Season of Birth, Daylight Hours at Birth, and High Myopia

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Purpose: Mandel et al recently reported that season of birth and daylight hours (photoperiod) at birth were associated with moderate and high levels of myopia in Israeli conscripts. We sought to investigate whether these associations were evident in subjects from the United Kingdom (UK).

Design: Retrospective cross-sectional study.

Participants: The study population comprised 74,459 subjects aged 18 to 100 years attending UK optometry practices for an eye examination.

Methods: Data comprising non-cycloplegic spectacle prescription, sex, date of birth, and date of eye examination were collected from UK optometry practices. The average refractive error in fellow eyes was used to classify the degree of myopia in diopters (D) for each subject as follows: absent (>-0.75 D), low (-0.75 to -2.99 D), moderate (-3.00 to -5.99 D), or high (<-6.00 D). The average monthly hours of daylight for London, UK, were classified into 1 of 4 "photoperiod categories," following Mandel et al. The odds ratio (OR) for each level of severity of myopia was calculated using multivariate logistic regression with age, sex, and either season of birth or photoperiod category as risk factors.

Main Outcome Measures: The OR for season of birth and photoperiod category as potential risk factors for myopia.

Results: Season of birth was significantly associated with the presence of high myopia: Subjects born in summer or autumn were more likely to be highly myopic compared with those born in winter (summer OR = 1.17; 95% confidence interval [CI], 1.05–1.30; $P = 0.006$; autumn OR = 1.16; 95% CI, 1.04–1.30; $P = 0.007$). However, season of birth was not a significant risk factor for low or moderate myopia. Photoperiod category was weakly associated with low myopia (OR = 0.94; 95% CI, 0.89–0.99; $P = 0.019$), but with a direction of effect opposite to that observed by Mandel et al.

Conclusions: As in Israel, a disproportionate number of UK high myopes were born in summer or autumn rather than in winter. However, unlike the situation in Israel, this association does not seem to be related to daylight hours during the postnatal period, implicating alternative physiologic influences that vary with season, such as birth weight.

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Myopia is a condition in which parallel rays of light are brought to a focus in front of the retina, which leads to blurred distance vision. Generally, the symptoms can be alleviated by the use of corrective lenses or refractive surgery. The prevalence of myopia varies widely with ethnicity, especially in children (e.g., 1% in Nepal, 80% in Taiwan).[1–4] The major structural correlate of myopia is an increase in the axial length of an eye.[5]

Light levels have been linked to the development of myopia. For instance, Czepita et al[6] reported a higher prevalence of hyperopia in children from homes with fluorescent lamps compared with children from homes with incandescent lamps. Quinn et al,[7] Chapell et al,[8] and Czepita et al[9] found that infants who slept with a night light or bedroom light on were at an increased risk of myopia development in later life. However, other authors have failed to find an association between light exposure at night in infancy and myopia prevalence.[6,10–15]

Midelfart[16] suggested the idea of examining the influence of seasonal changes in light levels on the development of myopia, particularly in population groups such as the Norwegians, for whom seasonal changes in photoperiod are dramatic. She noted that, in the far north of Norway, children born during summer might experience relatively high levels of light at night time in their first weeks, because day lengths are close to 24 hours at this latitude and the strong nighttime sunlight would be hard to screen out. By contrast, children born during winter, when day lengths are very short, might experience relatively darker nights in their first weeks after birth. Thus, if photoperiod during early infancy affects refractive development, it might be manifested as an association between refractive error and season of birth, which would be particularly evident in populations born at northern latitudes. This idea was tested by Vannas et al[17] in a questionnaire survey of 3551 Finnish military conscripts. However, no association between myopia prevalence and season of birth was detected. In the same study, however, there was a trend toward a higher prevalence of myopia among conscripts living at the most northerly latitudes compared with those living further south.[17] The relationship

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between myopia and season of birth was also studied in a second group of military conscripts (276,911 subjects aged 16–22 years, from Israel) by Mandel et al.[18] In contrast with the findings of the Finnish study,[17] these authors did find a significant association between season of birth and the prevalence of both moderate and severe myopia. The odds ratio (OR) for moderate myopia versus no myopia was 1.08 (95% confidence interval [CI], 1.04–1.13) in those subjects born during the 3 months with the longest photoperiod compared with those with the shortest photoperiod.[18] For high myopia versus no myopia, the OR was higher still (OR = 1.24; 95% CI, 1.16–1.33). We examined the relationship among season of birth, photoperiod, and myopia prevalence for subjects in the United Kingdom (UK), which has a slightly wider range of daylight hours than Israel.

Materials and Methods

Subjects

Ethical approval for this study was granted by the Cardiff University School of Optometry and Vision Sciences, Human Science Research Ethics Committee. The research adhered to the tenets of the Declaration of Helsinki. The study population comprised 90,884 subjects attending UK optometry practices for a sight test and has been described in detail.[19,20] Noncycloplegic spectacle prescription, sex, date of birth, and date of eye test of all subjects were obtained from the practices participating in the study. The refractive error for only the most recent visit was recorded for subjects who attended more than once during the sampling period. Information regarding the ocular health of the subjects was not available; thus, we were unable to exclude subjects with ocular abnormalities. We removed from the data set individuals with missing data or likely data entry errors (N = 2942). Because their subjective refractions might have been less reliable, we also removed individuals aged less than 18 years at the time of visit (N = 13,483). This left 74,459 subjects aged 18 to 100 years with data available for analysis.

Photoperiod Categories

The "Civil Twilight" hours (the period from dawn until dusk) in London during 2006 were downloaded from a public repository (Available at: http://aa.usno.navy.mil/data/docs/RS_OneYear.php. Accessed May 31, 2008). These data were used to define 4 photoperiod categories following Mandel et al[18] (Table 1). Months were also grouped together to divide the year into 4 seasons: Winter (December–February), Spring (March–May), Summer (June–August), and Autumn (September–November). Civil twilight hours for Tel Aviv, Israel, in 2006 were also downloaded for comparison (Table 1). These latter daylight hours were similar to those reported by Mandel et al[18] in their analysis of myopia and season of birth. Finally, daylight hours for London in 1998, 1988, 1978, and 1968 were downloaded for an analysis of variation across decades.

Table 1. Comparison of Photoperiod Categories in the United Kingdom and Israel

Photoperiod Category	Daylight Hours	
	United Kingdom	*Israel*
1	9.31–10.15	10.99–11.39
2	10.16–13.03	11.40–12.82
3	13.04–15.71	12.83–14.14
4	15.72–18.01	14.15–15.16

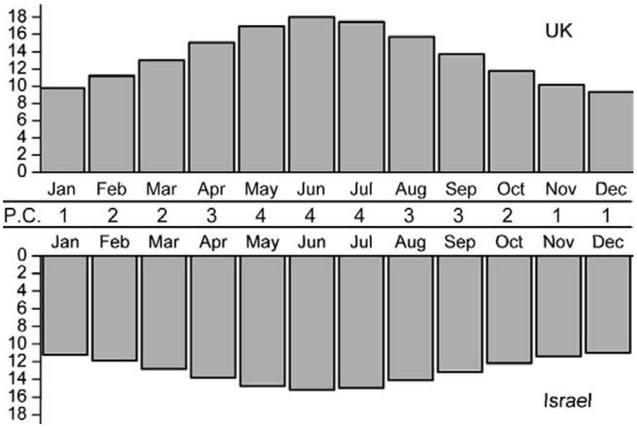

Figure 1. Comparison of daylight hours in the United Kingdom and Israel. Daylight hours are shown on the *y*-axis. Months with similar daylight hours were grouped into 1 of 4 photoperiod categories numbered 1 to 4. Note that the photoperiod categories for Israel were taken from Mandel et al.[18] P.C. = photoperiod category.

Statistical Analyses

For each subject, refractive error was calculated as the average spherical equivalent (sphere power plus half of the cylinder power) in the 2 eyes. Refractions, in diopters (D), were classified into 4 categories as described by Mandel et al:[18] "non-myopic" >-0.75 D; "low myopia" -0.75 to -2.99 D; "moderate myopia" -3.00 to -5.99 D; and "high myopia" <-6.00 D.

Association between photoperiod category and refraction group was evaluated using the chi-square test (using a 4 × 4 table comprising the counts of subjects in each of the 4 photoperiod categories tabulated against the 4 refraction groups: non-myopic, low, moderate, and high myopia). Association between season of birth and myopia was evaluated similarly. Multivariate logistic regression analyses were carried out to test the effects of the categoric variables *photoperiod category* (groups 1–4) and *season* (winter, spring, summer, and autumn) on the presence or absence of myopia, while adjusting for age and sex. When investigating the risk of myopia in each one of the severity categories (low, moderate, and high), the data for the other 2 categories were considered as missing, as in the study by Mandel et al.[18] For subjects with high myopia, association between the degree of myopia and season of birth was evaluated using the Kruskal–Wallis test. All analyses were carried out using SPSS 12.0 (SPSS Inc., Chicago, IL).

Results

Photoperiod Categories

Daylight hours in London were taken as characteristic of those across the United Kingdom. Daylight hours were found not to vary by decade from 1968 to 2006; thus, data of 2006 were assumed to be representative of those daylight hours that occurred at the time

Table 2. Prevalence of Myopia Severity Category by Photoperiod Category

Photoperiod Category	Myopia Severity Category *Mild* (*N* = *14,902*)	 *Moderate* (*N* = *8967*)	 *Severe* (*N* = *2876*)
1	20.4% (19.8–21.0)	12.1% (11.6–12.6)	3.8% (3.6–4.1)
2	20.0% (19.4–20.6)	11.9% (11.5–12.4)	3.7% (3.4–4.0)
3	20.0% (19.5–20.6)	12.3% (11.8–12.8)	3.8% (3.6–4.1)
4	19.7% (19.1–20.2)	11.8% (11.4–12.3)	4.1% (3.8–4.3)

Figures in brackets are 95% CIs.

Table 4. Prevalence of Myopia Severity Category by Season

Season	Myopia Severity Category *Mild* (*N* = *14,902*)	 *Moderate* (*N* = *8967*)	 *Severe* (*N* = *2876*)
Winter	20.0% (19.4–20.5)	12.0% (11.5–12.5)	3.6% (3.3–3.9)
Spring	19.9% (19.4–20.5)	12.0% (11.5–12.4)	3.6% (3.3–3.9)
Summer	19.8% (19.3–20.4)	11.9% (11.4–12.4)	4.1% (3.9–4.4)
Autumn	20.4% (19.8–21.0)	12.3% (11.9–12.8)	4.1% (3.8–4.4)

Figures in brackets are 95% CIs.

of birth of the entire study population. In comparison with data from Tel Aviv, Israel, during 2006, the United Kingdom exhibited a wider range of photoperiods (Fig 1; Table 1). The United Kingdom had shorter daylight hours in the winter (~10 hours vs. 11 hours) and longer daylight hours in the summer (~17 hours vs. 15 hours). Thus, if photoperiod at birth is an important determinant of refractive error, then this suggests that the UK subjects would be exposed to at least as wide a range of environmental variability as that occurring in Israel.

Statistical Analyses

There were 74,459 subjects aged 18 to 100 years available for analysis. The prevalence of myopia in the study population was 35.9% (20.0% with low myopia, 12.0% with moderate myopia, and 3.9% with high myopia). As shown in Table 2, there was no indication that the prevalence of myopia varied as a function of photoperiod category ($\chi^2 = 8.6$, $df = 9$, $P = 0.45$). Multivariate logistic regression analysis controlling for age and sex confirmed that photoperiod category was not a significant risk factor for moderate and high myopia in this group of subjects (Table 3). A weak association was found between low myopia and photoperiod category 4 ($P = 0.019$), but it was in the opposite direction to that observed by Mandel et al.[18] Specifically, subjects in the longest photoperiod duration group were less likely to be mildly myopic in our study (OR = 0.94; 95% CI, 0.89–0.99).

Season of birth was weakly associated with the prevalence of myopia ($\chi^2 = 20.5$, $df = 9$, $P = 0.02$; Table 4). By using logistic regression analysis and controlling for age and sex (Table 5), season of birth was a significant risk factor for the development of high myopia, although this was not the case for low or moderate myopia. Specifically, the odds of a subject having high myopia versus no myopia were increased 1.17-fold (95% CI, 1.05–1.30, $P = 0.006$) for subjects born in summer compared with those born in winter and 1.16-fold (95% CI, 1.04–1.30, $P = 0.007$) for subjects born in autumn compared with those born in winter. As shown in Figure 2, the level of myopia in high myopes was not related to the season of birth (Kruskal-Wallis test $\chi^2 = 2.9$, $df = 3$, $P = 0.41$). Age was significantly associated with the presence of myopia, irrespective of the severity level, with older subjects being affected less often than younger subjects. Sex was significantly associated with the presence of moderate and high myopia, with men being affected less often than women (Tables 3 and 5).

Discussion

To date, the relationship between ambient photoperiod and myopia has been investigated in 2 large, well-defined cohorts.[17,18] In both studies, the authors proposed that exposure to relatively longer periods of ambient light at birth might be a risk factor for myopia. In the study of Vannas et al,[17] myopia prevalence was higher in subjects born in the upper latitudes of Finland (where the photoperiod is extremely long during the summer but reciprocally short in winter) compared with southern Finland (where seasonal photoperiods are similar to those in central Europe). Mandel et al[18] found that the prevalence of moderate and high myopia was greater in subjects from Israel born during (summer) months in which the photoperiod was relatively long, compared with those born during winter.

We have investigated the relationship between myopia and photoperiod at birth in a large UK cohort but found it to

Table 3. Logistic Regression Analysis for Presence of (Low, Moderate, or High) Myopia Versus No Myopia, with Photoperiod Category, Age, and Sex as Risk Factors

	Low Myopia *OR (95% CI)*	 *P Value*	Moderate Myopia *OR (95% CI)*	 *P Value*	High Myopia *OR (95% CI)*	 *P Value*
Photoperiod Category						
1	Referent	0.940*	Referent	0.218*	Referent	0.278*
2	0.95 (0.90–1.00)	0.520	0.95 (0.89–1.02)	0.169	0.94 (0.84–1.05)	0.246
3	0.97 (0.92–1.02)	0.258	1.01 (0.94–1.08)	0.803	1.00 (0.90–1.11)	0.964
4	0.94 (0.89–0.99)	0.019	0.96 (0.89–1.02)	0.191	1.05 (0.94–1.16)	0.446
Age	0.96 (0.96–0.96)	<0.001	0.95 (0.95–0.96)	<0.001	0.97 (0.96–0.97)	<0.001
Sex	0.99 (0.95–1.03)	0.581	1.16 (1.11–1.22)	<0.001	1.36 (1.25–1.47)	<0.001

CI = confidence interval; OR = odds ratio.
*P value for the risk factor photoperiod category overall.

Table 5. Logistic Regression Analysis for Presence of (Low, Moderate, or High) Myopia Versus No Myopia, with Season of Birth, Age, and Sex as Risk Factors

	Low Myopia		**Moderate Myopia**		**High Myopia**	
	OR (95% CI)	*P Value*	*OR (95% CI)*	*P Value*	*OR (95% CI)*	*P Value*
Season						
Winter	Referent	0.481*	Referent	0.435*	Referent	0.002*
Spring	0.99 (0.93–1.04)	0.585	0.98 (0.92–1.05)	0.622	1.00 (0.89–1.12)	0.973
Summer	0.99 (0.94–1.05)	0.779	1.00 (0.93–1.07)	0.903	1.17 (1.05–1.30)	0.006
Autumn	1.03 (0.97–1.08)	0.356	1.04 (0.97–1.11)	0.284	1.16 (1.04–1.30)	0.007
Age	0.96 (0.96–0.96)	<0.001	0.95 (0.95–0.96)	<0.001	0.97 (0.96–0.97)	<0.001
Sex	0.99 (0.95–1.03)	0.596	1.17 (1.11–1.22)	<0.001	1.36 (1.25–1.47)	<0.001

CI = confidence interval; OR = odds ratio.
**P* value for the risk factor *season* overall.

be an unlikely risk factor for myopia. Photoperiod was found to be weakly associated with myopia prevalence, but only where refractive error had not reached moderate or severe levels, and in a direction opposite to that found by Mandel et al.[18] The range of photoperiod in the United Kingdom is wider than that in Israel, and therefore it was expected that any relationship between photoperiod at birth and myopia progression in later life would be apparent to a similar or even greater degree here than in Israel. A power calculation tool (Lenth RV. Java Applets for Power and Sample Size. Available at: http://wwwstatuiowaedu/∼rlenth/Power 2006. Accessed March 20, 2008) was used to estimate how much power our study had to identify an effect of the same magnitude as that observed in the study of Mandel et al,[18] given that our sample size was approximately 4 times smaller. The calculation suggested that our study had 80% power to observe an effect of the same size.

In contrast with photoperiod category, season of birth was associated with the prevalence of high myopia in our analysis. Although there is a clear connection between season of birth and photoperiod at birth (Fig 1), such that the "low" photoperiod categories 1 and 2 occur during winter and the "high" photoperiod categories 3 and 4 occur in summer, the fact that season was a significant risk factor for myopia, but photoperiod category was not, suggests that photoperiod at birth, per se, is not the source of the season of birth/myopia relationship (otherwise, photoperiod would be expected to show a stronger association than season). We conclude that the postnatal photoperiod is unlikely to be a risk factor for myopia, at least in the United Kingdom. Nevertheless, we cannot rule out that an unaccounted-for variable that is associated with both photoperiod and season of birth, but less well defined by photoperiod in the UK sample compared with photoperiod in Israel, is responsible for the association reported by Mandel et al[18] but not replicated here.

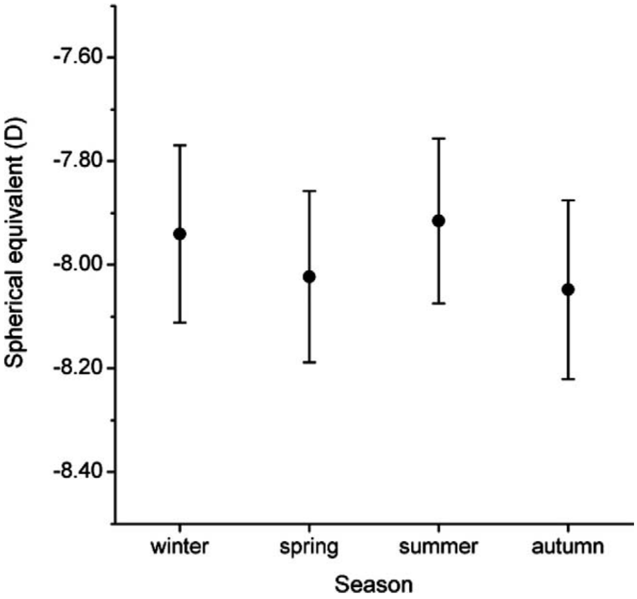

Figure 2. Spherical equivalent refractive error (measured in diopters, D) in high myopes as a function of season of birth. Error bars show 95% CIs.

Moreover, there were several important differences between our study and the study by Mandel et al that may have contributed to our disparate findings regarding an association between myopia and photoperiod at birth. First, our subjects had a wide age range (18–100 years), whereas those of Mandel et al[18] had a relatively narrow age range (16–22 years). Because refractive error varies with age, this could have provided a source of "noise" in our analysis that limited our ability to detect an association between photoperiod and myopia. Alternatively, it could be that photoperiod has an observable influence on refractive development until subjects are aged in their early twenties, but that other factors dominate refractive error later in life. Second, Mandel et al[18] used an essentially population-based cohort, whereas in the present study individuals were clinically selected. It is not obvious why the higher prevalence of myopia in our subjects compared with those studied by Mandel et al (35.9% vs. 29.9%) should have obscured a potential association between myopia and photoperiod. However, our clinically selected subjects would probably have had a greater level of all types of refractive error, and so it is conceivable that this difference was somehow important (e.g., presumably, fewer of our non-myope subjects would have been young emmetropes than would the non-myopes in the study by Mandel et al). Finally, the different geographic locations of the 2 studies may have been critical.

Photoperiod is a poor indicator of the intensity[21] (Rose et al. Ophthalmic Physiol Opt 2006;26:S016) and wavelength[22] of light received by subjects; therefore, although subjects in the United Kingdom were exposed to longer summer photoperiods than those in Israel, the highly variable degree of cloud cover in the United Kingdom, even in summer, would have meant they were rarely exposed to high ambient light levels. By contrast, in Israel, summers are characterized by prolonged periods of strong, bright sunshine.

In addition to the variation in photoperiod, season of birth reflects other population-wide changes in environment, for example, temperature, rainfall, humidity, and pollen count. Given the large number of such variables, and the paucity of data addressing their potential roles as risk factors for myopia, one can only speculate which of these variables, if any, might be important in relation to myopia. It is known, for example, that experimental myopia can be induced in rabbits by increasing body temperature (in tandem with increasing ocular pressure).[23] Thus, rather than photoperiod being the crucial determinant of being born in summer, it could be that other features, such as those mentioned previously,[21,22] are key.

As well as a potential biological explanation, an additional explanation for the relationship between season of birth and myopia would be human behavior.[24,25] Knowing that myopia is related to socioeconomic status and is highly heritable,[26,27] one could imagine that high myopes and their families might choose—either actively or subconsciously—to have children in summer rather than winter. However, Mandel et al[18] used 2 elegant analyses of the sibling pairs present within their cohort to argue against family planning behavior being the cause of the photoperiod/myopia association. In the first of these analyses, the refractive error of the subject's sibling was used as an additional risk factor in their logistic regression analysis, under the assumption that this would (partially) adjust for the effect of parental refractive error. Because the adjustment had no effect on the strength of the association between photoperiod and myopia, this result supported the idea that season of birth was independent of parental refractive error. In the second analysis, Mandel et al replaced the photoperiod category of the subject with the photoperiod category of their sibling when carrying out their logistic regression analysis. If myopic parents chose to give birth in a particular season, this second analysis would preserve the association between the subject's odds of myopia and the photoperiod of the sibling's birth. Therefore, the negative result obtained (i.e., no association between the subject's myopia and their sibling's photoperiod at birth) again supported the theory that parental myopia and season of birth were independent.

There is a large body of evidence suggesting that season of birth can affect prenatal or postnatal development. For instance, there is often an association between season of birth and birth weight.[28–31] Therefore, because associations have been reported between birth weight and axial eye length at age 6 years,[32,33] and hyperopia in childhood[34] and myopia in adulthood[35] (Cumberland et al. Invest Ophthalmol Vis Sci 2007;48:E2383), a connection between season of birth and high myopia may be due in part to an association between season of birth and birth weight. Alternatively, other developmental, possibly neurochemical, mechanisms may be suggested by the observed link between season of birth and mental health disorders in later life.[31,36]

Birth during the summer or autumn was a significant risk factor for high myopia in subjects from the United Kingdom, increasing the risk by approximately 16% compared with subjects born in winter. However, season of birth was not a significant risk factor for low or moderate myopia. These findings are similar to those of Mandel et al,[18] who reported birth during the summer to be a risk factor for moderate and high myopia, but not low myopia, in Israel. Our results suggest that the seasonal variation in photoperiod is unlikely to be the cause of the association between high myopia and season of birth.

References

1. Grosvenor T, Goss DA. Clinical Management of Myopia. Boston, MA: Butterworth-Heinemann; 1999:3–48.
2. Wu HM, Seet B, Yap EP, et al. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. Optom Vis Sci 2001;78:234–9.
3. Pokharel GP, Negrel AD, Munoz SR, Ellwein LB. Refractive error study in children: results from Mechi Zone, Nepal. Am J Ophthalmol 2000;129:436–44.
4. Lin LL, Shih YF, Tsai CB, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. Optom Vis Sci 1999;76:275–81.
5. Wildsoet CF. Structural correlates of myopia. In: Rosenfield M, Gilmartin B, eds. Myopia and Nearwork. Oxford, UK: Butterworth-Heinemann; 1998:31–56.
6. Czepita D, Goslawski W, Mojsa A. Refractive errors among students occupying rooms lighted with incandescent or fluorescent lamps. Ann Acad Med Stetin 2004;50:51–4.
7. Quinn GE, Shin CH, Maguire MG, Stone RA. Myopia and ambient lighting at night [letter]. Nature 1999;399:113–4.
8. Chapell M, Sullivan B, Saridakis S, et al. Myopia and night-time lighting during sleep in children and adults. Percept Mot Skills 2001;92:640–2.
9. Czepita D, Goslawski W, Mojsa A, Muszynska-Lachota I. Role of light emitted by incandescent or fluorescent lamps in the development of myopia and astigmatism. Med Sci Monit 2004;10:CR168–71.
10. Zadnik K, Jones LA, Irvin BC, et al, CLEERE Study Group. Myopia and ambient night-time lighting. Nature 2000;404:143–4.
11. Saw SM, Zhang MZ, Hong RZ, et al. Near-work activity, night-lights, and myopia in the Singapore-China study. Arch Ophthalmol 2002;120:620–7.
12. Gwiazda J, Hyman L, Dong LM, et al, COMET Group. Factors associated with high myopia after 7 years of follow-up in the correction of Myopia Evaluation Trial (COMET) cohort. Ophthalmic Epidemiol 2007;14:230–7.
13. Saw SM, Wu HM, Hong CY, et al. Myopia and night lighting in children in Singapore. Br J Ophthalmol 2001;85:527–8.
14. Guggenheim JA, Hill C, Yam TF. Myopia, genetics, and ambient lighting at night in a UK sample. Br J Ophthalmol 2003;87:580–2.
15. Zadnik K. Association between night lights and myopia: true blue or a red herring [letter]? Arch Ophthalmol 2001;119:146.

16. Midelfart A. Association between light exposure during the night and myopia in children [letter]. Arch Ophthalmol 2002; 120:406–7.
17. Vannas AE, Ying GS, Stone RA, et al. Myopia and natural lighting extremes: risk factors in Finnish army conscripts. Acta Ophthalmol Scand 2003;81:588–95.
18. Mandel Y, Grotto I, El-Yaniv R, et al. Season of birth, natural light, and myopia. Ophthalmology 2008;115:686–92.
19. Farbrother JE, Kirov G, Owen MJ, Guggenheim JA. Family aggregation of high myopia: estimation of the sibling recurrence risk ratio. Invest Ophthalmol Vis Sci 2004;45:2873–8.
20. Qin XJ, Margrain TH, To CH, et al. Anisometropia is independently associated with both spherical and cylindrical ametropia. Invest Ophthalmol Vis Sci 2005;46:4024–31.
21. Jones LA, Sinnott LT, Mutti DO, et al. Parental history of myopia, sports and outdoor activities, and future myopia. Invest Ophthalmol Vis Sci 2007;48:3524–32.
22. Prepas SB. Light, literacy and the absence of ultraviolet radiation in the development of myopia. Med Hypotheses 2008; 70:635–7.
23. Tokoro T. Experimental myopia in rabbits. Invest Ophthalmol 1970;9:926–34.
24. Kabai P, Bakk J. Myopia risk factors [letter]. Ophthalmology 2008;115:919.
25. Mandel Y, Polat U, Belkin M, Grotto I. In reply to: Kabai P, Bakk J. Myopia risk factors. Ophthalmology 2008;115: 919–20.
26. Guggenheim JA, Kirov G, Hodson SA. The heritability of high myopia: a reanalysis of Goldschmidt's data. J Med Genet 2000;37:227–31.
27. Young TL, Metlapally R, Shay AE. Complex trait genetics of refractive error. Arch Ophthalmol 2007;125:38–48.
28. McGrath JJ, Barnett AG, Eyles DW. The association between birth weight, season of birth and latitude. Ann Hum Biol 2005;32:547–59.
29. Chodick G, Shalev V, Goren I, Inskip PD. Seasonality in birth weight in Israel: new evidence suggests several global patterns and different etiologies. Ann Epidemiol 2007;17:440–6.
30. McGrath J, Barnett A, Eyles D, et al. The impact of nonlinear exposure-risk relationships on seasonal time-series data: modelling Danish neonatal birth anthropometric data. BMC Med Res Methodol [serial online] 2007;7:45. Available at: http://www.biomedcentral.com/1471-2288/7/45. Accessed September 17, 2008.
31. McGrath JJ, Saha S, Lieberman DE, Buka S. Season of birth is associated with anthropometric and neurocognitive outcomes during infancy and childhood in a general population birth cohort. Schizophr Res 2006;81:91–100.
32. Ojaimi E, Robaei D, Rochtchina E, et al. Impact of birth parameters on eye size in a population-based study of 6-year-old Australian children. Am J Ophthalmol 2005;140:535–7.
33. Saw SM, Tong L, Chia KS, et al. The relation between birth size and the results of refractive error and biometry measurements in children. Br J Ophthalmol 2004;88:538–42.
34. Czepita D, Zejmo M, Mojsa A. The influence of low birth weight on the prevalence of refractive errors among schoolchildren. Ann Acad Med Stetin 2006;52:63–6.
35. Grjibovski AM, Harris JR, Magnus P. Birthweight and adult health in a population-based sample of Norwegian twins. Twin Res Hum Genet 2005;8:148–55.
36. Davies G, Welham J, Chant D, et al. A systematic review and meta-analysis of Northern Hemisphere season of birth studies in schizophrenia. Schizophr Bull 2003;29:587–93.

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