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Time outdoors and the prevention of myopia

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ABSTRACT

Recent epidemiological evidence suggests that children who spend more time outdoors are less likely to be, or to become myopic, irrespective of how much near work they do, or whether their parents are myopic. It is currently uncertain if time outdoors also blocks progression of myopia. It has been suggested that the mechanism of the protective effect of time outdoors involves light-stimulated release of dopamine from the retina, since increased dopamine release appears to inhibit increased axial elongation, which is the structural basis of myopia. This hypothesis has been supported by animal experiments which have replicated the protective effects of bright light against the development of myopia under laboratory conditions, and have shown that the effect is, at least in part, mediated by dopamine, since the D2-dopamine antagonist spiperone reduces the protective effect. There are some inconsistencies in the evidence, most notably the limited inhibition by bright light under laboratory conditions of lens-induced myopia in monkeys, but other proposed mechanisms possibly associated with time outdoors such as relaxed accommodation, more uniform dioptric space, increased pupil constriction, exposure to UV light, changes in the spectral composition of visible light, or increased physical activity have little epidemiological or experimental support. Irrespective of the mechanisms involved, clinical trials are now underway to reduce the development of myopia in children by increasing the amount of time they spend outdoors. These trials would benefit from more precise definition of thresholds for protection in terms of intensity and duration of light exposures. These can be investigated in animal experiments in appropriate models, and can also be determined in epidemiological studies, although more precise measurement of exposures than those currently provided by questionnaires is desirable.

1. Introduction

An epidemic of myopia has emerged in children and young adults in some of the countries of East and Southeast Asia (Morgan et al., 2012), in particular in Singapore (Wu et al., 2001), China (He et al., 2004; Qian et al., 2009), including Hong Kong (Goh and Lam, 1994) and Taiwan (Lin et al., 2004; Shih et al., 2009), Japan (Matsumura and Hirai, 1999) and Korea (Jung et al., 2012). In these locations, around 80% or more of children completing school are now short-sighted, and the prevalence of sight-threatening high myopia in these children is now approaching 20% or more (Lin et al., 2004; Jung et al., 2012). In other parts of the world, the prevalence of myopia also seems to be increasing. The rate of increase is somewhat less than in some parts East and Southeast Asia, but nevertheless, in the United States (Kempen et al., 2004; Vitale et al., 2008, 2009), and perhaps in Europe (Logan et al., 2005; Jobke et al., 2008), the prevalence of myopia in younger adults is now in the range of 30–50%.

These high prevalences of myopia pose a major public health challenge. The high prevalence of ordinary myopia, which can be largely corrected with glasses, contact lenses or refractive surgery, poses the challenge of providing appropriate correction to the large number of people who now require it, because World Health Organisation (WHO) analyses show that uncorrected refractive error is the major cause of visual impairment in the world (Resnikoff et al., 2008). In addition, a meta-analysis of 11 cross-sectional studies has shown an increased risk of open angle glaucoma with both low and high myopia, with odds ratios of 1.77 and 1.88 respectively (Marcus et al., 2011). Myopia also poses an increased risk of retinal detachment which increases with the severity of myopia (Chou et al., 2007), and there are associations between myopia and cataract (Leske et al., 1991). Serious

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complications due to retinal and choroidal pathologies associated with myopia also increase with myopia severity (Vongphanit et al., 2002), and pose a major challenge, because prevention of the associated uncorrectable vision loss requires costly ophthalmic treatment (Morgan et al., 2012).

These challenges have focussed attention on the importance of prevention of myopia. Fortunately, recent reviews, from both environmental (Morgan and Rose, 2005) and genetic (Wojciechowski, 2011) perspectives, have concluded that this epidemic is largely due to exposure to environmental risk factors, which may be modifiable, with little evidence of increased susceptibility to the development of myopia based on genetic differences in those ethnic groups which often show higher prevalences of myopia. This conclusion is based on the evidence that within one ethnic group, there are marked differences in the prevalence of myopia in different environments, implicating environmental factors (see for example Rose et al., 2008b). In addition, within one location, specifically Singapore, the prevalence of myopia is high in younger adults from all the major ethnic groups – even in the population of South Asian (Indian) origin which is closer in genetic terms to populations of European and Middle Eastern origin. This evidence has been extensively reviewed elsewhere (Morgan and Rose, 2005; Morgan et al., 2012; Wojciechowski, 2011).

There is, in fact, considerable evidence that myopia is more common in adults who have completed more years of schooling, and who achieved higher qualifications (Au Eong et al., 1993a,b). In children, there is also an almost universal pattern of increasing myopia prevalence with years of schooling, and increased myopia with children with higher examination results (Saw et al., 2007) and those in academically selective schools or streams (Quek et al., 2004). Near work has been intensively investigated as a specific risk factor which could explain these associations, but attempts to quantify near work in recent years have not provided strong support for this idea (Mutti et al., 2002; Ip et al., 2008). Recent work has identified an association at the national level between locations with a high prevalence of myopia and intensive use of extracurricular classes (coaching or cram schools) (Morgan and Rose, 2013), and there is a similar association at the individual level (Saw et al., 2001a,b). It also seems likely that heavy homework and home study loads may have a role. However, given that mass intensive education has been a key component of economic development for many countries, it is not clear that educational loads can be markedly reduced, even though there are a few countries, characterised by more limited use of coaching or cram schools and lower homework loads, where educational outcomes are high, but the prevalence of myopia is low (Morgan and Rose, 2013).

Fortunately, again, recent work has identified an environmental exposure which appears to protect from the development of myopia – children who spend more time outdoors appear to be less likely to be, or become myopic (Mutti et al., 2002; Jones et al., 2007; Rose et al., 2008a,b; Dirani et al., 2009; Jones-Jordan et al., 2011; French et al., 2013a). The aim of this review is to outline the evidence for a protective role for time spent outdoors, to examine the biological mechanisms which underpin it, and to consider the potential of interventions which increase the amount of time that children spend outdoors for prevention of myopia.

2. Evidence for a protective effect of time outdoors

2.1. Major epidemiological studies

Studies which have addressed the issue of the protection from the development of myopia by time spent outdoors are summarised in Table 1. A direct link between time spent outdoors and myopia was first established in a longitudinal investigation of the factors associated with rate of myopic progression in a cohort of Finnish school children with established myopia (Parssinen and Lyyra, 1993). Greater time spent outdoors and in sports activities was associated with a less myopic refraction at follow-up and a marginally slower rate of myopic progression, but the association was only statistically significant for boys.

This finding was followed up in the large population-based Orinda Longitudinal Study of Myopia (OLSM) in the United States (Mutti et al., 2002), which reported that children with myopia engaged in significantly less sports activities than children who were emmetropic. The authors proposed that children who spend more time in sport performed less near work and thus did not develop myopia. They also suggested two alternative hypotheses; that children with myopia may participate less in sport due to the impact of spectacle wear or due to a more introverted personality, or that increases in blood flow during exercise might influence eye growth. These findings received little clinical attention, until two abstracts presented at the 2006 ARVO meeting (Jones et al. IOVS 2006; 47: ARVO E-Abstract 5452; Rose et al. IOVS 2006; 47: ARVO E-Abstract 5453) stimulated interest in the application of these findings to the prevention of myopia.

Subsequently, Jones et al. (2007) reported that children who became myopic participated in significantly less time outdoors and in sports activities, compared to children who remained emmetropic. They also showed in predictive models that children who spent less time outdoors and on sport had significantly greater odds of becoming myopic. This trend was observed in children with no myopic parents, and in those with two myopic parents. Less protection was observed in children with only one myopic parent, suggesting that there might be an interaction between parental myopia and time outdoors and on sport, which was also found in regression analysis. Nevertheless, protection by increased time outdoors and sport occurred to some extent, irrespective of the number of myopic parents a child had. A subsequent report showed that children who became myopic spent significantly less time outdoors and in sport than children who remained emmetropic, both before and after the onset of myopia (Jones-Jordan et al., 2011). These results strongly suggested that less time spent outdoors was a potentially causal factor for the development of myopia.

Systematic evidence for an effect of time spent outdoors on prevalent myopia was also published in 2008 from the Sydney Myopia Study (SMS), a population-based study of school-aged children in Sydney, Australia (Rose et al., 2008a). Time spent outdoors was strongly and inversely related to myopia. Children who spent greater amounts of time outdoors had more hyperopic spherical equivalent refractions and a lower prevalence of myopia than children who spent little time outdoors. This paper separately analysed sport performed outdoors as well as outdoor leisure activities including family picnics, playing outdoors and bushwalking, and indoor sport, and showed that the important factor was the total time spent outdoors, while indoor sport was not protective. Greater time spent outdoors was associated with less myopia even in children performing large amounts of near work. Comparison of the prevalence of myopia in children from the two major ethnic groups in Sydney, those of European and East Asian ancestry, also showed that the lower prevalence of myopia in those of European ancestry was associated with a higher level of time spent outdoors.

To this point, epidemiological studies of time spent outdoors and myopia had been based primarily on samples from populations of largely European origin, with a relatively low prevalence of myopia. However, a similar protective effect of greater time outdoors was reported in a sample of children predominantly of East