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Refractive Change and Incidence of Myopia Among A Group of Highly Selected Senior High School Students in China: A Prospective Study in An Aviation Cadet Prerecruitment Class

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Purpose. To assess the incidence rate of myopia, refractive change, and the effects of influencing factors on a group of highly selected senior high school students in an Aviation Cadet prerecruitment class in China.

Methods. A total of 800 nonmyopic, male, Grade 9 students aged 14- to 16-years old with cycloplegic refraction of −0.25 or greater diopters (D) to 1.75 D or less in both eyes were enrolled in May 2016. During their senior high school studies, students had one 20-minute physical training period a day, and they were encouraged to participate in outdoor activities during class recess without any time limits. The first follow-up was 8 months after enrollment when they were in Grade 10, and the second follow-up was 1 year after the first follow-up when they were in Grade 11. Comprehensive ocular examinations and a detailed questionnaire, which included questions about outdoor activity time, parental myopia, and near work, were completed at each follow-up.

Results. The average spherical equivalent refraction (SER) of the right eyes was 0.39 ± 0.44 D at baseline, 0.16 ± 0.41 D at the first follow-up, and −0.10 ± 0.38 D at the second follow-up. The cumulative refractive change was −0.50 D (95% confidence interval [CI], −0.53 to −0.47). The cumulative incidence rate of myopia was 15.5% (124/800). Incident myopia was significantly associated with outdoor activity for more than 1 versus less than 0.5 hr/d (odds ratio [OR] = 0.272, 95% CI, 0.132–0.560), baseline refraction (OR = 0.079, 95% CI, 0.041–0.153), maternal myopia (OR = 2.251, 95% CI, 1.160–4.368), longer class time (OR =3.215, 95% CI, 1.088–9.499), frequent, continuous, and long time reading/writing (OR = 1.620, 95% CI, 1.022–2.570), and shorter reading/writing distance (OR = 1.828, 95% CI, 1.065–3.140). In multiple linear regression model, having outdoor activity for more than 1 hr/d was protective from cumulative SER decrease. A higher baseline refraction together with longer reading/writing time, frequent, continuous, and longtime reading/writing, and shorter reading/writing distance were risk factors for SER decrease.

Conclusions. In this cohort of highly selected, nonmyopic students, longer outdoor activity time was a protective factor for both incident myopia and refractive change of myopic shift. The risk factors for incident myopia included lower hyperopic baseline refraction, more near work, and maternal myopia. The risk factors for refractive change of myopic shift included more hyperopic baseline refraction and more near work.

Keywords: myopia, outdoor activity, refractive change, juvenile

In recent decades, there has been a global increase in the prevalence of myopia,[1–5] especially in East and Southeast Asian countries compared with many developed Western countries and less developed countries, and the amount of myopic, school-aged children and adolescents has dramatically increased in these regions.[6–8] The prevalence of myopia in 18- to 19-year olds in some urban areas was over 80%.[9–11] Additionally, the increased proportion of those with an early onset of myopia and a high rate of myopia progression[12,13] would lead to an increase in high myopia[14] and, therefore, might increase the risk of having complications, such as myopic retinopathy and other ocular pathologies.[15]

Many studies have shown that myopia is influenced by both hereditary and environmental factors,[16] although it remains unclear whether genes and environmental factors act independently or interact in some way to cause myopia. At present, several loci have been mapped for myopia and are mainly associated with early-onset high myopia, but the effects and mechanisms of these loci still need to be identified.[17–19] The high prevalence of myopia in East and Southeast Asia may have

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led to an assumption that people in these regions were more susceptible to myopia, but Tedja et al.[20] found a substantial overlap of significant loci and a high correlation of genetic effects of common variants in the Europeans and Asians, indicating a largely shared genetic predisposition to myopia in the two populations. School myopia is now considered to be caused by multiple factors, of which environmental factors, such as educational level, the intensity of near work, and outdoor activity, are thought to be the major influencing factors.[21–24] The high academic burden in these Asian countries, especially Singapore, South Korea, and China, cannot be ignored; in some less developed and educational places in China, the prevalence of myopia was relatively low compared with urban areas.[25] In contrast, a study on 19-year olds in rural areas of South Korea reported a high prevalence (83.3.%) compared with that for other rural places in Asian countries; however, the author noted the high educational pressure even in rural places in South Korea, and over 50% of Korean young adults having received university education.[26] As for outdoor activity time, longitudinal studies and clinical trials have shown that longer outdoor activity time was protective of incident myopia.[27,28] The theory that brighter light is related to the control of eye growth by dopaminergic mechanisms was generally proven to be the underlying mechanism, by animal models, of the protective effect of outdoor activity against myopia in children and adolescents.[29–31] Furthermore, baseline refraction was also found to be an independent influencing factor for myopia: a more myopic or less hyperopic baseline refraction was associated with the risk of incident myopia.[32]

The peak of the occurrence of myopia is often considered to be in elementary school at approximately 9- to 12-years old in China and some other Asian countries,[33] but new onset of myopia is also common in the teenage years and early adulthood, owing to the educational burden, a low amount of outdoor activity time, and other factors.[23,34] Because the academic pressure of senior high school is particularly heavy and the competition is fierce among students in East and Southeast countries, this could potentially lead to a rise in a new onset of myopia among the students who remained nonmyopic during this period. Few longitudinal studies exist, however, that have investigated the onset of myopia in students in senior high school only.

In China, the Air Force recruits senior high school graduates to be Air Force cadets at the Aviation University each year, and eligible students should be nonmyopic and with good scores on the national college entrance examination. Because the prevalence of myopia is high in China, it is challenging to identify students who meet the criteria. Therefore, to increase the source of outstanding students, an Aviation Cadet prerecruitment class called the Experimental Aviation Class, which is a special class established by the Chinese Air Force and Ministry of Education in recent years, recruits nonmyopic junior high school graduates in Grade 9 (aged 14- to 16-years old) in different regions of China to ordinary local public senior high schools with similar educational levels. Students in the Experimental Aviation Class are educated to be Air Force cadet candidates when they graduate from senior high school, accommodations and meals are provided throughout schooling, and a certain amount of outdoor physical training is arranged every day. Otherwise, the classwork and academic pressure are equal to their peers in the same school. Moreover, students who fail the national college entrance examination or become myopic are not eligible to become Air Force cadets when they graduate and must attend other colleges. This present study was a longitudinal study to investigate the refractive change and incidence rate of myopia of students in the Experimental Aviation Class, aiding in understanding the influencing factors on refractive change and incident myopia in Chinese senior high school students to some extent.

Methods

This study was part of a larger, 3-year longitudinal study. The students participating in the study participated in the Experimental Aviation Class. The study protocol was approved by the ethics committee of the General Hospital of the Air Force and adhered to the provisions of the Declaration of Helsinki. The purpose and the content of the study were explained to the students and their parents, and written and oral consents were obtained from the students and their parents. Participants were enrolled in May 2016; the first follow-up was in December 2016, the second follow-up was in December 2017, the third follow-up was in December 2018, and the final follow-up will be in May 2019. Students who became myopic were not to be dropped from the study until the second follow-up. Students dropped from the study after the second follow-up were transferred to other classes in their high school and will go to other colleges when they graduate. The present manuscript reported up to the second follow-up.

Because the Air Force primarily enrolls male pilots, all students enrolled in this study were male students aged 14- to 16-years old who passed a physical examination and the national senior high school entrance examination. Visual acuity was tested by Landolt C chart at a distance of 5 m. The criteria for uncorrected visual acuity was 1.0 or greater (20/20 and better in converted Snellen VA) in both eyes, spherical equivalent refraction (SER; calculated as sphere + 1/2 cylinder) –0.25 diopters (D) or more to 1. 75 D or less in both eyes, and cylinder refraction of 0.50 D or less in both eyes. Students with a history of ocular trauma, surgery, and pre-existing ocular morbidity that affected vision were excluded. The study population consisted of 811 students in the Experimental Aviation Class from 14 ordinary senior high schools in 12 cities in China. The locations of these schools were classified into Eastern, Northern, Central, and Southwestern China, and the SER difference among the four regions at baseline was not significant ($P = 0.52$).

All students participating in the study had scheduled physical training outdoors for 20 min/d on school days and weekends. Additionally, all students were encouraged to participate in other forms of outdoor activity during class recess without any specific time limits. Education about myopia prevention and the importance of outdoor activity were provided by teachers and school administrators through a health brochure and relevant lectures once a month to all participants. The study staff went to all the schools every 6 months. All participants were given questionnaires to estimate the time spent outdoors. In addition, illumination in the classroom was controlled at 500 lux, and all students were provided a balanced diet according to the standards of the Air Force.

All students in the study population received a comprehensive physical examination, including height and weight at the time of enrollment and every follow-up. Ocular examinations containing slit-lamp examination, fundoscopy, visual acuity, and cycloplegic refraction were conducted by two ophthalmologists and two optometrists who had been trained on standard protocols. Visual acuity was tested at a 5-m distance using a Landolt C chart, with illumination of the chart around 500 lux. After ensuring the safety of cycloplegia, pupils were dilated with one drop of 0.5% tropicamide-phenylephrine ophthalmic solution (Tropicamide Phenylephrine Eye Drops; Santen, Osaka, Japan) every 5 minutes for 20 to 30 minutes, and pupil dilation was determined 20 minutes later. Autorefraction was performed (auto-refractor KR-8900; Topcon,

TABLE 1. SER and SER Change for All Participants

Variables	First Follow-up	Second Follow-up	*P*
SER, D (95% CI)	0.16 (0.13 to 0.19)	−0.10 (−0.13 to −0.07)	0.0001
SER change, D (95% CI)	−0.24 (−0.27 to −0.21)	−0.25 (−0.28 to −0.23)	0.24

Tokyo, Japan), and three measurements were taken separately for each eye. The mean value of three valid measurements was calculated for the analysis of the right eye only, as there was a high concordance between the SERs of right and left eyes ($r = 0.84$, $P = 0.0010$). SER −0.5 D or less was defined as myopia, while -0.5 D $<$ SER $\leq$ 1.75 D was defined as nonmyopic. Incident myopia was defined as not myopic at the baseline or the previous follow-up but became myopic in the subsequent follow-up. SER change was defined as the refractive change from subsequent follow-ups to baseline. The development of myopia was identified as an endpoint, and students who developed myopia in the first follow-up were included in the subsequent second follow-up, while all students who developed myopia would be dropped after the second follow-up.

All enrolled students were asked to complete a detailed questionnaire that included questions about their basic information, such as age, age when starting primary school (school ages), history of parental myopia, and daily activities, such as how many hours spent sleeping (≥7 hours or <7 hr/d), watching television (<0.5 hours or ≥0.5 hr/d), and using a computer and electronic equipment (<0.5 hours or ≥0.5 hr/d). The definition of outdoor activity time was the sum of time spent outdoors doing all kinds of activities, including the arranged 20 minutes of physical training and spontaneous sports and leisure. Students were asked how many hours spent on outdoor activities per day (<0.5 hours, ≥0.5 hours, and ≤1 hour or >1 hour). Class time was considered as the total time spent attending classes at school per day, including regular classes and extracurricular classes (≤8 hours or >8 hr/d). Reading/writing time was defined as the total time spent per day on reading textbooks or extracurricular books, writing homework, or practicing calligraphy, and performing other forms of near work (≤4 hours or >4 hr/d). Reading distance was the distance between the eyes and the book (<30 or ≥30 cm). Continuous reading/writing over 1 hour reflected the intensity of continuous near work without a break. Bad reading/writing postures included lying down on the table or bed and tilting the body or head while reading/writing.

Statistical Analysis

Only the data on students who completed both ocular examinations and questionnaires were used in the analysis. Statistical analyses were performed using Statistical Package for the Social Sciences for Windows software, version 24.0 (SPSS, Inc., Chicago, IL, USA). Continuous variables are presented as the mean ± standard deviation or mean (95% confidence intervals [CI]), and median (P25, P75). The differences of SER and SER change of all participants in the first and the second follow-up were assessed with paired *t*-test. The differences of baseline SER and cumulative SER change of students who became myopic and students who remained nonmyopic were determined by *t*-test. To examine the differences of baseline information, SER change, and incidence of myopia based on different outdoor activity time group, Kruskal-Wallis, one-way ANOVA, and X^2 tests were used. Trend tests were also used to investigate the variation tendency of SER change and incidence of myopia along with the increase of outdoor activity time. The differences and variation tendency of SER change and incidence of myopia based on different baseline SER groups were examined by one-way ANOVA, X^2 test, and trend test.

To investigate the differences of variables between students who became myopic and students who remained nonmyopic, Wilcoxon test, *t*-test, and X^2 test were used. Univariate and multivariate logistic regressions were applied to analyze factors associated with incident myopia. Odds ratios (ORs) were calculated, and 95% CIs were presented. Simple linear regression and multiple linear regression analyses were conducted to investigate the association of factors with refractive change. All *P* values were two sided and considered statistically significant when less than 0.05.

RESULTS

A total of 811 male students were enrolled in this study, of which 800 students completed the physical examination and questionnaire, and their data were used in the analyses. The average age of the 800 students was 15 (P25, P75, 15, 16) years, and the average SER of the right eyes was 0.39 ± 0.44 D (95% CI, 0.36–0.43, $N = 800$) at baseline. The SER and SER change for all the participants in two follow-ups are shown in Table 1. SER changes in the first and the second follow-up were not statistically significant ($P = 0.24$). The cumulative SER change was −0.50 D (95% CI, −0.53 to −0.47). The incidence rate of myopia at the first follow-up was 5.25% (42/800), and it was 10.82% (82/758) at the second follow-up. The cumulative incidence rate of myopia was 15.5% (124/800). The baseline SER of students who remained nonmyopic was significantly higher than that of students who became myopic (mean of 0.45 vs. 0.10 D, $P = 0.0001$), and the cumulative SER change for students who remained nonmyopic was significantly lower than that of students who became myopic (mean of −0.45 vs. −0.73 D, $P = 0.0001$).

Characteristics, Incident Myopia, and Refractive Change for Students With Different Outdoor Activity Times

The differences in baseline age, SER, height, body mass index (BMI), and distribution of myopic parents among different outdoor activity times were not statistically significant (Table 2). The SER and cumulative SER change at the end of the second follow-up in different outdoor activity time groups are shown in Table 3. The SER of students in the more than 1-hour group was higher than that of students in the other two groups ($P = 0.004$), and the SER decreased more with reduced outdoor activity time ($P_{trend} = 0.004$). The differences of the SER in the more than 1-hour group compared with the 0.5- to approximately 1-hour and less than 0.5-hour groups were 0.07 D (95% CI, 0.01–0.14, $P = 0.03$) and 0.14 D (95% CI, 0.03–0.25, $P = 0.01$), respectively. The difference between the 0.5- to approximately 1-hour and less than 0.5-hour groups was 0.07 D (95% CI, −0.04 to 0.17, $P = 0.34$).

The cumulative SER change was different among the three groups ($P = 0.011$), and the SER change decreased with the increase in outdoor activity time ($P_{trend} = 0.012$). The differences in the more than 1-hour group compared with the 0.5- to approximately 1-hour and more than 0.5- hour

TABLE 2. Baseline Characteristics of Subjects With Different Outdoor Activity Times

Variables	<0.5 hr/d	0.5~1 hr/d	> 1 hr/d	*P*
Age, y (P25, P75)	15 (15, 16)	15 (15, 16)	15 (15, 16)	0.71
SER, D (95% CI)	0.34 (0.25–0.43)	0.41 (0.36–0.45)	0.39 (0.36–0.43)	0.41
Height, cm (95% CI)	172.28 (171.24–173.32)	172.35 (171.94–172.76)	172.40 (171.87–172.92)	0.98
BMI (95% CI)	21.17 (20.65–21.69)	21.05 (20.85–21.25)	21.18 (20.91–21.45)	0.72
Parental myopia, % (*N*)				
One or both parents	15.91 (7)	19.14 (71)	22.05 (84)	0.46
None	84.09 (37)	80.86 (300)	77.95 (297)	

groups were 0.09 D (95% CI, 0.05–0.17, $P = 0.034$) and 0.13 D (95% CI, 0.01–0.26, $P = 0.031$), respectively. The difference between the 0.5- to approximately 1-hour and less than 0.5-hour groups were 0.05 D (95% CI, –0.72 to 0.17, $P = 0.59$).

The incidence rate of myopia was gradually decreased in the less than 0.5-hour group, 0.5- to approximately 1-hour group, and more than 1-hour group ($P_{trend} = 0.0001$). The incidence rate of myopia was significantly lower in students with the highest amount of outdoor activity time ($P = 0.0001$), and the incidence rate of myopia was not significantly different in students with outdoor activity times of 0.5- to approximately 1-hour and less than 0.5-hours per day groups ($P = 0.051$).

Incident Myopia and SER Change for Students With Different Baseline SER

The SER until the second follow-up relative to the baseline SER is presented in Figure 1. The SER increased along with the baseline SER ($P_{trend} = 0.0001$, Fig. 1A), while this trend was converse to that of the SER change according to baseline SER in Figure 1B. The magnitude of SER change increased along with the increase in baseline SER ($P_{trend} = 0.0001$). The magnitude of SER change was significantly higher in those with a baseline SER of 0.25 or more to less than 0.5 D (–0.45 D, 95% CI, –0.49 to –0.40), 0.5 or more to less than 1 D (–0.64 D, 95% CI, –0.69 to –0.59) and 1 D or more (–1.02 D, 95% CI, –1.11 to –0.92) than in those with a baseline SER of –0.25 or more to less than 0 D (–0.17 D, 95% CI, –0.23 to –0.11) and 0 or more to less than 0.25 D (–0.28 D, 95% CI, –0.34 to –0.22). The difference in SER change for those with a baseline SER of –0.25 or more to less than 0 D and 0 or more to less than 0.25 D was not statistically significant ($P = 0.14$).

The proportion of students with incident myopia according to their baseline SER at the end of the second follow-up is shown in Figure 2. Students with a higher baseline SER showed a lower incidence rate of myopia at the second follow-up ($P_{trend} = 0.0001$). The incidence rate of myopia was relatively high in those with a baseline SER of –0.25 or more to less than 0 D (32.5%), 0 or more to less than 0.25 D (21.7%), and 0.25 or more to less than 0.5 D (20.0%) compared with a baseline SER of 0.5 or more to less than 1 D (5.4%) and 1 D or more (1.0%) ($P = 0.0001$).

Analysis of Factors Associated With Incident Myopia

The difference of baseline age, baseline height, baseline BMI, and height and BMI at the second follow-up was not statistically significant between students who became myopic and students who remained nonmyopic (Table 4). Table 5 showed some variables from the questionnaire that were related to incident myopia. The proportions of myopic parents including paternal, maternal, and both parents, were relatively higher in myopic students than in nonmyopic students, but the difference was not statistically significant ($P = 0.11$). The proportions of longer class time ($P = 0.033$), frequent continuous reading or writing over 1 hour ($P = 0.003$), and shorter reading/writing distance ($P = 0.002$) were all higher in students who became myopic than in students who remained nonmyopic. Besides, there was no significant difference in other variables acquired from the questionnaire, including time spent on watching television ($P = 0.95$), using computer and electronic equipment ($P = 0.98$), sleeping ($P = 0.54$), and the frequency of bad reading/writing postures ($P = 0.78$) between students who became myopic and students who remained nonmyopic.

In univariate logistic regressions (Table 6), baseline SER (OR = 0.089, 95% CI, 0.048–0.165), outdoor activity for more than 1 hour versus less than 0.5 h/day (OR = 0.240, 95% CI, 0.126–0.458), maternal myopia (OR = 1.861, 95% CI, 1.050–3.301), class time more than 8 hours versus 8 or less hr/d (OR=2.648, 95% CI, 1.046–6.707), frequent continuous reading/writing over 1 hour (OR = 1.865, 95% CI, 1.229–2.830), and reading/writing distance less than 30 versus 30 cm re more (OR = 2.106, 95% CI, 1.303–3.403) were all significantly associated with incident myopia. In a multivariate logistic regression model, when adjusted for baseline age, height, and BMI, the OR for baseline SER was 0.079 (95% CI, 0.041–0.153), and the OR for outdoor activity for over 1 hr/d was 0.272 (95% CI, 0.132–0.560). The ORs for maternal myopia, class time more than 8 hr/d, frequent continuous reading/writing over 1 hour, and reading/writing distance less than 30 cm were 2.251 (95% CI, 1.160–4.368), 3.215 (95% CI, 1.088–9.499), 1.620 (95% CI, 1.022–2.570), and 1.828 (95% CI, 1.065–3.140), respectively. A less myopic or more hyperopic baseline SER and spending more than 1 hr/d for outdoor activity were protective from incident myopia, while longer class time, frequent continuous reading/writing over 1 hour, maternal myopia, and shorter reading/writing distance were risk factors for incident myopia.

Analysis of Factors Associated With Cumulative SER Change

Baseline SER, outdoor activity time, reading/writing time, and the frequency of continuous reading/writing over 1 hour were

TABLE 3. SER and Incidence of Myopia With Different Outdoor Activity Times at the Second Follow-Up

Variables	<0.5 hr/d	0.5~1 hr/d	>1 hr/d	*P*	P_{trend}
SER, D (95% CI)	−0.18 (−0.27 to −0.09)	−0.11 (−0.15 to −0.08)	−0.04 (−0.08 to 0.03)	0.004	0.004
SER change, D (95% CI)	−0.56 (−0.66 to −0.48)	−0.52 (−0.56 to −0.47)	−0.43 (−0.48 to −0.38)	0.011	0.012
Incidence of myopia, % (*N*)	27.8 (22)	18.3 (79)	8.6 (25)	0.0001	0.0001
Nonmyopia, % (*N*)	72.2 (57)	81.7 (352)	91.4 (265)		

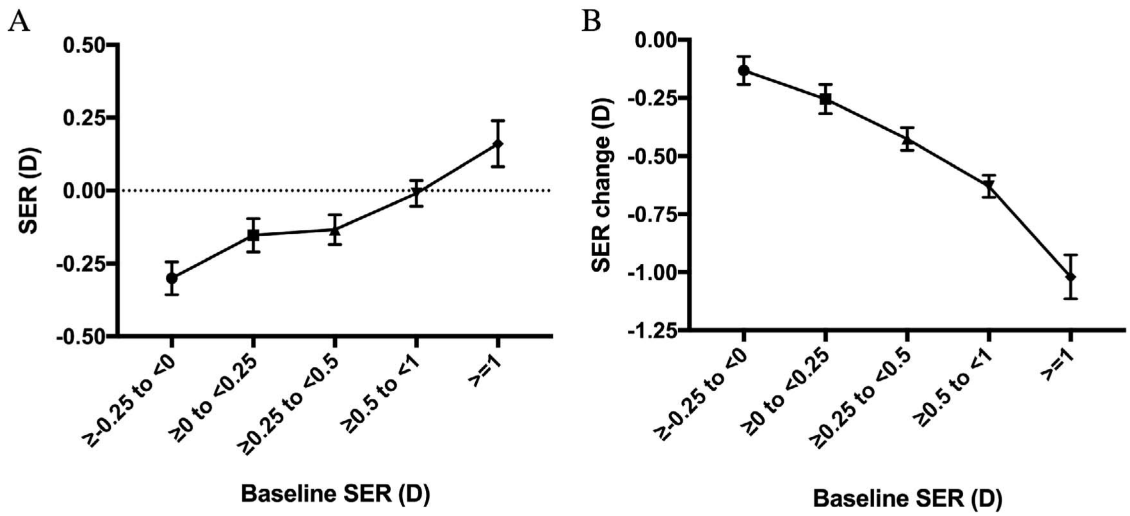

FIGURE 1. SER and cumulative SER change until the second follow-up according to the baseline SER.

significantly associated with cumulative SER change by simple linear regression (Table 7). After multiple linear regression adjusted for baseline age, height, and BMI, each 1-D increase in baseline was significantly associated with a 0.626 D (95% CI, –0.684 to –0.568) increase in SER change of myopic shift, and students with greater than 1 hr/d of outdoor activity had less of a SER change of myopic shift, at 0.077 D (95% CI, 0.023–0.130). Longer reading/writing time, frequent continuous reading/writing over 1 hour, and shorter reading/writing distance were significantly associated with SER decline. Having outdoor activity for more than 1 hr/d was protective from a cumulative SER decline. A less myopic or more hyperopic baseline SER together with longer reading/writing time, frequent continuous reading/writing over 1 hour, and shorter reading/writing distance were risk factors for cumulative SER decline.

DISCUSSION

In the present study, we investigated the incidence rate of myopia and refractive change for a highly selected group of students from an Experimental Aviation Class in China who were not myopic when recruited in the 9th grade (aged 14- to 16-years old) and observed that having outdoor activity for more than 1 hr/d was the protective factor for both the onset of myopia and the decline of SER. A less myopic or more hyperopic baseline SER, longer reading/writing time, frequent continuous reading/writing over 1 hour, and shorter reading/writing distance were risk factors for cumulative SER decline. As for incident myopia, less hyperopic baseline SER, longer class time, frequent continuous reading/writing over 1 hour, maternal myopia, and shorter reading/writing distance were risk factors.

The prevalence of myopia in ninth grade students aged 14- to 16-years old in Beijing, especially in urban areas, increased from 55.9% to 65.5% in the past 10 years,[7] and the prevalence rate for 15-year olds was nearly 73% in a study in 2004 conducted in Guangzhou.[35] Students in the present study did well in examinations and were nonmyopic when enrolled. In terms of the high prevalence rate of myopia in students of their age related to high academic burden and fierce competition, the highly selected students in our study might have some differences from their myopic peers, perhaps due to previously having longer outdoor activity time, having had more hyperopic refraction in childhood, or being more resistant to environmental factors. The incidence rate of myopia varied in different studies in terms of ethnicity, age, areas of residence and study design. The overall incidence rate of myopia in our study was 15.5% in 20 months, with an annual incidence of

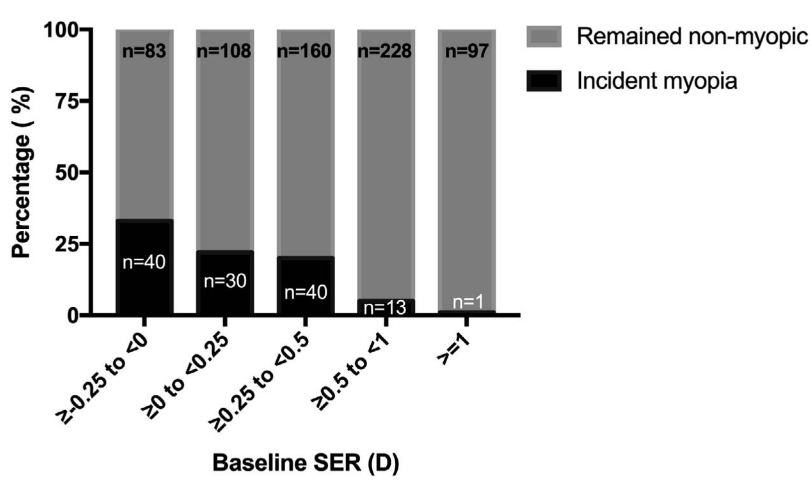

FIGURE 2. The proportion of the cumulative incidence rate of myopia according to the baseline SER.

TABLE 4. Continuous Variables of Subjects With Incident Myopia

Continuous Variables	Incident Myopia	Remained Nonmyopic	P
Baseline age, y	15 (15, 16)	16 (15, 16)	0.36
Baseline Height, cm	172.52 (4.84)	172.34 (4.30)	0.68
Baseline BMI	20.93 (2.20)	21.13 (2.22)	0.36
Height, cm	173.24 (4.58)	173.07 (4.31)	0.69
BMI	20.93 (2.20)	21.13 (2.22)	0.15

Height and BMI refers to the data at the second follow-up. Results were presented as mean (SD) or MD (P25, P75).

approximately 9%, which was comparable to the incidence rate of 14- to 15-year-old students in a 5-year, longituginal study in Western China,[36] in which most participants that had follow-up examinations were from urban areas and experienced intense schooling. While in some younger Asian populations, the incidence rate of myopia was higher than our reults, and even reached an annual incidnece rate of 31.7% in students aged 7- to 8-years old in Taipei.[37] The intensity of near work, which would be a potential risk factor for myopia, in Chinese senior high school students was significantly increased compared with that in junior high school and primary school students. The effect of near work has been controversial, with some longitudianl studies not reporting a significant correlation for myopia and near work.[38–40] Our study confirmed that near work was an important factor for incident myopia and refractive change, which was consistant with the results by Huang et al.[41]

Longer outdoor activity time has generally been regarded as a protective factor for myopia and myopic shift,[42] which was consistant with our findings. Our study revealed that longer outdoor activity time was protective from both incident myopia and refractive progression. The cumulative incidence rate of myopia was significantly lower in students who had more than 1 hour of outdoor activity per day (8.6%) than students who spent less than 0.5 (27.8%) and 0.5 to approximately 1 hr/d (18.3%), indicating a 53% to 69% relative reduction in incidence of myopia. An inverse relationship with increased time outdoors and myopia onset was found by dose-response analysis in a systemetic review,[43] but the threshold for the amount of time outdoors that could reduce the incidence of myopia was not yet determined. An intervention study in Northeast China showed that two extra 20-minute recesses per day during class reduced the onset cases of myopia by 50% in 1 year.[44] Another school-based study reported that spending 80 min/d on outdoor activity reduced the occurrence of myopia by 50% in 1 year.[45] The differences in the effect of time outdoors might be attributed to variations in age, ethnicity, and the definition of time outdoors among different studies. Notably, the differences in cumulative SER change among the different groups of outdoor activity time were not massive in the present study. The mean difference of the of more than 1-hour group compared with the less than 0.5-hour group was 0.13 D, while the cumulative incidence rate of myopia in these two groups was 8.6% and 27.8%, respectively. This was similar to the results of the randomized control trial by He et al.[28]: a small decrease in SER change produced a substantial change in incident myopia.

The significant association between higher baseline refraction and lower incidence of myopia has been confirmed by several studies,[23,32] which was consistant with our results. The overall SER change was lower in students who remained nonmyopic than those who became myopic, but students with a more hyperopic refection at baseline had a significantly larger SER change, which was an unusual

TABLE 5. Categoric Variables of Subjects With Incident Myopia

Categoric Variables	Incident Myopia % (N)	Remained Nonmyopic % (N)	P
Parental myopia			
Both	18.2 (4)	81.8 (18)	0.11
Paternal	20.6 (13)	79.4 (50)	
Maternal	23.1 (18)	76.9 (60)	
None	13.9 (88)	86.1 (546)	
Class time (hr/d)			
>8	16.3 (118)	83.7 (606)	0.033
≤8	6.8 (5)	93.2 (68)	
Reading/writing time (hr/d)			
>4	16.9 (89)	83.1 (438)	0.11
≤4	12.5 (34)	87.5 (237)	
Continuous reading/writing >1 hr			
Frequent	18.6 (87)	81.4 (381)	0.003
Seldom or none	10.9 (36)	89.1 (294)	
Reading/writing distance (cm)			
<30	25.2 (28)	74.8 (83)	0.002
≥30	13.8 (95)	86.2 (593)	

pattern because many studies showed the opposite or no correlation between refractive change and baseline SER.[37] The reason for the SER change pattern along with baseline SER was unknown. We speculated that it may reflect the process of accelerated emmetropization, axial length growth, or refractive progression due to environmental factors. Further studies should be performed to investigate this phenomenon.

As for parental myopia, many studies have reported a significant association of parental myopia with myopia.[46,47] In young children in Singapore, a more negative of refraction and increased odds of having myopia was observed when both parents had myopia.[48] An increasing number of myopic parents was also reported to be significantly associated with an increased prevalence of myopia and a greater increase in SER change of myopic shift, especially in those of East Asian ethnicity.[49] Ghorbani Mojarrad et al.[50] found that refraction and incident myopia were both independently associated with the number of myopic parents and the genetic susceptibility, which was calculated based on genetic variants in children. Although the ability of the number of myopic parents and genetic susceptibility for predicting refraction and incident myopia was poor, the predictive ability improved when combined the two factors.[50] This may suggest that parental myopia conveyed not only genetic inheritance, but also similar environmental factors. A study in Beijing revealed the relationship between parental refraction and children's, that children's average refractions were already close to their parents at the age of 11 but that their refractions were more myopic by approximately 2.0 D than their parents at the age 18. The changes for refractive error difference of parents and children along with age were speculated to be the result of genetic inheritance, environmental factors, and increasing prevalence of myopia in the young generations.[51] In our present study, maternal myopia was found to be a risk factor for incident myopia, while paternal myopia or having two myopic parents were not significantly associated with incident myopia, which was similar to the results of a cross-sectional study in China.[52] The reason for this is not clear. Since the proportion of myopic parents in our study was only 15.37% and the case of myopia in both parents was even less, the results might be due to inheritance or statistical reasons. On the other hand, the low proportion of myopic parents may

TABLE 6. Analysis of Factors Associated With Incident Myopia

Variables	Univariate Analysis		Multivariate Model	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Outdoor activity time (hr/d)				
0.5∼1 vs. <0.5	0.577 (0.333–1.001)	0.050	0.692 (0.369–1.298)	0.252
>1 vs. <0.5	0.240 (0.126–0.458)	0.0001	0.272 (0.132–0.560)	0.0001
Baseline SER	0.089 (0.048–0.165)	0.0001	0.079 (0.041–0.153)	0.001
Class time (>8 vs. ≤8 hr/d)	2.648 (1.046–6.707)	0.040	3.215 (1.088–9.499)	0.035
Continuous reading/writing >1 hr (frequent vs. seldom or none)	1.865 (1.229–2.830)	0.003	1.620 (1.022–2.570)	0.040
Reading/writing distance (<30 vs. ≥30 cm)	2.106 (1.303–3.403)	0.002	1.828 (1.065–3.140)	0.029
Parental myopia				
Both vs. none	1.379 (0.456–4.169)	0.569	1.868 (0.556–6.278)	0.313
Paternal vs. none	1.613 (0.842–3.091)	0.150	1.724 (0.831–3.576)	0.144
Maternal vs. none	1.861 (1.050–3.301)	0.034	2.251 (1.160–4.368)	0.017

The multivariate model was adjusted for baseline age, baseline height, and BMI.

TABLE 7. Analysis of Factors Associated With the Cumulative SER Change

Variables	Univariate Analysis		Multivariate Analysis	
	SER Change, D (95% CI)	*P*	SER Change, D (95% CI)	*P*
Baseline SER	−0.613 (−0.690 to −0.576)	0.0001	−0.626 (−0.684 to −0.568)	0.0001
Outdoor activity time (>1 hr vs.≤1 hr/d)	0.090 (0.023 to 0.157)	0.009	0.077 (0.023 to 0.130)	0.005
Reading/writing time (≥3 hr vs.< 3 hr/d)	−0.073 (−0.141 to −0.006)	0.033	−0.056 (−0.111 to −0.001)	0.046
Continuous reading/writing >1 hr (frequent vs. seldom or none)	−0.072 (−0.137 to −0.007)	0.029	−0.062 (−0.115 to −0.009)	0.023
Parental myopia (both vs. none)	−0.016 (−0.238 to 0.152)	0.664	−0.004 (−0.161 to 0.154)	0.961
Parental myopia (paternal vs. none)	−0.040 (−0.188 to 0.051)	0.105	−0.044 (−0.139 to 0.050)	0.356
Parental myopia (maternal vs. none)	−0.045 (−0.180 to 0.040)	0.210	−0.019 (−0.106 to 0.069)	0.672
Reading/writing distance (<30 vs. ≥30 cm)	−0.078 (−0.171 to 0.015)	0.101	−0.093 (−0.168 to −0.018)	0.016

The multivariate model was adjusted for baseline age, baseline height, and BMI.

have been one of the protective factors for myopia when the students were recruited. The effect of maternal myopia still needs further observation.

There are several limitations of this study. Time outdoors and some other information was acquired through questionnaire in our study, which has low validity. The enrolled students were a highly selected group with the same sex and similar age, education, and living environment, so the results of the study may not apply to the general population but could provide information about myopia in senior high school students in China, as they share a similar academic burden.

In conclusion, we investigated the incidence rate of myopia, refractive change, and the effects of influencing factors of a group of highly selected senior high school students in China. Time outdoors was the protective factor for both incident myopia and myopic refraction change. Baseline refraction, near work, and maternal myopia were also significant influencing factors.

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