Eye (2016) 30, 796–804

www.nature.com/eye

CLINICAL STUDY

Prevalence and associated factors of myopia among primary and middle school-aged students: a school-based study in Guangzhou

L Guo[1,2,4], J Yang[3,4], J Mai[3,4], X Du[3,4], Y Guo[3,4], P Li[1], Y Yue[1], D Tang[1], C Lu[1] and W-H Zhang[2]

Abstract

Purpose **To estimate the prevalence of myopia among primary and middle school-aged students in Guangzhou and to explore the potentially contributing factors to myopia.**

Methods **This cross-sectional study was based on a sample of students in grades 1–6 and grades 7–9. Data were collected from refractive error measurements and a structured questionnaire.**

Results **A total of 3055 participants were involved in this analysis, and the overall prevalence of myopia was 47.4% (95% confidence interval (CI) = 45.6–49.2%). The prevalence of myopia in students increased along with the growth of grade level; the prevalence of myopia in students in grade 1 was only 0.2%, as it increased to 38.8% in students in grade 3, and the rate was the highest (68.4%) in students in grade 9. Girls were at a higher risk of myopia than boys (adjusted odds ratio = 1.22, 95% CI = 1.04–1.44). Both male and female students whose distance of reading was longer than 25 cm were less likely to have myopia and who have one or two myopic parents were at a higher risk of myopia. In addition, reading for pleasure more than 2 h per day (adjusted odds ratio = 1.84, 95% CI = 1.09–3.12) was only positively associated with myopia in boys and spending time watching television per week was only positively associated with myopia in girls.**

Conclusion **Myopia in students is a significant public health problem in Guangzhou. Female gender, higher grade, longer time spent for near work, shorter distance of near work, and parental myopia were shown to be associated with the increasing risk of myopia in children.**

[1]Department of Medical Statistics and Epidemiology, School of Public Health, Sun Yat-sen University, Guangzhou, People's Republic of China

[2]Epidemiology, Biostatistics and Clinical Research Centre, School of Public Health, Université Libre de Bruxelles (ULB), Brussel, Belgium

[3]Health Promotion Centre for Primary and Secondary Schools of Guangzhou Municipality, Guangzhou, People's Republic of China

Correspondence:
C Lu, Department of Medical Statistics and Epidemiology, School of Public Health, Sun Yat-sen University, 74 Zhonshan Rd 2, Guangzhou 510080, People's Republic of China
Tel: +86 20 8733 2477;
Fax: +86 20 8733 4921.
E-mail: luciyong@mail.sysu.edu.cn

[4]These authors contributed equally to this work.

Received: 4 November 2015
Accepted in revised form: 4 February 2016
Published online: 11 March 2016

Eye (2016) **30,** 796–804; doi:10.1038/eye.2016.39; published online 11 March 2016

Introduction

Myopia ('near sightedness') is an increasingly common refractive error among school-aged students worldwide,[1] especially in east Asia where the prevalence of myopia is now very high, with around 80% of students completing middle school myopic.[2,3] According to the World Health Organization report, uncorrected or under-corrected myopia is a major cause of visual impairment, and the cost of myopia corrections is very high compared with personal and family resources.[4] However, although myopia imposes such a great health burden, the exact pathogenic mechanism of myopia is still unclear. There has been a continuing debate over whether myopia is environmentally determined or is inherited, and the theory about both environmental and genetic factors contribute to the development of myopia is widely acknowledged recently.[5,6]

Many environmental factors have been documented for having possible associations with risks for developing myopia in children, such as socioeconomic factors, near work, and outdoor activity. Population-based prevalence studies in China and Korea showed that children from families with higher income were at a higher risk of myopia.[7,8] Near work activities (eg, studying, reading, watching television, and using computer) have been identified in previous studies as possible environmental risk factors for myopia.[9] Evidences from animal experiments indicated that an accommodative lag during prolonged near work lead to hyperopic defocus on the retina which might

result in excessive growth of the eye and a myopic refractive error.[10,11] A cohort study in Australia showed that primary school students with incident myopia were more likely to spend significantly more time studying and reading,[12] and a cross-sectional study in Beijing also demonstrated that a higher prevalence of myopia in high-school students was associated with shorter near work distance.[7] However, there have also been some studies reporting a weak or absent association between heavier load of near work and the prevalence or incidence of myopia.[9,13] Furthermore, recent epidemiological studies have demonstrated that increasing time spent outdoors could protect against the development of myopia, and minimizes the increased risk of myopia associated with near work or with having myopic parents.[14,15]

A parental history of myopia is associated with the likelihood of their child developing myopia.[16] Previous studies have demonstrated that a greater prevalence of myopia exists in children with myopic parents than in children without myopic parents, and have shown an increased risk of myopia in children with increasing numbers of myopic parents.[13,17]

Overall, although we conclude that myopia is universal phenomenon among adolescents, it is clear that the prevalence of myopia in Chinese school-aged children is one of the highest in the world and shows an upward trend according to the Reports on the Physical Fitness and Health Research of Chinese School Students in 2010.[18] Prior studies in Asia point out that it is different from western countries that the rigorous schooling system, the long hours children spend studying, and the less time children spend outdoors in Asia.[19,20] Therefore, we conducted this cross-sectional study to investigate the prevalence of myopia among primary and middle school-aged students in Guangzhou and to explore the potentially contributing factors to myopia.

Methods

Study design and participants

This cross-sectional study was based on a sample of students in grades 1–6 (ie, primary school) and grades 7–9 (ie, middle school) attending public or private schools in Guangzhou. Guangzhou is the political, economic, cultural, and scientific center of Guangdong province (located in South China), with a population of 12.70 million in the 2010 census.[21] We used a multi-stage stratified cluster sampling method to select our study participants. In stage 1, there were a total of 11 districts in Guangzhou, and we randomly selected one primary school and one middle school from each district. In stage 2, one class was randomly selected from each grade

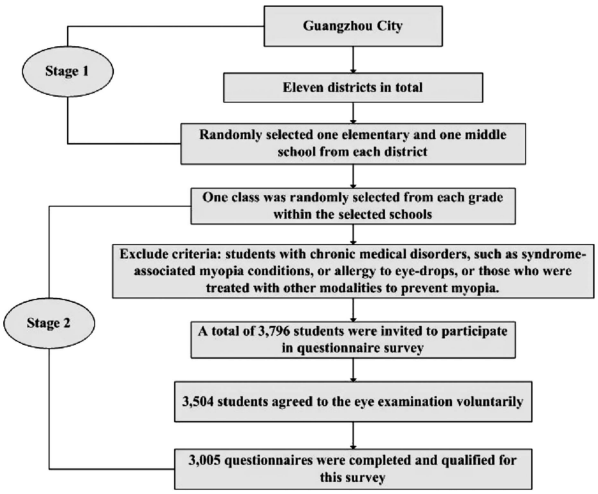

Figure 1 Flow diagram of sampling participants.

within the selected schools. All available students in the selected classes were invited to participate in our study, except students with chronic medical disorders, or allergy to eye-drops, or those who were treated with other modalities to prevent myopia. A total of 3796 students were invited to participate in the study, and 3504 students agreed to the eye examination voluntarily, resulting in a participation rate of 92.3%. Of the 3504 students, 3005 student questionnaires were completed and qualified for our survey (see Figure 1). Informed consent letters for each child examined was obtained from one of the students' parents or other responsible adult after the nature of the study was explained, and the conduct of the study followed the tenets of the Declaration of Helsinki. The study was approved by the Sun Yat-sen University, School of Public Health Institutional Review Board.

Refractive error measurements

The children were examined on the school classrooms in December 2014. Myopia in the children was determined by cycloplegic autorefraction. Cycloplegia was induced with two drops of 1% cyclopentolate hydrochloride instilled 5 min apart to each eye after instillation of 0.5% proparacaine hydrochloride, with a third drop instilled after 15 min. Cycloplegia was considered complete if the children dilated to 6 mm or greater, and a light reflex was absent after a further 15 min. Refraction was measured by an optometrist using a streak retinoscope (Welch-Allyn, Skaneateles, NY, USA) and then a handheld autorefractor (ARK-30; Nidek Corp., Saitama, Japan), and was carried out five times in each eye. The mean was computed automatically, and was as the participant's autorefraction value.

Questionnaire

The research assistants visited the schools 3 days before the eye examination to distribute questionnaires. Each participating student who was in grades 4–9 completed the detailed questionnaire administered by research assistants in the classrooms. For each participating student who was in grades 1–3, the same questionnaire was completed by one of the student's parents at home and then returned to research assistants during the eye examination. In addition, the question about parental myopia was written on a separate strip which was required to be completed by each participating student's biological parents and returned to research assistants during the examination.

Information on sociodemographic factors were collected, including gender, age, grade level, ethnicity, family economic status, and school academic achievement.

Many recent studies have used questionnaires to quantify near work activities.[22,23] In our study, children's near work was assessed by asking: (1) how many hours the child spent in reading or studying for school assignments daily, reading for pleasure daily, using computer weekly, watching television weekly, and playing electronics weekly; (2) what is the distance when the child reading and watching television.

Children's outdoor activity was measured by asking how many hours the child spent in outdoor activities per week.

Parental myopia was assessed by asking the following question for each parent: 'Is the child's father (or mother) myopic?' The response categories were 'yes' and 'no'.

Definition of myopia

All refractive error readings were reported as the spherical equivalent refraction of the eye (sphere power plus half negative cylinder power). Myopia was defined as an spherical equivalent refraction of at least −0.5 diopters (D). This definition was chosen to reduce the number of false-positive results for myopia, to reach a level of myopia likely to produce clinical symptoms, and to agree with the definition widely used in previous studies.[23–27] Subjects were further divided three refractive error groups based on their spherical equivalent refraction: low myopia (≤ −0.5 to > −3.0 D), moderate myopia (≤ −3.0 to > −6.0 D), and high myopia (≤ −6.0 D).

Statistical analysis

All statistical analyses were conducted using SAS (version 9.2, Cary, NC, USA). The data on the right and left eyes were initially analyzed separately. However, considering the correlation between the right and left eyes for spherical equivalent refraction was high in this study ($r = 0.857$, $P < 0.001$), only the right eye data are presented; many previous studies also adopted this method.[28] The data was presented as number (%), mean (± standard deviation), or median (interquartile range) as appropriate. The prevalence rates and 95% confidence intervals (CIs) of myopia were reported. Our study used a complex sampling design with multi-stage sampling, and the students were grouped by schools, and therefore may not be independent; two-level multiple logistic regression analyses, in which the schools were treated as clusters were performed in SAS using the PROC GLIMMIX procedure. All statistically significant factors in the univariate analyses were further analyzed using multivariate logistic regression models to determine the risk factors for myopia in children based on the adjusted odds ratios (AORs) and 95% CIs. The modeling was first done with the interaction items (between parental myopia and near work) included, but as these interaction items were not statistically significant in the models, they were eliminated. Only the models with main effects were reported in this study. An AOR > 1 with $P < 0.05$ indicated a risk factor and vice versa. The percentage of missing data was <2% for all relevant variables, and missing data were eliminated in the two-level analyses. All statistical tests were two-sided, and a P-value of < 0.05 was considered significant.

Results

As shown in Table 1, a total of 3055 participants were involved in this analysis. The mean refractive error was −1.9 (±2.2) D, and the overall prevalence of myopia was 47.3% (95% CI = 45.6–49.2%). Regarding to myopia categories, the prevalence of low myopia was 30.7%, the prevalence of moderate myopia was 14.8%, and the prevalence of high myopia was only 1.8%. In addition, the prevalence of myopia in girls was 49.7% and in boys was 45.1%. The prevalence of myopia in students increased along with the growth of grade level; the prevalence of myopia in students in grade 1 was only 0.2%, although it increased to 38.8% in students in grade 3, and the rate was the highest (68.4%) in students in grade 9. The prevalence of myopia in Han ethnicity was 48.9% and the prevalence of myopia in other ethnic groups was 35.6%. The gender, grade level, and ethnicity distribution differences between myopia and no myopia group were statistically significant ($P < 0.05$).

As shown in Table 2, students with myopia spent more time engaged in reading or studying for school assignments daily, reading for pleasure daily, using computer weekly, watching television weekly, and playing electronics weekly, compared with students

Table 1 Associated sociodemographic factors of myopia in children

Variables	*Total*, n *(%)*	*Myopia*, n *(%)*	*No myopia*, n *(%)*	P-*value*[a]
Total	3055 (100)	1447 (47.3)	1608 (52.6)	—
Refractive error (D)[b]	−1.9 (±2.2)	−2.7 (±1.6)	1.0 (1.5)	<0.001
Myopia categories		—	—	—
No myopia	1608 (52.6)			
Low myopia	938 (30.7)			
Moderate myopia	453 (14.8)			
High myopia	56 (1.8)			
Age (years)[b]	13.6 (±1.6)	15.4 (±1.3)	12.6 (±1.2)	<0.001
Gender				
Boy	1579 (51.7)	713 (45.1)	866 (54.8)	0.011
Girl	1476 (48.3)	734 (49.7)	742 (50.3)	
Grade				
1	324 (10.6)	7 (0.2)	317 (97.8)	<0.001
2	308 (10.1)	41 (13.3)	267 (86.7)	
3	340 (11.1)	132 (38.8)	208 (61.2)	
4	284 (9.3)	135 (47.5)	149 (52.5)	
5	277 (9.1)	170 (61.3)	107 (38.6)	
6	442 (14.5)	249 (56.3)	193 (43.7)	
7	366 (12.0)	241 (65.8)	125 (34.2)	
8	398 (13.0)	256 (64.3)	142 (35.7)	
9	316 (10.3)	216 (68.4)	100 (31.6)	
Ethnicity				
Han	2696 (88.3)	1319 (48.9)	1377 (51.1)	0.016
Other ethnic groups	359 (11.7)	128 (35.6)	231 (64.3)	
Family economic status				
Above average	875 (28.6)	411 (46.9)	464 (53.0)	0.081
Average	1871 (61.2)	911 (48.7)	960 (51.3)	
Below average	263 (8.6)	109 (41.4)	154 (58.6)	
Missing data	46 (1.5)	—	—	
Academic achievement				
Above average	1123 (36.8)	537 (47.8)	586 (52.2)	0.254
Average	1039 (34.0)	476 (45.8)	563 (54.2)	
Below average	834 (27.3)	414 (49.6)	429 (51.4)	
Missing data	59 (1.9)	—	—	

Abbreviation: SD, standard deviation. [a]χ^2 tests were used to examine the differences between myopia and no myopia group based on the above-mentioned categorical variables, and a *t*-test was used to examine the refractive error and age differences between myopia and no myopia group. [b]Refractive error data and age data are presented as the mean (±SD).

without myopia ($P<0.05$). Myopic students also had a closer distance of watching television or reading than students without myopia ($P<0.05$). The median hours spent in outdoor activity daily of myopic students were 2.0 (interquartile range: 0.9) hours and those without myopia were 2.1 (interquartile range: 0.9) hours, but the difference between the two groups was not statistically significant ($P=0.051$).

Table 3 demonstrated that of the students who read or studied for school assignments more than 2 h per day, read for pleasure more than 2 h per day, used computer more than 2 h per week, watched television more than 2 h per week, played electronics more than 2 h per week, and read closer than 25 cm, as well as watched television closer than 3 m, the proportions of myopia group were greater than no myopia group, respectively ($P<0.05$).

Table 3 also illustrated that of the students in families with two myopic parents, 60.5% had myopia. By contrast, the students with only one myopic parent, 53.0% had myopia; the students without myopic parents, 43.7% had myopia. Parents with myopia tend to have children with myopia ($P<0.001$), and this tend to follow a dose-dependent pattern ($\chi^2_{trend}=36.944$, $P<0.001$).

Table 2 Near work and outdoor activity among children with or without myopia

Variables	*Total*	*Myopia*	*No myopia*	P-*value*[a]
Daily hours of reading or studying for school assignments	1.9 (0.6)	2.1 (0.5)	1.8 (0.6)	<0.001
Daily hours of reading for pleasure	1.2 (0.8)	1.2 (0.8)	1.1 (0.8)	0.007
Weekly hours of watching television	2.8 (0.8)	2.9 (0.8)	2.6 (0.9)	<0.001
Weekly hours of using computer hours	2.8 (1.1)	2.9 (0.9)	2.6 (1.2)	<0.001
Weekly hours of playing electronics	3.5 (1.0)	3.8 (1.2)	3.2 (1.1)	<0.001
Distance of reading (cm)	24.9 (4.1)	24.3 (3.7)	25.4 (4.4)	<0.001
Distance of watching television (m)	3.3 (1.1)	3.2 (1.1)	3.3 (1.1)	0.012
Daily hours of outdoor activity	2.0 (0.9)	2.0 (0.9)	2.1 (0.9)	0.051

Abbreviation: IQR, interquartile range. [a]Wilcoxon rank-sum test comparing myopia group with no myopia group.
Data are presented as median (IQR).
Wilcoxon testing was used because of the non-normal distribution of variables.

As shown in Table 4, the results first demonstrated that after incorporating all significant variables in the logistic regression model 1, girls were at a higher risk of myopia than boys (AOR = 1.22, 95% CI = 1.04–1.44). Considering the association between gender and myopia was significant, the following stratification analyses across gender were conducted (models 2 and 3). The final results demonstrated that the higher grade children were at a higher risk of myopia both in boys and girls. Both male and female students whose distance of reading was longer than 25cm were less likely to have myopia. The results also showed that reading for pleasure more than 2 h per day (AOR = 1.84, 95% CI = 1.09–3.12) was only positively associated with myopia in boys and spending time watching television per week was only positively associated with myopia in girls. Girls whose distance of watching television was between 3 and 5 m (AOR = 0.38, 95% CI = 0.23–0.62) and was longer than 5 m (AOR = 0.61, 95% CI = 0.47–0.81) were less likely to have myopia than girls whose distance of watching television was shorter than 3 m. In addition, the results indicated that both male and female students with one myopic parent or two myopic parents were at a higher risk of myopia than those without myopic parents, for instance, girls with one myopic parent (AOR = 1.77, 95% CI = 1.30–2.42) or two myopic parents (AOR = 3.38, 95% CI = 1.96–5.80) were more likely to have myopia than girls without myopic parents.

Discussion

Our study based on cycloplegic autorefraction indicated that the overall prevalence of myopia was 47.4% (95% CI = 45.6–49.2%) among primary and middle school-aged students in Guangzhou, which was higher than found in a prior survey also using cycloplegic autorefraction in 2004, which demonstrated that 38.1% of school-aged children (5–15 years of age) in Guangzhou were myopic (standrd error ≤ -0.5 D).[29] These data can reflect that there might be an increase in the prevalence of myopia in school-aged children in Guangzhou. In addition, a prior study in 2012 showed that the prevalence of child myopia in Korea was 22.6%,[8] and a recent study in the United States demonstrated that the prevalence of myopia in non-Hispanic white children was only 1.20% and in Asian children was 3.98%;[30] the prevalence of myopia in these studies were lower than that described in our study. A possible explanation for the variance in the prevalence of myopia in children could be differences in the nature of the samples, in the ethnic backgrounds, in the age, or in the definition of myopia.

In addition, the current results revealed that the prevalence of myopia in girls was higher than in boys (49.7% *vs* 45.1%), and girls had 1.21 (95% CI = 1.01–1.45) times greater risk of myopia than boys. This result is consistent with a previous study that was conducted in Beijing showing that the girls were more likely to be myopic than boys (odd ratio = 1.31, 95% CI = 1.11–1.55),[7] and aligns with a prior Caucasian study reporting that myopia occurs more frequently in girls than in boys.[31] These findings provide a plausible explanation for the following stratification analysis results across genders to discuss the relationships between associated factors and myopia.

Although a prior study in Delhi reported that children in the upper-middle socioeconomic status had a slightly higher risk of myopia,[26] we did not find any significant association between family economic status and myopia in children in this study. Mutti's study[13] using subjects from the Orinda Longitudinal Study of Myopia illustrated that the association between myopia and school achievement as measured by the Iowa Tests of Basic Skills may be weak. Similarly, our study in Guangzhou also did not demonstrate any significant association between school academic achievement and myopia.

In this study, we not only evaluated the amount of time spent for reading or studying for school assignments, reading for pleasure, watching television, using computer, and playing electronics, but also assessed the reading distance and the distance to the television set.

Table 3 Associations between near work activity, outdoor activity, parental myopia, and myopia in children

Variables	*Total,* n *(%)*	*Myopia,* n *(%)*	*No myopia,* n *(%)*	P-*value*[a]
Daily hours of reading or studying for school assignments				
≤2 h	1867 (100)	766 (41.0)	1101 (59.0)	<0.001
>2 h	1111 (100)	664 (59.8)	447 (40.2)	
Daily hours of reading for pleasure				
None	526 (100)	229 (43.5)	297 (56.5)	0.041
≤2 h	2272 (100)	1105 (48.6)	1167 (51.4)	
>2 h	187 (100)	99 (52.9)	88 (47.1)	
Weekly hours of watching television				
None	391 (100)	156 (39.9)	235 (60.1)	<0.001
<2 h	1288 (100)	542 (42.0)	746 (58.0)	
2–4 h	842 (100)	448 (53.2)	394 (46.8)	
>4 h	472 (100)	301 (63.8)	171 (36.2)	
Weekly hours of using computer				
None	495 (100)	220 (44.4)	275 (55.6)	<0.001
<2 h	1081 (100)	482 (44.6)	599 (55.4)	
2–4 h	809 (100)	414 (51.2)	395 (48.8)	
>4 h	590 (100)	316 (53.6)	274 (46.4)	
Weekly hours of playing electronics				
None	217 (100)	55 (25.3)	162 (74.7)	<0.001
<2 h	818 (100)	318 (38.9)	500 (61.1)	
2–4 h	868 (100)	457 (52.6)	411 (47.4)	
>4 h	1076 (100)	602 (55.9)	474 (44.1)	
Distance of reading				
<25 cm	2126 (100)	1120 (52.7)	1006 (47.3)	<0.001
25–29 cm	593 (100)	239 (40.3)	354 (59.7)	
>29 cm	226 (100)	63 (27.9)	163 (72.1)	
Distance of watching television				
<3 m	1402 (100)	703 (50.1)	699 (49.9)	0.044
3–5 m	1230 (100)	575 (46.7)	655 (53.3)	
>5 m	306 (100)	132 (43.1)	174 (56.9)	
Daily hours of outdoor activity				
<2 h	2072 (100)	1032 (49.8)	1040 (50.2)	0.212
2–3 h	436 (100)	197 (45.2)	239 (54.8)	
>3 h	327 (100)	159 (48.6)	168 (51.4)	
Number of parents with myopia				
None	1999 (100)	874 (43.7)	1125 (56.3)	<0.001
One parent	783 (100)	415 (53.0)	368 (47.0)	
Two parents	238 (100)	144 (60.5)	94 (39.5)	

[a]χ^2 tests were used to examine the differences between myopia and no myopia group.

We first demonstrated that children with myopia spent more time engaged in reading or studying for school assignments daily, reading for pleasure daily, using computer weekly, watching television weekly, and playing electronics weekly, compared with children without myopia ($P<0.05$). Similarly, Saw's study[23] in Singapore and China found that compared with children without myopia, myopic children spent more hours in reading per day, and a higher proportion of myopic children used the computer regularly ($P<0.05$); Mutti's study[13] in the United States revealed that the children with myopia spend more time engaged in studying or reading for pleasure, compared with children without myopia, but his study also showed that hours spent per week in watching television and playing video games/working on the computer did no differ between the two groups. A possible explanation for the different results about hours spent on watching television and using computer may be related to that the nearly universal exposure to television or computer among children in the United States make this a different variable than in Asia.[32] In addition, after incorporating all the significant variables (eg, gender, age, outdoor activity, and parental myopia) in the two-level logistic regression models 2 and 3, the final results demonstrated that reading for pleasure more than 2 h per day (AOR = 1.84, 95% CI = 1.09–3.12) was only positively associated with myopia in boys, and spending time watching television per week was only positively associated with myopia in girls. These results were consistent with Saw's study[23] showing that students who read more than 2 h per day were more likely to be myopia, Ip's study[33] reporting that longer time spent on reading for pleasure was associated with a myopic refraction, and Saxena's study[26] illustrating that positive association of myopia was observed with children study/reading more than 5 h per day, watching television more than 2 h per day, and playing computer/video games.

In addition, although many previous studies revealed that the distance of near work was associated with myopia in children, some of these studies only consider the distance of close-up reading was an important risk factor for myopia,[33,34] and others regarded the distances of different near work activities as a composite variable (distance from near work) and roughly thought that a higher prevalence of myopia was associated with shorter near work distance.[7] In our study, the results first demonstrated that myopic children had a closer distance of reading or watching television than children without myopia, and the final models demonstrated that both male and female students whose distance of reading longer than 25 cm were less likely to have myopia. The results were consistent with the findings of the Sydney Myopia Study showing that close reading distance (<30 cm) independently increased the risk of having myopia in children.[33] The final models 2 and 3 also showed that girls whose distance of watching television was between 3 and 5 m (AOR = 0.38, 95% CI = 0.23–0.62) and was longer than 5 m (AOR = 0.61, 95% CI = 0.47–0.81) were less likely to have myopia than girls whose distance of watching television was shorter than 3 m. Similarly, the results of a prior study in Singapore revealing that

Table 4 Predictors of myopia based on two-level multiple logistic regression models

Variables	*Total (Model 1)*		*Boys (Model 2)*		*Girls (Model 3)*	
	AOR	*95% CI*	*AOR*	*95% CI*	*AOR*	*95% CI*
Gender			—	—	—	—
Male	1.00					
Female	1.21	1.01–1.45*				
Grade						
1	1.00		1.00		1.00	
2	7.94	3.06–20.63*	5.00	1.59–15.71*	19.07	2.51–145.12*
3	33.51	13.35–84.10*	22.74	7.94–65.09*	73.63	9.87–548.96*
4	43.14	17.10–108.84*	20.94	7.18–61.02*	135.05	18.07–1009.53*
5	83.82	33.08–212.43*	49.62	17.12–143.84*	240.21	31.75–1817.46*
6	71.78	28.80–178.90*	40.41	14.25–114.62*	186.04	25.16–1375.72*
7	100.50	40.03–252.30*	65.00	22.69–186.23*	234.75	31.47–1751.28*
8	86.85	34.74–217.16*	54.77	19.35–155.06*	221.04	29.63–1649.22*
9	108.98	43.18–275.07*	74.68	26.06–214.02*	231.60	30.62–1751.81*
Daily hours of reading for pleasure						
None	1.00		1.00		—	—
≤2 h	1.38	1.08–1.77*	1.37	0.98–1.87		
>2 h	1.51	1.01–2.27*	1.84	1.09–3.12*		
Weekly hours of watching television			—	—		
None	1.00				1.00	
<2 h	1.54	1.16–2.05*			1.77	1.21–2.58*
2–4 h	1.60	1.22–2.08*			1.94	1.29–2.90*
>4 h	1.96	1.38–2.77*			2.60	1.53–4.41*
Distance of reading						
<25 cm	1.00		1.00		1.00	
25–29 cm	0.46	0.32–0.67*	0.38	0.24–0.62*	0.54	0.30–0.97*
>29 cm	0.61	0.49–0.77*	0.60	0.45–0.81*	0.58	0.41–0.83*
Distance of watching television			—	—		
<3 m	1.00				1.00	
3–5 m	0.61	0.45–0.83*			0.38	0.23–0.62*
>5 m	0.68	0.56–0.83*			0.61	0.47–0.81*
Number of parents with myopia						
None	1.00		1.00		1.00	
One parent	1.73	1.40–2.13*	1.71	1.28–2.28*	1.77	1.30–2.42*
Two parents	2.81	1.94–4.06*	2.38	1.43–3.95*	3.38	1.96–5.80*

Abbreviations: AOR, adjusted odds ratio; 95% CI, 95% confidence interval. *$P<0.05$.
Model 1 included age, gender, grade level, ethnicity, daily hours of reading or studying for school assignments, daily hours of reading for pleasure, weekly hours of watching television, weekly hours of using computer, weekly hours of playing electronics, distance of reading, distance of watching television, and number of parents with myopia.
Model 2 for boys and model 3 for girls included age, grade level, ethnicity, daily hours of reading or studying for school assignments, daily hours of reading for pleasure, weekly hours of watching television, weekly hours of using computer, weekly hours of playing electronics, distance of reading, distance of watching television, and number of parents with myopia.

watching television from a close distance was associated with myopia.[35]

As spending time outdoor activity was recently shown to be another major environmental factor associated with myopia, it is possible that increasing outdoor activity time may protect children against myopia.[14,15] A prior randomized clinical trial in Guangzhou have also demonstrated that the addition of 40 min of outdoor activity at school compared with usual activity resulted in a reduced incidence rate of myopia over the next 3 years.[36] However, in this study, we failed to find a significant association between outdoor activity and myopia. Similarly, some previous studies among Chinese children also showed that there was no significant association or weak association between outdoor activity and myopia.[7,37–39] The different results may be related to

the different target populations and methodological definitions of outdoor activity in different studies.[40,41]

Consistent with previous findings showing that parental myopia was significantly related to myopia, and illustrating an increased risk of myopia in children with increasing numbers of myopic parents,[13,17,24,28] the current study demonstrated that there was a trend for higher myopia prevalence among children with a parental myopia history. Both male and female students with one myopic parent or two myopic parents were at a higher risk of myopia than those without myopic parents.

The present study has noteworthy strengths, including the analysis of survey data that were collected from not only questionnaires but also from refraction measurements. Furthermore, the sample was school-based, with a high-participation rate and statistical randomization in recruitment. Considering our study was a complex sampling design using multi-stage sampling, we used a two-level multiple analysis to explore the independent risk factors for myopia in children; other same type of studies using multi-stage sampling method did not adopt this analysis method.[7,38] Notably, myopia in children was based on cycloplegic autorefraction in this study, and previous studies have showed that non-cycloplegic refractometry may overestimate the prevalence of myopia in children with active accommodation.[42] In addition, in this study, the questionnaires was completed by children themselves to minimize the misclassification bias; only for the children in grades 1–3, with the poor literacy and comprehensive ability, the questionnaire was completed by one of the students' parents.

Despite these strengths, the results of our analyses are tempered by some methodological limitations that should be considered. First, the cross-sectional nature of the study; therefore these associations should not be construed as causal. Second, the questionnaire may not be the most accurate tool to assess near work or other activities associated with myopia; although it is a common and accepted method to collect data, we could not completely rule out the possibility of recall bias.

In conclusion, myopia among primary and middle school-aged students is a significant public health problem in Guangzhou that warrants the attention of policy makers, researchers, and practitioners. Effective interventions to prevent and control myopia in children are highly recommended. Parents and schools should focus on myopia in children, particularly those who had a parental history of myopia. Furthermore, educational campaigns directed at families and schools are needed to improve awareness of the serious consequences of myopia.

Summary

What was known before

- Myopia ('near sightedness') is an increasingly common refractive error among school-aged children worldwide, especially in east Asia where the prevalence of myopia is now very high, with around 80% of students completing secondary school myopic.
- There has been a continuing debate over whether myopia is environmentally determined or is inherited, and the theory about both environmental and genetic factors contribute to the development of myopia is widely acknowledged recently.

What this study adds

- Myopia in children is a significant public health problem in Guangzhou.
- The overall prevalence of myopia was 47.4% (95% CI = 45.6–49.2%).
- The prevalence of myopia in students increased along with the growth of grade.
- Girls, longer time spent for near work, shorter distance of near work, and parental myopia were shown to be associated with the increasing risk of myopia in children.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We gratefully acknowledge the contribution of the Guangdong Education Bureau and its participating schools. Funding: This study was supported by Health Promotion Centre for Primary and Secondary Schools of Guangzhou Municipality. The funders had no role in study design and data analysis.

References

1 Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *LANCET* 2012; **379**(9827): 1739–1748.
2 Lin LL, Shih YF, Hsiao CK, Chen CJ. Prevalence of myopia in Taiwanese schoolchildren: 1983 to 2000. *Ann Acad Med Singapore* 2004; **33**(1): 27–33.
3 Wu HM, Seet B, Yap EP, Saw SM, Lim TH, Chia KS. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. *Optom Vis Sci* 2001; **78**(4): 234–239.
4 Resnikoff S, Pascolini D, Mariotti SP, Pokharel GP. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. *Bull World Health Organ* 2008; **86**(1): 63–70.
5 Goldschmidt E, Jacobsen N. Genetic and environmental effects on myopia development and progression. *Eye (Lond)* 2014; **28**(2): 126–133.
6 Feldkamper M, Schaeffel F. Interactions of genes and environment in myopia. *Dev Ophthalmol* 2003; **37**: 34–49.

7 Wu LJ, You QS, Duan JL, Luo YX, Liu LJ, Li X *et al.* Prevalence and associated factors of myopia in high-school students in Beijing. *PLoS One* 2015; **10**(3): e0120764.
8 Lim HT, Yoon JS, Hwang SS, Lee SY. Prevalence and associated sociodemographic factors of myopia in Korean children: the 2005 third Korea National Health and Nutrition Examination Survey (KNHANES III). *Jpn J Ophthalmol* 2012; **56**(1): 76–81.
9 Saw SM, Chua WH, Hong CY, Wu HM, Chan WY, Chia KS *et al.* Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci* 2002; **43**(2): 332–339.
10 McBrien NA, Moghaddam HO, Reeder AP. Atropine reduces experimental myopia and eye enlargement via a nonaccommodative mechanism. *Invest Ophthalmol Vis Sci* 1993; **34**(1): 205–215.
11 Irving EL, Sivak JG, Callender MG. Refractive plasticity of the developing chick eye. *Ophthalmic Physiol Opt* 1992; **12**(4): 448–456.
12 French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian schoolchildren: the Sydney adolescent vascular and eye study. *Ophthalmology* 2013; **120**(10): 2100–2108.
13 Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci* 2002; **43**(12): 3633–3640.
14 Jones LA, Sinnott LT, Mutti DO, Mitchell GL, Moeschberger ML, Zadnik K. Parental history of myopia, sports and outdoor activities, and future myopia. *Invest Ophthalmol Vis Sci* 2007; **48**(8): 3524–3532.
15 Rose KA, Morgan IG, Ip J, Kifley A, Huynh S, Smith W *et al.* Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology* 2008; **115**(8): 1279–1285.
16 Zadnik K, Satariano WA, Mutti DO, Sholtz RI, Adams AJ. The effect of parental history of myopia on children's eye size. *JAMA* 1994; **271**(17): 1323–1327.
17 Lim LT, Gong Y, Ah-Kee EY, Xiao G, Zhang X, Yu S. Impact of parental history of myopia on the development of myopia in mainland China school-aged children. *Ophthalmol Eye Dis* 2014; **6**: 31–35.
18 Reports on the physical fitness and health research of chinese school students. 2010, The Ministry Of Education of China. (in Chinese).
19 Zhao J, Pan X, Sui R, Munoz SR, Sperduto RD, Ellwein LB. Refractive error study in children: results from Shunyi District, China. *Am J Ophthalmol* 2000; **129** (4):427–435.
20 Tay MT, Au EK, Ng CY, Lim MK. Myopia and educational attainment in 421,116 young Singaporean males. *Ann Acad Med Singapore* 1992; **21**(6): 785–791.
21 Statistical Annual Report of Guangzhou in the Sixth National Population Census in 2010. 2011, Guangzhou Bureau of Statistics. (in Chinese).
22 Saw SM, Nieto FJ, Katz J, Chew SJ. Estimating the magnitude of close-up work in school-age children: a comparison of questionnaire and diary instruments. *Ophthalmic Epidemiol* 1999; **6**(4): 291–301.
23 Saw SM, Zhang MZ, Hong RZ, Fu ZF, Pang MH, Tan DT. Near-work activity, night-lights, and myopia in the Singapore–China study. *Arch Ophthalmol* 2002; **120**(5): 620–627.
24 Xiang F, He M, Morgan IG. The impact of parental myopia on myopia in Chinese children: population-based evidence. *Optom Vis Sci* 2012; **89**(10): 1487–1496.
25 Mirshahi A, Ponto KA, Hoehn R, Zwiener I, Zeller T, Lackner K *et al.* Myopia and level of education: results from the Gutenberg Health Study. *Ophthalmology* 2014; **121**(10): 2047–2052.
26 Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Menon V *et al.* Prevalence of myopia and its risk factors in urban school children in Delhi: the North India Myopia Study (NIM Study). *PLoS One* 2015; **10**(2): e0117349.
27 Villarreal GM, Ohlsson J, Cavazos H, Abrahamsson M, Mohamed JH. Prevalence of myopia among 12- to 13-year-old schoolchildren in northern Mexico. *Optom Vis Sci* 2003; **80**(5): 369–373.
28 Xiang F, He M, Morgan IG. The impact of severity of parental myopia on myopia in Chinese children. *Optom Vis Sci* 2012; **89**(6): 884–891.
29 He M, Zeng J, Liu Y, Xu J, Pokharel GP, Ellwein LB. Refractive error and visual impairment in urban children in southern china. *Invest Ophthalmol Vis Sci* 2004; **45**(3): 793–799.
30 Wen G, Tarczy-Hornoch K, McKean-Cowdin R, Cotter SA, Borchert M, Lin J *et al.* Prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children: multi-ethnic pediatric eye disease study. *Ophthalmology* 2013; **120**(10): 2109–2116.
31 Czepita D, Mojsa A, Ustianowska M, Czepita M, Lachowicz E. Role of gender in the occurrence of refractive errors. *Ann Acad Med Stetin* 2007; **53**(2): 5–7.
32 Demissie Z, Lowry R, Eaton DK, Park S, Kann L. Electronic media and beverage intake among United States high school students—2010. *J Nutr Educ Behav* 2013; **45** (6):756–760.
33 Ip JM, Saw SM, Rose KA, Morgan IG, Kifley A, Wang JJ *et al.* Role of near work in myopia: findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci* 2008; **49**(7): 2903–2910.
34 Lee YY, Lo CT, Sheu SJ, Yin LT. Risk factors for and progression of myopia in young Taiwanese men. *Ophthalmic Epidemiol* 2015; **22**(1): 66–73.
35 Ling SL, Chen AJ, Rajan U, Cheah WM. Myopia in ten year old children—a case control study. *Singapore Med J* 1987; **28**(4): 288–292.
36 He M, Xiang F, Zeng Y, Mai J, Chen Q, Zhang J *et al.* Effect of time spent outdoors at school on the development of myopia among children in china: a randomized clinical trial. *JAMA* 2015; **314**(11): 1142–1148.
37 Low W, Dirani M, Gazzard G, Chan YH, Zhou HJ, Selvaraj P *et al.* Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. *Br J Ophthalmol* 2010; **94**(8): 1012–1016.
38 Zhou Z, Ma X, Yi H, Pang X, Shi Y, Chen Q *et al.* Factors underlying different myopia prevalence between middle- and low-income provinces in China. *Ophthalmology* 2015; **122**(5): 1060–1062.
39 Lu B, Congdon N, Liu X, Choi K, Lam DS, Zhang M *et al.* Associations between near work, outdoor activity, and myopia among adolescent students in rural China: the Xichang Pediatric Refractive Error Study report no. 2. *Arch Ophthalmol* 2009; **127**(6): 769–775.
40 Cheng D, Schmid KL, Woo GC. Myopia prevalence in Chinese–Canadian children in an optometric practice. *Optom Vis Sci* 2007; **84**(1): 21–32.
41 French AN, Ashby RS, Morgan IG, Rose KA. Time outdoors and the prevention of myopia. *Exp Eye Res* 2013; **114**: 58–68.
42 Funarunart P, Tengtrisorn S, Sangsupawanich P, Siangyai P. Accuracy of noncycloplegic refraction in primary school children in southern Thailand. *J Med Assoc Thai* 2009; **92**(6): 806–811.