Sports and Myopia: An Investigation on the Prevalence and Risk Factors of Myopia in Young Sports-Related Groups in Tianjin, China

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Received: March 31, 2022
Accepted: June 13, 2022
Published: June 27, 2022

Citation: Zhang M, Sun Z, Zhu X, Zhang H, Zhu Y, Yan H. Sports and myopia: An investigation on the prevalence and risk factors of myopia in young sports-related groups in Tianjin, China. *Invest Ophthalmol Vis Sci*. 2022;63(6):27. https://doi.org/10.1167/iovs.63.6.27

Objective. To explore the relationship between sports and the prevalence of myopia in young sports-related groups in Tianjin, China.

Methods. In this cross-sectional study, a cluster sampling method was used to survey professional athletes in Tianjin, students at Tianjin University of Sport, and Tianjin Vocational College of Sports. All participants completed epidemiological questionnaires and ophthalmic examinations. Multivariable logistic regression models were used to explore the potential risk factors of myopia.

Results. This study recruited 1401 participants. The prevalence of myopia was 50.18%. The prevalence of low, moderate, and high myopia were 52.63%, 37.41%, and 9.96%, respectively. There were no sex-related differences in the prevalence of myopia. The odds of having myopia was 1.788 times higher in the indoor sports group than the outdoor sports group (the adjusted odds ratio [OR], 95% confidence interval [CI], 1.391–2.297). Training time of more than 4 h/d (4–6 h/d: OR, 0.539; 95% CI, 0.310–0.938; >6 h/d: OR, 0.466; 95% CI, 0.257–0.844) resulted in a lower risk of myopia. Participants who often used the electronic screen (OR, 1.406; 95% CI, 1.028–1.923) and/or had a family history of myopia (OR, 2.022; 95% CI, 1.480–2.763) were more likely to suffer from myopia.

Conclusions. Outdoor sports do not necessarily guarantee to insulate against myopia. Youngsters engaged in outdoor sports had a lower prevalence of myopia than those participating in indoor sports. Electronic screen use, training time, and family history of myopia were also associated with the prevalence of myopia in young sports-related groups.

Keywords: myopia, sport, young people, prevalence, risk factors

Myopia has become a global public health concern with rapidly increasing incidence, especially in East and Southeast Asia. It is estimated that 5 billion people will be affected by myopia worldwide by 2050.[1] The prevalence of myopia among young adults has reached 80% to 90%.[2–5] Similarly, myopia is becoming more common in Western countries; the prevalence in the United States has increased from 25% in 1971 to 1972 to 41.6% in 1999 to 2004.[6] According to the data released by the National Health Commission of China, the overall myopia rate in Chinese adolescents is 53.6%; specifically, the rates were 36.0%, 71.6%, 81.0%, and 90% among students in elementary school, junior high school, high school, and college, respectively. Myopia not only brings great inconvenience to daily life and learning of young people, but also develops into high myopia, which is often accompanied by complications such as glaucoma, cataracts, and retinopathy, which can lead to severe and irreversible visual impairment.[7]

Myopia is likely to result from complex interactions between genetic and environmental factors. Studies have confirmed that parental myopia is a risk factor for myopia development in children. Compared with children with only one myopic parent, children with both myopic parents were more likely to develop myopia,[8,9] and the risk was positively correlated with the degree of parental myopia.[10] So far, genome-wide association studies have identified more than 70 genetic loci related to myopia.[11–13] However, the role of environmental factors in the occurrence and development of myopia cannot be disregarded. Known environmental factors related to myopia include near work, sports, light, diet, education level, socioeconomic status, and urbanization.[14,15] Many studies have shown that outdoor sports and activities are effective in preventing myopia.[16] However, most of the existing researches are hospital based rather than population based. Athletes and students in professional sports schools are a relatively special group, whose outdoor activity levels and time spent in sports are significantly longer than their peers. However, to the best of our knowledge, no study has evaluated the prevalence of myopia in this population. Therefore, we conducted a cross-sectional survey among athletes and sports school students in Tianjin, China, aiming to understand their myopia prevalence and related risk factors, which may provide potential countermeasures to reduce myopia.

Methods

Study Participants

From March 2018 to November 2018, 1413 persons (914 males and 499 females) were recruited, including professional sports athletes in Tianjin and students of Tianjin University of Sport (TUS) and Tianjin Vocational College of Sports (TVCS). Twenty-five sports were investigated: badminton, swimming, weightlifting, taekwondo, judo, table tennis, wrestling, water polo, diving, synchronized swimming, martial arts, rhythmic gymnastics, fencing, soccer, basketball, baseball, track and field, volleyball, tennis, takraw, cycling, archery, shooting, handball, and hockey. Based on the eye protection standard developed by Standardization Administration in China, such as "Personal Protective Equipment, Eye and Face Protection for sports use, Ski Goggles," the participants wore eye protection during sports, including patients with an eye injury. Eye examinations, including visual acuity and refractive status, were performed. In addition, personal and family eye history was collected, and all participants completed questionnaires. The study excluded people who had undergone refractive surgeries or those with a best-corrected visual acuity of less than 1.0 induced by ocular trauma ($n = 12$). The final sample size was 1401 participants (902 males and 499 females) (Fig. 1).

Examination of Visual Acuity and Eye

The international standard visual chart was used to check for uncorrected and corrected visual acuity. Those with an uncorrected visual acuity in both eyes 1.0 or more were regarded as having normal vision, and those with an uncorrected visual acuity of any one eye of less than 1.0 were considered to have an abnormal vision. A slit lamp, tonometer, and ophthalmoscope were used to monitor the eyes of the participants. In addition, refractive error without cycloplegia was measured by autorefractor (NIDEK, Gamagori, Japan), and the average value of multiple measurements was recorded.

Criteria for Myopia

Myopia was defined as spherical equivalent refraction worse than −0.5 diopters (D) in one eye. Patients in the myopia group were further divided into mild myopia (≤−0.5 D and ≥−3.00 D), moderate myopia (≤−3.25 D and >−6.00 D), and high myopia (≤−6.00 D).[17,18]

Questionnaire

All the participants completed an epidemiological questionnaire through on-the-spot inquiries by ophthalmologists and students. The questionnaire mainly included questions concerning the general situation of the participants (such

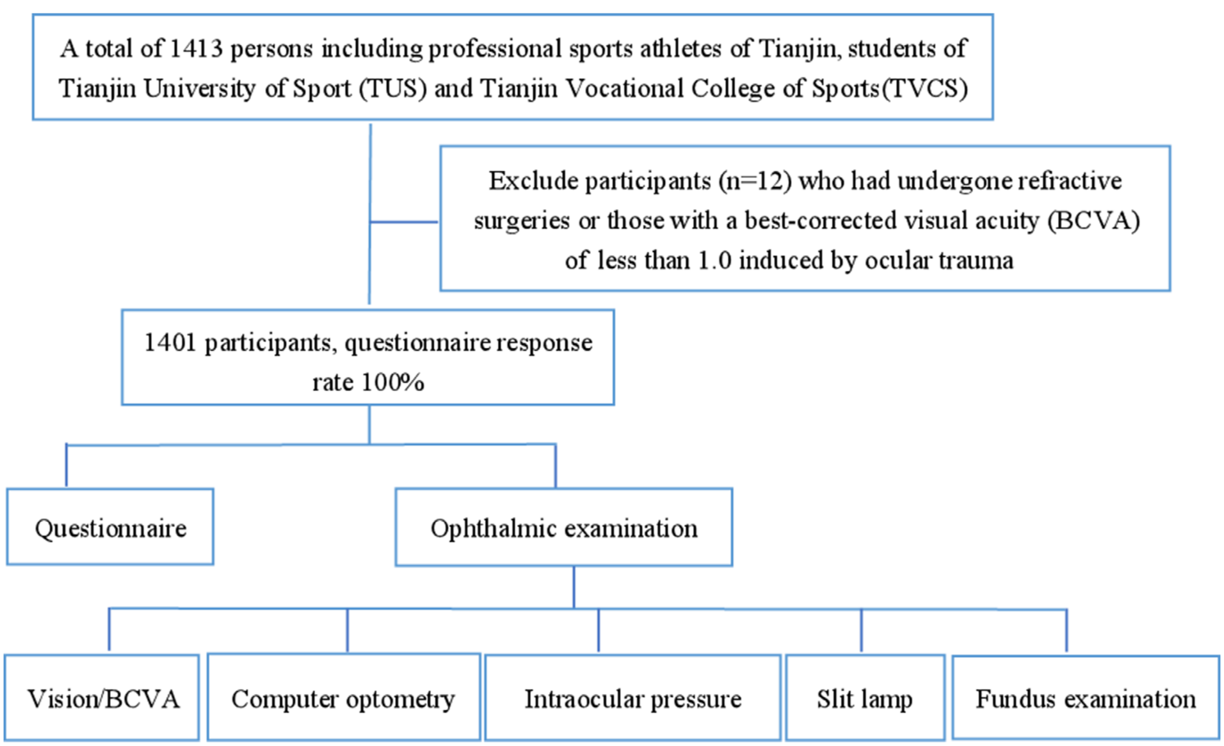

Figure 1. Flow diagram summarizing the systematic search and review process. BCVA, best-corrected visual acuity.

as name, age, sex, date of birth, level of education, and monthly family income, body weight, and height), type of sports (outdoor sports or indoor sports based on the training ground), daily training time, wearing eye protection, daily reading time, electronic screen using time, family history of eye diseases, personal history of eye diseases, history of surgery, and routine ophthalmic examination. Regarding the type of sports, indoor sports included badminton, swimming, weightlifting, taekwondo, judo, table tennis, wrestling, water polo, diving, synchronized swimming, martial arts, rhythmic gymnastics, and fencing. Outdoor sports included soccer, basketball, baseball, track and field, volleyball, tennis, takraw, cycling, archery, shooting, handball, and hockey. The body mass index (BMI) was calculated as weight in kilograms (kg) divided by the square of height in meters (m^2).

Quality Control

The ophthalmologists and students participating in the study were trained before the investigation. Measurements and analyses were performed according to a uniform standard. The results were recorded truthfully and interpreted according to uniform standards. In addition, we checked the data on-site in a timely manner to avoid missing items.

Ethical Approval

This study was approved by Tianjin Medical General Hospital Ethics Committee, Tianjin, China (No. IRB2019-114-01). Detailed information about the study, including objectives, significance, and procedures, was provided to the participants using information leaflets. This study followed the tenets of the Declaration of Helsinki for research involving human participants.

The binocular data were used for data analysis. The *t*-test was used to compare the mean of two independent samples, and the χ^2 test was used to compare the sample rate. Multivariable logistic regression analysis was performed to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) of myopia in relation to sex, age, BMI, monthly family income per person, daily training time, type of sports, time of daily reading, electronic screen using time (electronic devices used for near work, mainly including mobile phones and tablet computers), family history of myopia, personal habits, and study locations of sample sources (i.e., athletes, students from TUS, and students from TVCS). Statistical analyses were performed using SPSS version 25.0. Statistical significance was set at a P value of less than 0.05

Results

Characteristics of the Participants

Table 1 shows the baseline characteristics of the study population. The 1401 athletes included 902 (64.38%) males and 499 (35.62%) females. The mean age of participants was 19.03 ± 2.78 years (range, 7–30 years). The average age and BMI were 19.03 ± 2.78 years and 21.90 ± 3.36 kg/m^2 for the entire sample, specifically, 19.25 ± 2.24 years and 22.29 ± 3.24 kg/m^2 for males and 18.65 ± 3.29 years and 21.11 ± 3.45 kg/m^2 for females. There were 179 participants (12.77%) who wore eye protection among all athletes during sports.

Myopia in Young Sports-related Groups

Among the 1401 participants, 703 had myopia and 698 did not have myopia; the prevalence rate of myopia was 50.18%. Among them, 370 (52.63%), 263 (37.41%), and 70 (9.96%) had mild, moderate, and high myopia, respectively. Among the 902 male participants, 447 were myopic, with a prevalence of 49.56%, whereas the proportion of female participants was 51.30% (256 myopia cases among 499 persons). Participants who engaged in water polo (71.43%) reported the highest prevalence of myopia, followed by those who participated in rhythmic gymnastics (70.00%), and badminton (67.16%) (Fig. 2). The prevalence of myopia differed significantly among the different types of sports ($P < 0.001$).

We observed a lower prevalence of myopia among these sports-related youngsters who were younger, longer daily training time, less or without family history of myopia, less electronic screen use, and were more likely to engage in outdoor sports. In addition, students from TVCS had a significantly higher prevalence of myopia than athletes or students from TUS (Table 1). No significant differences were found in sex, BMI, unbalanced nutrition, reading, drinking, and smoking.

Association Between Daily Training Time (hours/day) and Myopia Prevalence

Table 2 shows the ORs and 95% CIs for the association between daily training time and the prevalence of myopia. Positive associations were observed in the crude model (Supplementary Fig. S1). The crude and multivariable-adjusted ORs for myopia were 0.767 (95% CI, 0.703–0.836) and 0.893 (95% CI, 0.800–0.997), respectively. The estimated ORs did not change substantially after multivariable adjustment. The ORs of the other covariates in model B (covariates except for study locations) are summarized in Supplementary Figure S2. The ORs of the other covariates in model C (the model adjusted for myopia) are shown in Figure 3.

Risk Factors for Myopia

The other potential risk factors for myopia are listed in Table 1. The results from the multivariable logistic regression analysis (model C) are shown in Figure 3. The results showed that the young people participating in outdoor sports (indoor sports vs. outdoor sports: OR, 1.788; 95% CI, 1.391–2.297) and training time of more than 4 h/d (4–6 h/d: OR, 0.539; 95% CI, 0.310–0.938; >6 h/d: OR, 0.466; 95% CI, 0.257–0.844) had a lower risk of myopia. In contrast, individuals with frequent electronic screen use (OR, 1.406; 95% CI, 1.028–1.923) and/or a family history of myopia (OR, 2.022; 95% CI, 1.480–2.763) had a higher risk of myopia. Study locations (OR, 1.946; 95% CI, 1.543–2.453) were also associated with myopia prevalence; students from TVCS had a higher risk of myopia than the risk in athletes and those from TUS. In addition, monthly family income was also related to the prevalence of myopia; the prevalence was least in the lowest income group (average monthly income per person of <1000 yuan). In addition, in higher income group (average monthly income per person of >1000 yuan), with the increase in family income, the prevalence of myopia decreased. No interactions were observed for age, sex, education level, reading time, alcohol consumption, sleep

Table 1. Baseline Characteristics of the Case ($n = 1401$)

	Total ($n = 1401$)	Myopia ($n = 703$)	No Myopia ($n = 698$)	*P* Value
Age, mean ± SD, *n* (%)	19.03 ± 2.78	19.18 ± 2.48	18.88 ± 3.04	<0.001
≥18 years	1097 (78.30)	582 (53.05)	515 (46.95)	
<18 years	304 (21.79)	121 (39.80)	183 (60.20)	
Sex, *n* (%)				0.531
Male	902 (64.38)	447 (49.56)	455 (50.44)	
Female	499 (35.62)	256 (51.30)	243 (48.70)	
Types of sports, *n* (%)				
Indoor sports	521 (37.19)	278 (53.36)	243 (46.64)	0.033
Outdoor sports	880 (62.81)	425 (48.30)	455 (51.70)	
Use electronic screen, *n* (%)				<0.001
Often	1135 (81.01)	601 (52.95)	534 (47.05)	
Not often	266 (18.99)	102 (38.34)	164 (61.65)	
Family history of myopia, *n* (%)				<0.001
Yes	224 (15.99)	139 (60.05)	85 (37.95)	
No	1177 (84.01)	564 (47.92)	613 (52.08)	
Reading, *n* (%)				0.525
Often	311 (22.20)	161 (22.90)	150 (21.59)	
Not often	1090 (77.80)	542 (77.10)	548 (78.51)	
Study locations, *n* (%)				<0.001
Athletes	428 (30.55)	162 (29.44)	266 (62.15)	
Students from TUS	629 (44.90)	318 (50.56)	311 (49.44)	
Students from TVCS	344 (24.55)	223 (64.83)	121 (35.17)	
Training time (h/d), *n* (%)				<0.001
<1	86 (6.14)	56 (65.12)	30 (34.88)	
1-2	454 (32.40)	254 (55.95)	200 (44.05)	
2–4	350 (24.98)	185 (52.86)	165 (47.14)	
4–6	230 (16.42)	106 (46.09)	124 (53.91)	
>6	281 (20.06)	102 (36.30)	179 (42.35)	
Family income (RMB),[a] *n* (%)				0.003
<1000	121 (8.64)	51 (42.15)	70 (57.85)	
1000–2000	210 (14.99)	128 (60.95)	82 (39.05)	
2000–5000	549 (38.18)	273 (49.73)	276 (50.27)	
>5000	521 (37.19)	251 (48.18)	270 (51.82)	
Smoking status, *n* (%)				0.130
Smoker	234 (16.70)	128 (54.70)	106 (45.30)	
Nonsmoker	1167 (83.30)	575 (49.27)	592 (50.73)	
Alcohol, *n* (%)				0.472
Drinker	294 (20.99)	153 (52.04)	141 (47.96)	
Nondrinker	1107 (79.01)	550 (49.68)	557 (50.32)	
Unbalanced nutrition, *n* (%)				0.241
Yes	260 (18.56)	139 (53.46)	121 (46.64)	
No	1141 (81.44)	564 (49.43)	577 (50.57)	
Sleep deficiency, *n* (%)				0.020
Yes	587 (41.90)	316 (53.83)	271 (46.17)	
No	814 (58.10)	387 (47.54)	427 (52.46)	
Education level, *n* (%)				
Primary school and below	28 (2.00)	6 (21.43)	22 (78.57)	<0.001
Junior high school	113 (8.07)	45 (39.82)	68 (60.18)	
Senior high school	231 (16.49)	90 (38.96)	141 (61.03)	
University and above	1029 (73.45)	562 (54.62)	467 (45.38)	
BMI (kg/m^2), mean ± SD, *n* (%)	21.90 ± 3.36	22.04 ± 3.41	21.36 ± 3.31	0.120

[a] Family income: average monthly income per person.
The *t*-test was used to compare continuous variables.
The χ^2 test was used to compare the sample rate.

deficiency, unbalanced nutrition, BMI, or smoking status in the relationship between sports and myopia.

Discussion

A large number of studies have found that genetic and environmental factors affect the occurrence and progression of myopia,[14,19] among which sports, particularly outdoor sports, can effectively prevent myopia and slow its development.[20] The participants of our study were athletes or students majoring in sports, whose opportunities and time spent in sports were obviously more than that of ordinary people. Theoretically, the prevalence rate of myopia should be lower; however, the results from our study showed that

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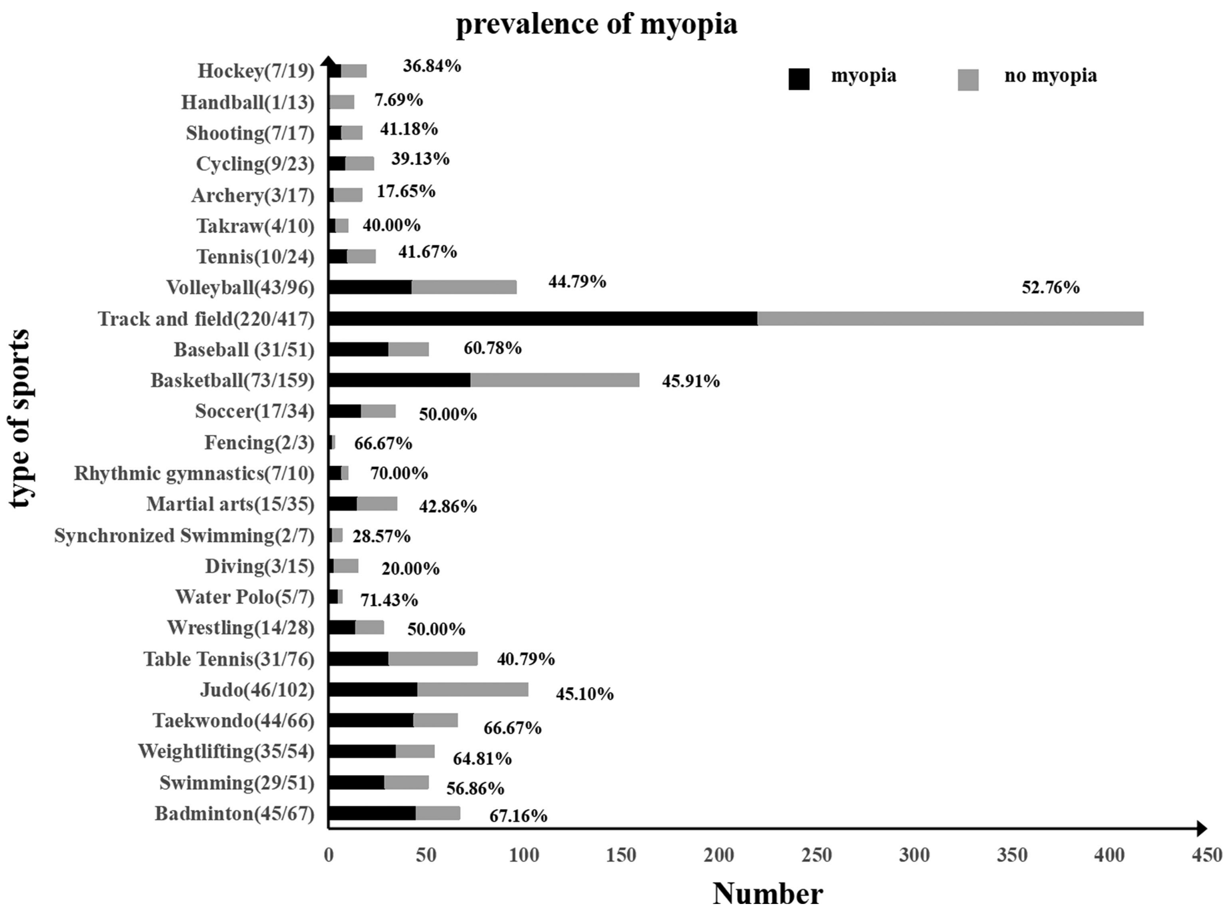

Figure 2. The prevalence of myopia in different sports. The number in the parentheses was the young sports-related groups (myopia/total) for each sport.

Table 2. Adjusted ORs (95%CI) for Prevalence of Myopia in Relation to Daily Training Time (Hours/Day)

Baseline Variable Adjusted for	ORs	95% CI	*P* Value
Crude model	0.767	0.703–0.836	<0.001
Model A	0.791	0.718–0.870	<0.001
Model B	0.818	0.737–0.907	<0.001
Model C	0.893	0.800–0.997	0.043

Crude model: adjusted no factors associated with myopia and daily training time.

Model A: adjusted for sex (male vs. female), age (≥18 years vs. <18 years).

Model B: adjusted for model A plus types of sports (indoor sports vs. outdoor sports), reading time (reading every day is defined as often), use electronic screen time (using electronic screens every day is defined as often), family history of myopia, education level (primary school and below vs. junior high school vs. senior high school vs. university and above), smoking (yes vs. no), alcohol consumption (drinkers vs. nondrinkers), sleep deficiency (yes vs. no), dietary bias (yes vs. no), family income (average monthly income per person, RMB, <1000 vs.1000–2000 vs. 2000–5000 vs. >5000), and BMI (kg/m^2).

Model C: adjusted for model B plus study locations (athletes vs. students from TUS vs. students from TVCS)

sports did not effectively decrease the prevalence of myopia in young sports-related groups (the prevalence of myopia was 50.18%). Similar results were found in a survey of 1573 adult individuals involved in sports activities, which revealed that sports activities were not related to the prevalence of myopia in adults.[21] Subdivision analysis based on different types of sports demonstrated that the indoor sports group had a higher risk of myopia (95% CI, 1.391–2.297). Further analysis showed that many factors might be related to the prevalence of myopia, including the long-term use of electronic screens and family history of myopia.

In our study, participants who often used the electronic screens had 1.406 times higher prevalence of myopia than those who seldom used electronic screens. A total of 601 participants who often used electronic screens (viewing distance of <33 cm) had myopia, accounting for 52.95% of all the participants. Several studies have speculated on the potential mechanisms underlying these observations. For example, some studies have suggested that an increased using of screen products may cause widespread ciliary paralysis in school-aged children, resulting in pseudomyopia, thereby increasing the prevalence of myopia.[22,23] Indeed, future research is still needed to further our understanding of the potential mechanisms underlying the association between myopia and electronic screen use.

Many studies have confirmed family history of myopia is an independent risk factor for developing myopia.[24–26] Similar results were observed in the present study. Specifically, persons with a family history of myopia (OR, 2.022; 95% CI, 1.480–2.763) had a higher risk of myopia. Several studies[8,27] have reported that myopic parents significantly influence their offspring. Children with both myopic parents

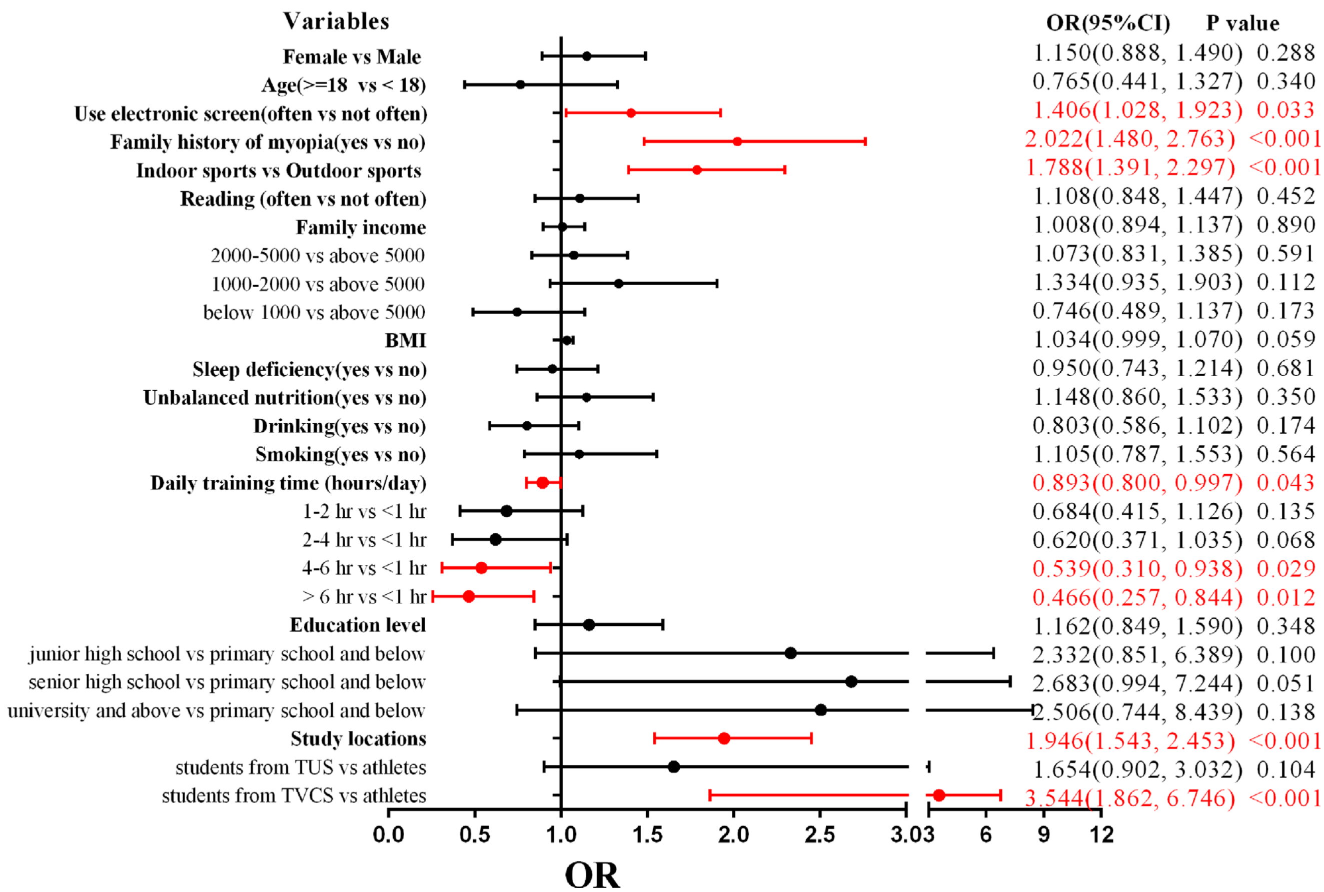

Figure 3. Estimated ORs (95% CI) in myopia prevalence associated with young sports-related groups by multivariate logistic regression analysis.

had a higher risk of developing myopia than those with only one myopic parent. In a survey of 1813 participants in Shanxi, China, the family aggregation of myopia in the myopic student group (34.7%) was significantly higher than that in the nonmyopic group (8.5%). The rate of high myopia (6.33%) was significantly higher among students with one or both myopic parents than those without myopic parents (3.85%).[28] Dirani et al.[24] recruited 345 monozygotic and 267 dizygotic twin pairs and found that the heritability of myopia was 88% in men and 75% in women. A survey[29] of 1601 children from various autonomous communities in Spain in 2020, showed that the prevalence of myopia in children aged between 5 and 7 years increased significantly between 2016 and 2020, and there was a link between the time spent at near work, family history, and the prevalence of myopia ($P < 0.05$). The results showed that heredity contributed to myopia, which varied among different regions due to different population samples and estimation methods.

In our study, the prevalence of myopia in the participants involved in indoor sports was higher than in those involved in outdoor sports, indicating that outdoor sports may be more effective in preventing myopia. This result is consistent with the findings of previous studies.[21] However, the potential mechanisms underlying the effects of outdoor exposure on myopia remain unclear. Some studies have revealed that outdoor sports could increase the duration of light exposure, increase the release of retinal dopamine, and effectively inhibit the growth of the eye axis, thereby preventing the occurrence of myopia.[30–33] Many studies investigating outdoor time in relation to myopia found that the longer children's outdoor activities, the lower the incidence of myopia.[34,35] The Sydney Myopia Study found a lesser odds of myopia with more than 2 hours of outdoor time every day.[36] A meta-analysis in 2012 reported a 2% lesser odds of developing myopia for every additional hour spent outdoors per week.[37] In addition, some longitudinal cohort studies and clinical trials have illustrated that outdoor time protects against myopia.[38–41] A prospective study on school-aged children suggested that an increase in outdoor sports time can effectively decrease the occurrence and development of myopia.[19] Another meta-analysis[42] of time spent in outdoor activities in relation to myopia showed that increasing outdoor time can effectively prevent the onset of myopia and slow the myopic shift in refractive error. However, paradoxically, outdoor time cannot effectively slow down the progression of myopia. A school-based intervention study that included 373 students aged 6 to 7 years without myopia at baseline in Beijing, China, showed that an outdoor program of 30 minutes performed every school day for 1 year temporarily decreased myopia progression in students. However, a complete rebound effect was observed within 3 years after the program ended.[43] Other studies have shown that outdoor time slowed down the change of axial length and decreased the risk of myopia.[44] In this study, a multivariable analysis of training time in relation to myopia showed that more than 4 hours of time spent outdoors daily was related to reduced odds of myopia (Table 2). The results were similar to those of previous studies; however, the time needed to be determined. Compared with those results mentioned elsewhere in this article, the study by Jones-Jordan et al.[45] with 594 children showed different results, indicating that the time spent in outdoor and sports activities was not a significant risk factor for myopia. This discrepancy may be attributable to differences in the ethnicity of subjects, season, and blue wavelengths.[45] The association between time spent outdoors and myopia and the underlying mechanisms require further investigation.

The results of our analysis suggest that reading time had no effect on myopia, which is inconsistent with those of other studies.[36,46] The null association may be due to the shorter reading time of the subjects in this study, resulting in insufficient power to detect the relationship between reading time and myopia. The effects of average monthly income per person on myopia were found in our study. In the crude analysis, the prevalence of myopia was low in people with low household income ($P = 0.003$), which is similar to the results of studies by Saw et al.[47] and You et al.[48] However, the association was not significant after adjusting for potential confounders (such as education level and study locations). The crude odds of education level ($P < 0.001$) and study locations ($P < 0.001$) were more sensitive to the effects of myopia. These results were consistent with the high prevalence of myopia among Chinese college students. However, the study locations were more sensitive to the adjusted OR, and the prevalence of myopia in students from TVCS was higher than that in athletes and those from TUS. We observed no associations between myopia and age, sex, BMI, or unhealthy living habits, such as smoking, alcohol consumption, sleep deficiency, and unbalanced nutrition.

Some other countermeasures, including topical atropine, spectacle lenses, dual-focus contact lenses, multifocal soft contact lenses, and overnight orthokeratology, were related to significantly slower myopia progression clinically.[49] Atropine is an antimuscarinic agent that causes pupil dilation and loss of accommodation. Low doses seem to decrease adverse effects and rebound effects.[50] Atropine 0.01% has been used clinically, and 0.02% and 0.04% atropine are used in clinical trials. Overnight orthokeratology can effectively slow axial elongation and inhibit myopia progression.[51] Many researchers have suggested that overnight orthokeratology could improve the defocus on the peripheral retina with corneal epithelial redistribution.[52] In recent years, some studies have suggested that the combination of overnight orthokeratology and 0.01% atropine is more effective in slowing axial elongation than monotherapy over a short treatment duration.[53] The combination treatment may provide a new approach to improve the effectiveness of myopia control interventions.

Our study had some limitations. First, the study was not completely representative of the population in China because only young sports-related groups in Tianjin were evaluated. Second, there was a potential for recall bias because the lifestyle data were collected through questionnaires from the past. Third, we found an association between myopia and study locations. These findings require replication in future studies. Fourth, other factors such as axial length may also affect the prevalence of myopia, which needs further study.

Conclusions

Outdoor sports do not necessarily guarantee to insulate against myopia. Various factors are associated with the prevalence of myopia, and regular outdoor sports may effectively prevent the occurrence of myopia and delay its development. Training time, electronic screen using time, and family history of myopia might also influence the occurrence of myopia. Additionally, low-dose atropine, overnight orthokeratology, and combination therapy were effective in slowing the myopia progression.

Acknowledgments

Supported by National Natural Science Foundation of China under Grant Numbers 82020108007; National Natural Science Foundation of China under Grant Numbers 81830026; and Beijing-Tianjin-Hebei Special Project under Grant Number 19JCZDJC64300(Z).

Author contributions: Conception of idea, critical reviews for important intellectual content and final approval for submission: Hua Yan; design of study, data collection, analysis and drafting of article: Mingxue Zhang, Zhiyong Sun, Xinlei Zhu; revision of article: Haokun Zhang; analysis and drafting of article: Yun Zhu.

The authors also do not discuss the use of off-label products, which includes unlabeled, unapproved, or noninvestigative products or devices. No potential conflicts of interest relevant to this article were reported.

Disclosure: **M. Zhang,** None; **Z. Sun,** None; **X. Zhu,** None; **H. Zhang,** None; **Y. Zhu,** None; **H. Yan,** None

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