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Review Article

Modifiable Environmental Risk Factors Affecting Myopia

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ABSTRACT

Purpose: The global rise in the prevalence of myopia calls for evidence-based strategies to be devised to reduce the incidence and delay the progression of Myopia. The aim of this study is to review the current literature on modifiable environmental risk factors that control the development and progression of Myopia, specifically in paediatric population.

Method: A comprehensive literature review was conducted using PubMed, ScienceDirect, Elsevier, and Google Scholar databases, including keywords such as "environmental risk factors"; "myopia"; “outdoor activity”; “near work”; “high body mass index”; “LED lamps usage”; “watching television”; “digital devices”; “sleep”; “melatonin”; “low vitamin D levels”; “sports”; “socioeconomic status”; “COVID-19 and online education”. English language full-text articles published between Jan 2010 and Oct 2020 were included in the study. Studies were critically reviewed for study methodology and robustness of data. Thirty six studies are included in this literature review.

Conclusion: Prevention of onset of myopia and delay in progression of myopia can be altered by modifying the contributing environmental risk factors. Increase in outdoor time with adequate sunlight exposure, rural environment, less duration of near work, use of incandescent lamp, normal circadian rhythms with adequate regular sleeping hours can prevent the onset and progression of myopia. Myopia association with high BMI, watching television, playing digital devices, serum vitamin D levels, participation in sports yet to be established. High socioeconomic status associated with more indoor activity, increased academic pressure, sedentary life style contributes to prevalence of myopia. COVID-19 pandemic control measures with consequent online education resulted in increased digital screen time, near work, and limited outdoor activities, causing rise of myopia pandemic.

Keywords: Myopia; Television; BMI; COVID-19

BACKGROUND

The global rise in the prevalence of myopia reflects a trend in many countries where children are getting more habituated to computers, digital devices and increasing study hours thus, resulting in prolonged near work and less physical and outdoor activity. Recent COVID-19 pandemic has forced the children all over the world to restrict themselves to homes and online education, which contributed to increase in incidence of paediatric myopia. Myopia is a complex disease with both genetic and environmental risk factors. Genetic risk factors cannot be modified but environmental risk factors can be modified to a certain extent and thereby help in reducing the prevalence of myopia. This study concentrates mainly on the modifiable environmental risk factors that can alter the progression of myopia.

EPIDEMOLOGY OF MYOPIA

The prevalence of myopia and high myopia are increasing globally at an alarming rate, with significant increases in the risks for vision impairment from pathologic conditions associated with high myopia, including retinal damage, cataract and glaucoma. Measures for the detection and management of

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myopia should be an integral part of plans for the provision of eye-care services. Access to correction for myopia is essential to avoid vision impairment [1].

The definition of myopia is “a condition in which the spherical equivalent objective refractive error is ≤−0.50 diopter (−0.50 D) in either eye”. The definition of high myopia is “a condition in which the spherical equivalent objective refractive error is ≤−5.00 D in either eye”. The clinical definition of myopic macular degeneration (MMD) is “a vision-threatening condition in people with myopia, usually high myopia, which comprises diffuse, patchy macular atrophy with or without lacquer cracks, choroidal neovascularization and Fuchs spot” [1].

Myopia is classified into early onset myopia (EOM) which manifests before 13 years of age, resulting in high degree of refractive error, and late onset myopia (LOM) manifests after 15 years of age, resulting in low degree of refractive error. EOM is mostly due to genetic factors and family history, while LOM is due to environmental factors. Environmental factors are modifiable; hence we can reduce the burden of late onset myopia and reduce the progression of myopia in both early onset and late onset myopia.

In 2010, it was reported, one of the leading causes of blindness and MSVI (moderate and severe visual impairment) worldwide was uncorrected refractive error, 21% and 53%, respectively [2]. There is significant increases in prevalences of myopia globally. According to published studies, the prevalence of myopia is highest in east Asia, where China, Japan, the Republic of Korea and Singapore have a prevalence of approximately 50%, and lower in Australia, Europe and north and south America [2].

Published epidemiological studies indicate that 1406 million people are affected with myopia (22.9% of the world population) and 163 million people with high myopia (2.7% of the world population) in 2000. It is predicted by 2050 there will be 4758 million people with myopia (49.8% of the world population) and 938 million people with high myopia (9.8% of the world population) [3].

The prevalence of myopia in children and teenagers and young adults is substantially higher in urban East Asian countries (49.7%-63% among 12-year-old children,65.5%-96.5% in teenagers and adults) compared to other countries (6%-20% among 12-year-old children, 12.8%-35% in teenagers and adults) [4].

STUDY SECTION

This review article mainly focusses on the environmental modifiable risk factors that influence the onset and the progression of myopia, especially in young children.

Methodology

A comprehensive literature review was conducted using PubMed, ScienceDirect, Elsevier, and Google Scholar databases, including keywords such as "environmental risk factors"; "myopia"; “outdoor activity”; “sports”; “near work”; “high body mass index”; “LED lamps usage”; “watching television”; “digital devices”; “sleep”; “melatonin”; “low vitamin D levels”; “socioeconomic status”; “COVID-19 and online education”. English language full-text articles published between Jan 2010 and Oct 2020 were included in the study. Studies were critically reviewed for study methodology and robustness of data. Thirty six studies are included in this literature review.

Less outdoor activity

A systematic review followed by a meta-analysis and a dose–response analysis of published clinical trials considers increased time outdoors is effective in preventing the onset of myopia as well as in slowing the myopic shift in refractive error. But paradoxically, outdoor time was not effective in slowing progression in eyes that were already myopic [5]. Studies conducted in chicks showed that sunlight induces dopamine release from the retina, prevents eyeball enlargement, and inhibits axial elongation [6]. Sunlight can promote the skin’s production of Vitamin D to influence refractive development, stimulate retinal neurons to secrete dopamine to regulate the sclera, and prevent eye elongation [7,8].

A cross-sectional study conducted on Norflok island, authors revealed a protective association of conjunctival UVAF (ultraviolet autofluorescence-taken using digital single-lens reflex camera, macro lens, and filtered electronic flash) —an objective marker of ocular outdoors light exposure and time spent outdoors—with myopia. This study objectively supports the hypothesis that exposure to light outdoors is protective against myopia. An alternate hypothesis is that light intensity is typically higher outdoors than indoors, and pupils tend to be more constricted outdoors, resulting in a larger depth of field and reduced image blur. This is underscored by a consistently lower prevalence of myopia in rural environments where light intensities are generally higher and optical field depth is greater [9].

No evidence of limbal ischaemia or conjunctival involvement was seen clinically. LE was free of any signs of ocular involvement but patient had mild burning sensation in it. Patient was admitted, diagnosed with grade 1 ocular surface burn and started on topical antibiotic, lubricants and corticosteroids in tapering doses.

Prolonged near work/increased study hours

Near work-Induced Transient Myopia (NITM), refers to the small, transient, pseudomyopic shift in the far point of the eye after a period of sustained near work. It reflects an inability of the crystalline lens to reduce its power appropriately and rapidly, thus reflecting an accommodative aftereffect/hysteresis phenomenon of presumed pharmacologic origin [10]. It Is reported that myopes demonstrated larger NITM than emmetropes, early onset myopes exhibited prolonged decay of NITM. NITM is sensitive to prolonged task duration. Progressive myopes (PM) are more susceptible to NITM than stable myopes (SM). NITM is additive over repeated and sequential closely spaced near work tasks, in progressive myopes. These findings may be attributed to impaired sympathetic function in the subjects with myopia. Underlying anomalous autonomic input to the ciliary muscle results in anomalous accommodation responses resulting in myopia development and progression [10].

Prolonged near work and stress triggers spasm of accommodation due to prolonged contraction of the ciliary muscle, causing pseudomyopia [11].

During longer periods of continuous reading, children may be likely to take up their preferred relaxed postures, such as a head tilt or reading in bed with a close reading distance. Children with closer nib-to-fingertip distance had greater head tilt when writing. Head tilt, may cause higher dioptric stimuli, abnormal contractions of extraocular muscles and markedly out-of focus in the peripheral retina, which could be associated with myopia [12].

Axial elongation was observed following a prolonged near task. Both EOM and PM groups showed increases in axial length that were significantly greater than emmetropes [13]. Ciliary muscle got thinner after prolonged near work. Further research is needed in this path [14].

A good quality visual signal, made up of a variety of spatial frequencies and contrasts, is critical for normal visual development. Eyes experiencing poor retinal images induced by diffusers or minus lenses have excessive growth and become myopic. Reading involves looking at high-contrast text at near for prolonged periods of time which produces contrast adaptation leading to decrease contrast sensitivity to spatial frequencies. The contrast adaptation and its potential myopigenic effect would likely increase with longer reading durations. However, further studies are needed to provide evidence for this [15].

High Body Mass Index (BMI)

High BMI is significantly associated with high myopia (spherical equivalent ≤−6.0D) and not significantly associated with myopia [16]. Obese children who engage in fewer outdoor activities or have increased near work activity are more at risk for myopic refractive error [17]. Myopic children spent more time indoors and less outdoors than non-myopic children, had lower vitamin D, had a higher body mass index and participated less in sports [18]. Higher saturated fat and cholesterol intake are associated with longer AL in otherwise healthy Singapore Chinese schoolchildren [19].

But on the contrary decreased BMI was associated with an increased prevalence of myopia and high myopia, was reported in an epidemiological study of the risk factors associated with myopia in young adult men in Korea [20]. Same finding was reported in a study conducted in Beijing where high BMI is not associated with high myopia in school children [21].

Hence, further research is needed to evaluate the association of high body mass index with myopia in children.

Use of LED lamps for homework

School children using LED lamps for homework had a more myopic refractive error and a longer axial length (AL) compared with those using incandescent or fluorescent lamps [22]. There were no significant differences in myopia prevalence between children using incandescent and fluorescent lamps for homework. The population attributable risk percentage for myopia associated with using LED lamps for homework after schools was 11.2% [23].

Anyang Childhood Eye Study Group reported using a fluorescent desk lamp was associated with myopic refraction and increase axial length. Incandescent lamps provide relatively higher light levels and a wider light spectrum which is relatively close to that of outdoors [24].

Watching television or digital devices for more than 2 hours per day:

Prolonged (>60 minutes/day) computer usage and smart phone usage were significantly associated with greater refractive error, while television viewing and after-school study were not reported in Chinese school going children [10].

Similar study in urban area of Tianjin showed on an average, a more myopic spherical equivalent refraction (SER) and longer axial length (AL) were both associated with more time spent using smart phones and computers, but not with time spent using tablets and watching television. The magnitude of the association between SER and time spent reading and writing was a substantially larger than that for smart phone or computer use. Different types of electronic devices had differing levels of association with myopic refraction [25].

Children who spent more than 3-5 h daily on homework, watched television more than 2-3 h daily or played with electronics more than 1 h daily all had a higher risk of myopia [26,27].

The rationale behind the myopia and >2 hours watching television is yet to be established by further studies.

Less sleeping hours

Melatonin, a neurohormone synthesized in the brain (by the pineal gland), mainly at night, helps to regulate sleep and alertness, and circadian rhythms that are ubiquitous to all biological functions in the body. A specialized set of retinal photoreceptors known as intrinsically photosensitive retinal ganglion cells (ipRGCs) relay the environmental light information to the suprachiasmatic nuclei in the hypothalamus, which in turn regulates the endogenous release of melatonin. Melatonin levels are elevated during the biological night and are negligible during the day. Changes in systemic melatonin concentrations could influence ocular growth by entering into the eye through retinal or choroidal vasculature [28].

One recent study reported a significant positive association between morning serum melatonin concentration and the magnitude of myopia, with myopes demonstrating up to three times greater serum melatonin concentration than emmetropes. The higher serum melatonin level in myopes may be a result of myopic individuals having a delayed timing of the melatonin circadian rhythm, greater melatonin output in total, or both [29].

Young adult myopes have significantly delayed melatonin circadian timing as measured by Dim Light Melatonin Onset (DLMO), lower melatonin secretion as measured by urinary aMT6s (6-Sulphatoxymelatonin) levels, delayed sleep timing (as indicated by delayed sleep onset time, greater sleep onset latency and shorter sleep duration), and more evening-type diurnal preference than emmetropes [28].

In addition to the pineal gland, melatonin is also synthesized in the retina and other structures within the eye by a circadian clock. Given the visual signaling for eye growth is primarily regulated at the retina, changes in local dopamine and melatonin signaling in the retina may result in the development of refractive errors, as shown in laboratory animals [28]. Therefore, number of sleeping hours per day and circadian rhythms is very crucial in regulating the melatonin release and development of refractive error.

Low Vitamin D levels

A study found that higher annual lifetime UVB exposure, directly related to time outdoors and sunlight exposure, was associated with reduced odds of myopia. Exposure to UVB between ages 14 and 29 years was associated with the highest reduction in odds of adult myopia. Myopia was more than twice as common in participants in the highest tertile of education. Proposed mediating mechanisms include activation of dopaminergic retinal amacrine cells, which are stimulated by light and influence ocular axial growth, and higher serum vitamin D concentrations induced by sunlight, but no evidence to support the association between myopia and serum vitamin D concentrations or genes involved in vitamin D metabolism [30].

Another recent study also suggested that true contribution of vitamin D levels to degree of myopia is very small and indistinguishable from zero [31].

Further evidence based studies are required to assess the association between serum Vitamin D levels and ocular axial growth.

Less participation in sports

Lower amounts of sports and outdoor activity increased the odds of becoming myopic in those children with two myopic parents more than in those children with either zero or one myopic parent. The chance of becoming myopic for children with no myopic parents appears lowest in the children with the highest amount of sports and outdoor activity, compared with those with two myopic parents [32].

Another randomized controlled trial estimated nearly half of the cases, myopia beginning at school continued to progress into adulthood. Higher adulthood myopia was mainly related to parents' myopia and less time spent on sports and outdoor activities in childhood [32].

Socioeconomic status

Economic development is associated with behavioral and lifestyle changes that are detrimental to eyesight. Modern industrialization requires more close, indoor vision compared with agricultural or even some older industrial occupations. Unfortunately, with increased academic pressure and a near work–focused sedentary lifestyle associated with new information technology, less time may be available for playing outdoors [33].

COVID-19 and online education

Increased digital screen time, near work, and limited outdoor activities were found to be associated with the onset and progression of myopia, and could potentially be aggravated during and beyond the COVID-19 pandemic outbreak period [34]. COVID-19 pandemic control measures have pushed the world towards digital virtual learning, home quarantine, limiting outdoor activities.

The prevalence of myopia appeared to be approximately 3 times higher in 2020 than in other years for children aged 6 years, 2 times higher for children aged 7 years, and 1.4 times higher for those aged 8 years. Such a substantial increase in the prevalence of myopia was not seen in the older age groups (9-13 years), despite the fact that the older children (grades 3-6) were offered more intense daily online learning courses (2.5 hours) compared with the younger students (grades 1-2, 1 hour daily). These findings led us to a hypothesis that younger children are more sensitive to the environmental change than older children [35].

The term quarantine myopia is finding its place in debates and discussions in the eye care world. Emphasis should be put on visual hygiene during near work and on outdoor activity [36].

DISCUSSION

Literature review suggests increased outdoor time prevents the onset of myopia as well as delaying the progression. Animal studies showed that sunlight increases dopamine release which inhibits axial elongation. Conjunctival UVAF (ultraviolet autofluorescence) an objective marker of ocular outdoors light exposure and time spent outdoors. Alternate hypothesis suggests that light intensity is more outdoors which makes pupil to constrict thereby reducing image blur and resulting in larger depth of field. Hence there is lower prevalence of myopia in rural environment.

Near work Induced Transient Myopia (NITM) is larger in myopes than emmetropes, early onset myopes exhibited prolonged decay of NITM, progressive myopes are more susceptible than stable myopes. NITM is additive to repeated and prolonged near work. It reflects impaired sympathetic function, anomalous autonomic input to the ciliary muscle results in anomalous accommodation responses resulting in myopia development and progression. Prolonged near work and stress triggers spasm of accommodation due to prolonged contraction of the ciliary muscle, causing pseudomyopia. Head tilt or close reading distance may cause higher dioptric stimuli, abnormal contractions of extraocular muscles and markedly out-of focus in the peripheral retina inducing development of myopia. Axial elongation observed following prolonged near work in early onset myopia and progressive myopia group. Ciliary muscle got thinner after prolonged near work. Further research is needed in this path. A good quality visual signal is necessary for normal ocular development. Looking at high-contrast text at near for prolonged periods of time has potential myopigenic effect. Further evidence-based studies are needed in this path of research.

High BMI (Body Mass Index) is significantly associated with high myopia. Higher saturated fat and cholesterol intake are associated with longer AL (Axial Length) in otherwise healthy Singapore Chinese schoolchildren. On the contrary, an epidemiological study conducted on young adult men in Korea reported decreased BMI is associated with myopia. Similar inference is gathered in a study conducted in Beijing on school children with high myopia. Hence, further research is needed to evaluate the association of high body mass index with myopia in children.

School children using LED lamps for doing homework were associated with myopic refractive error when compared with children using incandescent and fluorescent lights. In Anyang Childhood Eye Study Group reported myopia association while using fluorescent lamp for doing homework and recommended usage of incandescent lamps for close reading and writing work, as they provide higher light levels and wider light spectrum like outdoors.

Children who spent more than 3-5 h daily on homework, watched television more than 2-3 h daily or played with electronics more than 1 h daily all had a higher risk of myopia. The rationale behind the myopia and >2 hours watching television is yet to be established.

Melatonin a neurohormone secreted by pineal gland mainly at night, regulates the circadian rhythms of the body. A specialized photosensitive retinal ganglion cells (ipRGCs) relay the environmental light information to the suprachiasmatic nuclei in the hypothalamus, which in turn regulates the endogenous release of melatonin. Changes in systemic melatonin concentrations could influence ocular growth. One recent study reported a significant positive association between morning serum melatonin concentration and the magnitude of myopia. The higher serum melatonin level in myopes may be a result of myopic individuals having a delayed timing of the melatonin circadian rhythm, greater melatonin output in total, or both. Given the visual signaling for eye growth is primarily regulated at the retina, changes in local dopamine and melatonin signaling in the retina may result in the development of refractive errors, as shown in laboratory animals. Therefore, number of sleeping hours per day and circadian rhythms is very crucial in regulating the melatonin release and development of refractive error.

Studies show time spent outdoors, adequate sunlight exposure especially UVB rays reduce the prevalence of myopia. Proposed rationale is activation of dopaminergic retinal amacrine cells stimulated by sunlight and higher levels of serum Vitamin D concentration influences ocular axial growth, but further evidence based studies are required in this field [36].

Randomized controlled trials suggested significant association between participation in sports and decreased odds of development of myopia, especially in children born to two myopic parents. Rationale behind this association is yet to be established.

Economic development, modern industrialization and their associated factors like behavioral and lifestyle changes, more close and indoor vision, increased academic pressure and a near work–focused sedentary lifestyle, less time spent in playing outdoors, contribute to development of myopia.

COVID-19 pandemic, its control measures and consequent online education resulted in increased digital screen time, near work, and limited outdoor activities, causing rise of myopia pandemic. Younger children aged 6–8 years have been more affected due to this environmental change. Quarantine myopia laid emphasis on visual hygiene during near work and on outdoor activity. Some of the components to attend are compulsory no gadget break for 15 mins after 1 hour class, maintain arm working distance, natural light ambience or better illumination while working with gadgets and reading, larger and better resolution gadget screens, frequent blinking, enlarged font size.

CONCLUSION

Myopia is classified into Early Onset Myopia (EOM) which manifests before 13 years of age, resulting in high degree of refractive error, and Late Onset Myopia (LOM) manifests after 15 years of age, resulting in low degree of refractive error. EOM is mostly due to genetic factors and family history, while LOM is due to environmental factors. Prevention of onset of myopia and delay in progression of myopia can be altered by modifying the contributing environmental risk factors.

Increase in outdoor time with adequate sunlight exposure, rural environment, less duration of near work, use of incandescent lamp, normal circadian rhythms with adequate regular sleeping hours can prevent the onset and progression of myopia. Myopia association with high BMI, watching television, playing digital devices, serum Vitamin D levels, participation in sports yet to be established. High socioeconomic status associated with more indoor activity, increased academic pressure, sedentary life style contributes to prevalence of myopia. COVID-19 pandemic control measures with consequent online education resulted in increased digital screen time, near work, and limited outdoor activities, causing rise of myopia pandemic.

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