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Research Progress on the Impact of Outdoor Activities on Myopia in Children and Adolescents

Chenxin Huang *, Chenyu Gu

School of Physical Education, South China University of Technology, Guangzhou Guangdong 510641, China
* **Corresponding author**: Chenxin Huang (Email: 2929632036@qq.com)

Abstract: The issue of myopia among children and adolescents has become a global public health concern. Existing research indicates a close correlation between outdoor activities and myopia in children and adolescents, with increased outdoor activity effectively preventing the rise in myopia incidence. This study reviews the impact of outdoor activities on myopia in children and adolescents by searching databases such as CNKI and Web of Science, aiming to explore effective strategies for myopia prevention and control, thereby providing theoretical references for myopia prevention efforts. Currently, scholars have conducted cross-sectional studies, cohort studies, and intervention studies across various countries, confirming that long-term engagement in outdoor activities can improve the average refractive index of children and adolescents, reducing the risk of myopia. However, it has also been found that the protective effect of outdoor activity duration on myopia in children and adolescents has a certain threshold. Additionally, numerous animal and human experiments have investigated the mechanisms by which outdoor activities influence myopia, revealing that outdoor activities can reduce the incidence of myopia by promoting ocular refractive development, stimulating dopamine release, and alleviating eye fatigue. Based on the literature review, this study proposes targeted suggestions for myopia prevention and control from the perspectives of the government, schools, and families.

Keywords: Outdoor Activities; Children; Adolescents; Myopia; Mechanisms of Influence.

1. Introduction

Myopia is a refractive error caused by the elongation of the axial length of the eye, resulting in decreased vision[1]. Over the past decades, the prevalence of myopia and high myopia has continuously increased worldwide, making it a pressing global public health issue. According to epidemiological surveys, it is predicted that by 2050, the global myopic population will reach 4.758 billion, accounting for 49.8% of the world's total population, with 938 million being highly myopic, constituting 9.8% of the global population[2]. Notably, the distribution of myopia globally shows distinct regional characteristics, with the incidence of myopia in Asia being significantly higher than in Europe, America, and Africa. Particularly among children and adolescents, about 70% to 80% are affected by myopia[3]. China, as one of the countries with the highest myopia incidence rates, has seen a significant upward trend in myopia among children and adolescents. In response, in 2018, the Chinese Ministry of Education, the National Health Commission, and six other departments jointly issued the "Implementation Plan for Comprehensive Prevention and Control of Myopia in Children and Adolescents," aiming to control the myopia rate among six-year-olds to around 3%, reduce the myopia rate among primary school students to below 38%, among junior high school students to below 60%, and among senior high school students to below 70% by 2023. Measures such as increasing outdoor activities, reducing academic burdens, and controlling the use of electronic devices were recommended to reduce the incidence of myopia among children and adolescents[4]. The causes of myopia are complex, with the primary factors being genetic and environmental. Increased indoor study time and reduced outdoor activity time are major contributors to the rising incidence of myopia in children and adolescents[5].

Outdoor activities, as a primary form of physical activity for children and adolescents, have a positive impact on their physical and mental health. The concept of outdoor activities is broad, encompassing walking, picnicking, playing, physical education classes, and outdoor sports, among other activities[6]. In recent years, researchers worldwide have explored the impact of outdoor activities on myopia in children and adolescents, but few studies have systematically summarized these findings. Therefore, this study reviews the effects of outdoor activities on myopia in children and adolescents, aiming to explore effective ways to reduce myopia and provide scientific and diverse recommendations for myopia prevention and control in children and adolescents.

2. The Hazards of Myopia

In recent years, the rising prevalence of myopia among children and adolescents, along with the complications associated with high myopia, has become a societal focus. This issue not only manifests in the decline of visual function but also potentially affects socioeconomic development and the physical and mental health of children and adolescents, with severe cases leading to blindness (Figure 1).

From a macro perspective, governments worldwide need to invest substantial funds in myopia prevention and education, making the rise in myopia incidence a significant societal burden. In 2015, myopia resulted in an estimated global economic loss of $244 billion, with East Asia alone accounting for over $150 billion of this loss[7].From a meso perspective, myopia negatively impacts the normal life of children and adolescents. Firstly, it harms their physical and mental development. Myopia makes it difficult for young people to participate in various physical activities, reducing opportunities for social interaction, which can affect normal physical development and indirectly lead to weaker health.

Secondly, it decreases learning and work efficiency. Childhood and adolescence are critical periods for knowledge acquisition, and healthy vision is fundamental for effective learning. Myopia can result in difficulty recognizing text and maintaining concentration, thereby reducing learning efficiency. Finally, myopia affects the appearance of children and adolescents. High myopia can cause protruding eyeballs, loose eyelids, and eyes that appear dull and lifeless. From a micro perspective, due to the chronic nature of the condition, children and adolescents who develop myopia early are at higher risk for high myopia. High myopia increases the risk of retinal detachment, macular hemorrhage, cataracts, glaucoma, and other diseases, ultimately leading to blindness [8].

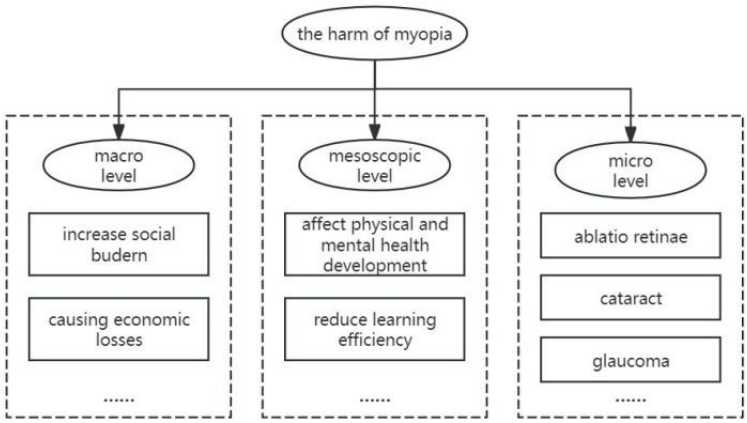

Figure 1. Damage of myopia to children and adolescents

3. The Relationship between Outdoor Activities and Myopia in Children and Adolescents

Currently, an increasing number of scholars emphasize outdoor activities as a significant factor influencing myopia in children and adolescents. Cross-sectional, intervention, and cohort studies conducted in various countries have further established the relationship between outdoor activities and myopia in children and adolescents (Table 1).

In cross-sectional studies, Rose et al.[9] conducted a study involving 1765 six-year-olds and 2367 twelve-year-olds from 51 schools in Sydney, Australia. The results showed a significant correlation between outdoor activities (both physical and leisure activities) and the refractive index and incidence of myopia in twelve-year-olds. With an increase in outdoor activity time, the refractive index increased, and the incidence of myopia decreased. Xiao et al.[10] conducted a cross-sectional survey of children aged 7-9 in China in 2012 and 2019, collecting data from 623 children in 2012 and 536 in 2019. The results indicated that the myopia incidence rate among primary school students in 2019 was somewhat controlled, possibly due to improvements in daily behaviors, though insufficient outdoor activity time remained an issue. Yang et al.[11] conducted a cross-sectional study on 166 children from ten schools in Canada. The findings revealed that outdoor activities had a positive effect on myopia, showing that an additional hour of outdoor activity per week reduced the incidence of myopia by 14.3% in the surveyed age group.

In cohort studies, Philipp et al.[12] followed 1416 children and adolescents aged 3-18 in Germany for ten years, using logistic regression analysis with vision as the dependent variable. The results showed that children and adolescents who participated in outdoor activities once a week had over four times the likelihood of developing myopia compared to those who went out twice or more per week (OR = 4.35, 95% CI: 1.89-9.98). French et al.[13] conducted a 5-6 year follow-up of 863 six-year-olds and 1196 twelve-year-olds in Sydney. The data indicated that children who engaged in less than 16 hours of outdoor activity per week and spent more than 19.5 hours on near-work activities at age six had a significantly higher incidence of myopia by age twelve (OR = 15.90, 95% CI: 3.45-73.4). Similarly, twelve-year-olds who spent less than 13.5 hours per week on outdoor activities and more than 22.5 hours on near-work activities had a significantly increased risk of myopia by age seventeen (OR = 5.10, 95% CI: 1.91-13.45). Xu Ke et al.[14] followed six to eight-year-olds from twelve schools in China for one year, using a multivariate conditional logistic regression model to analyze the relationship between outdoor activities and myopia. The results showed that, after controlling for factors such as gender, grade, and parental myopia, outdoor activity emerged as a protective factor against myopia. An additional hour of outdoor activity per day could reduce the risk of myopia by 37.3% (OR = 0.627.35, 95% CI: 0.421-0.934).

In intervention studies, He et al.[15] conducted a three-year cluster randomized trial involving first-grade students from twelve primary schools in Guangzhou, China. The intervention group (n=952) received an additional 40 minutes of outdoor activity daily from Monday to Friday, and parents were encouraged to engage their children in outdoor activities after school. The control group (n=951) received no intervention. The results indicated that for six-year-olds, increasing outdoor activity at school by 40 minutes per day effectively reduced the incidence of myopia over the next three years. Wang Sijia et al.[16] conducted a nine-month intervention study involving 177 students from grades 2-6 in a Beijing school, with the intervention group (n=89) ensuring at least 4 hours of outdoor activity per week, further divided into three subgroups based on different durations, and the control group (n=88) receiving no intervention. The results showed no significant difference in vision test results between students who increased outdoor activity by 4-6 hours per week and the control group. However, students who increased outdoor activity by more than 6 hours per week showed significant improvement compared to both their pre-

intervention results and the control group. Li Jingyi et al.[17] conducted a one-year intervention study on first to third graders from three primary schools in Wenzhou, China, with three groups: Experimental Group 1 (n=357) engaging in free outdoor activities, Experimental Group 2 (n=353) having an additional hour of free outdoor activity after class and after school, and the control group (n=366) receiving no intervention. The results showed that long-term adherence to outdoor activities effectively controlled axial elongation.

Table 1. Experimental Studies on the Association Between Outdoor Activities and Myopia in Children and Adolescents

Author	Location	Study Design	Subjects and Groups	Study Content	Main Conclusion
Rose et al. [9]	Sydney, Australia	Cross-sectional Study	Age 6 (1765 subjects); Age 12 (2367 subjects)	Comprehensive eye exams for children and adolescents; detailed activity questionnaires completed by parents and children	Controlling for variables, the total duration of outdoor activities correlates with higher average refraction and lower myopia rates in children and adolescents
Yang et al. [11]	Waterloo, Canada	Cross-sectional Study	Age 6-8 (83 subjects) ;Age 11-13 (83 subjects)	Measured myopia in children and adolescents; parents completed a survey on children's daily activities	Myopia prevalence increased from 6% in ages 6-8 to 29% in ages 11-13; increased outdoor activity time helps prevent myopia onset
Philip et al. [12]	Leipzig, Germany	Cohort Study	Age 3-18 (1416 subjects) Follow-up: 10 years	Measured myopia in children and adolescents; parents and children provided information on leisure activities through a questionnaire	Myopia is related to environmental factors; daily outdoor activities in sunlight and reduced near work can prevent pathological myopia
Xu Ke et al. [14]	Guangzhou, China	Cohort Study	Age 6-8 (1868 subjects) Follow-up: 1 year	Conducted myopia checks in schools; parents filled out questionnaires on outdoor activity time, near work time, sleep time, etc.	Outdoor activity time is related to myopia risk in lower grade students in Guangzhou; increased outdoor activity time reduces myopia risk
He et al. [15]	Guangzhou, China	Intervention Study	Grade 1 Primary School Intervention: 3 years Experimental group (952 subjects); Control group (**951** subjects)	Experimental group students had 40 extra minutes of outdoor activity daily after school; parents and children were encouraged to engage in outdoor activities on weekends and holidays	In 6-year-olds, increasing outdoor activity by 40 minutes at school significantly reduced myopia incidence over the next three years
Wang Sijia et al. [16]	Beijing, China	Intervention Study	Grades 2-6 Primary School Intervention: 9 months Experimental group (89 subjects); Control group (88 subjects)	The intervention group had at least 4 hours of outdoor activity per week, divided into three subgroups based on duration	Children's vision gradually declines over time; increasing outdoor activity time has a protective effect on vision in children and adolescents

In conclusion, there is a significant association between outdoor activities and myopia in children and adolescents. Increasing outdoor activity time has a notable protective effect on their vision, improving average refractive index and reducing the risk of myopia. However, for children and adolescents who have already developed true myopia, outdoor activities do not seem to reverse the condition. Additionally, many existing studies have increased outdoor activity time to a certain level without considering the baseline outdoor activity level, indicating that the protective effect of outdoor activity duration on myopia has a threshold[18]. This is an issue that future experimental research needs to address.

4. Mechanisms by Which Outdoor Activities Affect Myopia in Children and Adolescents

Current research on the mechanisms by which outdoor activities affect myopia in children and adolescents primarily focuses on the impact of outdoor light environments and physical exercise. These mechanisms include promoting ocular refractive development, stimulating dopamine release, alleviating eye fatigue, and promoting vitamin D synthesis, effectively reducing the incidence of myopia in children and adolescents (Figure 2).

4.1. Outdoor Environment Promotes Ocular Refractive Development

Ultraviolet (UV) light, which encompasses wavelengths from 10 to 400 nm in a vacuum, has been shown to potentially slow the progression of myopia in children and adolescents, particularly near-ultraviolet light (360-400 nm), which can be considered violet light. In an animal study, Strickland et al.[19] found that short-wavelength violet light inhibited myopia in wild mice. In a human study, Mori et al.[20] conducted a two-year randomized double-blind trial and found that participants who engaged in less than 180 minutes of near work daily and

had never worn glasses experienced significant inhibition of axial length growth after wearing violet-light-transmitting glasses, with a 21.4% inhibition rate over two years. Indoor lighting typically ranges from 400 to 700 nm, missing the violet light component that inhibits myopia. Thus, it can be inferred that the preventive effect of outdoor activities on myopia in children and adolescents may be due to the inhibitory effect of violet light in outdoor environments on the development of myopia.

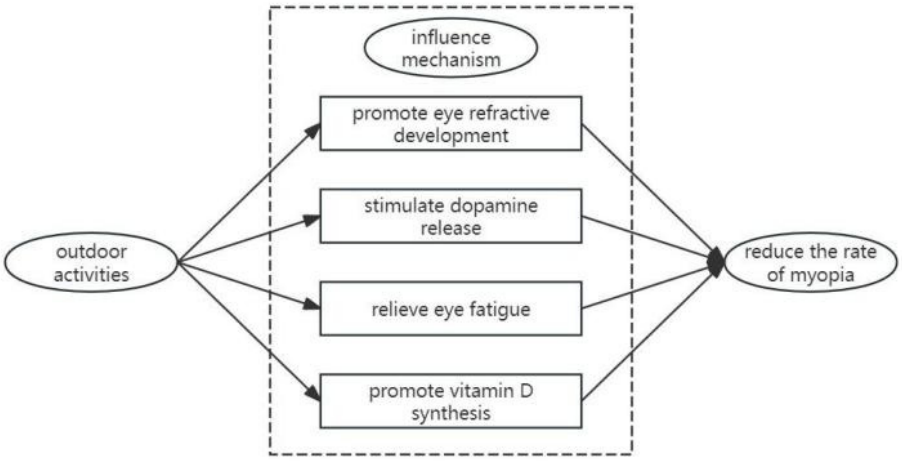

Figure 2. Mechanism of the effect of outdoor activities on myopia in children and adolescents

4.2. Outdoor Light Stimulates Dopamine Release

Exposure to light stimulates the retina to release more dopamine, a neurotransmitter that acts as an inhibitor of axial elongation and plays a crucial role in protecting against myopia in children and adolescents. This hypothesis has been confirmed in various animal studies. For instance, Mccarthy et al. [21] used chicks as experimental subjects and found that removing translucent diffusers from chicks' eyes during light periods prevented the progression of myopia. Conversely, chicks reared in darkness did not benefit from this protective effect, but injecting dopamine receptor agonists into the vitreous of dark-reared chicks effectively inhibited the progression of myopia. This suggests that during outdoor activities, light exposure stimulates the release of dopamine, preventing the worsening of myopia and reducing its incidence in children and adolescents.

4.3. Outdoor Exercise Alleviates Eye Fatigue

Besides genetic factors, environmental factors are major contributors to myopia in children and adolescents, such as prolonged near work and excessive use of electronic devices, which cause chronic eye fatigue and reduced self-regulation of the refractive system, ultimately leading to myopia. Outdoor activities, through various forms of exercise, provide an opportunity to alleviate eye fatigue. Research has shown that different types of exercise and their intensities have varying effects on preventing myopia. For example, ball sports require the eyes to continuously adjust to follow the ball's movement, engaging the ciliary muscles and surrounding ligaments, which helps relieve eye fatigue and prevent myopia.

4.4. Outdoor Light Promotes Vitamin D Synthesis

Vitamin D plays roles in endocrine and paracrine functions, including bone metabolism, insulin secretion, and calcium transport in the small intestine, as well as inhibiting cell proliferation and modulating immunity. Studies have shown that outdoor light environments promote the synthesis of vitamin D, which can act on the sclera to exert antiproliferative effects, contributing to the reduction of myopia progression in children and adolescents. Mutti et al. [22] found polymorphisms in the rs2239182, rs3819545, and rs2853559 loci of the vitamin D receptor gene, suggesting that vitamin D synthesis may inhibit myopia progression. Additionally, vitamin D synthesis in the body can prevent the weakening of scleral toughness due to calcium deficiency, reducing the likelihood of axial length elongation and periorbital muscle spasms.

5. Conclusion and Recommendations

Both cross-sectional, cohort, and intervention studies confirm the intrinsic link between outdoor activities and myopia in children and adolescents, identifying increased outdoor activity as an effective means to reduce the incidence of myopia. Numerous animal and human experiments have enriched the understanding of the mechanisms by which outdoor activities affect myopia. However, gaps remain, especially regarding the efficacy of different forms of outdoor activity organization, which impedes a deeper understanding of the mechanisms of myopia prevention and the implementation of precise preventive practices[23]. Future research should focus not only on the keyvariable of outdoor activity duration but also on the effects of different organizational forms of outdoor activities.

From a practical perspective, myopia prevention efforts for children and adolescents should begin early, involving a multi-faceted collaborative mechanism among government, schools, and families, with each playing its role. Firstly, the government should design top-level strategies to reduce academic pressure on children and adolescents, continually optimizing educational exams and assessments. Government investments should guide the provision of public sports services, creating a supportive environment for outdoor activities. Secondly, schools should adjust curricula to ensure at least one hour of outdoor activity daily for children and adolescents, integrating various sports and outdoor activities

to form diverse organizational forms. Lastly, parents should set an example by encouraging children to engage in outdoor activities, strictly controlling the use of electronic devices to prevent addiction, and guiding children to participate in enriching outdoor activities through incentives. Regular vision checks are also crucial to ensure stable eyesight.

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