Prevalence and Influencing Factors of Myopia and Axial Length in Children and Adolescents Aged 4 to 18 Years in Northern China

Mingming Cui

Submitted to: JMIR Formative Research
on: October 23, 2024

Table of Contents

Prevalence and Influencing Factors of Myopia and Axial Length in Children and Adolescents Aged 4 to 18 Years in Northern China

Mingming Cui[1]

[1]Capital Institute of Pediatrics, Beijing, China Beijing CN

Corresponding Author:
Mingming Cui
Capital Institute of Pediatrics, Beijing, China
Capital Institute of Pediatrics, 2 YaBao Rd, Beijing 100020, China
Beijing
CN

Abstract

Background: Childhood myopia has become an increasingly serious public health problem worldwide.

Objective: This study aims to explore the prevalence of myopia, axial length changes, and their influencing factors among children and adolescents aged 4 to 18 years in Beijing. The findings are expected to provide a scientific basis for taking effective measures to prevent and control myopia for government decision-making.

Methods: This cross-sectional survey involved 2595 children from 9 randomly selected educational institutions (1 kindergarten and 8 schools) in northern China. The survey included a questionnaire, visual acuity examination, refractive screening, and axial length measurement.

Results: The prevalence of myopia among the tested students was 56.53%, and 50.98% of students had an axial length (AL) of >23.5 mm. The AL is elongated with age, and the right was longer than the left (P<0.05). Excluding preschool children, the AL was significantly different between students with and without myopia (P<0.05). The univariate analysis showed significant differences in the myopia rates by age, reading distance, close learning time, lighting environment, and myopia in parents (P<0.05). The multivariate logistic analysis showed that older children and myopia in parents were risk factors for myopia and a longer AL, with girls being more likely to develop myopia than boys (odds ratio, 1.35; 95% confidence interval, 1.133–1.597).

Conclusions: The prevalence of myopia and the proportion of excessive increase of AL were high in children and adolescents aged 4 to 18 years. Therefore, it is possible to predict the occurrence and development of myopia in children by measuring the AL and to prevent and control myopia in children and adolescents by reducing the short-distance reading time and maintaining an adequate reading distance.

(JMIR Preprints 23/10/2024:67869)
DOI: https://doi.org/10.2196/preprints.67869

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Prevalence and Influencing Factors of Myopia and Axial Length in Children and Adolescents Aged 4 to 18 Years in Northern China

Abstract

Objective: This study aims to explore the prevalence of myopia, axial length changes, and their influencing factors among children and adolescents aged 4 to 18 years in Beijing. The findings are expected to provide a scientific basis for taking effective measures to prevent and control myopia for government decision-making.

Methods: This cross-sectional survey involved 2595 children from 9 randomly selected educational institutions (1 kindergarten and 8 schools) in **northern China**. The survey included a questionnaire, visual acuity examination, refractive screening, and axial length measurement.

Results: The prevalence of myopia among the tested students was 56.53%, and 50.98% of students had an axial length (AL) of >23.5 mm. The AL is elongated with age, and the right was longer than the left (P<0.05). Excluding preschool children, the AL was significantly different between students with and without myopia (P<0.05). The univariate analysis showed significant differences in the myopia rates by age, reading distance, close learning time, lighting environment, and myopia in parents (P<0.05). The multivariate logistic analysis showed that older children and myopia in parents were risk factors for myopia and a longer AL, with girls being more likely to develop myopia than boys (odds ratio, 1.35; 95% confidence interval, 1.133–1.597).

Conclusions: The prevalence of myopia and the proportion of excessive increase of AL were high in children and adolescents aged 4 to 18 years. Therefore, it is possible to predict the occurrence and development of myopia in children by measuring the AL and to prevent and control myopia in children and adolescents by reducing the short-distance reading time and maintaining an adequate reading distance.

KEYWORDS

adolescents; children; epidemiological; investigation; myopia; axial length; influencing factors

Introduction

Myopia is a type of refractive error in which the refractive system of the eye causes parallel light to focus in front of the retina instead of directly on it in the relaxed state[1,2]. Childhood myopia has become an increasingly serious public health problem worldwide. According to the latest report by the World Health Organization(WHO), more than 3.36 billion people worldwide are projected to have myopia by 2030, with an increase by 72.3% from the figure in 2010[3]. The WHO also reported that the highest overall prevalence of myopia worldwide is in high-income countries in the Asia Pacific region (53.4%), followed by East Asian countries (51.6%)[3]. Thus, the prevalence of myopia in children will also increase[4]. The prevalence of myopia in children and adolescents in Korea ranges from 50% in children aged 5–11years to 78.8% in children aged 12–18 years[5].

In recent years, the rate of myopia among children and adolescents in China has been increasing, and myopia has become a significant public health concern in China. According to a survey conducted by the National Health Commission, the overall rate of myopia among children and adolescents was 52.7% in 2020, an increase of 2.5% compared with 2019. Among these children and adolescents, the rate of myopia was 14.3%, 35.6%, 71.1%, and 80.5% in 6-year-old children, primary school students, middle school students, and high school students, respectively [6]. The blurred vision and dry eyes caused by myopia can impact children's learning, daily life, and physical and mental health. Myopia can also increase the risk of retinopathy, which cannot be reversed after onset. If not controlled, the condition may progress to high myopia and even result in irreversible vision damage or other eye diseases.

Multiple studies have reported the prevalence and risk factors associated with myopia in China. Few surveys in China have included evaluation of axial myopia in children and further exploration is needed to investigate the factors related to myopia. The increase in axial length inevitably leads to stretching and thinning of the sclera, which increases the risk of high myopia, pathological myopia, and lesions of the sclera and macula, leading to more serious eye diseases[7]. Research has shown that

excessive AL increases the risk of myopia, which is of great significance for the occurrence and development of myopia[8]. Therefore, analysis of axial data is necessary.

Childhood is an important stage for the occurrence and development of myopia, and the effectiveness of preventing myopia during this stage is clinically significant. This study was performed to explore the prevalence of myopia, AL changes, and their influencing factors in children and adolescents aged 4 to 18 years in Beijing. The overall aim was to provide a reference for effective myopia prevention and control and thus reduce the occurrence and development of myopia in children.

Methods

Participants

In 2022, we conducted a vision survey in which all students from 9 educational institutions in Beijing (186 students from 1 kindergarten, 1452 students from 5 primary schools, 1394 students from 2 middle schools, and 664 students from 1 high school) eligible for the inclusion criteria were selected as survey subjects. The inclusion criteria were (1) an age of 4 to 18 years and permanent resident of Beijing; (2) no history of eye diseases, eye injuries, or surgeries except for refractive errors; (3) good physical and mental health with no congenital developmental abnormalities or related diseases that affect vision and refractive examination; (4) no wearing of corneal shaping lenses within 1 month; and (5) willingness to cooperate by both children and their parents. In total, 2742 children aged 4 to 18 years were selected for screening of nonciliary muscle paralysis refractive errors, binocular naked eye vision examination, AL measurement, eye position and eye movement examination, and color vision examination. A questionnaire survey was simultaneously conducted (that for kindergarten children was filled out by their parents, and that for children in primary school and above was jointly answered by themselves and their parents). After making logical corrections and eliminating unreasonable records, 2595 children’s information was ultimately obtained (effective questionnaire response rate: 94.6%). The detailed selection process was presented in FIGURE1. The

children were divided into four groups according to age (4–6, 7–9, 10–12, and 13–18 years), with 207 children (414 eyes), 371 children (742 eyes), 702 children (1404 eyes), and 1315 children (2630 eyes) in each group, respectively [total of 2595 children (5190 eyes)]. This study was approved by the Medical Ethics Committee of the Capital Institute of Pediatrics (SHERLL2022043). The children and their parents provided informed consent and were willing to participate, and the investigation was approved by the local education bureau and school.

Measurements

The visual acuity chart used in the study is from GB/T 11533-2011 Standard for logarithmic visual acuity charts, which is a 5-mark record. A desktop automatic computer refractometer (KR-800; Topcon Corporation, Tokyo, Japan) that met the ISO 10342 ophthalmic instrument refractometer standard was used to detect the refractive status of nonciliary muscle paralysis. The AL was measured using a biometer (IOL Master; ZEISS Group, Oberkochen, Germany). All instruments and equipment were tested and approved by relevant departments. Both the computer refractometers and biometric instruments underwent simulated human eye calibration before use[9]. The myopia screenings were performed according to the Guidelines for Appropriate Techniques for Myopia Prevention and Control in Children and Adolescents (Updated Version) issued by the National Health Commission[10].

Questionnaire survey

The questionnaire was developed by the Capital Institute of Pediatrics and and students or their parents filled out questionnaires. It took approximately 15–20 min to complete the questionnaire. Before completing the questionnaire, the survey or explained the significance of the survey, emphasized the confidentiality of the questionnaire, and any questions that were not understood would be explained by the investigator until the students could understand the questions correctly in order to guarantee the credibility of the results. The survey content was mainly included several aspects such as sex, age, parents' myopia, environment and habits of using eyes, electronic screen

use, reading posture and time, etc.

Judgment criteria

Previous studies have shown that both computerized optometry and AL measurement under nonciliary muscle paralysis are safe and reliable options for myopia screening in children and adolescents[11].

Screening myopia determination

Myopia screening in children aged 0 to 6 years: According to the recommended standards of the Guidelines for Eye Health and Vision Examination Services for Children aged 0 to 6 years[12], and the Guidelines for Pediatric Eye Evaluations Preferred Practice Pattern (Updated Version) issued by the American Academy of Ophthalmology [13], the criteria for determining myopia were that children aged 4 years with a spherical lens power of <−3.00 dioptres(D) and children aged 5 to <7 years with a spherical lens power of <−1.50 D are considered to have myopia (detected using a computer refractometer in a nonciliary muscle paralysis state)[14].

Myopia screening in children aged ≥7 years: According to the criteria for determining myopia, the standard logarithmic visual acuity of the naked eye was below 5.0 and the spherical equivalent by computerized optometry was below −0.50D under non-ciliary muscle paralysis. Anyone who was determined to be myopic in one eye or confirmed to be wearing an orthokeratology lens would be counted in the total number of myopia[15].

Determination of excessive increase of AL

Referring to the expert consensus on the reference range of AL for school-age children in 2022[16], an AL of >23.5 mm is considered an abnormal value for excessive axial growth. In this study, an AL of >23.5 mm and naked eye vision of <5.0 were considered to indicate excessive increase of AL. Anyone who was determined to be excessive increase of AL in one eye would be counted in the total number of excessive increase of AL.

Quality control

The on-site investigation was conducted by trained and qualified medical personnel using unified vision examination methods and survey questionnaires. The original data were collected and organized by the school as a unit, and the data were verified and entered by a dedicated person. Health records were created for follow-up and notification of the examination results. The light box and method of visual inspection complied with national standards, and the testing environment and distance also met relevant requirements. In a semi-dark room, refractive testing of children in the natural state (nonciliary muscle paralysis) was performed to ensure that the system error was within a reasonable range. The environment was fixed and the lighting was suitable. The child's seat was fixed within a radius of 50 cm, the head was kept upright, and the eyes were level with the instrument. The interocular distance between the right and left eyes was 35 cm. The average value of at least three consecutive readings from a computer optometer was used for analysis, and the average value of at least five consecutive readings from an axial biometric instrument was used for analysis.

Statistical analysis

The data were entered into an Excel 2007 spreadsheet. All statistical analyses were performed with Stata 10.0 software (StataCorp, College Station, TX, USA). Descriptive data are presented as frequency and percentage or mean with Wald 95% confidence interval (CI). Categorical variables are presented as frequency and percentage, and continuous variables are expressed as mean with standard deviation. These associations were tested using chi-square analyses or the correlation index, depending on the type of variables involved. Relevant outcomes are presented as odds ratio (OR) with 95% CI. Statistical significance was defined as $P<0.05$.

Results

Basic situation of myopia in children

In total, 2595 children (5190 eyes) were surveyed. The myopia detection rate was 56.53% (1467/2595) (52.71% in boys, 60.23% in girls). The children's mean age was 12.55±3.17 years, and

the myopia rate was 7.73% in children aged 4 to 6 years, 36.12% in those aged 7 to 9 years, 58.26% in those aged 10 to 12 years, and 69.05% in those aged 13 to 18 years. The number of tested eyes was 5190, and the total myopia rate was 47.94% (2488/5190) (left eye, 45.74%; right eye, 50.13%). There was a statistically significant difference in the incidence of myopia among the different age groups (χ^2=537.578, *P*=0.00). The rate of myopia in boys was 44.90% (1145/2550) and that in girls was 50.87% (1343/2640), with a statistically significant difference (χ^2=18.519, *P*=0.00) (Table 1).

Basic information of children's AL

The mean binocular AL among all children was 24.14±1.29 mm (right eye, 24.19±1.28 mm; left eye, 24.11±1.29 mm). The difference in the binocular AL was statistically significant (t=2.221, *P*=0.026), especially in children aged 13 to 18 years. There was also a statistically significant difference in left and right AL (t=2.271, *P*=0.023), with the right AL being longer than the left. The 1275 boys (49.13%) had an AL of 24.39±1.27 mm, whereas the 1320 girls (50.87%) had an AL of 23.90±1.25 mm. There was a statistically significant difference in AL between the two sexes of children with myopia (*P*<0.001). The AL increased with age as follows: 22.58±0.71 mm in children aged 4 to 7 years, 23.36±0.96 mm in children aged 7 to 10 years, 24.05±1.08 mm in children aged 10 to 13 years, and 24.66±1.22 mm in children aged 13 to 18 years. The mean AL of myopic eyes was 24.72±1.14 mm, whereas that of non-myopic eyes was 23.63±1.19 mm. The AL of myopic eyes was longer than that of non-myopic eyes (t=23.856, *P*=0.000). Excluding the 4- to 7-year-old children, the differences in AL between myopic and non-myopic children in the other age groups were statistically significant (*P*<0.001). Details are shown in Table 2 and Figures 2 to 4.

Single-factor analysis of myopia and excessive increase of AL in children

The analysis of the influencing factors of myopia and excessive increase of AL in children showed statistically significant differences in children's age, reading distance, long-distance reading time on electronics, close-distance learning time, children's knowledge of the Rule of 20, learning lighting, and myopia in parents (*P*<0.05). However, the time spent on close-range electronic products, daily

reading posture, and study table placement were not significant influencing factors for myopia or a longer AL in this population (P>0.05). Girls were significantly more prone to develop myopia than boys (χ^2=14.93, P<0.001), whereas the difference in AL was not statistically significant (χ^2=0.15, P=0.696). Myopia and excessive increase of AL showed a strong correlation with age (χ^2=330.91, P<0.001 and χ^2=353.04, P<0.001, respectively). Details are shown in Table 3.

Multivariate regression analysis of myopia in children

We applied multivariable logistic regression models to identify the effects of the investigated factors on Myopia and excessive increase of AL. A total of nine variables with a P-value≤0.5 (Table 2) in the analysis were entered into the multivariable logistic regression model for Myopia. A total of eight variables with P≤0.5 (Table 2) in the analysis were entered into the multivariable logistic regression analysis for excessive increase of AL. In the adjusted multivariable model, girl, older age and parental myopia were significantly associated with myopia. The survey shows that older age and parental myopia were significantly associated with excessive increase of AL. According to this analysis, 1 additional year of age was associated with a 1.27-fold higher risk for myopia (95% CI, 1.229–1.304; P<0.001), 1 additional year of age was associated with a 1.31-fold higher risk for myopia (95% CI, 1.269–1.350; P<0.001).

Children who were girls were more likely to be myopic children (boy is the reference group for the exposure, adjusted OR=1.35, 95% CI, 1.133–1.597; P=0.001). Additionally, children with myopic father were more likely to have great risk for myopia and have excessive increase of AL(children without myopic father is the reference group for the exposure, adjusted OR=0.76, 95% CI, 0.625–0.923; P=0.006; adjusted OR=0.68, 95% CI, 0.556–0.822; P<0.001). Children with myopic mother were more likely to have great risk for myopia and have excessive increase of AL(children without myopic mother is the reference group for the exposure, adjusted OR=0.67, 95% CI, 0.555–0.802; P<0.001; adjusted OR=0.64, 95% CI, 0.528–0.764; P<0.001). (Table 4).

Discussion

Myopia can be defined as a mismatch between the optical power and ocular axial dimensions. The intersection of light rays falls in front of the photoreceptor retinal layer, producing a blurred image. Some studies have confirmed that the AL is an important factor in the development of refractive error, especially in myopia. Compared with other ocular structures, such as the cornea and crystalline lens, an increased AL is the principal morphological factor related to myopia progression[17]. Therefore, it is important to evaluate the structural changes associated with myopia and develop strategies to prevent the progression of myopia and its complications. The ability to predict which eyes are at risk of developing an extreme AL would be clinically useful.

Our study found a high prevalence of myopia and excessive increase of AL among children and adolescents aged 4 to 18 years in Beijing city, located in the north of China, at 56.53% and 50.98%, respectively. The rate of myopia was higher than that the national average [18]and Other cities in China [19,20]and even above the highest overall prevalence of myopia worldwide[3]. The rate of myopia was lower than that Shenyang and Weifang cities in china [21,22]. The multivariate analysis revealed that excessive increase of AL was significantly associated with older age and parental myopia. The myopic spherical equivalent was significantly associated with older age, female sex, and parental myopia.

Prevalence and influencing factors of myopia in children and adolescents

The rate of myopia in children increased with age, and it increased particularly rapidly after 7 years of age. The greatest increase in myopia was seen in children aged 7 to 10 years (from 7.73% to 36.12% in preschool), followed by children aged 10 to 12 years. These findings are consistent with the survey results on myopia in primary and secondary school students by Hongbin[23]and Li et al. [24]. First, myopia is usually difficult to reverse, and the number of people with myopia is increasing; thus, the rate of myopia in older individuals is higher. Second, children generally enter school from about 7 years of age, and as their academic burden increases, they generally spend less time outdoors and more time engaged in close reading [23]. This prolonged close-up work can strain the ciliary

muscles, increasing the risk of myopia. Consequently, the incidence of myopia naturally increases with age. The results of this survey are basically similar to those reported by Li et al.[24] and Huibin [25] on myopia in children and adolescents in Chengdu. They found that the rate of myopia increased with age starting from 7 years old. Therefore, it is necessary to begin prevention and control of myopia in children at the preschool stage.

In this survey, we also found that the rate of myopia in girls was higher than that in boys, which is similar to the findings reported by Zhen [25]regarding myopia in seven provinces in China. Previous studies have suggested that outdoor activities are a protective factor for myopia [26], perhaps because many boys prefer outdoor sports whereas many girls prefer quieter activities. Thus, the occurrence of myopia differs based on the learning and living habits of male and female students, leading to the higher rate of myopia in female than male students. Some studies have also suggested that myopia is related to the hormone fluctuation that occurs during female development [27]. Further research is needed on this topic.

Myopia is caused by a variety of complex factors, including genetics, eye structure and visual development, lifestyle, and eye habits [28]. Previous studies have suggested that myopia in children is related to myopia in their parents [29], which is consistent with the results of the present survey. The occurrence of myopia depends on interactions between genetic and environmental factors. Congenital factors are difficult to change, whereas environmental factors and behavioral habits are particularly important in the occurrence and development of myopia. Therefore, prevention and control of myopia should be focused on the cultivation of individual behavioral habits, such as eye use habits, lifestyle, and outdoor sports. Detrimental eye habits include reading and writing at a close distance for a long time, maintaining incorrect reading and writing postures, using electronic video products, and reading in bed or in a shaking car; all of these habits may increase the risk of myopia [30].

Whether the use of electronic products can increase the risk of myopia has been controversial, and

the results of a meta-analysis showed no significant correlation between the use of electronic products and the ccurrence of myopia [31]. The present survey showed no significant correlation between the electronic products use time at close distance and the development of myopia. Previous studies have suggested that children are in a critical period of growth and development characterized by incomplete nervous system development and poor self-control ability, and they are easily stimulated by mobile phones, tablets, and other electronic products; this combination of factors may result in decreased vision ability [32]. The present study also showed a correlation between the long-distance electronic device use time and myopia, but children who used long-distance electronic devices for more than 1 hour had a lower rate of myopia. A possible reason for this is that the longer children watch television and other long-distance electronic products, the less autonomous learning behavior they engage in both inside and outside the classroom and the shorter the close-eye learning time, to a certain extent [33]. Additionally, long-distance electronic products can reduce close-eye use and avoid high tension of the ciliary muscles and excessive lens flexion to a certain degree. These factors may reduce the risk of myopia. In addition, many parents of children with myopia require that the use of electronic products by children does not exceed 1 hour a day. In the past, it was believed that correct reading and writing posture should be maintained to achieve “one punch, one foot, and one inch”[9]. Different reading postures may affect reading comfort, but the main factor affecting the occurrence of myopia is reading distance [34]. The present study showed that a short-distance learning time of >60 minutes and a distance of <33 cm between the eyes and the book during reading are associated with myopia.

Interestingly, we found that using both a fluorescent desk lamp and roof light was associated with myopic refraction and axial length. It is Inconsistent with those of Shi-Ming Li et al. Reported[35]. In our study, most families were still using a traditional fluorescent lamp with low frequency of flicker and desk LED lamp, but fluorescent lamp with low frequency of flicker has been reported to be capable of inducing myopia in mice [36]. In addition, low light levels [37] and the narrow

light spectrum of fluorescent lamps could also contribute. Whether this association attributes to the lamp characteristic remains unclear. Second, placement of the study desk facing the window did not have an impact on myopia (P>0.05). The study desk may receive more natural light from the window, and exposure to sunlight has a protective effect on children's eyes. However, harsh, uneven, and reflective sunlight exposure can damage the eyes. As a benefit, however, the presence of a window may cause children to occasionally look outside during learning, distracting their gaze and relieving eye pressure [38]. In summary, many indirect factors are involved in the association between the placement of a desk facing the window and the development of myopia, making it difficult to determine whether a direct correlation exists.

The AL of myopic eyes was significantly longer than that of non-myopic eyes

Studying the development of the eye is essential to better understand complex pathophysiologic processes that affect vision. Many factors affect the differentiation and maturation of the eye, and the most important are genetic factors. One of the earliest signs of pathology in the eye is an alteration of normal AL [39]. Genetic, environmental, and aging factors are the main controllers of AL[40]. Previous studies have shown that children whose parents had myopia had longer ALs than children whose parents did not have myopia [41]. Another study showed that the refractive error and ALs of parents and children were positively correlated[32] [42]. One of the earliest signs of pathology in the eye is an alteration of normal AL [39]. When the refractive power and AL are both within the normal range and match each other, emmetropia can occur. We found that the AL of myopic eyes was significantly longer than that of non-myopic eyes. Previous studies have found that children with longer ALs are more prone to develop myopia, the occurrence of which usually peaks by the age of 10 years [43]. The younger the age at which myopia occurs, the higher the degree of myopia in adulthood.

Prevalence and influencing factors of excessive increase of AL in children and adolescents

The present survey showed that the AL increases with age, similar to previous research results; specifically, the AL tends to grow faster in the front and slower in the back of the eye as age

increases. Children aged 9 to 11 years old have faster AL growth, which significantly slows with age. Overall, the AL tends to initially grow rapidly and then more slowly as age increases [9,44]. In some children, however, myopia progresses rapidly during the school age years. Furthermore, sex-related differences in the ocular structures have been found [45], which is consistent with the results of the present study.

This study also showed that the right AL was longer than the left AL. A statistically significant difference in the AL was found between the left and right eyes of children aged 13 to 18 years (P<0.05), while there was no such difference in children aged 4 to 12 years. Li et al [24]. found a difference in the right AL among children aged 5 to 18 years. Yihui et al[46]. found that the right AL was longer than the left AL in children aged 10 to 18 years, whereas the difference between the left and right eyes of children aged 4 to 9 years was not statistically significant; this finding is consistent with the results of the present study. After the age of 12 years, eyeball development basically stops in most individuals, and effects due to developmental inconsistencies can therefore be ruled out. The development and self-regulation of the left and right eyes may be influenced by genetic and environmental factors that are not completely symmetrical [47], resulting in differences in the AL. In addition, in daily life, there may be situations of preferential or advantageous use of both eyes, and overuse of a certain eye can result in a significant difference in the AL between the two eyes. Notably, research has shown that myopia is more pronounced in both eyes of myopic individuals. Additionally, in nearsighted individuals, the degree of nearsightedness is more pronounced in their dominant eye. Furthermore, in patients with myopic anisometropia, the dominant eye typically exhibits a deeper degree of myopia and longer AL than the non-dominant eye[48]. Research has also shown that in patients with myopic anisometropia, the dominant eye is often the right eye, which exhibits a higher degree of myopia and longer AL, thus increasing the risk of myopia [49].

The present study suggests that the right eye is more prone to myopia than the left and that protecting the dominant eye is also one of the key points for myopia prevention. Excluding preschool

children aged 4 to 7 years, who are still young and have less severe myopia, we found no statistically significant difference in the AL between eyes with and without myopia. In age groups beyond this, however, the AL of myopic eyes was significantly longer than that of non-myopic eyes, which is consistent with previous research results [50]. Therefore, by monitoring the AL, we can predict the development trend and evaluate the severity of myopia. This study suggests that the prevention and treatment of myopia should start at the age of 7 years at the latest. Surveys of the refractive status and AL in children of all ages can provide a reference for developing personalized intervention measures.

This study has two major strengths. First, we investigated the visual status of children and adolescents aged 4 to 18 years in a specific district of Beijing, covering a wide age range and providing intervention measures for myopia prevention and control in children of different age groups. Second, most previous studies used the equivalent spherical diopter to determine myopia; the present study adds axial data to provide a more comprehensive and in-depth study of myopia. The main limitation of the study is that a questionnaire survey was used to understand the influencing factors, and recall bias may be present as a result. Another limitation is that because this was a cross-sectional study, myopia and its influencing factors cannot be considered as having a causal relationship. Further case–control or cohort studies are needed. In addition, our study was conducted in the capital city of China and its generalizability is limited for other settings.

Conclusion

In summary, the rate of myopia among children and adolescents in a specific district of Beijing was 56.53%. More extensive measures are needed to prevent and control myopia. After enrollment at the age of 7 years, the refractive state gradually shifted toward myopia. As children grow, those who simultaneously experience long periods of close learning and too-close reading are more likely develop myopia. To reduce the occurrence and development of myopia, it is recommended to move the threshold for preventing myopia to before the age of 7 years, provide targeted health education

and guidance to children of different age groups, and cultivate good eye hygiene and lifestyle habits in children from an early age.

Acknowledgements

We would like to thank all the parents, children and data collectors who participated in this study. We also would like to thank the following individuals for their contribution and all of the medical workers and teachers involved in the study, for their enthusiasm, hard work and enduring support. Zhilong Luo and Ting Zhang et al.

Authors' contributions

All the authors were active participants. MC and ZH had full access to all the data, formulated the research question and made a design for the study; ZY, SL, JL, FC, XZ collected the data; MC have made substantial contributions to the interpretation and statistical analysis of the data; MC and ZH participated in the discussion and drafted the manuscript; TY and YG participated in the discussion. MC and ZH have made substantial contributions to the interpretation of data and substantively revised the manuscript. All authors have approved the submitted the final version and have agreed both to be personally accountable for the author's own contributions and for ensuring that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, were appropriately investigated, resolved, and the resolution documented in the literature.

Funding

This project was supported by Public service development and reform pilot project of Beijing Medical Research Institute (BMR2021-3). The funding body had no role in the design, analysis or writing of this article.

Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The research was performed in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee of Capital Institute of Pediatrics under the code (NO.SHERLL2022043). Informed consent was obtained from children's parents or guardians.

Consent for publication

Not applicable

Conflicts of interests

The authors declare no conflict interest related to this work.

References

[1] Zhao K X, Yang P Z. Ophthalmology. Beijing: People's Medical Publishing House, Mar 1,2013:221.

[2] Flitcroft DI, He M, Jonas JB, et al. IMI – Defining and classifying myopia: a proposed set of standards for clinical and epidemiologic studies. Invest Ophthalmol Vis Sci. Mar 2019;60(3):M20-M30.[doi:10.1167/iovs.18-25957]

[3] WHO launches first World report on vision. URL:https:/www.who.int/zh/news-room/detail/08-10-2019-who-launches- first-world-report-on-vision[accessed 2019-10-11].

[4] Rudnicka AR, Kapetanakis VV, Wathern AK, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. Br J Ophthalmol. 2016;100(7):882-890.[doi:10.1136/bjophthalmol-2015-307724]

[5] Kim H, Seo JS, Yoo WS, et al. Factors associated with myopia in Korean children: Korea National Health and nutrition examination survey 2016-2017 (KNHANES VII). BMC Ophthalmol. Jan 20,2020;20(1):31. [doi:10.1186/s12886-020-1316-6]

[6] National Health Commission of the PRC. The total myopia rate of children and adolescents in our country is 52.7% in 2020,the problem of myopia in young children was still prominent. URL:http://www.gov.cn/xinwen/2021-07/13/content_5624709.htm[accessed 2023-03-21]

[7] Yan X , Kang ZF , Li SJ , et al.Research progress of fundus morphology in high myopia. International Eye Science.Feb 2023;23(2),212-216.[doi:10.3980/j.issn.1672-5123.2023.2.06]

[8] Tideman JWL, Polling JR, Vingerling JR, et al. Axial length growth and the risk of developing myopia in European children. Acta Ophthalmol.Dec 19,2017;96(3):301-309.[doi:10.1111/aos.13603]

[9] Xiang KD, Wang JJ, Pan CW,et al. Refractive progression among students aged 4-14

in Shanghai and associated factors. Chinese Journal of School Health.sep 2022;43(9): 1309-1313+1318.[doi:10.16835/j.cnki.1000-9817.2022.09.008]

[10] National Health Commission of the PRC. Appropriate technical guide-lines for prevention and control of myopia in children and adolescents(updated version) and interpretation. URL:http://www.gov.cn/xinwen/2021-10/13/content_5642345.htm[accessed 2022-03-02].

[11] Zhong PL, Ma N, Liu YF, et al. Trend of the detection rate of myopia among Chinese Han children and adolescents aged 7-18 years from 2010 to 2019. Chinese Journal of Preventive Medicine. Apr 2023;57(4): 479-485.[doi:10.3760/cma.j.cn112150-20221008-00964]

[12] National Health Commission of the PRC. "Standard of eye care and visual acuity examination for children aged 0-6(trial) " document and interpretation. URL:https://www.gov.cn/zhengce/2021-06/24/content_5620642.htm[accessed [2023-03-12].

[13] American Academy of Ophthalmology."Pediatric eye evaluations preferred practice pattern".URL:https://www.aaojournal.org/content/preferred-practice-pattern[accessed 2023-03-12].

[14] Cui MM, Sui GH, Zhang H, et al. Refractive screening status of 1390 children aged 2-6 years old in Huaibei, Anhui province. Chinese Journal of Child Health Care. Sep 2023;31(9):1028-1032.[doi:10.11852/zgetbjzz2023-0014]

[15] Zhang D, Sun B, Wu M, et al. Prevalence and associated factors of myopia among school students in Shenyang, China: a cross-sectional study. Front Public Health.Aug 30, 2023;11:1239158. [doi:10.3389/fpubh.2023.1239158]

[16] Public Health Ophthalmology Branch of Chinese Preventive Medicine Association. Chinese expert consensus on the reference interval of ocular hyperopia reserve, axial length, corneal curvature and genetic factors in school-age children(2022) . Chinese Journal of Ophthalmology. Feb 2022;58(2):96-102

[17] Fan Q, Wang H, Jiang Z. Axial length and its relationship to refractive error in Chinese university students. Fan Q, Wang H, Jiang Z. Axial length and its relationship to refractive error in Chinese university students. Cont Lens Anterior Eye. 2022;45(2):101470.?

[18] Chen S. Overall myopia rate of 52.7% among children and youth in China by 2020. Chinese Women's Newspaper. (2021) 2. [doi: 10.28067/n.cnki.ncfnb.2021.002094]?

[19] Xu S, Zong Z, Zhu Y, et al. Association between sleep-wake schedules and myopia among Chinese school-aged children and adolescents: a cross-sectional study. BMC Ophthalmol. Apr 3,2023;23(1):135. [doi:10.1186/s12886-023-02874-9]

[20] Mu J, Zhong H, Liu M, et al. Trends in myopia development among primary and secondary school students during the COVID-19 pandemic: a large-scale cross-sectional study. Front Public Health.Mar 22,2022;10:859285. [doi:10.3389/fpubh.2022.859285]

[21] Zhang D, Sun B, Wu M, et al. Prevalence and associated factors of myopia among school students in Shenyang, China: a cross-sectional study. Front Public Health. Aug 30,2023;11:1239158. [doi:10.3389/fpubh.2023.1239158]

[22] Zhang J, Li Z, Ren J, et al. Prevalence of myopia: a large-scale population-based study among children and adolescents in weifang, China. Front Public Health. Jul 25,2022;10:924566. [doi:10.3389/fpubh.2022.924566]

[23] Dai HB, Cai CY, Ou YF, et al. Analysis the incidence of myopia and its related factors in students in Wuchang district□Chinese Journal of Strabismus & Pediatric Ophthalmology. Jun 2015;23(2):

31-33.

[24] Li L, Bian SL, Lin J. Current situation of refractive status and axial length in children and adolescents aged 3-18 years in Qingyang District of Chengdu. International Eye Science. Feb 2021;21(2): 325-330.[doi:10.3980 /j.Issn.1672-5123.2021.2.27]

[25] Guo Z, Xie S, Du XL, et al. Analysis of influencing factors of screened myopia in primary school students in seven provinces[J]Chinese Journal of School Health.Dec 2020; 41(12),1872-1875.[doi:10.16835/j.cnki.1000-9817.2020.12.027]

[26] He M , Xiang F , Zeng Y ,et al.Effect of time spent outdoors at school on the development of myopia among children in China:a randomized clinical trial. The Journal of the American Medical Association.2015;314:1142.[doi:10.1001/jama.2015.10803]

[27] Gong JF,Xie HL,Mao XJ,et al.Relevant factors of estrogen changes of myopia in adolescent females.ChinMed J(Engl).Mar 2015;128(5):659-663.

[28] Morgan IG, Wu PC, Ostrin LA, et al. IMI Risk Factors for Myopia. Invest Ophthalmol Vis Sci. May 2021;62(5):3.[doi:10.1167/iovs.62.5.3]

[29] Yang XW, Zhang SB. Current advance in the research of related influencing factors of myopia[J]International Eye Science. Oct 2017;17(10),1871-1873.

[30] Yang GY[J]Huang LH[J]Schmid KL[J]et al.Associations between screen exposure in early life and myopia amongst chinese preschoolers[J]Int J Environ Res Public Health.Mar 2020;17(3):1056.[doi:10.3390/ijerph17031056]

[31] Lanca C, Saw SM. The association between digital screen time and myopia: a systematic review. Ophthalmic Physiol Opt.Feb 2020; 40(2): 216-229.

[32] Certain LK, Kahn RS. Prevalence, correlates, and trajectory of television viewing among infants and toddlers. Pediatrics. Apr 2002;109(4):634–642.

[33] Pagani LS, Fitzpatrick C, Barnett TA[J]et al. Prospective associations between early childhood television ex-posure and academic, psychosocial, and physical well-being by middle childhood. Arch Pediatr Adolesc Med. May 2010;164(5):425–431.[doi:10.1001/archpediatrics.2010.50]

[34] Ip JM , Saw SM , Rose KA , et al. Role of near work in myopia : findings in a sample of Australian school children . Invest Opthalmol Vis Sci.Jul 2008;49(7) : 2903-2910.

[35] Li SM, Li SY, Kang MT, et al. Near work related parameters and myopia in Chinese children: the anyang childhood eye study. PLoS One. Aug 2015;10(8):e0134514.[doi:10.1371/journal.pone.0134514]

[36] Yu Y, Chen H, Tuo J, et al. Effects of flickering light on refraction and changes in eye axial length of C57BL/6 mice. Ophthalmic Res. Feb 2011;46(2):80-87. [doi:10.1159/000323179]

[37] Norton TT, Siegwart JT Jr. Light levels, refractive development, and myopia--a speculative review. Exp Eye Res. May 13,2013;114:48-57.[doi:10.1016/j.exer.2013.05.004]

[38] Zhou PF, Tao FB, Wu XY. Light exposure and myopia in children and adolescents[J]Chinese Journal of School Health. Mar 2022;43(3),467-471.[doi:10.16835/j.cnki.1000-9817.2022.03.036]

[39] Bach A, Villegas VM, Gold AS, et al. Axial length development in children. Int J Ophthalmol. May 2019;12(5):815-819.[doi:10.18240/ijo.2019.05.18]

[40] Fan Q, Wang H, Jiang Z. Axial length and its relationship to refractive error in Chinese

university students. Cont Lens and Anterior Eye. Feb 2022;45(2):101470.

[41] Lam DS, Fan DS, Lam RF, et al. The effect of parental history of myopia on children's eye size and growth: results of a longitudinal study. Invest Ophthalmol Vis Sci. Mar 2008 ;49(3):873-6.[doi: 10.1167/iovs.06-1097]

[42] Koomson NY, Kobia-Acquah E, Abdul-Kabir M, et al. Relationship between peripheral refraction, axial lengths and parental myopia of young adult myopes-sciencedirect.
J Optom.Feb2022;15(2):122-128.[doi:10.1016/j.optom.2020.10.007]

[43] Holden BA，Fricke TR，Wilson DA,et al，Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050，Ophthalmology .May 2016; 123(5) : 1036-1042.[doi:10.1016/j.ophtha.2016.01.006]

[44] Diez PS, Yang LH, Xu ML, et al. Growth curves of myopia-related parameters to clinically monitor the refractive development in Chinese schoolchildren. Graefes Arch Clin Exp Ophthalmol. May2019;257(5):1045-1053. [doi:10.1007/s00417-019-04290-6]

[45] Fan Q, Wang H, Jiang Z. Axial length and its relationship to refractive error in Chinese university students. Cont Lens and Anterior Eye. Feb 2022;45(2):101470.

[46] Chen YH, Peng RH, Yang XL. Analysis of axis length characteristics of 4-22 years old ametropic population in Dongguan area in recent 10a . International Eye Science.Jul 2019;19(7):1248-1251.[DOI:10.3980/j.issn.1672-5123.2019.7.40]

[47] Lin Z ,Vasudevan B , Mao GY , et al. The influence of near work on myopic refractive change in urban students in Beijing : a three-year follow-up report. Graefe 's Arch Clin Exp Ophthalmol.Nov 2016;254(11): 2247-2255.

[48] Wang HY, Wang LS, Gao YP, et al. The study between dominant eye and nondominant eye in myopia anisometropia. Chinese Journal of Practical Ophthalmology. Dec 2016;34(12):1267-1270.

[49] Fu J, Wu JJ, Guo Y, et al. Refractive status and its accommodation of dominant eye in myopic anisometropia. Ophthalmology in China. Apr 2016; 25(2): 102-105.[doi10.13281/j.cnki.issn.1004-4469.2016.02.008]

[50] Morgan IG, French AN, Ashby RS, et al. The epidemics of myopia: aetiology and prevention.
Prog Retin Eye Res. Jan 2018;62:134-149.

TABLE 1. Characteristics of children with myopia

mber of ildren ested	Children with myopia	Number of eyes examined	left eye myopia	Right eye myopia	χ^2	*P*	Number of myopia eyes	Number of non-nearsighted eyes
%)	N(%)	N(%)	N(%)	N(%)			N(%)	N(%)
					0.408	0.939		
207(7.98)	16(7.73)	414(7.98)	14(6.76)	16(7.73)			30(7.25)	384(92.75)
71(14.30)	134(36.12)	742(14.30)	104(28.03)	105(28.30)			209(28.17)	533(71.83)
02(27.05)	409(58.26)	1404(27.05)	321(45.73)	357(50.85)			678(48.29)	726(51.71)
15(50.67)	908(69.05)	2630(50.67)	748(56.88)	823(62.59)			1571(59.73)	1059(40.27)
					0.495	0.482		
75(49.13)	672(52.71)	2550(49.13)	555(43.53)	590(46.27)			1145(44.90)	1405(55.10)
20(50.87)	795(60.23)	2640(50.87)	632(47.88)	711(53.86)			1343(50.87)	1297(49.13)
5(100.00)	1467(56.53)	5190(100.00)	1187(45.74)	1301(50.13)			2488(47.94)	2702(52.06)

$^{*}P<0.05$, $^{**}P<0.001$

TABLE 2. Characteristics of axial length by age and sex（$\bar{x}\pm s$）

nber of ildren ested （%）	Mean axial length of the eye(mm)	Length of left eye axis(mm)	Length of right eye axis(mm)	*t*	*P*	Length of nearsighted eye axis (mm)	Non-myopic axial length (mm)	*t*
14(7.98)	22.58±0.71	22.57±0.70	22.59±0.73	0.328	0.743	22.64±1.05	22.57±0.68	0
2(14.30)	23.36±0.96	23.33±0.95	23.39±0.98	0.790	0.430	23.89±0.99	23.15±0.87	10
4(27.05)	24.05±1.08	24.02±1.08	24.07±1.08	0.962	0.336	24.45±0.96	23.67±1.05	14
0(50.67)	24.66±1.22	24.60±1.23	24.71±1.19	2.271	0.023*	24.97±1.12	24.19±1.21	16
0(49.13)	24.49±1.27	24.45±1.36	24.51±1.37	1.300	0.194	25.00±1.11	23.89±1.18	24
0(50.87)	23.90±1.25	23.85±1.26	23.95±1.24	1.899	0.058	24.46±1.10	23.32±1.12	26
(100.00)	24.14±1.29	24.11±1.29	24.19±1.28	2.221	0.026*	24.72±1.14	23.63±1.19	23

*P<0.05, **P<0.001

TABLE 3. Single-factor analysis of myopia and axial length in children

Variables	Number of children	Myopia rate			The rate of excessive increase of AL		
	N（%）	N（%）	χ^2	*P*	N（%）	χ^2	*P*
Age (years)			348.24	<0.001**		360.79	<0.001**
4~	207(7.98)	16(7.73)	Linear correlation	<0.001**	11(5.31)	Linear correlation	<0.001**
7~	371(14.30)	134(36.12)	330.91		99(26.68)	353.04	
10~	702(27.05)	409(58.26)			361(51.42)		
13~18	1315(50.67)	908(69.05)			852(64.79)		
Sex			14.93	<0.001**		0.15	0.696
boy	1275(49.13)	672(52.71)			655(51.37)		
girl	1320(50.87)	795(60.23)			668(50.61)		
Long distance reading time on electrics			6.85	0.009*		11.84	<0.001**
<60 minutes	655(25.24)	399(60.92)			372(56.79)		
≥60 minutes	1940(74.76)	1068(55.05)			951(49.02)		
Close distance reading time on electrics			1.41	0.235		2.93	0.087
<60 minutes	300(11.56)	160(53.33)			139(46.33)		
≥60 minutes	2295(88.44)	1307(56.95)			1184(51.59)		
Close distance learning time			11.86	0.001**		11.73	0.001**
<60 minutes	143(5.51)	61(42.66)			53(37.06)		
≥60 minutes	2452(94.49)	1406(57.34)			1270(51.79)		
Reading distance>33cm			5.42	0.020*		4.74	0.029*
yes	1330(51.25)	716(53.83)			642(48.27)		
no	1114(42.93)	652(58.53)			587(52.69)		
deficiency	151(5.82)						
Children know the 20 rules			7.22	0.007**		5.93	0.015*
yes	1120(43.16)	660(58.93)			594(53.04)		
no	1292(49.79)	691(53.48)			621(48.07)		
deficiency	183(7.05)						
Daily reading posture			3.92	0.141		1.87	0.393
Sit up	1727(66.55)	964(55.82)			862(49.91)		

Lie prostrate	428(16.49)	231(53.97)			220(51.40)		
Lie supine	313(12.06)	191(61.02)			169(53.99)		
deficiency	127(4.89)						
Learning lighting			8.21	0.016*		9.92	0.007*
Table lamp	320(12.33)	169(52.81)			149(46.56)		
Roof light	697(26.86)	367(52.65)			327(46.92)		
Desk lamp - Roof light	1477(56.92)	864(58.50)			786(53.22)		
deficiency	101(3.89)						
Desk arrangement			1.1	0.295		2.46	0.117
Facing the window	724(27.90)	417(57.60)			384(53.04)		
Away from the window	1675(64.55)	926(55.28)			830(49.55)		
deficiency	196(7.55)						
Father with myopia			12.56	<0.001**		21.71	<0.001**
yes	708(27.28)	435(61.44)			409(57.77)		
no	1739(67.01)	932(53.59)			824(47.38)		
deficiency	148(5.70)						
Mother with myopia			7.89	0.005*		10.55	0.001**
yes	939(36.18)	557(59.32)			510(54.31)		
no	1528(58.88)	818(53.53)			727(47.58)		
deficiency	128(4.93)						
Total	2595(100)	1467(56.53)			1323(50.98)		

*P<0.05, **P<0.001

Note:

1. Long-distance reading time on electronics refers to the average total time that children spend watching medium- and long-distance electronic products such screens each day, excluding the class time required by the school.

2. Close-distance reading time on electronics refers to the average total time that children spend watching mobile phones, tablets, and other near-distance electronic products each day, excluding the class time required by the school.

3. Learning time at a close distance refers to the total eye-use time for children to read and do homework at home every day, excluding class time.

TABLE 4. Multivariable logistic regression analysis of factors affecting myopia and axial length among children

Variables	OR	SE	z	*P*	95% CI
Children with myopia					
Child sex	1.35	0.12	3.39	0.001**	1.133–1.597
Child age group	1.27	0.02	15.62	<0.001**	1.229–1.304
father with myopia	0.76	0.08	-2.76	0.006*	0.625–0.923
mother with myopia	0.67	0.06	-4.32	<0.001**	0.555–0.802
Children with excessive increase of AL					
Child sex	0.92	0.08	-0.89	0.372	0.778–1.099
Child age	1.31	0.02	16.96	<0.001**	1.269–1.350
father with myopia	0.68	0.07	-3.93	<0.001**	0.556–0.822
mother with myopia	0.64	0.06	-4.82	<0.001**	0.528–0.764

*P<0.05, **P<0.001

Note:

Child sex (1=male, 2=female), Child age group (1= 4 to <7 years old, 2 = 7 to <10 years old, 3 = 10 to <13 years old, 4=13 to 18 years old), father with myopia (1=yes, 2=no), mother with myopia (1=yes, 2=no)

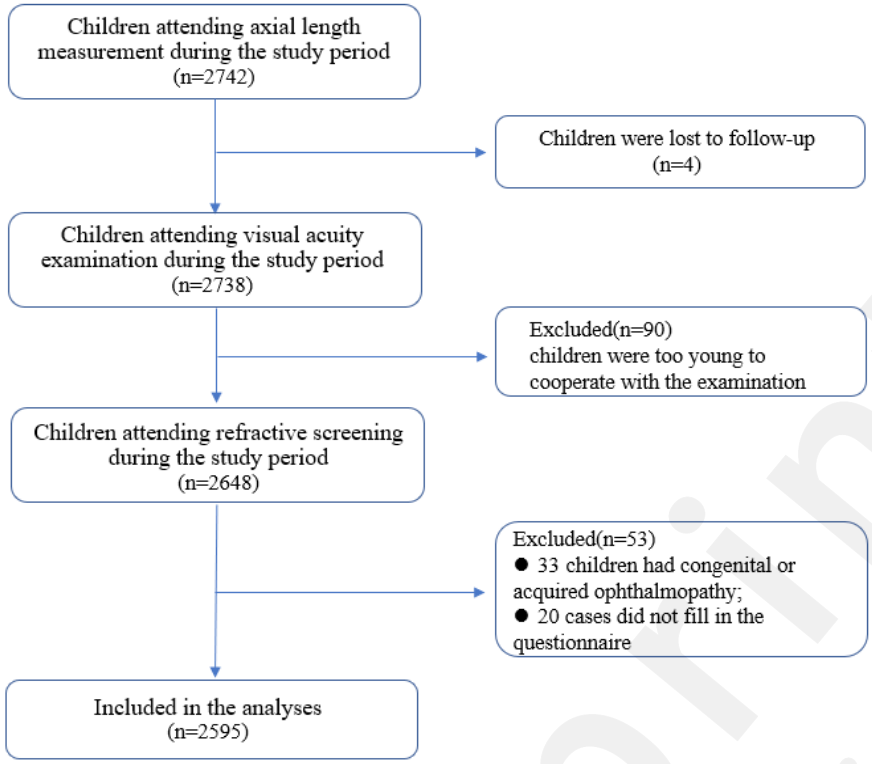
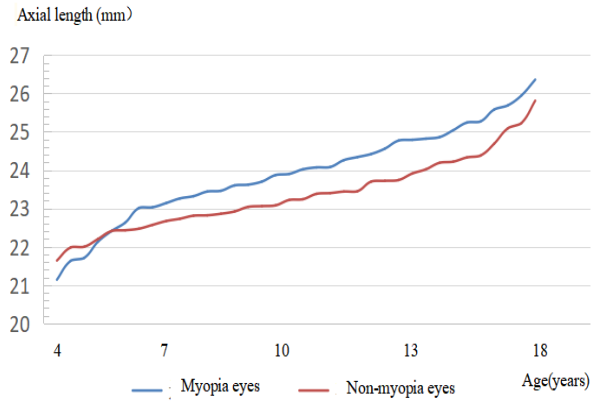
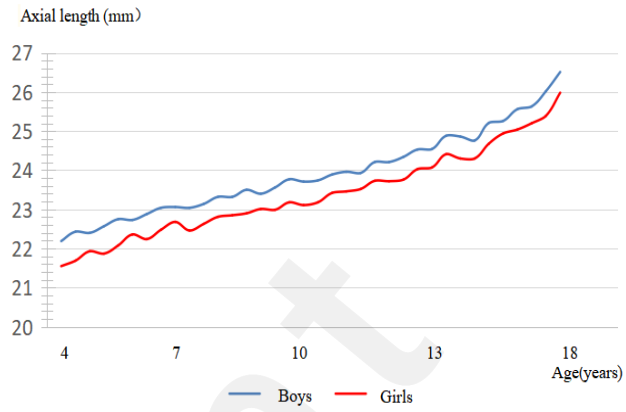


FIGURE1. Flow chart of the selection of participants



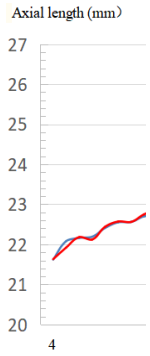
Note: $P>0.05$ in 4- to 6-year age group, $P<0.05$ in other age groups

FIGURE2. Comparison of axial length between myopic and non-myopic eyes at different ages



Note: The eye axis of boys was longer than that of girls ($P<0.05$)

FIGURE3. Comparison of axial length in boys and girls



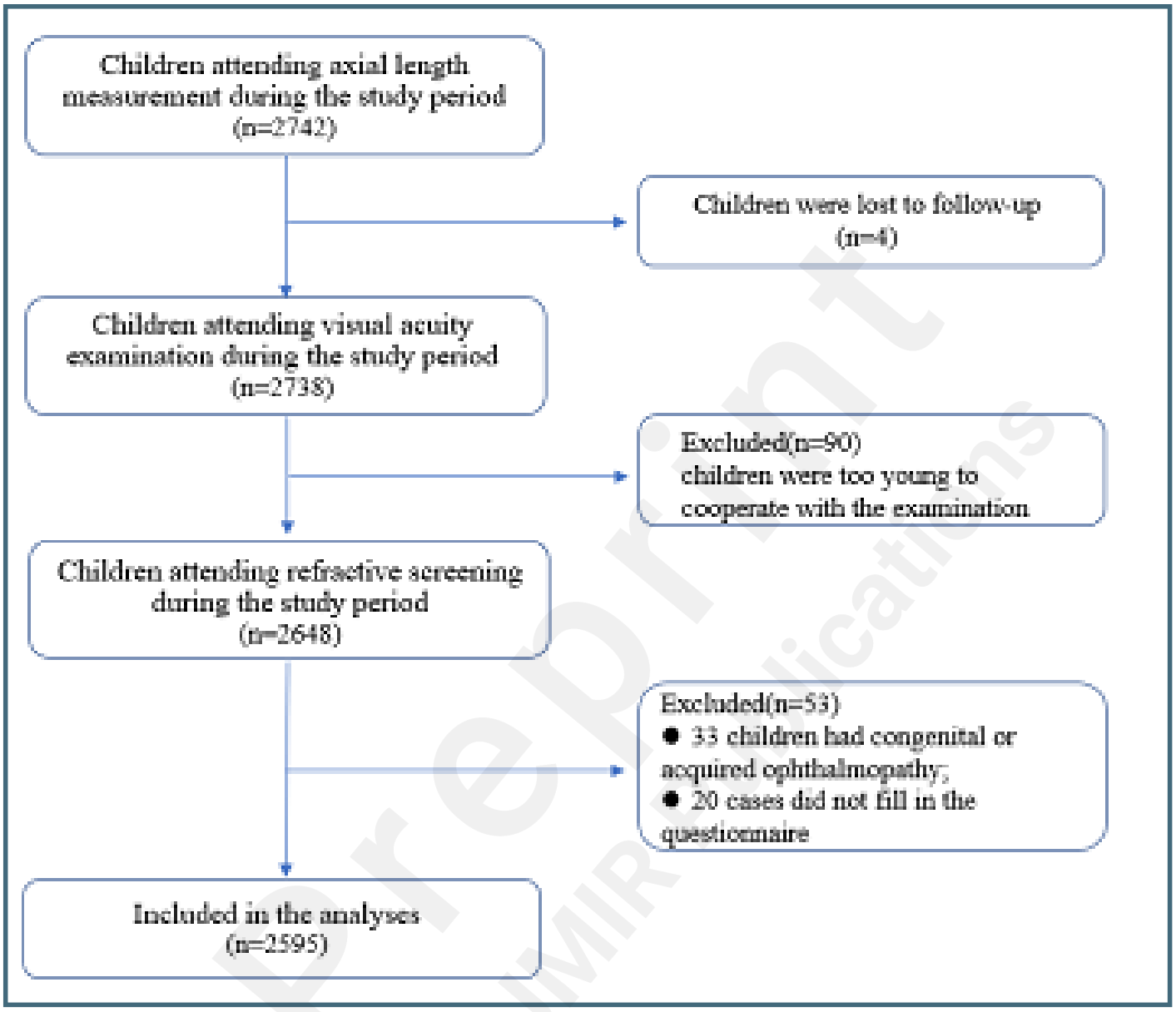
Note: $P>0.0$
for other age

FIGURE4. C
right eyes

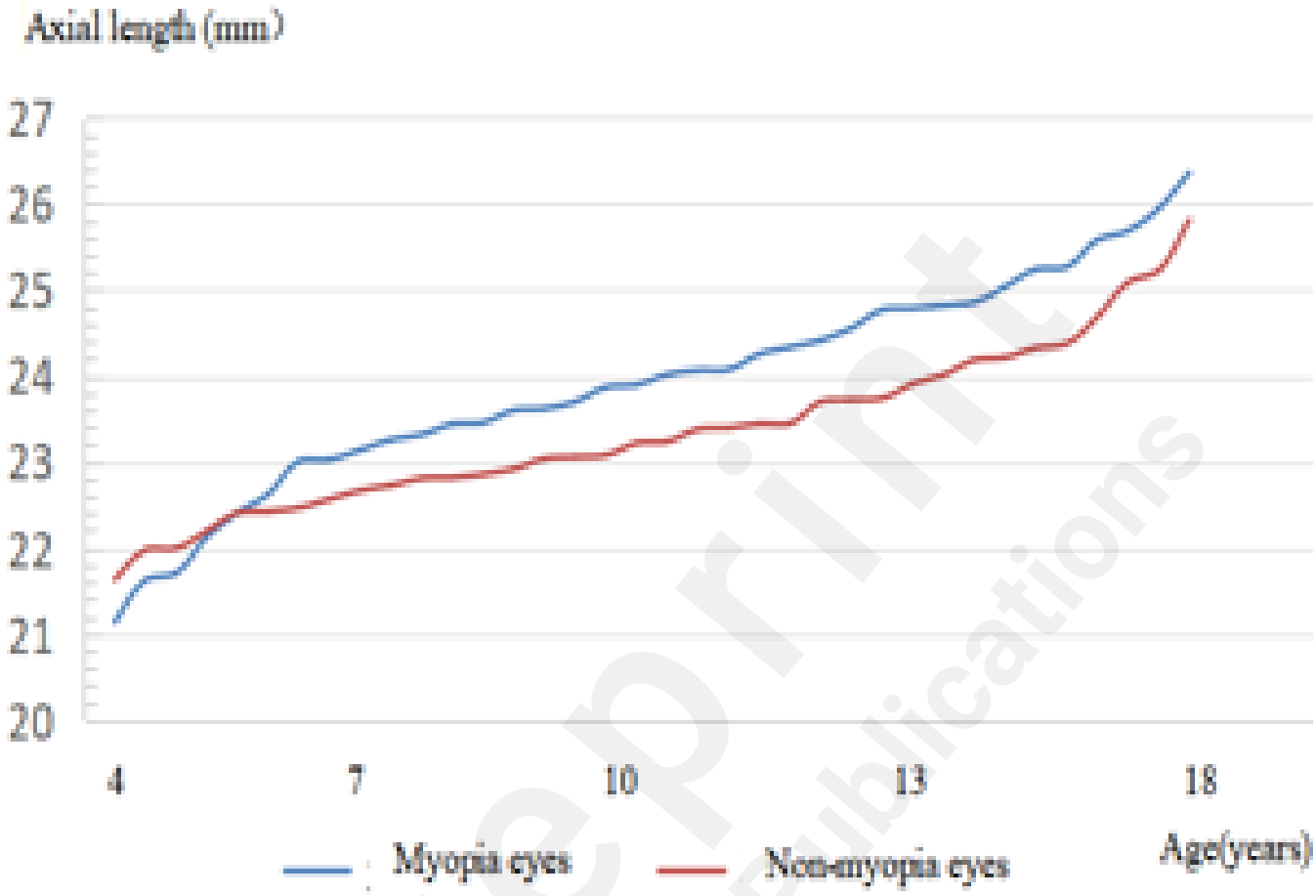
Supplementary Files

Figures

Flow chart of the selection of participants.



Comparison of axial length between myopic and non-myopic eyes at different ages.

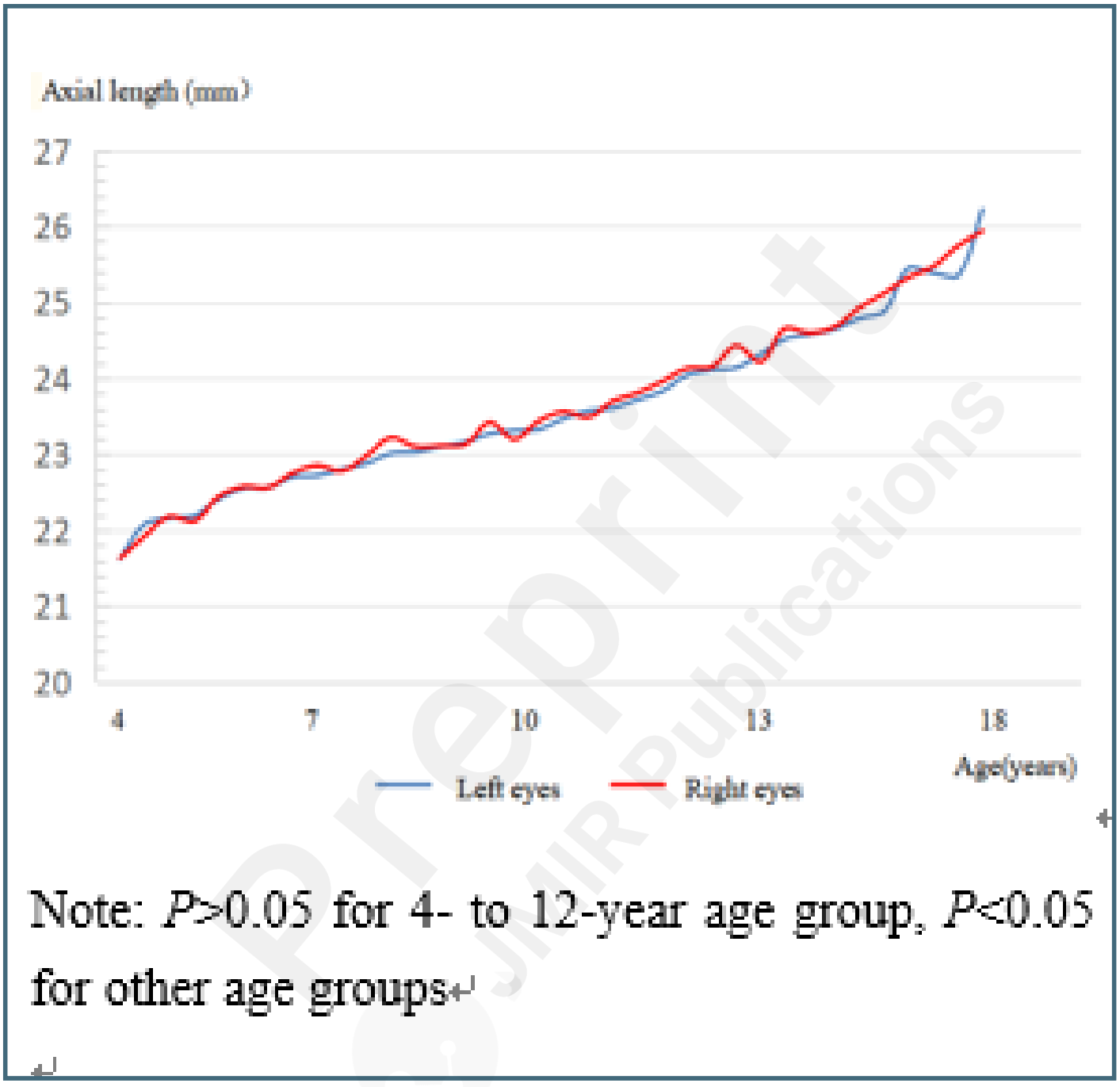


Note: $P>0.05$ in 4- to 6-year age group, $P<0.05$ in other age groups

Comparison of axial length in boys and girls.

Note: The eye axis of boys was longer than that of girls (P<0.05)

Comparison of axial length of left and right eyes.



Note: $P>0.05$ for 4- to 12-year age group, $P<0.05$ for other age groups