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Research Progress on Prevention and Treatment of Myopia in Children and Adolescents by Physical Activity

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Abstract:

The low visual acuity of children and adolescents in China, especially myopia, is worrying. Not only is the myopia rate increasing rapidly, but also the strength of glasses is deepening at an unprecedented rate, and its development trend of group, family, and pathology has drawn great attention from the state and scholars. This paper reviews recent studies on the relationship between physical activity and myopia in children and adolescents, and explores comprehensive prevention and control measures to provide reference for the government, schools, families, and individuals to carry out myopia prevention and control in children and adolescents at multiple levels.

Keywords*: myopia, physical activity, children, adolescents, prevention and control.*

I. INTRODUCTION

"The eyes are the windows of the human mind, and good vision is inseparable from the healthy growth of children and adolescents." However, in recent years, myopia has become a major social problem that endangers the eye health of children and adolescents. The overall prevalence of myopia among children and adolescents in China reached 52.7% in 2020, including 14.3% among 6-year-old children, 35.6% among elementary school students, 71.1% among junior high school students, and 80.5% among high school students, an increase of 2.5 percentage points from 2019. [1] General Secretary Xi Jinping made an important instruction that myopia among students in China shows a trend of high incidence and low age, which seriously affects their physical and mental health, and must be paid great attention to it and cannot be allowed to develop. [2] In August 2018, the Ministry of Education and eight other departments jointly issued the Implementation Plan for Comprehensive Prevention and Control of Myopia among Children and Adolescents, which clearly states that physical activity is an important means to prevent and treat myopia. [3] Some studies have pointed out that the high prevalence of myopia among children and adolescents is closely related to increased academic pressure and lifestyle changes, while the decrease in physical activity time and the increase in study time are important factors contributing to myopia among children and adolescents. [4] Several studies have shown that different modes of physical activity have different

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demands on visual function and different effects on the promotion of visual function development. [5][6] In order to explore the effective ways of myopia prevention and control in children and adolescents, this study will focus on the role of physical activity on the prevention and control of myopia in children and adolescents in a comprehensive manner.

II. FORMATION MECHANISM AND ETIOLOGY OF MYOPIA IN CHILDREN AND ADOLESCENTS

2.1 Formation Mechanism of Myopia in Children and Adolescents

Accommodation is the ability of the human eye to increase the refractive power of the eye by changing the morphology of its own crystalline lens when looking at near objects, so that the object is accurately focused on the retina and produces a clear object. A growing number of myopia clinical researchers [5] have found that abnormalities in accommodation are associated with the development of myopia, mainly in the form of reduced accuracy and synergistic dysfunction of ciliary muscle accommodation.

In terms of ciliary muscle adjustment accuracy, myopic individuals (especially those with pseudomyopia), have low regulatory function, with the ciliary muscle unable to relax when looking at distance and mostly with a regulatory lag when looking at near. [7] In progressive myopia, the amount of ciliary muscle adjustment lag increases, and the sensitivity, accuracy, and positive relativity of adjustment are reduced. [8] The improvement of ciliary muscle regulation plays a positive role in delaying the development of myopia in children and adolescents [9].

In terms of ciliary muscle synergistic function, studies [10] have shown that myopic eyes are less sensitive to blur than orthoptic eyes, with the former relying more on eye aggregation cues (non-visual clarity) for accurate regulation. The visual object is not clear, and its adjustment reflexes are also prone to instability. [11] Blurred vision can lead to dysfunction of the regulation-convergence synergy, and wearing corrective glasses increases the ciliary muscle regulation load. Yin Rongbing [5] et al. concluded that improving the accuracy of ciliary muscle regulation is the best way to treat myopia.

2.2 Etiology of Myopia in Children and Adolescents

2.2.1 Genetic factors

Current research suggests that myopia has a high degree of heritability, with higher heritability in second-degree relatives than in first-degree relatives, and that those with a family history of myopia are more likely to develop myopia than those without a family history of myopia. [12][13] A study of children aged 12-13 years in Northern Ireland [14] showed that the risk of myopia in children with one or both myopic parents was 2.91 and 7.79 times higher than in children with normal vision parents. In addition, parental myopia will also promote the development of myopia in children and adolescents. Thus, it is clear that genetic factors play an important role in the development of myopia. About 25 genetic loci

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(MYP1-MYP25) have been clearly associated with the development of myopia. [15]

2.2.2 Prolonged close proximity to the eyes

Close proximity to the eyes includes reading, writing homework, and using electronic devices. A survey of Spanish children [16] showed that the longer the time spent in close proximity to the eyes, the higher the prevalence of myopia. A study by Hu Xiaoqin et al [17] also pointed out that reading and writing at a distance of less than 30 CM and looking at the computer for too long are risk factors for the development of myopia. This is because prolonged close eye use causes the ciliary muscle to be contracted for a long time and not fully relaxed, leading to the elongation of the eye axis and myopia. [18] It is very important to look far away frequently for myopia prevention and control. When reading and writing, you should take a long-distance view for about 10 min every 30 min. [19] The doctrine of accommodation created by Von Helmholtz in 1855 also fully supports this principle. Therefore, the principle of 320 should be strictly observed when using electronic devices, i.e., after 20 min of eye use, 20 ft away from the distance, and 20 s or more.

2.2.3 Decrease in physical activity

Physical activity guidelines for children and adolescents in China clearly recommend that children and adolescents should spend $\geqslant$1 h per day in moderate-to-intense physical activity and $\leqslant$2 h per day in visual screen time. However, survey data [20] found that less than 1/3 (29.9%) of children and adolescents in China achieved the recommended amount of physical activity, of which the average daily duration of high-intensity physical activity was about 45.5 min. As early as the 1990s, it was found [21] that the myopia rate of students who participated in 1.5 h of physical activity per day was 43.0%, which was much lower than the 84.5% of students with <0.5 h per day. Many studies in recent years have verified the conclusion. Guo Yin et al [22] found that children with normal vision spent significantly more time outdoors than children with myopia. A foreign study of 6-7-year-old children in Singapore and Sydney [23] found that myopia was much higher among Chinese children in Singapore (3.05 h/W of outdoor activity) than in Sydney (13.75 h/W of outdoor activity).

2.2.4 Inappropriate light intensity

Light intensity has a crucial influence on the refractive state of the human eye. Short wavelengths of light can stop the growth of the eye axis, and strong light has an inhibitory effect on form-deprived myopia. [24] Adequate light stimulates reactive pupil narrowing in children and adolescents, and the focal point of focus is elongated, thus inhibiting the lengthening of the ocular axis. [25] A survey of primary and secondary school students' visual acuity and classroom lighting conditions in Tianjin [26] showed a positive correlation between the average illumination of classroom desks and the average class visual acuity ($r=0.688$, $P<0.01$).Thomas [27] found that low-light (1-50 lux) environments and constant darkness (<1 lux) can cause enlargement of the eye and growth of the eye axis, leading to myopia; while strong light (1000-2800 lux) will delay the development of myopia. In addition, the appropriate light intensity

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stimulates the release of dopamine, which inhibits eye axis lengthening. [28].

III. DEFINITION OF THE CONCEPT OF PHYSICAL ACTIVITY

Physical activity was introduced by Casperson in 1985 and refers to any physical movement that is produced by skeletal muscle movement and accompanied by energy expenditure. The Physical Activity Guidelines for Chinese Children and Adolescents (2017) classifies the intensity level of physical activity into three levels according to metabolic volume, which are Light Physical Activity, including standing, slow walking, stretching, etc.; Moderate Physical Activity, including brisk walking, cycling, skating, etc.; and Vigorous Physical Activity, including fast running, soccer, etc. Physical activity can be divided into closed-skill physical activity and open-skill physical activity according to the degree of dependence of the movement on the environment.

In the WHO Global Recommendations for Physical Activity for Health [29], it is stated that the type of physical activity varies according to the characteristics of the population in order to achieve optimal health promotion. For children and adolescents, physical activity is mainly games, sports, recreation, physical education, or planned exercise performed at home, school, and in the community. The learning and exercise of occluded skills are the most widely engaged physical activities, such as walking, running, jumping, and throwing.

IV. THE ROLE OF PHYSICAL ACTIVITY IN THE PREVENTION AND CONTROL OF MYOPIA IN CHILDREN AND ADOLESCENTS

4.1 Association between Physical Activity and Myopia in Children and Adolescents

The association between physical activity and myopia in children and adolescents has been discussed for a long time; Parssinen [30] et al. explored the relationship as early as 1985. Since then, scholars around the world have also conducted studies, mainly divided into cross-sectional study and longitudinal cohort study.

4.1.1 Cross-sectional study

The vast majority of relevant studies have concluded that physical activity among children and adolescents is significantly and negatively associated with myopia. In a study by Yang Dongling et al [31] on the correlation between physical activity and myopia prevalence among primary and secondary school students in Shanghai, after correcting for gender, age, and parental myopia, a logistic regression analysis found that MVPA (moderate to vigorous physical activity) of up to 1 h per day was a protective factor for myopia prevalence among students. Students with MVPA up to 1 h per day had a smaller risk of myopia than students with MVPA less than 1 h per day. A study on the effect of current physical activity on visual acuity in Shenzhen senior students [32] found that students in the normal vision group participated in physical activity $\geqslant$1 h per day for more days than students in the myopic group. A multifactorial analysis

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revealed that more participation in moderate intensity physical activity was a protective factor for visual acuity. A study of 661 children aged 12-13 years in Northern Ireland [33] showed that regular physical activity was associated with low myopia after correcting for age, gender, family size, and school type. However, very few studies have concluded that physical activity in children and adolescents is not associated with myopia rates. Lundberg et al [34] tested 307 children and adolescents aged 14-18 years in Denmark and showed that none of the time spent in physical activity was significantly associated with myopia rates in children and adolescents, and increasing the time and frequency of physical activity in children and adolescents did not reduce the risk of myopia occurrence. In a study of children and adolescents in grades 3-9 in Shanghai, Wang Bingnan [35] found that high-intensity, but not low- or medium-intensity, physical activity was significantly and negatively associated with myopia in children and adolescents. This suggests that there may be an "intensity threshold" for the effect of physical activity on the visual acuity of children and adolescents.

4.1.2 Longitudinal cohort study

In 2008, a 2-year cohort study in Denmark [36] showed that physical activity time was negatively associated with myopic refractive error change, with a 0.175 D decrease in myopic refractive error growth for every 1 h/d increase in physical activity time. In 2012, a large sample cohort study in the United Kingdom [37] also verified that physical activity was associated with myopia in students, but the researchers concluded that physical activity was primarily associated with myopia by increasing outdoor activity time to achieve a protective effect on myopia. A growing number of national researchers [38][39] have also systematically addressed the association between outdoor activity and myopia in children and adolescents, and have proposed intervening in the source environment and going outdoors to be close to the sun to prevent and control the occurrence and development of myopia.

However, some studies have also concluded that physical activity is not correlated with myopia progression in children and adolescents. Wang Bingnan et al [40] found no correlation between physical activity time and myopia progression in a 1-year investigation of children and adolescents who were already myopic in a baseline cross-sectional study. This suggests that increasing physical activity time does not decrease the probability of myopia progression. An 18-month follow-up survey of Spanish children and adolescents aged 6-15 years [41] showed that daily physical activity time was not significantly associated with myopia progression at 18 months. Wu et al [42] investigated children and adolescents aged 6-12 years in Beijing and showed that the difference in daily physical activity time between children and adolescents with high myopia progression and those with low myopia progression was not statistically significant. After correction for age, gender, area of residence, parental myopia, and baseline refraction, multiple regression analysis showed that time spent in physical activity was not associated with the magnitude of myopia progression.

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4.2 Intervention Studies on Physical Activity to Prevent and Control Myopia in Children and Adolescents

In addition to enhancing the physical fitness of children and adolescents, open-skill physical activity, which "highlights" the visual task, and closed-skill physical activity, which "mosaics" the visual task, can prevent the onset of myopia and slow down the progression of myopia in children and adolescents.

Open-skill physical activity requires the participant's eyes to continuously capture the visual target and follow it with alternating near and far vision. In this process, the ciliary muscles alternately complete contraction and relaxation, increasing the flexibility and accuracy of ciliary muscle adjustment, thus allowing the ciliary and extraocular muscles to be exercised and improved. An increasing number of studies have found that open-skill physical activity (especially ball sports) is effective for visual acuity intervention. Chen Guangwei et al [43] found that table tennis training had a significant effect on visual acuity improvement and that there was a correlation between visual acuity and ball age. Zhao Qingfeng [44] found that table tennis combined with badminton sports intervention (⩾3 times a week for ⩾1 h) prevented the occurrence of myopia and improved the visual acuity level of already myopic adolescents. Zhang Zening [45] found in a retest of the same students 3 months after the end of the experiment that the visual acuity of the students who adhered to table tennis exercise continued to improve, while the students who gave up had significantly lower visual acuity in both eyes compared to the end of the experiment. Wu Xiangning [46] and Xiao Bojuan [47] both concluded that table tennis exercise has a better effect on myopia protection in children and adolescents. A study by Pan Jingling et al [48] on dynamic visual acuity in students aged 6-10 years found that participation in physical activities had a positive effect on visual acuity development and that ball and fighting sports were more effective for dynamic visual acuity, which is consistent with the findings of Muiños et al. Jin Gang et al [49] found that ball sports had a positive effect on improving dynamic visual acuity in lower elementary school students, and the effect was most pronounced in the large ball category.

Closed-skill physical activity relies mainly on internal feedback from proprioceptors, is less dependent on the external environment, does not require constant capture of visual targets, does not require high dynamic visual acuity, and has a weaker regulatory effect on ciliary muscles than open-skill physical activity. However, some studies have demonstrated that additional closed-skill physical activity with alternating near and far vision tasks can also exercise ciliary and extraocular muscles, thus improving visual acuity and achieving a preventive and controlling effect on myopia. Zhou Sheng et al [50] conducted a 16-week blocked-skill physical activity intervention with additional visual switching tasks for 37 fourth-grade myopic students in Suzhou, China, and showed that the visual function of the students with mild to moderate myopia improved, and the recovery of dynamic and static visual acuity was greater in the students with moderate myopia. Cao Jiaoyan et al [51] found that physical activity with additional visual tasks had a positive effect on improving dynamic and static visual acuity in children aged 6-9 years, and that dynamic visual acuity improvement preceded static visual acuity. Liu Yang et al [52] pointed out that orienteering exercises have a good regulatory effect on eye muscles and have a targeted exercise value for myopia prevention and control, and suggested the design of visual tracking training at different

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distances and visual perception training such as color recognition and perceptual perception.

In summary, it can be seen that children and adolescents' visual acuity is closely related to physical activity. The physical activity of "highlighting" or "mosaic" visual tasks can prevent the occurrence of myopia in children and adolescents, reduce the degree of myopia in myopic children and adolescents, inhibit the process of refractive error, and improve the visual acuity of those who are already myopic (especially those with pseudomyopia). The effect is better for those who are already myopic (especially pseudomyopia). Increasing physical activity time can protect children and adolescents' eyesight. Physical activities such as running, jumping, throwing and other closed skills are the basic components of outdoor activities. Thus, Sheng Zhou et al [50] suggested that part of the intervention effect of occluded skill physical activity may need to be attributed to outdoor activities. Therefore, it is important not only to strengthen the visual interaction between children and adolescents and the external environment to increase the ciliary muscle regulation, but also to guide students to go outdoors and bask in the sunlight. In the current study, most of the subjects were tested using the "E" visual acuity scale, and the lack of professional ophthalmological examination may lead to bias in the final experimental results. More professional equipment and scientifically rigorous experimental designs should be used subsequently to verify the potential role of physical activity in preventing and controlling myopia in children and adolescents. In addition, the current research on the relationship between physical activity and myopia in children and adolescents is relatively generalized, and there are few studies on the correlation between different exercise intensities ("intensity thresholds"), different activity venues (outdoor and indoor), and different types of physical activity (closed and open) and myopia, which need to be explored in depth.

V. SUGGESTIONS FOR MYOPIA PREVENTION AND CONTROL FOR CHILDREN AND ADOLESCENTS IN CHINA

The structural and functional development of the eye is fully developed around the age of 7. The sensitive period of visual development occurs before the age of 9, and the plastic period of visual development continues throughout childhood and adolescence. It has been pointed out [53] [54] that physical activity has an important influence on the development of the refractive system, especially for the protection of vision in younger children (6-12 years old). The Opinion of the State Council on the Implementation of Health China Action clearly states that prevention is the most economical and effective health strategy by strengthening early intervention and forming a lifestyle conducive to health. Therefore, the prevention and control of myopia in children and adolescents should be started at an early age. Combined with the systematic analysis of relevant studies in this paper, recommendations will be made on the comprehensive prevention and control of myopia among children and adolescents in China from four levels.

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5.1 Government Level

5.1.1 Strengthen organizational leadership and improve long-term prevention and control mechanism

The government, education and health departments set up a leading group for the comprehensive prevention and control of common diseases such as myopia among students, form a team of experts, and hold regular joint meetings every year to strengthen the guidance, supervision and assessment of the prevention and control of myopia among children and adolescents; incorporate vision prevention and control into quality education, include children and adolescents' physical and mental health and the burden of schoolwork into the compulsory education quality monitoring and assessment system, strictly implement the evaluation and assessment of the prevention and control of myopia, and Governments and schools that do not have proper supervision will be held accountable.

5.1.2 Widely carry out publicity and guidance to create a good social atmosphere

Make use of various new media platforms to announce the progress of myopia prevention and control among children and adolescents in China; take the initiative to publicize the typical experiences, effective initiatives and results achieved in myopia prevention and control across the country; collaborate with medical education and organize medical experts and cadres to go to schools to carry out popular knowledge propaganda and nutritional health guidance on myopia prevention in conjunction with the National Eye Care Day, World Sight Day and other thematic educational activities; Draw on the experience of the Health Promotion Board of Singapore in improving the guidance manual on myopia prevention and control, combine the long-standing Chinese traditional culture with vision care, and adapt the eye care and eye protection publicity manual to facilitate vision care education at home and school.

5.2 School Level

5.2.1 Open full and complete physical education classes and strictly implement the 1 h activity of sunshine sports

To build an education that satisfies the people, we can't just meet the score and promotion rate, but turn a blind eye to the youth physical health problems including myopia. Schools should strictly implement the "ease the burden of excessive homework and off-campus tutoring for students undergoing compulsory education" policy, open all physical education classes according to the standards, and provide enough physical education teachers; enrich the content of physical education classes, add more "visual tracking" ball (especially small ball), combat classes and other courses, and adapt to local conditions with "improved" visual training methods interspersed with the physical activities of occlusion skills, so that the ciliary and extraocular muscles can be exercised; according to the alternating rules of movement and stillness, distance and nearness, students are encouraged and urged to leave their seats and go to outdoor activities; the implementation of "sunshine recess", and the promotion of sunshine sports, according to different stages. We promote sunshine sports, design and develop fun and exercise physical activities

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according to the characteristics of students at different stages, so that students can move and ensure that students spend >1 h in physical activities at school.

5.2.2 Materials and methodology

The school shall strive for project funds through multiple channels to improve teaching equipment and lighting conditions and provide students with a learning environment that meets standards; implement lighting and illumination requirements for classrooms, libraries (reading rooms), dormitories, etc., and choose equipment that is conducive to visual health as much as possible; control seating perspectives, classroom lighting, and changes in class students' visual acuity in real time and make timely adjustments as needed; strictly organize all students to do eye exercises on time and complete them according to the process to ensure maximum effect.

5.3 Family Level

5.3.1 Home and school linkage, implementation of family education responsibilities

Parents should play a leading role, often take their children to participate in outdoor physical activities, to ensure that the exercise time is not less than 1 h/D, to create a strong family physical activity atmosphere, to cultivate the lifelong exercise habits of children; make full use of weekends or holidays to take children out of the home, into the nature, close to the sun, according to the time and place to carry out various physical activities, such as badminton, kite flying, Frisbee, hiking, etc.; the "ease the burden of excessive homework and off-campus tutoring for students undergoing compulsory education" policy should be put into practice, and extracurricular classes should be reduced, so as to truly "reduce the burden"; give children more company, and strictly control the time children use electronic devices to avoid blue light damage.

5.3.2 Protect sleep and nutrition, and keep an eye on child's vision

Create a good sleep environment and ensure that children get enough sleep every day; provide children with foods that are good for vision health, and guide children to consume more fish, fruits, and green vegetables; establish a sense of prevention, have children's vision checked every 3-6 months with the help of a vision chart, observe them frequently in their lives, and seek medical attention immediately if they find any irregularities in their eyes.

5.4 Student Level

5.4.1 Strengthen the awareness of healthy eye care and fully mobilize students' subjective initiative

Students should strengthen the main responsibility awareness, enhance health consciousness, actively learn eye care knowledge; always pay attention to their vision status, consciously maintain vision health,

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notice any abnormality, should promptly inform parents and consult with relevant teachers, early examination and timely treatment.

5.4.2 Develop good reading, writing and living habits, and conduct eye care exercises carefully and regularly

Pay attention to the correct posture of reading and writing, reading, continuous close eye use for half an hour, should look far out of the window, rest or go outdoors for physical activities to avoid visual fatigue; take the initiative to participate in various physical activities (especially projects with more visual tracking), ensure ⩾2 h/D of physical activity time; use electronic products reasonably, and consciously reduce the time of use (<2 h/D); develop healthy living habits, early to bed and early to rise and ensure sufficient sleep, not to be picky about food, not to be partial to food, to consume less sweets, to pay attention to dietary structure, and to ensure balanced nutrition; do eye exercises seriously and regularly, and to avoid being formal.

VI. CONCLUSION

The development of myopia is mainly related to various factors such as genetics and the environment. Under current conditions, we can only prevent and control myopia from environmental and other factors. The occurrence of myopia is irreversible. Therefore, prevention is the first and foremost task, and early diagnosis and early intervention is the key. Reducing near eye time and increasing physical activity time, especially outdoor activities, are effective measures that we can take to prevent and control the development of myopia. Education departments and medical institutions should increase their efforts to popularize eye care knowledge among children and adolescents, parents and teachers, and inform them of scientific methods to protect their eyesight and prevent myopia. Health departments, education departments, and the community should combine the characteristics of children and adolescents, cooperate, and work together to develop and promote evidence-based programs to ultimately achieve victory in the battle against myopia prevention and control, and "give children a bright future.

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