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Sunlight Does Explain the Protective Effect of Outdoor Activity Against Myopia

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Abstract

Myopia is a huge public health burden globally, with particular reference to East Asian countries. Progressive high myopia leads to sight threatening ocular pathologies that may require laser treatment or surgery as well as impose huge economic costs towards spectacles, contact lenses, therapeutic and surgical interventions. Hence, delaying the onset myopia is of utmost importance. Recent literatures imply that increased outdoor time is an important environmental factor for myopia prevention. The potential role of sunlight as a protective factor in myopia development is discussed in this review.

Keywords: Contact lenses; Pathologies; Myopia; Hyperopic

Introduction

"Keep myopia away! Go outdoors and play!" This is the slogan for the 21st century children as there is a mounding burden of myopia globally. Both genetics and environment play a role in myopia. Time spent outdoors has recently emerged as a protective factor against myopia and this relationship has been studied extensively for more than a decade (refer reviews by French et al. [1], Ngo et al. [2], Sherwin et al. [3], through cross-sectional [4-9] and cohort studies [10-12] as well as the randomized controlled trials [13,14]. Results from these studies, particularly, the cohort studies and randomized controlled trials have addressed the question of the protective role of increased outdoor time on myopia prevention.

Time spent outdoors and myopia – facts from cross sectional studies

In the SMS, Rose et al. [5] reported that an increase in the time spent outdoors was significantly associated with a more hyperopic refractive error and lower myopia prevalence in 12-year-old Australian children. They also reported a significant interaction between near work and the time spent outdoors. With increasing levels of outdoor activity, the refractive error was more hyperopic in children with low and moderate levels of near work. Children with high levels of near work and low levels of outdoor activity were 2.6 times more likely to have myopia when compared to children with low near work and high outdoor activity. Dirani et al. [6] showed lower myopic refraction and smaller axial length in Singaporean teenagers aged 11-20 years with an increase in the outdoor time. Furthermore, children with increased hours of outdoor activity were less likely to be myopic, thus showing a protective effect of outdoor activity on myopia. In a recent cross-sectional study among 681 Chinese children in Beijing, time spent outdoors was significantly associated with myopia (adjusted OR=0.32, 95% CI: 0.21, 0.48, P<0.001) [8]. Chinese children (n=370) with low level of outdoor activity had significantly more myopic refractive error (-1.34 ± 2.45D) compared to those with moderate (-0.29 ± 2.11D) & higher levels of outdoor activity (-0.25 ± -2.06D; Ptrend=0.003) [9].

Time spent outdoors and myopia – facts from cohort studies and randomized intervention trials

In a population-based cohort study of 7 to 15-year-old British children [11], increased time spent outdoors was associated with a lower risk of developing myopia compared to less time outdoors (HR=0.75, 95% CI: 0.60, 0.96, P=0.023). In yet another population based cohort study [12] among 6 & 12 year old children in Australia, low and moderate levels of outdoor activity were linked with higher odds of developing myopia compared to increased outdoor activity in both younger (adjusted ORs=2.84, 95% CI: 1.56, 5.17 & 1.14, 95% CI: 0.59, 2.21, respectively for low & moderate groups, Ptrend<0.0001) and older cohorts (adjusted ORs=2.15, 95% CI: 1.35, 3.42 & 2.00, 95% CI: 1.28, 3.14 respectively for low & moderate groups, Ptrend<0.001).

The Guangzhou Outdoor Activity Longitudinal study (GOAL), a randomized controlled intervention trial of schoolchildren in China, showed that 40 min/day outdoor activity decreased myopia onset by 9% after 3 years [13]. Another intervention study in Taiwan showed that 80 min/day of intermittent outdoor time during recess could decrease myopia onset up to 9% in only 1 year [14]. A recent meta-analysis showed that with every additional one hour of outdoor time per week, the risk of myopia onset reduced by 2% in children and adolescents [3].

Underlying causes of protective effect

High light levels–facts from animal models: There is compelling evidence from animal studies that exposure to high light intensities can retard experimental myopia in chicks [15,16] and monkeys [17]. Exposure to a light level of 15,000 lux for 5 hours per day produced significantly lower myopia and shorter axial length (-2.6 ± 0.5D; 8.73 ± 0.08 mm), whilst exposure to 500 lux did not retard eye growth and myopia in chicks (-3.5D ± 0.3D; 8.92 ± 0.04 mm; P<0.0001) [15]. The degree of protection was directly proportional to increasing light levels, with the onset of myopia being completely inhibited on exposure to

40,000 lux for 6 hours a day, resulting in a hyperopic refraction and shorter axial length (+2.97 ± 0.11D; 8.77 ± 0.03 mm) compared to exposure to 500 lux (-4.21 ± 0.17D; 9.31 ± 0.07 mm; P<0.0001) [16]. Similar response was seen in primate eyes, with exposure to 25,000 lux for 6 hours per day leading to a more hyperopic refraction (+4.20 ± 5.80D) than those exposed to normal indoor lighting (-1.30 ± 4.25D) [17]. It has been hypothesized that high light levels outdoors might trigger the release of dopamine, which is an ocular growth inhibitor [18-20]. This protective effect was more evident, when exposure to light intensity of about 10,000 lux was significantly associated with higher vitreous dopamine concentration and lesser myopia development in chicks, under both alternating light-dark cycles and continuous light exposure as compared to those exposed to light intensity of 50 lux and 500 lux. [21].

Light chromaticity and spectral composition – facts from animal models: Apart from high light levels, spectral composition of light also seems to have some impact on eye growth and myopia in experimental animal models [22-25]. Longitudinal chromatic aberration of the eye causes the short wavelength blue light to be focused in front of the retina and the long wavelength red light behind the retina. Guinea pigs reared in long wavelength light had significantly more myopic refraction (+1.78 ± 1.22D) compared to those reared in mixed wavelength light (+3.60 ± 1.65D) and white light 49 (+5.20 ± 1.67D, P<0.05) [22] while those reared under short wavelength light developed significantly more hyperopia (+6.08 ± 0.80D) compared to those reared under medium wavelength light (+2.96 ± 0.68D, P<0.01) and broadband light 50 (+1.36 ± 0.65D, P<0.001) [23]. In chicks, an excess of red light caused myopia (-2.83 ± 0.25D) and an excess of blue light caused hyperopia (+4.55 ± 0.21 D) [24]. Guinea pigs reared in red light developed nearly 2.50D more myopia (P<0.01) and 0.20 mm longer eye length (P=0.019) compared to those reared under blue light and white light [25]. Altering the chromaticity of ambient light could induce and reverse myopia and hyperopia in chicks and guinea pigs [24, 25]. Blue light induced hyperopia could be reversed to myopia by changing blue light to red light in guinea pigs [24] and red light induced myopia could be reversed to hyperopia in chicks [25] by changing red light to blue light. These results suggest that exposure to shorter wavelength blue light is protective against myopia and since outdoor sunlight is predominantly blue light, increased outdoor time may inhibit myopia in humans.

Vitamin D and myopia – facts from epidemiological studies: In a cross-sectional study of Caucasian teenagers and young adults done by Mutti, et al. [26] blood Vitamin D level was found to be significantly lower in myopes by 3.4 ng/ml (myopes=13.5 ng/ml; non-myopes=16.9 ng/ml, P=0.005). Similar results were shown in a cross-sectional study of Australian young adults with myopes having a significantly lower serum levels of vitamin D compared to non-myopes (67.6 nmol *vs.* 72.5 nmol, P=0.003) and subjects with vitamin D deficiency were more likely to be myopic (adjusted OR=2.07, 95% CI: 1.29–3.32, P=0.002) compared to those with sufficient levels of vitamin D [26,27]. Yet another epidemiological study of Korean adolescents reported that subjects with higher level of serum vitamin D were less likely to have high myopia ≤ -6.00D (adjusted OR=0.55; 95% CI: 0.34, 0.90; P=0.017) compared to those with lower serum vitamin D levels [28]. vitamin D Receptor (VDR) polymorphisms have been linked to early and late onset myopia in Indians [29] and low to moderate degree of myopia in Caucasians [30]. In a recent study on 7 to 15-year-old British children [31], although total vitamin D level was significantly higher in children with higher time outdoors (60.0 nmol/l) compared to those with lower time spent outdoors (56.9 nmol/l, P=0.01), increased vitamin D level was not significantly associated with the risk of incident myopia but was reported to be a biomarker for outdoor time. It has been hypothesized that increased vitamin D levels secondary to daylight exposure might inhibit myopia by regulating the scleral growth through its anti-proliferative effect or it may be important for the functioning of smooth ciliary muscle that is involved in crystalline accommodation to achieve clear retinal image both at distance and near [26,30,31]. Nevertheless, it is difficult to segregate the direct effect of vitamin D on myopia development from vitamin D as a surrogate measure of time spent outdoors.

Other factors: Other factors that could have a possible protective role include increased depth of focus and retinal image clarity due to pupillary constriction, low accommodative demand for distance vision while in outdoors [5,31] less peripheral hyperopic defocus and a more uniform dioptric structure of outdoor environment compared to indoors [32]. An outdoor environment (Eg: park scenario) has much less dioptric variations compared to an indoor environment (Eg: office setting) [32]. The retinal image is composed of a higher degree of peripheral defocus indoors and the magnitude of defocus varies considerably across the visual field; in contrast, an outdoor environment, presents a retinal image that consists of lesser degree of peripheral hyperopic defocus with a more or less uniform magnitude of defocus across the visual field [32].

Conclusion

In summary, sunlight does explain the protective role of increased outdoor activity against myopia. Thus, increasing time spent outdoors will be extremly beneficial, especially in urban Asian regions with more indoor-centric lifestyle. Children should be encouraged to engage in outdoor activities for at least 1-2 hours per day since significant protection could be achieved with about 40 to 80 minutes of outdoor activity in randomized intervention trials. Since repeated cycles of exposure to bright light offers higher protection against myopia onset [33], frequent regular outdoor activities is recommended along with appropriate sun protection measures such as wearing a wide-brimmed hat, wrap-around sunglasses, sunscreen and adequate hydration.

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