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A Comprehensive Analysis of the Effects of Physical Activity, Rehabilitation Methods, Environmental and Behavioral Interventions on the Development and Progression of Myopia

Małgorzata Łabuś M.Ł.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
gosia.labus@gmail.com
https://orcid.org/0009-0003-2799-4375

Karol Krzykawski K.K.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
krzykawski1poczta@gmail.com
https://orcid.org/0009-0007-4497-2927

Jakub Sadowski J.S.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
medsadowski@gmail.com
https://orcid.org/0009-0005-2259-0958

Łukasz Stanisław Papież Ł.S.P.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
lukaszpap14@gmail.com
https://orcid.org/0009-0000-1235-0057

Tomasz Maciejczyk T.M.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
tomasz.maciejczyk00@gmail.com
https://orcid.org/0009-0005-2517-2508

Julia Dołęga J.D.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
julkadolega1@gmail.com
https://orcid.org/0009-0001-0176-7145

Piotr Mól P.M.
The Sergeant Grzegorz Załoga Hospital
of the Ministry of the Interior and Administration
st. Wita Stwosza 39-41, 40-042 Katowice, Poland
piotrmol1999@gmail.com
https://orcid.org/0009-0006-8007-1934

Bartłomiej Zabawa B.Z.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
bartek.zabawa1@gmail.com
https://orcid.org/0009-0005-2419-4748

Patrycja Hudzińska P.H.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
patrycjahudzinska@gmail.com
https://orcid.org/0009-0000-5881-0733

Antoni Sieńko A.S.
Faculty of Medical Sciences in Katowice
Medical University of Silesia
antsienko@gmail.com
https://orcid.org/0009-0001-6753-7895

ABSTRACT

Introduction: Myopia has become a significant public health problem. Traditional approaches focused on optical correction, but evidence points to the role of comprehensive intervention strategies. The aim of this review is to assess the effectiveness of physical activity, rehabilitation, and environmental and behavioral interventions in controlling the development and progression of myopia.

Materials and Methods: Conducted study involved review of the literature using databases such as PubMed, NCBI, and Google Scholar. In the searching process the terms “myopia”, “physical activity”, “diet” and “rehabilitation” were used.

State of knowledge: The global prevalence of myopia increased from 28.3% in 2010 to 34.0% in 2020, with a projected increase to 50% of the world's population by 2050. Risk factors include genetic and environmental predispositions. Outdoor physical activity can reduce the risk of developing myopia by about 40%. Optical interventions, such as MiSight lenses, showed a 59% reduction in the change of uncorrected spherical equivalent. Low-concentration atropine eye drops also showed promising results. Environmental factors can influence the development of myopia. Dietary and supplementary interventions show potential in modulating myopia development, although results are inconclusive.

Conclusions: A comprehensive approach combining physical activity, optical and pharmacological interventions, environmental modifications, and health education appears to be a promising strategy in preventing and controlling myopia progression. Further research is needed on the mechanisms of myopia development and optimization of intervention strategies.

Keywords: myopia, physical activity, diet, rehabilitation

INTRODUCTION:

The global prevalence of myopia has risen dramatically in recent decades, emerging as a significant public health concern that affects both children and adults worldwide [1]. This refractive error, characterized by impaired distance vision, has garnered increasing attention from the scientific community due to its potential to cause severe visual impairment and associated complications if left unmanaged [2]. While traditional approaches to myopia management have primarily focused on optical corrections, there is growing evidence supporting the role of comprehensive intervention strategies, including physical rehabilitation, environmental modifications, and behavioral adjustments in managing myopia progression [3].

Recent advances in myopia research have expanded our understanding of its multifactorial nature, encompassing both genetic and environmental influences [4]. The scientific community has witnessed a paradigm shift from purely corrective approaches to preventive and control strategies, with particular emphasis on early intervention and personalized treatment protocols [5]. This evolution in myopia management has been supported by numerous clinical studies and systematic reviews that demonstrate the efficacy of various intervention methods [6].

This comprehensive analysis aims to evaluate the effectiveness of physical activity, rehabilitation methods, and environmental and behavioral interventions in controlling myopia development and progression. By examining these diverse approaches, this study aims to provide evidence-based insights into the most effective strategies for myopia management, considering both traditional and innovative treatment modalities [7]. The findings of this analysis will contribute to the growing body of knowledge in myopia research and potentially inform future clinical practice guidelines for myopia control and prevention [1].

MATERIALS AND METHODS: A comprehensive review was conducted using databases such as PubMed, NCBI, and Google Scholar. The search process involved the use of keywords such as “myopia”, “physical activity”, “diet” and “rehabilitation” to identify relevant data. The data sourced from the searched articles was subjected to a detailed analysis in terms of methodology, results and importance to the topic to ensure the reliability of the study. Furthermore, only studies available in full-text format were utilized.

STATE OF KNOWLEDGE

Myopia - introduction and epidemiology

Myopia is a common vision defect in which the eye focuses light in front of the retina, causing blurred vision of distant objects. It is typically classified as low (≤ −0.5 and > −6.00 diopters) and high (≤ −6.00 diopters) [2,8,9]. The global prevalence of myopia increased from 28.3% in 2010 to 34.0% in 2020, with a projected increase to 50% of the world's population by 2050 [1,8]. There are significant regional differences - in some East Asian countries, the prevalence of myopia among high school youth exceeds 80%, while in Africa it is 5.5% at 15 years of age [8,10]. In China, a significant increase in the prevalence of myopia has been observed, especially among children aged 4-6 years, where the prevalence increased from 15.6% in 2005 to 22.4% in 2021 [8].

Trend analysis indicates an increasing prevalence of myopia, especially among children and adolescents, with an earlier age of onset [8,11]. In China, a decrease in the average age of myopia onset from 10.6 years in 2005 to 7.6 years in 2021 has been observed [8].

Risk factors include genetic predisposition and environmental factors [9]. The role of genetic factors in increasing the risk of myopia seems to be confirmed by the more frequent occurrence of this visual defect in children of parents with myopia (myopia in one parent increases the risk of myopia in offspring 1.87 times, and its presence in both parents - 2.40 times) [9,11]. Environmental factors include, among others, prolonged time spent on near-vision activities, limited exposure to natural light, and increased educational stress[8,9]. Studies have shown that children with a hyperopic reserve less than 1.50 diopters (D) are more susceptible to developing myopia [8].

Pathophysiology and mechanisms of myopia development

Myopia arises from a discrepancy between the axial length (AL) of the eye and the optical power of its refractive components (cornea and lens). Under normal conditions, ocular growth is precisely regulated, enabling the achievement of emmetropia—a condition in which light rays converge accurately on the retina. In myopia, however, this process is disrupted [12,13]. The accurate mechanisms underlying the development of myopia remain unclear; however, research has shown that both interactions between genes and the interplay of genetic and environmental factors contribute to its pathogenesis, highlighting the need to consider its multifactorial nature [14].

Dopamine, a key neurotransmitter in the retina, is considered a regulator of ocular growth. Its activity is assessed through the DOPAC/DA (3,4-dihydroxyphenylacetic acid/dopamine) ratio, which reflects the metabolic efficiency of this pathway. Higher values of this ratio have been shown to correlate with delayed axial elongation of the eyeball and a tendency towards shifts towards hyperopia (farsightedness). Light conditions, such as wavelength and temporal frequency, modulate dopamine metabolism and can influence refractive development. Light with a long wavelength and low frequency (e.g., green light at 0 Hz) promotes shifts towards myopia, associated with an elevated DOPAC/DA ratio. In contrast, light with a short wavelength (e.g., blue light) induces shifts towards hyperopia, with a simultaneous decrease in DOPAC levels and a reduction in the DOPAC/DA ratio [15].

The choroid is essential in regulating ocular (AL) and refractive processes. During accommodation, its thinning is observed, which occurs simultaneously with axial elongation of the eye. According to research findings, the reduction in choroidal thickness accounts for approximately 60% of the total increase in ocular (AL) within a ±30° horizontal range during accommodation, with the greatest changes occurring in the central region, although this process also takes place in its peripheral areas. Notably, choroidal thinning is more pronounced in individuals with myopia, suggesting an increased sensitivity to adaptive processes that lead to excessive ocular elongation. These changes may result from disturbances in blood flow regulation and modifications to the biomechanical properties of the choroid, which play a key role in the mechanisms underlying the development of myopia [16,17].

Myopia is a multifactorial trait, with genetic predisposition playing a significant role. Studies have demonstrated significant associations between specific single nucleotide polymorphisms (SNPs) and the severity of myopia, as well as anatomical parameters of the eye in children. SNPs in the ZC3H11B and BICC1 genes have been identified as risk factors for moderate and high myopia, while the SNP in the GJD2 gene was primarily associated with mild myopia. Additionally, SNPs in the ZC3H11B, KCNQ5, and GJD2 genes were correlated with both spherical equivalent and AL. The SNTB1 polymorphism was linked to AL and corneal radius (CR). Furthermore, the ZC3H11B rs4373767-T, KCNQ5 rs7744813-A, and GJD2 rs524952-T alleles were correlated with the AL-CR ratio, suggesting their potential role in regulating the anatomical proportions of the eye [18,19].

Environmental factors have a significant impact on the development of myopia, particularly in the context of "school myopia." Two crucial environmental aspects influencing myopia development have been identified: the time spent on near-work activities and the amount of time spent on outdoor activities. Intensive near-vision tasks such as reading, writing, or using electronic devices increase accommodative stress, leading to improper adaptation of the eye structures and, consequently, an increase in AL. Time spent outdoors has a protective effect against the development of myopia. This is associated with increased levels of natural light exposure and the ability to focus on distant objects, which reduces accommodative strain. Exposure to natural light may also stimulate the release of dopamine in the retina, which plays a role in inhibiting axial eye elongation [20,21].

Myopia control methods: optical and pharmacological interventions

Why is myopia control so important? Bullimore et al. [22] analyzed the risks associated with the progression of myopia and the methods used for its correction, concluding that the benefits of controlling myopia outweigh the associated risks. Their analysis revealed that the predicted mean years of visual impairment increase significantly with higher levels of myopia, ranging from 4.42 years for individuals with myopia of -3 diopters (D) to 9.56 years for those with -8 D. Moreover, a reduction of 1 D in myopia was shown to lower these predicted years of visual impairment by 0.74 and 1.21 years, respectively.

An interesting method for controlling myopia involves the use of 0.01% atropine eye drops. This was investigated by Simonaviciute et al. [23]. The analysis included 55 patients in the group receiving 0.01% atropine eye drops and 66 patients in the control group, which did not receive the drops. The study examined healthy children aged 6–12 years with a cycloplegic spherical equivalent ranging from −0.5 D to −5.0 D and astigmatism ≤1.5 D. Unfortunately, no beneficial changes were observed between the groups regarding AL and spherical equivalent.

Higher concentrations of atropine eye drops, such as 0.1% and 0.5%, have also been studied [24]. However, the 0.01% concentration was found to be the most effective while producing the fewest side effects.

Fang et al [25] investigated the effects of 0.025% atropine eye drops on myopia progression. The study included 50 children with a spherical equivalent refraction of less than +1 D and cylindrical refraction of less than -1 D. Among them, 24 children (mean age: 7.6 years) were assigned to the 0.025% atropine group, while 26 children (mean age: 8.2 years) formed the control group. The average shift in spherical refractive myopia in the atropine group was -0.14 ± 0.24 D/year, significantly less than the -0.58 ± 0.34 D/year observed in the control group. Furthermore, statistically significant differences were noted between the atropine group and the control group in the incidence of myopia (21% vs. 54%) and rapid myopic shift. These findings suggest that low-dose atropine eye drops may be effective in the prevention of myopia progression.

Another intriguing pharmacological approach involves the use of the relatively selective M1 receptor antagonist, pirenzepine[26][27]. In one study[26], children aged 8 to 12 years with an initial spherical equivalent refractive error ranging from -0.75 to -4.00 D and astigmatism ≤1.00 D were enrolled. Participants were randomly assigned in a 2:1 ratio to receive either 2% pirenzepine ophthalmic gel or placebo gel, administered twice daily to each eye. At baseline, the spherical equivalent was -2.10 ± 0.90 D in the pirenzepine group ($n = 117$) and -1.93 ± 0.83 D in the placebo group ($n = 57$; $p = 0.22$). After one year, the mean progression of myopia was 0.26 D in the pirenzepine group compared to 0.53 D in the placebo group ($p < 0.001$). A subset of 84 patients chose to continue into the second year of the study (pirenzepine = 53, placebo = 31). After two years, the mean myopic progression was 0.58 D in the pirenzepine group versus 0.99 D in the placebo group ($p = 0.008$).

Another study also confirmed the effectiveness of 2% pirenzepine in slowing myopia progression. Tan et al. [27] recruited 353 healthy children aged 6 to 12 years with a spherical equivalent refraction between -0.75 and -4.00 D and astigmatism ≤1.00 D. Participants were randomized in a 2:2:1 ratio to receive either 2% pirenzepine gel twice daily (gel/gel), 2% pirenzepine gel once daily in the evening with a placebo in the morning (placebo/gel), or placebo twice daily (placebo/placebo) for one year. At baseline, the mean spherical equivalent refraction was -2.4 ± 0.9 D. After one year, the mean increase in myopia was 0.47 D in the gel/gel group, 0.70 D in the placebo/gel group, and 0.84 D in the placebo/placebo group ($P < 0.001$ for gel/gel vs. placebo/placebo).

Hope for a better future can be found in the study by Chamberlain et al. [28], a double-blind randomized trial. They investigated the effectiveness of MiSight one-day soft contact lenses in slowing myopia progression in young individuals. The study involved children with myopia (spherical equivalent refractive error, -0.75 to -4.00 D; astigmatism, <1.00 D) aged 8 to 12 years with no prior experience with contact lenses, conducted across four research centers in four countries. Participants in each group were matched for age, gender, and ethnicity and were randomly assigned to either MiSight 1-day (test) or Proclear 1-day (control) contact lenses, worn as daily disposables. The study duration was 3 years. The results are very promising. The uncorrected change in spherical equivalent refractive error was -0.73 D (59%) less in the test group compared to the control group, and the average change in AL was 0.32 mm (52%) smaller in the test group than in the control group.

Is there a difference in outcomes between diffusion optic technology lenses and regular one-day contact lenses? Wolffsohn et al.[29] investigated this using Diffusion Optics Technology™ 0.2 DOT lenses (SightGlass Vision Inc.) in a study involving 51 children (12.2 ± 1.3 years, 51% female). Participants were randomly assigned to wear DOT lenses ($n = 27$) or single-vision lenses ($n = 24$). The study duration was 3 years. Several parameters were measured, including mean binocular distance high-contrast and low-contrast visual acuity, near visual acuity with glare, contrast sensitivity, mean stereopsis, functional reading speed metrics, and the mean halo radius. No significant differences were found between the groups.

Another promising type of lenses showing favorable results are multifocal lenses. In a study by Walline et al. [30], wearing soft multifocal contact lenses resulted in a 50% reduction in myopia progression and a 29% reduction in axial elongation over a 2-year treatment period compared to a historical control group. The adjusted mean progression of spherical equivalent myopia after 2 years was -1.03 ± 0.06 D in individuals wearing single-vision contact lenses and -0.51 ± 0.06 D in those wearing soft multifocal contact lenses ($p < 0.0001$). Similarly, the adjusted mean axial elongation was 0.41 ± 0.03 mm and 0.29 ± 0.03 mm for wearers of single-vision and soft multifocal contact lenses, respectively.

The ROMIO study [31] evaluated the effectiveness of orthokeratology lenses for myopia control. A total of 102 patients aged 6 to 10 years, with myopia ranging from -0.50 to -4.00 D and astigmatism of no more than 1.25 D, were randomly assigned to wear orthokeratology lenses or single-vision glasses for a period of two years. On average, those using orthokeratology lenses experienced a 43% slower axial elongation compared to participants wearing single-vision glasses, demonstrating the significant potential of orthokeratology in myopia management.

Another effective type of lenses appears to be 'Defocus Incorporated Multiple Segments' (DIMS) lenses. Lem et al. [32] conducted a 2-year, randomized, double-masked study involving 183 Chinese children aged 8–13 years, with myopia ranging from -1.00 to -5.00 D and astigmatism ≤1.50 D. The children were randomly assigned to wear either DIMS spectacle lenses (n=93) or single-vision spectacle lenses (SV) (n=90). The DIMS lenses featured multiple segments with defocus myopia of +3.50 D. Daily wear of DIMS lenses significantly delayed myopia progression (by 52%) and axial elongation (by 62%) in myopic children.

A similar study was conducted by Aller et al [33]., in which subjects were randomly assigned to wear either Vistakon Acuvue 2 (single-vision soft contact lenses [SVSCLs]) or Vistakon Acuvue Bifocal (bifocal soft contact lenses [BFSCLs]). The study included 79 myopic patients aged 8 to 18 years, with an average refractive error of −2.69 ± 1.40 D. Statistically significant results were achieved, as follows: BFSCLs significantly slowed the progression of myopia after 6 months. After 12 months of treatment, the SVSCL group showed a progression of −0.79 ± 0.43 D, compared to −0.22 ± 0.34 D in the BFSCL group. The corresponding changes in AL were 0.24 ± 0.17 mm in the SVSCL group and 0.05 ± 0.14 mm in the BFSCL group.

Bao et al. [34] investigated the effectiveness of aspheric lenses. A total of 170 children aged 8–13 years with myopia ranging from −0.75 D to −4.75 D were randomly assigned to receive highly aspheric lens (HAL) spectacles, mildly aspheric lens (SAL) spectacles, or single-vision lens (SVL) spectacles. It was found that spectacles with aspheric lenses effectively slowed the progression of myopia and axial elongation compared to SVL. After one year, the mean changes in spherical equivalent refraction (SER) and axial length (AL) in the SVL group were −0.81±0.06 D and 0.36±0.02 mm, respectively. In comparison to SVL, the effectiveness of myopia control measured by SER was 67% for HAL and 41% for SAL, while effectiveness measured by AL was 64% for HAL and 31% for SAL. HAL lenses provided significantly better myopia control than SAL for both SER and AL.

The connection between exercise and myopia

Physical activity is well-known for its positive impact on general health, including cardiovascular fitness, muscle strength, and mental health. However, its effect on vision is often overlooked. To better understand how different types of exercise might influence vision, it's important to examine the potential mechanisms involved. Exercise, depending on its intensity and type, can affect intraocular pressure (IOP) in different ways. Moderate-intensity aerobic exercise typically leads to short-term reductions in IOP, whereas high-intensity resistance exercises and weightlifting can cause temporary increases in IOP. For instance, activities like planks and heavy lifting can cause IOP to rise by up to 26.5 mmHg during the exercise, but these effects usually return to normal after the activity. Different exercise types influence IOP regulation in varying ways. Isometric exercises are mostly linked to hyperventilation and reduced carbon dioxide levels, which lower IOP, while isotonic exercises are associated with increased colloid osmolality[35,36,37]. Dynamic exercises cause a more significant but short-lived decrease in IOP. Additionally, physical fitness is connected to lower baseline IOP, but may reduce the short-term IOP-lowering effects of exercise[38]. A study by Risner D et al. suggests that acute exercise may influence IOP by factors such as lowering blood pH, increasing plasma osmolality, raising blood lactate levels, reducing norepinephrine, boosting the nitric oxide/endothelin ratio (which enhances nitric oxide production and lowers endothelin), stimulating β2 receptors, and affecting ocular blood flow post-exercise[38]. Furthermore, the exercise-induced myokine Irisin may help prevent oxygen-induced pathological changes in the retina, such as angiogenesis, inflammation, and cell death[39]. These effects are important to consider when treating patients with glaucoma. Increased physical activity may also be linked to slower visual field progression in glaucoma patients[40].

On the other hand, two prospective studies show that both moderate-intensity (walking) and high-intensity (running) exercise significantly lower the risk of cataracts in both men and women[41,42]. Individuals involved in physically demanding work experienced a 16% reduced risk of developing cataracts compared to those with a sedentary lifestyle. Similarly, people who engaged in walking or biking for more than 60 minutes daily had a 12% lower occurrence of cataracts compared to those who rarely participated in such activities[43]. Research suggests that this effect is due to consistent aerobic exercise enhancing the body's ability to combat the excessive accumulation of reactive oxygen species (ROS)[44]. Systematic moderate-to-high-intensity exercise boosts the activity of antioxidant enzymes (SOD, GPX, and CAT), which enhances the lens's antioxidant capacity and helps slow down aging[45].

Exercise also has therapeutic effects on myopia. Hansen MH et al. found that individuals who engage in more than 3 hours of physical activity per week can reduce their risk of developing myopia by about 40%[46]. Another cohort study highlighted a strong connection between higher levels of physical activity and a decreased incidence of myopia, while sedentary behavior was shown to increase the risk of the condition[47]. This may be because outdoor sports often involve focusing on objects that are farther away, creating uniform refractive conditions that reduce peripheral defocus and slow the growth of the eye's axis, thereby preventing myopia[48]. Additionally, physical activity and exercise can cause the choroidal layer to dilate by improving blood flow, potentially limiting eye axis elongation[49] and further preventing the development of myopia.

This leads to the conclusion that in order to promote eye health through physical activity, the aforementioned evidence-based findings should be considered. We recommend engaging on a weekly basis in 30-45 minutes of exercise three to four times, such as brisk walking, cycling, or swimming, to help reduce IOP and improve ocular blood flow, which can benefit individuals with glaucoma. While strength training offers general health benefits, high-intensity exercises like heavy weightlifting can temporarily raise IOP. People with glaucoma or those at risk should avoid or modify such activities to minimize strain. It's important to tailor physical activity plans to each individual's condition. For instance, individuals with high myopia should avoid activities that pose a risk of head injury, such as contact sports.

Expanding further on the topic of myopia, Huang HM et al. conducted a meta-analysis showing that individuals who engage in more near work activities have an 80% higher risk of developing myopia[50]. Physical activity helps reduce the time spent on near work, such as reading or using screens, which are known risk factors for myopia progression. Children who spend more time outdoors are less likely to develop or worsen myopia. This protective effect seems to be related to time spent outdoors, rather than participation in sports, although sports that involve focusing on distant objects, such as soccer or tennis, may also benefit vision by encouraging varying focal distances. Moreover, exercising outdoors can stimulate dopamine release from exposure to bright outdoor light, which may help inhibit eye growth[51]. Spending time outdoors can also trigger the synthesis of Vitamin D, which has been shown to help prevent myopia[52].

Finally, the intensity of the exercises performed is a key factor when it comes to myopia. Low-intensity exercises are more sustainable over longer periods, increasing the overall time spent outdoors and enhancing their beneficial effects. Research suggests that spending about 76 minutes more outdoors per day, compared to baseline levels, can result in a 50% reduction in incident myopia[53]. This indicates that daily outdoor play is more effective than occasional high-intensity indoor exercise. The most beneficial approach involves a balance of moderate-intensity, frequent outdoor exercise and reduced time spent sedentary indoors. Nevertheless, high-intensity outdoor sports like soccer or basketball, which combine light exposure with varied focus distances, may offer additional support for myopia control.

Environmental determinants of myopia: beyond outdoor time

Environmental determinants of myopia is a concept that refers to environmental factors that may influence the development of myopia. These factors include air pollution, exposure to natural and blue light (emitted by electronic devices), as well as diet and lifestyle in a broader sense [54].

Air pollution is a mixture of gases and particulate matter in the air. Gas pollutants include carbon monoxide (CO), ozone (O3), and nitrogen oxides (NO). Particulate matter (PM), on the other hand, is primarily a product of fossil fuel combustion or, less frequently, volcanic eruptions and forest fires. The main classification of PM is based on particle size in micrometers (µm), such as PM10, PM2.5, and ultrafine PM [55]. Particularly PM2.5, due to its small size, is especially harmful to health, affecting the respiratory and cardiovascular systems. According to a study by Wei et al. involving 97,306 children aged 6-12 years, high levels of PM2.5 were correlated with an increased prevalence of myopia [56]. Another study by Yang et al. demonstrated a link between PM exposure and impaired visual acuity [57]. A study by Zainutidinova et al., which examined 62 schoolchildren living in areas with high vehicular traffic, showed that most of these children developed myopia, in contrast to a control group [58]. The mechanisms underlying these associations are complex and depend on the specific pollutant, requiring further research. However, they generally include the development of inflammation through the direct breakdown of substances, the formation of reactive oxygen species (ROS), and retinal ischemia [59].

Blue light is a type of visible light with short wavelengths and high energy, emitted by natural sources like the sun as well as artificial sources like energy-saving lighting and electronic devices (smartphones, monitors, TVs, computers). Blue light exposure is ubiquitous in our environment, and it is also necessary for the proper functioning of the body, particularly for maintaining the circadian rhythm [60]. In the era of technological advancement, the amount of time spent exposed to blue light from digital devices has been steadily increasing. This prolonged exposure, especially during the COVID-19 pandemic, negatively affects eye health [61]. It has been shown that blue light can cause photochemical reactions and damage to retinal cells [62]. Computer monitors and smartphones use LED backlighting technology, and the energy of this radiation may interact with the surface of the eye, potentially causing damage, such as exacerbating symptoms of dry eye [62]. Prolonged exposure to blue light with short wavelengths can contribute to oxidative stress, leading to the production of free radicals, which damage receptor cells in the retina, resulting in their degeneration and eventual vision impairment. Other mechanisms of damage include inflammation of the eye surface and cellular apoptosis. One potential method of protection could involve ophthalmic devices that filter out blue light. However, there is no scientific evidence showing that blue-light-blocking glasses reduce eye strain or improve visual performance [62].

There are reports suggesting that time spent outdoors in natural sunlight is a protective factor against myopia [63, 64]. In one study by Chen J et al. [x], 2,976 students participated, including 1,525 girls. The average (SD) time spent outdoors was 90 (28) minutes per day, and the average (SD) intensity of sunlight was 2,345 (486) lux. Of the 12 exposure patterns analyzed, the main ones involved spending at least 15 minutes outdoors, which accounted for 74.9% of all minutes (33,677,584 of 45,016,800 minutes). Only patterns where time spent outdoors exceeded 15 minutes and the intensity of light was at least 2,000 lux were associated with a reduced progression of myopia. The conclusion was that consistent outdoor exposure for at least 15 minutes, with light intensity of no less than 2,000 lux, was linked to a lower degree of myopic shift. Mechanisms that explain how outdoor time might reduce myopia include reduced screen time exposure to blue light and increased dopamine secretion, which helps regulate eye growth, preventing excessive axial elongation, characteristic of myopia [65].

Dietary factors have been suggested as potential risk factors for myopia, but the results of studies on this topic are inconclusive. Vitamins D, E, and C, omega-3 fatty acids, and antioxidants are considered essential for maintaining eye health and may potentially slow the progression of myopia [66]. A cross-sectional study [67] by Shetty et al. was conducted in the ophthalmology department in Goa, India, involving children aged 7 to 15 years. The study gathered information about daily food intake through a 24-hour dietary recall and conducted a detailed interview on participants' eating habits. A total of 60 children were included in the study. The study did not establish a clear link between diet and myopia. Although diet may influence overall eye health, and certain nutrients may support proper vision development, there is no conclusive evidence to suggest that diet alone is a primary risk factor for myopia. Genetic and environmental factors, such as outdoor time and near work, play a more significant role in myopia development. Nevertheless, a healthy diet may support eye health and help maintain proper vision.

Eye exercises and vision therapy in the context of myopia

Zhong Lin et al. [68] conducted a study to investigate the impact of eye exercises at acupoints on refractive errors, including myopia, among Chinese urban children. The study included a total of 409 participants. The methodology was based on cycloplegic autorefraction and a variety of surveys, including the "eye exercise questionnaire," and the "convergence insufficiency symptom survey,". The children were divided into four groups according to the frequency and precision with which they performed eye exercises. The primary outcomes demonstrated that the spherical equivalent of children who performed eye exercises more seriously exhibited a lesser degree of myopia. Furthermore, the eye exercises were demonstrated to have a protective effect against myopia, although this was not significant (odds ratio) following adjustments for age, sex, parental refractive error and time spent outside. It is noteworthy that children who performed additional exercises outside of school exhibited a more myopic SE. However, the author suggests that this may be attributed to the fact that these exercises were performed with less accuracy, for a shorter duration of time than those during school hours, and that these children may have been more motivated or under pressure from parents and teachers to exercise in order to prevent myopia progression. The authors highlight that there was no correlation between myopia prevalence and knowledge of acupoints and attitude towards exercises. In conclusion, the evidence does not support the hypothesis that these exercises have a preventive effect on myopia. The previously referenced group of researchers [68] investigated the impact of eye exercises on myopia and visual symptoms in a sample of Chinese rural children this time. The study included 836 children. Similar to the previous study, eye exercises had a modest protective effect on myopia. However, after adjustments for age, gender, parental refractive error and time spent outdoors, the effect became significant. Furthermore, a reduced likelihood of myopia was observed among children who performed exercises on a regular basis, at least three times per week. Following the adjustment for the previously mentioned variables, the risk of developing myopia was found to be lower among children who engaged in these exercises on a weekly basis. The authors propose that numerous variables may influence the observed outcomes, including the fact that children residing in rural areas are exposed to a reduced number of risk factors for myopia, such as having parents with less myopic refractive errors and spending more time outdoors.In a similar study [69] results showed insignificant corelation between performing eye exercises and risk of myopia development or myopia progression. The evidence presented in the mentioned studies indicates that the impact of eye exercises remains unclear. The studies are constrained by a number of limitations, which are highlighted by the researchers. In order to obtain definitive results, further research is required. In contrast to the inconclusive results regarding the efficacy of eye exercises in the control of myopia, numerous studies demonstrated that repeated low-level red light therapy, can effectively mitigate the progression of myopia in children. The authors suggest that this therapeutic approach may offer a promising alternative for the management of myopia. [70,71,72,73,74]

Nutritional and supplemental interventions in the prevention of myopia

Emerging evidence suggests that dietary factors and specific supplements may influence the development and progression of myopia. This subsection explores the current understanding of their roles and the potential mechanisms by which they may contribute to myopia prevention and overall eye health.

Eye is vulnerable to oxidative damage due to its metabolic and structural characteristics. Hence why nutrients play an intricate role in visual health and development. Carotenoids like lutein and zeaxanthin are central to protecting the retina and macula by mitigating light-induced oxidative stress and inflammation while also enhancing visual performance through improved glare recovery, photostress recovery, and chromatic contrast. Antioxidants such as vitamins C and E, often acting synergistically with carotenoids, protect retinal and lens cells from peroxidative damage, particularly in high-oxygen environments. Omega-3 fatty acids, especially DHA, are shown to be essential for the structural integrity and function of photoreceptor membranes, enhancing the efficiency of the visual signal transduction process. These nutrients interact dynamically across different stages of life, with specific nutritional demands during infancy and aging due to variations in metabolic activity and structural vulnerability [75].

Evidence suggests that nutrients intake might be significant for preventing development of myopia. A cross-sectional study by Lim et al. [76] involving 851 Chinese schoolchildren (mean age: 12.81 ± 0.83 years) revealed significant associations between dietary factors and AL, a key parameter linked to myopia. Children in the highest quartile of total cholesterol intake had a mean AL of 24.66 mm (95% CI: 24.62–24.71 mm) compared to 24.32 mm (95% CI: 24.27–24.36 mm) in the lowest quartile, with a significant trend (p=0.026). Similarly, the highest quartile of saturated fat intake corresponded to a mean AL of 24.65 mm (95% CI: 24.60–24.70 mm) compared to 24.36 mm (95% CI: 24.32–24.41 mm) in the lowest quartile (p=0.039). Despite these findings, no significant relationships were observed between cholesterol or saturated fat intake and spherical equivalent refraction or the diagnosis of myopia. The study also adjusted for potential confounders such as age, gender, body mass index, outdoor activity, parental education, and total energy intake, highlighting a potential but limited impact of dietary fat and cholesterol on axial elongation in children.

Supplements like Nigella sativa extract (NSE) also showed promising results in preventing AL elongation and possible myopia development in children. A double-blind, randomized controlled trial by Syawali et al. [77] evaluated the effects of NSE on AL elongation in 35 myopic children aged 12–18 years. Participants were divided into an NSE group (17 children, mean age 14.82 ± 2.24 years, 58.8% male) and a placebo group (18 children, mean age 15.39 ± 1.85 years, 72.2% male). Both groups received two capsules daily for 12 weeks. Baseline AL measurements were 24.73 ± 0.77 mm for NSE and 25.04 ± 0.88 mm for placebo. At 12 weeks, AL elongation was 0.06 ± 0.04 mm in the NSE group compared to 0.08 ± 0.04 mm in the placebo group, a significant difference (p=0.036). AL elongation within the NSE group showed a consistent increase across follow-ups: 24.76 mm at week 6 and 24.79 mm at week 12. Similar trends were observed in the placebo group: 25.08 mm at week 6 and 25.12 mm at week 12. NSE demonstrated a possible suppressive effect on AL elongation compared to the placebo, suggesting its potential as a therapeutic option for slowing myopia progression, possibly due to its antioxidant properties.

Recent findings by Kim J-M and Choi YJ [78] in a study that analyzed 18,077 Korean adolescents (mean age: 15.05 ± 1.67 years; 51.7% male), revealing a myopia prevalence of 87.6% and high myopia prevalence of 15.9%, suggest that high intake of carbohydrates (OR: 1.88; 95% CI: 1.70–2.07), proteins (OR: 1.54; 95% CI: 1.40–1.69), cholesterol (OR: 1.80; 95% CI: 1.64–1.98), sodium (OR: 1.75; 95% CI: 1.59–1.92), and vitamin B2 (OR: 2.39; 95% CI: 2.18–2.63) was associated with increased myopia risk, while vitamin C intake (OR: 0.62; 95% CI: 0.57–0.68) was protective. Key covariates included age, gender, BMI, parental myopia, near work (70.5% of myopic adolescents spent ≥3 hours/day on near work), and urban residence

(71% of myopic participants). The study highlights significant dietary influences on myopia prevalence, warranting further exploration of causal mechanisms.

Conversely, systematic review and meta-analysis of four observational studies (n=1,721) by Massoudi et al. [79] on the association between macronutrient intake and myopia in individuals under 18 years revealed no significant associations between carbohydrate (OR = 1.01, 95% CI: 0.94–1.08), protein (OR = 0.97, 95% CI: 0.86–1.08), or fat intake (OR = 0.99, 95% CI: 0.83–1.18) and myopia, AL, or spherical equivalent refractive error.

Similar conclusions were drawn in the Mendelian Randomization Study by Xu et al. [80] about supplementation of vitamin A. Study found no significant causal association between vitamin A supplementation and myopia risk (OR = 0.99, 95% CI = 0.82–1.20, p=0.40), though minimal evidence suggested a protective trend (OR = 0.002, 95% CI = 1.17×10^{-6}–3.099, p = 0.096), with findings indicating that vitamin A supplementation does not independently affect myopia but may influence intraocular processes indirectly, warranting further research to explore these mechanisms.

Current evidence is insufficient to establish a definitive role of micronutrients, macronutrients, and vitamin A in the development of myopia, highlighting the need for further robust studies to explore these associations and underlying mechanisms.

Behavioral interventions and a holistic approach to managing myopia

Myopia, as previously mentioned, has become an increasingly common health issue, gaining particular significance in recent years, especially in the context of the COVID-19 pandemic. During this period, significant lifestyle changes occurred -extended screen time on electronic devices and reduced outdoor activities created conditions conducive to both the development and progression of myopia. As a result, accelerated elongation of the AL of the eyeball was observed in many individuals [81].

Lifestyle plays a crucial role in preventing this vision impairment. Not only does diet matter, but also daily habits, such as prolonged near work,which increases the likelihood of developing myopia by 20% [82]. To address long-term screen use, the 20/20/20 rule was developed, according to which, after every 20 minutes of screen time, a 20-second break should be taken to look at objects located at a distance of approximately 20 feet (6 meters). Although its effectiveness in preventing myopia requires further research, it has already been shown to improve accommodative ability and reduce symptoms of dry eye [83,84].

Health education also proves to be a promising preventive measure, as confirmed by a study conducted by Li Q et al. among first-grade students in Chinese schools who did not have myopia at the start of the research. Participants were randomly divided into two groups: a control group and an experimental group. Over two years, parents in the experimental group received regular educational materials detailing methods to prevent myopia, such as reducing screen time and increasing outdoor activities. At the end of the study, comprehensive ophthalmologic exams were conducted on the children. The results showed that the incidence of myopia in the experimental group was 19.5%, significantly lower than in the control group (24.4%). Additionally, fewer cases of myopia progression by ≥2 diopters were noted in the experimental group. However, changes in the AL of the eyeball were not significantly different between the two groups [85].

These findings indicate that regular health education directed at parents can effectively reduce the incidence of myopia and slow its progression, highlighting the importance of prevention in combating this visual impairment.

Myopia, however, is not limited to visual problems alone. Increasing evidence points to its association with mental health issues, such as anxiety disorders and depression. Individuals with this condition are twice as likely to develop such psychological disorders, regardless of gender, visual acuity, or coexisting diseases. This data underscores the importance of a multidisciplinary approach to patient care that integrates preventive measures, education, and mental health support [86].

CONCLUSIONS: The increasing prevalence and negative impact of myopia on quality of life emphasize the need for further research into methods of preventing and managing this visual impairment. Physical activity, optical and pharmacological interventions, environmental modifications, and health education can be effective tools in the prevention and control of myopia. However, their effectiveness may be limited and dependent on individual factors. Some studies have shown that intense exercise can temporarily increase intraocular pressure, which should be considered in individuals susceptible to this condition. In conclusion, the presented interventions represent a promising form of treatment and may revolutionize the approach to myopia, therefore this topic requires further scientific research.

Authors' Contributions Statement:

Conceptualization: M.Ł.

Data Curation: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Formal Analysis: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Investigation: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Methodology: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Project Administration: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Resources: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Software: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Supervision: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S**.**

Validation: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Visualization: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Writing – Original Draft: M.Ł, J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

Writing – Review & Editing: M.Ł., J.D., P.M., Ł.S.P., T.M., A.S., B.Z., P.H., K.K., J.S.

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