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Effects of physical activity on the development and progression of myopia in children: a current review of the literature

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ABSTRACT

The aim of this study was to review the available literature evaluating the effects of various parameters of physical activity on myopia.

Results: Physical activity and its impact on various aspects of health are currently being widely studied by many researchers. In view of the increasing global incidence of myopia and the potential social and economic effects of myopia-related complications, methods to prevent occurrence are actively being sought. There are studies showing a reduction in the risk of myopia in physically active children.

Conclusions: Based on the review of the available literature, the authors conclude that performing physical activity outdoors for at least 60 minutes a day is associated with health benefits. However, further research is needed to determine the time and type of activity that may inhibit the development and progression of myopia. The authors also recommend an ophthalmological examination prior to the initiation of intense exercise, especially in children with high degree myopia, which may be associated with degenerative changes in the fundus, increasing the risk of retinal detachment.

KEY WORDS: children, physical activity, myopia.

INTRODUCTION

Physical activity and its impact on various aspects of health are currently being widely studied by many researchers. According to the WHO 2020 guidelines, adults should undertake 150-300 minutes of moderate-intensity or 75-150 minutes of vigorous-intensity physical activity per week. For children and adolescents, the recommended average duration of physical activity is 60 minutes a day [1]. Physical activity time expressed as the time spent outdoors is a factor contributing to a reduction in the risk of developing myopia [2, 3]. In view of the increasing prevalence of myopia and its associated complications, a review of the available literature was performed to determine the recommended amount and type of physical activity as factors contributing to the prevention of myopia in children.

The Pubmed database from 2015-2021 was searched for the terms "physical activity", "myopia", and "children". A total of 69 publications were found. Publications containing reviews of the literature and not relevant to the topic under study as well as articles written in Chinese and Russian were rejected. Eleven original papers were ultimately considered eligible for inclusion in the literature review. The publications were analyzed to determine the type and amount of physical activity and its effects on the development and progression of myopia. The studies included in the review are listed in Table I below.

Myopia is defined as a condition in which the spherical equivalent of refractive error of an eye is ≤ –0.5 D when ocular accommodation is relaxed [4]. This limit for the diagnosis of myopia was adopted by the authors of all reviewed publications with the exception of one study in which a refractive error was classified as myopia starting at values ≤ –1 D [5]. The difference referred to above significantly reduces the actual diagnostic frequency of myopia.

Time spent outdoors is a parameter with a proven inhibitory effect on the progression of myopia [6], though it is known to produce multifaceted effects. These include higher ambient brightness, reduced peripheral blur, elevation in vitamin D levels, different chromatic spectrum of light outdoors, increase in physical activity, reduced near work, circadian rhythm stability, and different spatial-frequency characteristics (degree of detail in spatial elements) [3].

Most of the time children spend outdoors is devoted to physical activity of medium to vigorous intensity. This leads to the overlap of factors that may potentially contribute to the progression of myopia. To date, there have been only

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Table I. Studies, in which were analyzed the type and amount of physical activity and its effects on the development and progression of myopia

Study – location and years	Age of subjects	Method for evaluating refraction	Method for evaluating physical activity	Conclusions	Notes
Los Angeles, 2008-2013 [5]	5-19 y/o	Retrospective study, differences in refractive assessment results between study subjects (autorefractometer/ subjective refraction/post-cycloplegia)	Questionnaire with questions about the frequency of exercise per week and the length of sessions	60 minutes of exercise per day is associated with a 10% lower risk of developing myopia	Myopia ≤ –1 D The type and conditions of physical activity are not specified
Szczecin [12]	6-18 y/o	Autorefractometer after administration of 1% tropicamide	Questionnaire with a question about the amount of time spent on outdoor physical activities	Exercising outdoors plays a minor contributory role in reducing the incidence of myopia.	
Copenhagen, 2016-2017 [10]	16-17 y/o	Autorefractometer without cycloplegia	Questionnaire with a question concerning the number of hours of physical activity per week over the past year	Physical activity of more than 3 hours per week is associated with a 40% lower risk of myopia	In addition, eye length was measured
Denmark, 2008- 2015 [13]	5-17.4 y/o (ophthalmological examination at the age of 14.3-17.5 y/o)	Autorefractometer after administration of 1% tropicamide	ActiGraph accelerometer	Physical activity showed no association with the magnitude of the refractive error or eye length	In addition, eye length was measured
Taiwan [15]	9.5-12.6 y/o	Where visual acuity was < 0.9 Sn at screening tests, children were referred for a complete ophthalmological evaluation (no information is provided on the method for determining refraction)	Questionnaire evaluating the level of activity over the past 7 days	Moderate to vigorous physical activity of at least 1 hour a day reduces the risk of myopia by 20%	Myopia risk reduction was also associated with spending time outdoors
Beijin, 2012- 2016 [11]	6-7 y/o	Autorefractometer without cycloplegia	Subjects in the study group participated in an outdoor activity (jogging) for 30 minutes a day on weekdays. In addition, a questionnaire was filled in to determine the amount of time spent outdoors and sports practice both during weekdays and at weekends	A program of physical activity practiced 30 minutes a day induced a temporary reduction in myopia progression, but at 4 years post-intervention there was no significant difference between the groups in the spherical equivalent of refractive error or eye length	
Czech Republic, 2016-2017 [16]	11-17 y/o	Only ocular axial length was assessed, without refractive error assessment	Questionnaire on ways of spending free time	The eye length was significantly smaller in a group of children who practiced sports for ≥ 3 hours a day	
Tokyo, 2018- 2019 [8]	6-2 y/o	There was no refractive error assessment. The study was based on a questionnaire with a question about wearing corrective spectacles (the questionnaire was filled in by children)	Comparison of the frequency of wearing spectacles in children attending a sports club or school offering extra-curricular activities	The children who attended only a school with extra-curricular activities were more likely, while children who attended a sports club were less likely to wear spectacles	The study provides no data on the type of spectacles worn by the subjects

Table I. Cont.

Study – location and years	Age of subjects	Method for evaluating refraction	Method for evaluating physical activity	Conclusions	Notes
Israel, 2019- 2020 [7]	8–12 y/o	29/36 children had refractive error assessment, but only some of them with cycloplegia. Data on the remaining children were obtained from a questionnaire	Actiwatch Spectrum (simultaneous measurement of the amount of light and physical activity)	Groups of ultra-Orthodox, religious, and secular Jewish boys were compared. The ultra-Orthodox and religious children had a greater myopia prevalence compared to the secular group. No differences in time spent outdoors, physical activity or amount of near work were noted	
Northern Ireland [14]	12-13 y/o	Autorefractometer after administration of 1% cyclopentolate	Questionnaire including a question about the level of physical activity	Children engaging in regular physical activity have a lower prevalence of myopia than children with sedentary lifestyles	
Mainz, 2003- 2006 [9]	3-17 y/o	There was no refractive error assessment. The study was based on a questionnaire with a question about whether the child was myopic and wore corrective spectacles (the questionnaire was filled in by parents)	Questionnaire including a question about the frequency of free-time physical activity	Among the subjects aged 11 to 17 y/o, frequent participation in sports has been shown to be negatively associated with myopia	

isolated prospective studies evaluating these two factors independently, taking into consideration the location and actual time of physical activity together with its intensity determined with the use of pedometers, accelerometers, and light sensors [7].

Another factor affecting the reliability of studies is the methodology for collecting information on the refractive error. Some of the studies were based on a refractive error questionnaire alone [7–9]. In one of them, the questionnaire was filled in by children aged 6 to 12 years, who were asked about wearing spectacles for refractive error correction. However, spectacle correction may have been used not only to remedy myopia, but also hyperopia, astigmatism, and the angle of ocular deviation in strabismus, which was not specified in the questionnaire [8]. Regarding ophthalmological examinations, the review included studies based on both non-cycloplegic assessment [10, 11] and evaluation with the use of tropicamide [12, 13] or cyclopentolate eye drops [14]. Not every study provided information on the method used for refraction assessment, so there may be differences in assessment methodology between study participants [5, 15]. One study focused on measuring the axial length of the eye without assessing refractive error. Consequently, there was no data on the percentage of children with myopia, and the onset of the condition [16]. The increase in axial ocular length itself may also have been associated with the process of emmetropization in cases of decreasing hyperopia. In addition to a refraction test, the most reliable studies also included ocular length measurement [10, 11, 13], so it was possible to objectify the findings, especially in cases where refractive error was assessed without cycloplegia.

Furthermore, there were major differences in the assessment of physical activity between the studies. The most reliable of them were based on a single use of an accelerometer or four measurements of physical activity performed on a smartwatch [7, 17]. In view of the method of device operation, certain types of physical activity either could not be included in the measurements or it was necessary to remove the device (for example for swimming). The vast majority of studies were based on a physical activity questionnaire with a varying degree of detail in the questions asked and the period covered [5, 9, 12-16]. One study was based on a physical activity regime consisting of jogging for 30 minutes a day on weekdays, which was imposed on the students enrolled in the study group. The results obtained in the study group were compared to the control group that was not subject to any intervention [11]. An interesting comparison of the level of physical activity was made between children taking part in extra-curricular school activities and those attending sports club practice [8]. Under- or overestimation of the amount of physical activity in questionnaires is a well-known phenomenon. In addition, the available descriptions contain no data about the type and intensity of exercises performed by the subjects, which can clearly influence the onset and progression of myopia. The main parameter under study was time spent on physical activity which, depending on the study, had a different cut-off point for division into groups.

Another factor analyzed was how the authors approached the problem of distinguishing the direct impact of physical activity from spending time outdoors. Only one study, based on the Actiwatch, allowed simultaneous measurement of the amount of light reaching the device and the level of physical activity [7]. In other studies based on questionnaires only, it is difficult to determine which factor had a more significant impact on the findings, as not all questionnaires contained questions about the type and location of physical activity.

Other factors under analysis include the time of near work, use of electronic screens, forms of spending free time, parent history of myopia, number of siblings, prematurity, ophthalmic history, and even eating habits. Unfortunately, there were very large discrepancies between the studies and not all of them were adjusted for known risk factors contributing to the development of myopia.

A cohort study on the prevalence and risk factors for myopia in children was launched in China in 2019 [18]. According to the protocol presented by the authors, the study involves a large study group and a reliable assessment of physical exercise with an activity sensor, and near work by using a device measuring distance and tracking eye movements. In addition, the researchers have planned pre- and post-cycloplegic refraction assessment, biometric measurements and OCT complementing the ophthalmic assessment of the anterior and posterior eye segments. The study, which is scheduled to end in February 2023, comprises three rounds of patient assessment. It appears to be the first prospective study comprising an independent and objective assessment of the amount of physical activity and near work, along with a complete ophthalmic evaluation including measurement of post-cycloplegic refractive error. It is expected that the study will yield relevant and reliable information on the impact of physical activity on the development and progression of myopia in children.

Theories accounting for the inhibition of myopia progression in children due to physical activity do not distinguish between the effect of physical activity and the time spent outdoors. Physical activity has a known positive effect on cardiovascular health. To date, there have been few studies on the ocular circulation status during exercise in children. Li *et al*. found that choroidal thickness decreased significantly after exercise, and the decrease persisted for at least 30 minutes after the cessation of exercise in all children [19]. In addition, changes in choroidal thickness are greater in myopic than emmetropic children. This change is most likely due to sympathetic system stimulation and fluid loss associated with perspiration, which causes water to shift from the extracellular matrix to the blood vessels in order to compensate for the decreased blood volume. This allows maintaining stable density of the choroidal blood vessels. In myopic children, the thickness of vessels in the deep retinal plexus was found to be significantly decreased after the cessation of physical activity, which was not observed in normally-sighted children. The observation is probably related to the higher vascular elasticity noted in normally-sighted children and faster recovery after exercise, which does not allow the detection of fluctuations in the study. As yet, it is not known how these changes contribute to myopia progression, especially as the long-term effects of exercise on the ocular circulation in children have not been determined. Another study looked at cumulative physical activity in children and its effects on retinal vessel diameters [20]. It was observed that longer duration of physical activity was associated with a decrease in retinal venular diameter, which has a beneficial effect on retinal microcirculation. Theories explaining these observations are based on the positive effects of activity induced by anti-inflammatory substances released during exercise and an increase in blood flow associated with physical activity. The absence of changes in the diameter of the retinal arterioles is most likely due to the efficient autoregulation mechanism in young people.

Despite essential differences in the methodology of the studies included in the review, the vast majority of them highlight the benefits of physical exercise in terms of the development of myopia, though two studies failed to confirm such a relationship. Interestingly, a short-term increase in the amount of physical activity is associated with a temporary reduction in the progression of myopia. As yet, it is not known what effect it would have to maintain an increased level of physical activity until the process of eye growth is complete.

The current U.S. guidelines for physical activity in the United States provide that exercise should be promoted and physical activity should commence in preschool children, with a recommendation for three hours of activity of any intensity daily. In school-age children, medium to vigorous intensity exercise for 60 minutes a day is recommended, with a special emphasis on bone strengthening exercises (at least three times a week) and muscle strengthening exercises (at least three times a week) [21].

CONCLUSIONS

It must be stressed that any amount of exercise has health benefits. Nevertheless, none of the guidelines published to date address the problem of increasing global prevalence of myopia. Even though the available standards contain examples of physical activities of medium to vigorous intensity, they fail to clarify whether such activities should be performed outdoors or indoors, and in what ways physical exercise affects the development of myopia. It is hoped that future research will take into account the deficiencies of the studies conducted to date and provide a basis for developing more comprehensive guidelines aimed at reducing the global development of myopia.

Based on the review of the available literature, the authors conclude that performing physical activity outdoors for at least 60 minutes a day is associated with health benefits. However, further research is needed to determine the time and type of activity that may inhibit the development and progression of myopia. The authors of this review also recommend an ophthalmological examination prior to the initiation of intense exercise, especially in children with high degree myopia, which may be associated with degenerative changes in the fundus, increasing the risk of retinal detachment [22, 23].

DISCLOSURE

The authors declare no conflict of interest.

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