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Effect of visual feedback on the performance of the star excursion balance test

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Abstract

Introduction: Visual feedback is an effective method to enhance postural and balance control in clinical and sports training. The aim of this study was to explore the effect of real-time visual feedback provided by a video camera on the performance of a dynamic balance test, which is the star excursion balance test in healthy subjects.

Methods: We compared the performance of the star excursion balance test using the maximum reach distance in 20 healthy participants (10 male and 10 female, 26.8 ± 3.7 years) under two conditions: without feedback and whilst they viewed their movements in real-time on a screen in front of them via a video camera.

Results: The results showed that real-time visual feedback had a significant effect on maximum reach distance of the star excursion balance test in the posterolateral direction ($P < 0.001$). There was a non-significant increase in the maximum reach distance in the anterior and posteromedial directions.

Conclusion: The result indicates that the real-time visual feedback appears to be an effective means for improving the performance of the star excursion balance test in the posterolateral direction, and may be a promising tool for clinical rehabilitation and athlete training to enhance dynamic postural control.

Keywords

Visual feedback, star excursion balance test, dynamic balance test, postural and balance control

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Introduction

The star excursion balance test (SEBT) is an important clinical functional performance test requiring adequate range of motion, muscle strength and proprioceptive and neuromuscular adjustments to keep balance.[1] It is being used to identify postural and balance control deficiencies related to lower-limb pathology, detect improvements in balance rehabilitation, predict lower-limb injury and train both patients and healthy people.[2] Its reliability and validity as a convenient and inexpensive clinical approach for dynamic postural control have been evaluated in clinical and research settings.[3] However, the performance of the SEBT can be influenced by complex physiological systems in addition to the musculoskeletal system, such as vision, somatosensory and vestibular systems, which provide information on body sway and adjustments for corrective anticipatory postural behaviours.[4] Vision plays an important role in postural and balance control as it provides unmatched, accurate and sophisticated information at the right time and a location that cannot be matched by other sensory modalities.[5] Visual feedback is a method using optical illusion to adjust and improve the motor strategy and movement,[6] which is originally used as mirror therapy to rehabilitate paralysed limbs using the reflection of the movement of the non-paralysed limb.[7] Visual feedback enhances the training effect by compensating for the loss of somatosensory function after injury and enhances motor process in the brain;

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thus it facilitates postural control and the effectiveness of the treatment.[8]

Real-time visual feedback provides immediate and continuous feedback that can be used to correct movements during a motor task. It can be used to improve dynamic balance control and avoid falls and mistakes by influencing force production, accuracy and balance control.[9,10] The combination of the SEBT and real-time visual feedback may have a beneficial effect on dynamic postural control. However, to the authors' knowledge, previous studies on the effect of visual feedback have mostly used stance, walking and upper-limb functional tasks,[6,11,12] and there is no literature evaluating the effect of real-time visual feedback provided by a video camera on the SEBT. Thus, exploring the use of a video camera as a means of providing visual feedback on the SEBT among able-bodied adults can provide a reference for clinical training and effective interventions for people with dynamic postural control problems. If real-time visual feedback improved the performance of the SEBT, it could be used with patients undergoing rehabilitation to increase the challenge placed on the motor system during the dynamic balance task in a safe and effective way.

The aim of the study was to quantify the performance of the SEBT with and without visual feedback. If the results showed significant improvements in the performance of the SEBT with visual feedback, this would support the use of this tool in clinical rehabilitation and athlete training to enhance the use of the SEBT for training dynamic postural control.

Methodology

Participants

A convenience sample of 20 healthy participants (10 male and 10 female) was recruited from Cardiff University to perform the SEBT under two conditions after providing written informed consent. All participants were physiotherapists who were familiar with the SEBT. Ethical approval was granted by the School of Healthcare Sciences Research Ethics Committee. The inclusion criteria were aged between 18 and 60 years, no history of neuromuscular diseases, and normal or corrected-to-normal vision. The exclusion criteria were musculoskeletal injury or other condition that may affect posture or balance control.

Procedure

After providing consent, participants were asked to perform a 5 min warm-up on a bicycle ergometer. After completing the warm-up, they were instructed to practice three SEBT trials in each direction to familiarise themselves with the procedure and to reduce the learning effect. The dominant limb was determined by asking the participants which leg they preferred to kick a ball with. The leg used to kick a ball has high consistency with the dominant leg in bilateral mobilising task, and it is also the dominant leg in a unilateral dynamic balance task.[13] The dominant leg was used as the stance leg for all subsequent SEBT trials. To perform the SEBT, participants were instructed to put their arms on their waist and to reach the non-dominant leg as far as possible along the anterior, posterolateral and posteromedial direction lines indicated by red tape on the floor, while keeping the dominant foot on the floor (see Figure 1). The posterolateral direction was to the side of the leg performing the task (i.e. reaching backwards and right if the right leg was performing the task), and the posteromedial direction was to the side of the stance leg (i.e. reaching backwards and left if the right leg was performing the task). The process of the SEBT was in the sequence of anterior, posterolateral and then posteromedial. This order was designed such that the degree of difficulty gradually increased (i.e., the task in anterior direction is easier than that in the posterolateral and posteromedial directions, and posterolateral is easier than posteromedial).[3] This sequence was chosen because it replicates the way the SEBT is performed in clinic and thus increases the external validity of the results.[14] The interval between subsequent trials was at least 1 min.

During the trials, participants were instructed to perform the SEBT without visual feedback first, and then to perform the SEBT with visual feedback. This order was chosen in order to minimise the influence of the learning effect on performing the SEBT with visual feedback. This is because participants might learn to adjust the movement strategy to enhance the performance through the feedback on the screen. In no-feedback condition, they could look at their feet to follow the direction lines indicated on the floor (Figure 1(b) to (d)). Then they were given a 2 min rest prior to performing the SEBT with visual feedback. In the visual feedback condition, they were able to view their lower-limb movements in real time on a screen located in front of them (Figure 1(e) to (g)). In both conditions, participants were instructed to reach the maximum excursion and then touch the tape lightly with the foot so as not to aid balance, before returning to their initial upright posture. The point at which the participant touched the tape was considered as the maximum reach distance (MRD). MRD was recorded manually using a measuring tape, and all data were recorded to the nearest

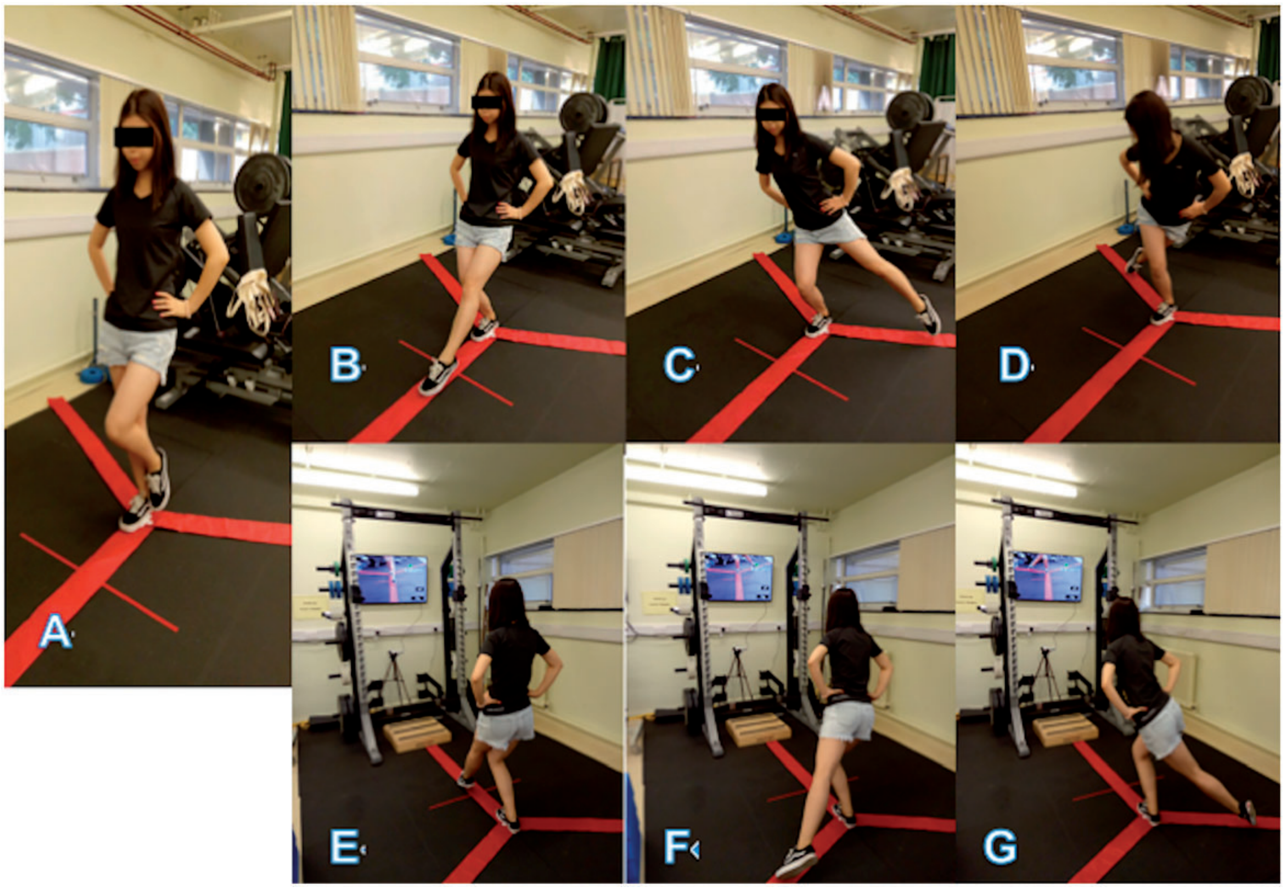

Figure 1. Setup of the SEBT and a participant performing the test. (a) Upright posture; (b) anterior without visual feedback; (c) posterolateral without visual feedback; (d) posteromedial without visual feedback; (e) anterior with visual feedback; (f) posterolateral with visual feedback; (g) posteromedial with visual feedback.

centimetre. MRD requires a combination of postural and balance control, related muscle strength, and range of motion of the stance limb.[2] Therefore, it is associated with dynamic postural control of the stance limb, and thus was considered as the primary outcome of this study.

Data analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS, software version 23, IBM Corporation). Demographic information (age, gender, height and weight) was quantified using descriptive statistics to evaluate the heterogeneity of the sample and inform the generalisability of the results. The average MRD in each direction was calculated for each condition, and used for statistical analysis. According to the Shapiro–Wilk test ($P > 0.05$), MRD was

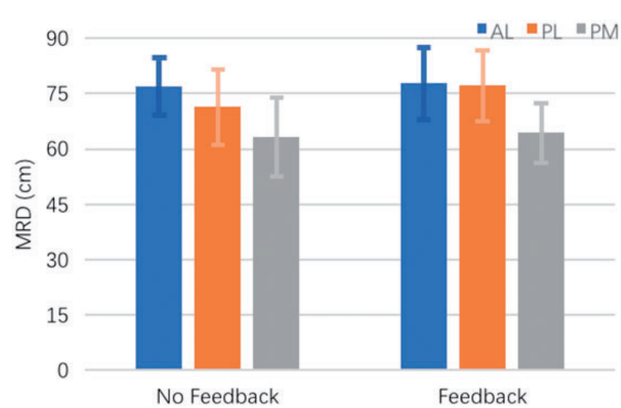

Figure 2. Average maximum reach distance (MRD) in each of the three directions under two conditions. AL: MRD in the anterior direction; PL: MRD in the posterolateral direction; PM: MRD in the posteromedial direction.

normally distributed for each of the three directions in each of the two conditions, and a repeated-measures ANOVA was therefore used to detect any effects of independent variables. Post-hoc comparisons were performed using paired t-tests with Bonferroni correction for multiple comparisons to explore significant main effects. Significance was defined as a probability level of $P \leq 0.05$.

Results

Twenty healthy participants (age: 26.8 ± 3.7 years; mass: 70.4 ± 19.0 kg; height: 170.2 ± 9.8 cm; gender: 10 male and 10 female) took part in the study. Fifteen participants used the left leg as their standing leg, and five participants used the right leg.

In the posterolateral direction, MRD with visual feedback was significantly larger ($F = 34.969$, $P < 0.001$) than that without visual feedback. There was no significant difference in MRD between the two feedback conditions in the anterior and posteromedial directions ($F = 0.412$ and 0.439, $P = 0.528$ and 0.515, respectively) (Figure 2).

Discussion and conclusion

Real-time visual feedback significantly improved the performance of the SEBT in the posterolateral direction, but not the anterior or posteromedial directions. The findings of this study are in line with previous research, which reported that real-time visual feedback provided by a video camera improved the movement of the upper limb by enhancing the activation of the related muscles.[15] Real-time visual feedback encourages people to pay more attention to the execution of the task, and enables physical self-control through continuous visual information.[15] The current study demonstrated a significant influence of visual feedback on the performance of the SEBT in the posterolateral direction. This has potential benefits for postural and balance control for healthy people.[5] This was evident by a positive effect of visual feedback on MRD in all directions, although it was not significant in the anterior and posteromedial directions. In the anterior direction, participants had almost the same view in both visual feedback conditions, and this may have resulted in the lack of any significant effect. The greater difficulty of the task in the posteromedial direction might have precluded any effects of the visual feedback.[2] The lack of significant effects in the anterior and posteromedial directions might also be due to the small sample size and the fact that all participants were physiotherapists who were familiar with the SEBT. Therefore, future work should increase the sample size and recruit a more diverse cohort of participants. The learning effect in this study was minimised by the performance of practice trials before the experiment.

The current study is, to our knowledge, the first study to explore the effect of visual feedback provided by a video camera on the performance of the SEBT. The results can inform future clinical research of using real-time visual feedback combined with the SEBT to improve posture and balance control. Further work should consider whether the addition of real-time visual feedback to the SEBT can help identify and treat patients with lower-extremity injuries and other neuromuscular diseases, and thus improve rehabilitation. People with balance problems may have lower MRD than healthy people, and perhaps greater difference in MRD of the left and right than healthy people, and the SEBT performed with real-time visual feedback may be useful for identifying deficiency at an early stage. As for treatment, performing the SEBT with visual feedback may reduce the risk of falls and help patients correct and enhance the postural control behaviours. By comparing movements of the left and right legs on the screen in front of them, patients may notice the difference and weakness of the affected leg, which might trigger re-learning and implementation of a compensation strategy to improve balance control. However, in this study, we only considered the SEBT performed with the dominant leg as the stance leg. Some people might use their non-dominant leg as the stance leg for unilateral balance tasks, and future studies are needed to determine if our results are replicated when the non-dominant leg is the stance leg.

In conclusion, our results indicate that real-time visual feedback can improve the performance of the SEBT in the posterolateral direction in healthy individuals. This supports the use of real-time visual feedback of the SEBT in clinical rehabilitation of patient populations and in athletic training that aims to enhance dynamic postural control. This training is easy to replicate in the home using a video camera on a tablet or phone. The visual feedback may enable people to notice and adjust their motor strategy during the dynamic balance task.

Declarations of conflicting interests

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Guarantor

YW.

Contributorship

MA conceived the initial study design and all authors agreed to the final design. YW researched literature and undertook the data collection and processing. YW, MA and JLD performed the data analysis. YW wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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