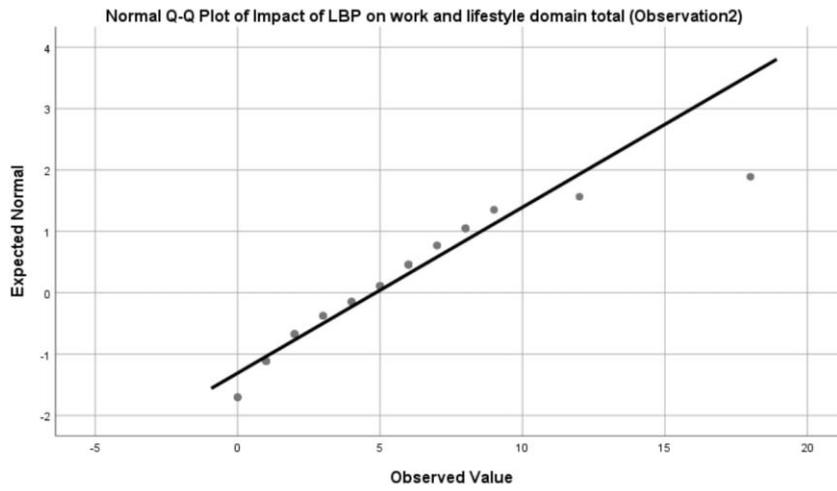


Figure 31 Experience with LBP domain total (Observation 1)

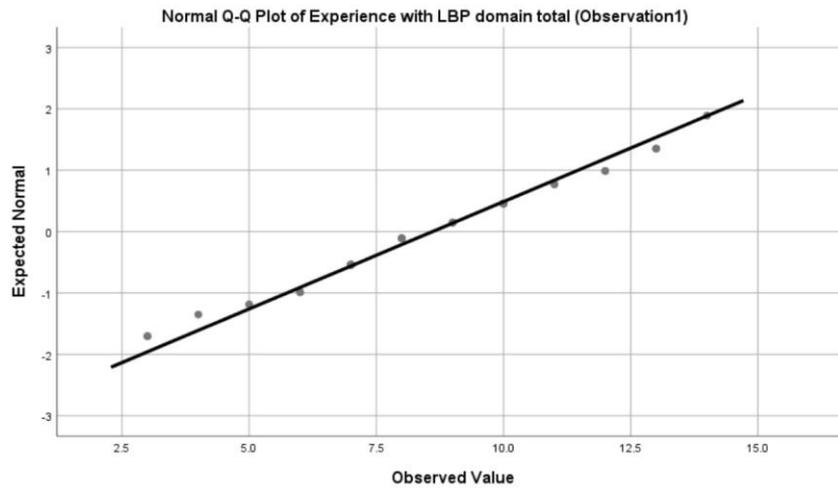
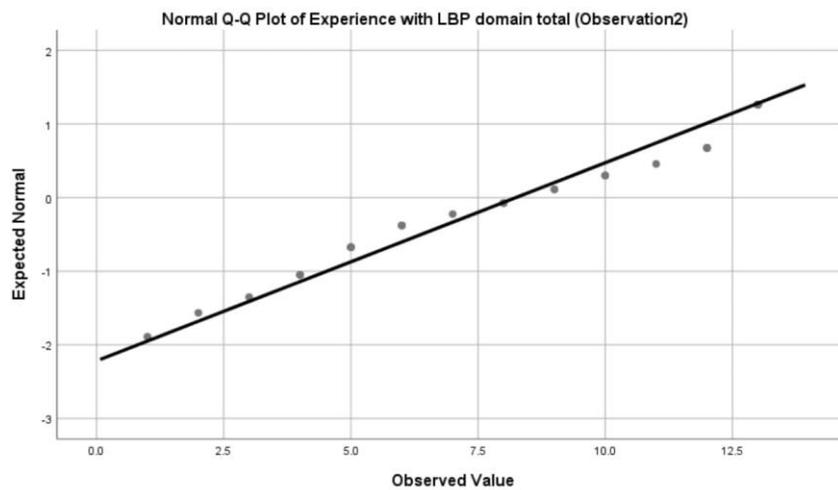


Figure 32 Experience with LBP domain total (Observation 2)



References:

Ghasemi, A. and S. Zahediasl (2012). "Normality tests for statistical analysis: a guide for non-statisticians." *International journal of endocrinology and metabolism* **10**(2): 486.

Gissane, C. (2016). "Is the data normally distributed?" *Physiotherapy Practice and Research* **37**(1): 57-60.