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Original Article

Investigation on the prevalence and influencing factors of myopia among children and adolescents in Liyang city

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Abstract: Objective: To investigate the prevalence of myopia among children and adolescents in a local area (Liyang City) of China and analyze the influencing factors, so as to formulate corresponding preventive measures. Methods: A questionnaire survey was conducted, mainly investigating subjects' age, gender, residence (urban/rural areas), parental myopia, daily time spent outdoors, daily sleep time, distance between computer screen and eyes, less than one punch (10 cm) from the chest to the edge of the desk when reading and writing, one inch (3 cm) between finger and pen tip when writing, number of in-school physical education (PE) classes, length of TV watching, and size of TV. The myopia of all participants was recorded. Results: This study enrolled 7,948 children and adolescents, including 4,733 (59.55%) cases of myopia, 1,025 (12.90%) of astigmatism, 251 (3.16%) of hyperopia, and 699 (8.79%) of anisometropia respectively. There were 2,519 (53.22%) cases of myopia in the left eye and 2,214 (46.78%) in the right eye. Low, moderate, and high myopia were determined in 2,682 (56.67%), 1,583 (33.45%), and 468 (9.89%), respectively. In terms of spherical equivalent (SEQ), a statistically lower SEQ was observed in urban areas (-1.56±0.46 d) versus suburban counties (-1.17±0.33 d), and in females (-1.68±0.30 d) compared with males (-1.17±0.44 d). The mean SEQ gradually decreased with age. The prevalence of myopia was 63.84% (2,436/3,816) in females, statistically higher than that of 55.59% (2,197/4,132) in males (χ^2=56.00, P < 0.0001). The incidence of myopia was statistically higher in urban areas (67.93% [3,321/4,889]) versus rural areas (46.16% [1,412/3,059]). Parental myopia, one inch between finger and pen tip when writing, daily time spent outdoors, daily sleep time, distance between computer screen and eyes, less than one punch from the chest to the edge of the desk when reading and writing, number of in-school PE classes, and daily length of TV watching were significantly correlated with the occurrence of myopia. Conclusions: Parents are advised to pay attention to daily time spent outdoors, sleep time, distance between the computer screen and the eyes, distance between the chest and the edge of the table when reading and writing, and length of TV watching of their children. As far as schools are concerned, PE activity time should be properly maintained to ensure that children have enough outdoor exercise time to reduce eye fatigue.

Keywords: Myopia, refractive error, epidemiological investigation, children, adolescents

Introduction

Myopia, the most common eye disease, is a kind of ametropia with the spherical equivalent (SEQ) of ≤ -0.5 D, and can be classified as primary myopia caused by factors such as eye axis elongation, secondary myopia induced by excessive refractive eye layer, and pseudomyopia that is reversible after correction [1]. During the onset and progression of myopia, abnormalities in the local retina-sclera pathway cause the inhibition of fibroblast proliferation in the sclera and the downregulation of collagen, resulting in loss or thinning of the sclera [2, 3]. According to statistics, 80-90% of young people in East and Southeast Asia suffer from myopia, of which 20% are highly myopic [4]. Myopia shows an increasing incidence among children and adolescents in recent years [5]. In China, it has become a public health issue, with a reported incidence as high as 63.1% in East China and a nonlinearly increased prevalence with the

increase of grades [6]. Another prospective analysis [7] based on school-age children in Tianjin, China, revealed a prevalence of myopia of 78.2%, and children and teenagers are facing a great threat of myopia. Time spent outdoors, dim light, short sleep duration, and living in urban areas may be the inducements of myopia in school-age children [8]. The high incidence of myopia means that more and more people may face the risk of low vision or even blindness. Therefore, it is necessary to know the prevalence of myopia in children and adolescents, and to screen the genetic and environmental factors that cause or influence myopia.

At present, there is no research discussing the incidence of ametropia and myopia among children and adolescents in Liyang City, China. Whereas, necessary epidemiology is helpful to describe the specific distribution of ametropia in local children and adolescents, help people understand the local myopia epidemic, and explore the pathogenesis of the disease, which is conducive to formulating targeted intervention, control and treatment strategies according to the related risk factors screened [9]. Accordingly, to understand the prevalence and risk factors of myopia in children and adolescents in Liyang City, China in recent years, this study went deep into urban and suburban schools and included 7948 cases to screen myopia and ametropia in the age groups from kindergarten to senior high school, and explore the potential influences of factors such as age, sex, area, outdoor activities time, and parental myopia on children and adolescents' myopia. The purpose is to understand the influence of related risk factors on myopia, and to formulate related interventions. The findings of this study will provide a new approach for the prevention and control of myopia among children and adolescents in the local area of China.

Methods

Research design

The method of stratified cluster random sampling was adopted to select kindergartens, primary schools, as well as junior and senior high schools in Liyang City and its suburbs to conduct school enrollment survey and subject screening.

Inclusion criteria: All the children and adolescents enrolled had corrected visual acuity (VA) ≥ 5.0 or VA of the corresponding age, no previous eye surgery, nor organic eye diseases as indicated by examinations like slit lamp microscope and ophthalmoscope.

Exclusion criteria: Those who were wearing orthokeratology and rigid gas permeable contact lenses were excluded.

Finally, 7,948 participants were included, including 3,816 females and 4,132 males. In terms of age groups, there were 629 cases in kindergartens, 3,416 in primary schools, 1,869 in junior high schools and 2,034 in senior high schools. As far as residential areas were concerned, 4,889 cases lived in urban areas and 3,059 in rural areas. This study followed the guidelines of the *Declaration of Helsinki* regarding humans as research subjects and was approved by the Ethics Committee of Liyang Hospital of Chinese Medicine.

Measurement methods

(1) The school enrollment survey was conducted with the cooperation of Liyang Municipal Health Commission and educational institutions. Each survey was simultaneously carried out by three groups that were composed of ophthalmologists and optometrists who carried standard VA charts, automatic refractors and other equipment to conduct a centralized survey in school classrooms or auditoriums. The results of the investigation were recorded on the spot, and a notice of abnormal VA was issued for those who met the diagnostic criteria of myopia and needed further reexamination in the ophthalmology center of our hospital.

(2) For each subject who met the diagnostic criteria of myopia, Compound Tropicamide Eye Drops was used as a cycloplegic agent, which was dropped once every 5 minutes for 3 times in total. After 20 minutes, the condition of cycloplegia was judged according to the pupillary light reflex, and cycloplegia was defined as the absence of pupillary light reflex and pupil diameter > 6 mm. Thirty minutes later when the ciliary muscle was determined to be paralyzed, static diopter (D) was obtained by an experienced optometrist. The SEQ (D) was calculated by the following formula: SEQ = sphere + 1/2 cylinder.

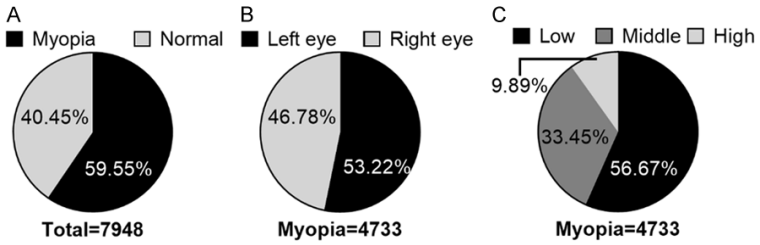

Figure 1. Overall situation of juvenile myopia. A: Total incidence of myopia; B: Statistics of left and right eye myopia in myopic patients; C: Statistics of myopia degree among myopia patients.

Table 1. Detection of refractive status in children and adolescents

Refractive status	Number of cases (percentage)
Myopia	4733 (59.55%)
Astigmatism	1025 (12.90%)
Hyperopia	251 (3.16%)
Anisometropia	699 (8.79%)

(3) Low VA referrers to VA < 1.0 or less than the normal value of children of the same age. Diagnostic criteria of emmetropia and ametropia: emmetropia: -0.25 D +1.50 D; hyperopia: ≥ +1.50 D; myopia: ≥ -0.50 D; astigmatism: D difference between two meridians of the same eye ≥ 0.50 D; anisometropia: spherical difference ≥ 1.50 D, cylindrical difference ≥ 1.00 D.

(4) Classification of myopia: (1) Low myopia: SEQ (sphere +1/2 cylinder) < -3.0 D. (2) Moderate myopia: -3.0 D < SEQ < -6.0 D. (3) High myopia: SEQ > -6.0 D. (4) Ultra-high myopia: SEQ > -9.0 D.

Quality control

Before the investigation, three full-time physicians received standardized training to conduct VA and eye examinations on the surveyed population. The kappa-test (κ) showed a check consistency rate of 0.94-0.97. Retinoscopy consistency control: 3 technicians with rich experience in retinoscopy were specially responsible for retinoscopy and optometry, and the check consistency rate (κ) was 0.93-0.96.

Statistical analysis

Quantitative data and enumeration data were expressed in the form of mean ± standard variance and number of cases (percentage), respectively. For the comparison of enumeration data, a Chi-square test was used for statistical difference identification between myopia and non-myopia groups. As to quantitative data, an independent sample t test and a one-way ANOVA were adopted to identify the differences between groups and among multiple groups, respectively. All tests were two-tailed t-tests, and the difference was statistical when $P < 0.05$. All statistical analyses were performed using SPSS 20.0 software, and data visualization was carried out by GraphPad Prism 8.0.

Results

Overall situation of juvenile myopia

A total of 7,948 children and adolescents were enrolled, of whom 4,733 (59.55%) had myopic and 3,215 (40.45%) had no (**Figure 1A**). Left-eye myopia was observed in 2,519 (53.22%) of myopia cases, and right-eye myopia in 2,214 (46.78%) (**Figure 1B**). As for the degree of myopia, low, moderate, and high myopia accounted for 2,682 (56.67%), 1,583 (33.45%), and 468 (9.89%) of myopia patients, respectively (**Figure 1C**). We also calculated the detection rate of refraction in children and adolescents, including 4,733 cases of myopia with a detection rate of 59.55%, 1,025 cases of astigmatism with a detection rate of 12.90%, 251 cases of hyperopia with a detection rate of 3.16%, and 699 cases of anisometropia with a detection rate of 8.79% (**Table 1**).

Statistics of myopia population in different age groups, genders and regions

The influences of different ages, genders and regions on myopia were analyzed. This study included 629 kindergarten children, 3,416 primary school students, 1,869 junior high school students and 2,034 senior high school students. As shown in **Table 2**, the incidence of myopia was 9.22% (58/629) in kindergartens, 40.54% (1,385/3,416) in primary schools, 82.18% (1,536/1,869) in junior high schools, and 86.23% (1,754/2,034) in senior high schools, showing statistical significance among different age groups and a higher prevalence in junior and senior middle school students.

Table 2. Statistics of myopia prevalence in different age groups

	Myopia	Non-myopia	χ^2	*P* value
Kindergarten	58	571	2172	< 0.0001
Primary school	1385	2031		
Junior high school	1536	333		
Senior high school	1754	280		

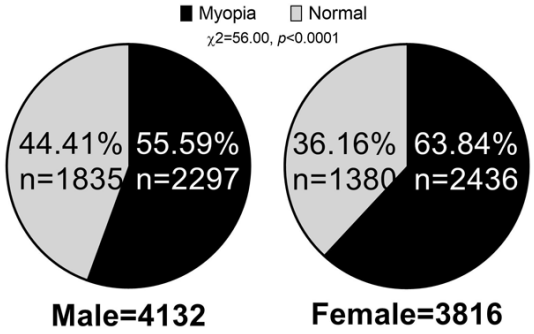

Figure 2. Prevalence of myopia in children and adolescents of different genders.

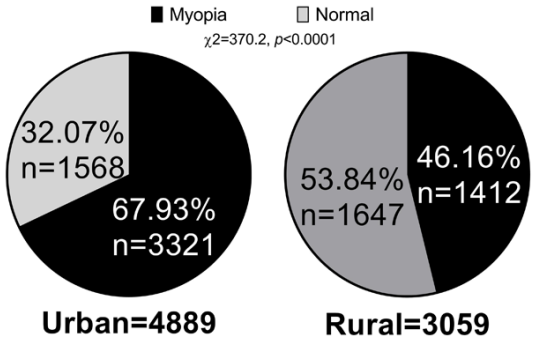

Figure 3. Prevalence of myopia among urban and rural children and adolescents.

Among the 3,816 females and 4,132 males included, the incidence of myopia was 63.84% (2,436/3,816) in females and 55.59% (2,297/4,132) in males, indicating a significantly higher prevalence of myopia in females (χ^2=56.00, P < 0.0001; **Figure 2**). In addition, there were 4,889 urban residents and 3,059 rural residents. The incidence of myopia in urban residents was 67.93% (3,321/4,889) and that in rural residents was 46.16% (1,412/3,059), suggesting a statistical higher incidence in urban residents (χ^2=370.2, P < 0.0001; **Figure 3**).

Univariate analysis of influencing factors of myopia in children and adolescents

In this study, the participants were divided into myopia group and non-myopia group according to whether they were nearsighted or not, and the influencing factors except age, gender and residence were explored. As shown in **Table 3**, parental myopia, one inch between finger and pen tip when writing, daily time spent outdoors, daily sleep time, distance between computer screen and eyes, less than one punch from the chest to the edge of the desk when reading and writing, number of in-school physical education (PE) classes, and daily length of TV watching were statistically associated with the occurrence of myopia in children and adolescents (all P < 0.05), while TV size has no correlation with it (P > 0.05).

Mean SEQ distribution in children and adolescents

The distribution of mean SEQ in different regions, age groups and genders was also statistically analyzed. Statistically, a lower SEQ was observed in urban areas (-1.56±0.46 d) versus suburban counties (-1.17±0.33 d), and in females (-1.68±0.30 d) compared with males (-1.17±0.44 d). In addition, the mean SEQ gradually decreased with age, as shown in **Table 4**.

Discussion

Myopia is a common eye disease that adversely affects most children and adolescents, which in severe cases, may even lead to irreversible visual impairment and blindness [10]. The incidence of myopia is increasing year by year and is estimated to increase from 28% in 2010 to 50% in 2050 when 4.9 billion people are affected [11-13]. This study surveyed 7,948 children and adolescents from a regional city in China and analyzed the distribution of myopia among these subjects.

Myopia is the one that accounts for the majority among various types of refractive error, as indicated by our research. Irving et al. [14] found that the distribution of ametropia was related to age, with the SEQ of children under 1 year old being the most positive and that of young peo-

Table 3. Univariate analysis of influencing factors of myopia in children and adolescents

	Myopia group (n=4733)	Non-myopia group (n=3215)	χ^2	*P* value
Parental myopia			143.3	< 0.0001
Yes	2621	1241		
No	2112	1974		
Daily time spent outdoors			1158	< 0.0001
< 30 min	2832	885		
30-60 min	1121	718		
61-120 min	497	1129		
> 120 min	283	483		
Daily sleep time			11.66	0.0006
< 7 h	2152	1587		
7-9 h	2581	1628		
Distance between computer screen and eyes			129.7	< 0.0001
< 50 cm	2048	1052		
50-60 cm	1273	1221		
60-70 cm	1412	942		
Less than one punch (10 cm) from the chest to the edge of the desk when reading and writing			256.1	< 0.0001
Never	924	698		
Occasionally	1263	1324		
Frequently	1524	796		
All the time	1022	397		
One inch (3 cm) between finger and pen tip when writing			21.81	< 0.0001
Never	1212	854		
Occasionally	1121	851		
Frequently	1265	718		
All the time	1135	792		
Number of in-school physical education classes			424.4	< 0.0001
0 per week	29	21		
1 class per week	2158	789		
2 classes per week	1183	1285		
3 classes per week	752	687		
4 classes per week	324	162		
5 or more classes per week	287	271		
Daily TV watching time				
< 30 min	658	981		
30-60 min	1024	1125		
61-120 min	1199	752		
> 120 min	1852	357		
TV size			6.334	0.1756
< 55 inches	925	651		
55 inches	1056	695		
65 inches	974	612		
75 inches	858	639		
> 75 inches	920	618		

ple aged under 27 being the most negative. Similarly, our results indicate that the mean SEQ becomes increasingly negative with age (kindergarten through high school), which cor-

Table 4. Distribution of mean spherical equivalent in children and adolescents

	n	Mean spherical equivalent	t	*P* value
Residence			40.26	< 0.0001
Urban areas	4889	-1.56±0.46		
Suburban counties	3059	-1.17±0.33		
Academic period			505.00	< 0.0001
Kindergarten	629	-0.49±0.41		
Primary school	3416	-1.19±0.27		
Junior high school	1869	-1.64±0.29		
High school	2034	-1.83±0.06		
Sex			59.39	< 0.0001
Male	4132	-1.17±0.44		
Female	3816	-1.68±0.30		

relates with the trend in the prevalence of myopia across age groups. We found that the incidence of myopia was the highest among high school students, while that among young children was only 9.22%. Besides, the incidence of myopia was found to be higher among women than in men, possibly because women spend more time working at close range, resulting in less time for outdoor activities [15]. The incidence of myopia also seems to vary depending on where you live. Our results suggest that living in urban areas is associated with a higher incidence of myopia than living in rural areas. A survey [16] reported that residents of high population density areas have a longer axial length and a more negative diopter. Compared with the countryside, urban population density is denser, and the relatively narrow living space is more likely to affect children's eye development, leading to myopia.

Interestingly, we determined that parental myopia, one inch between finger and pen tip when writing, daily time spent outdoors, daily sleeping time, distance between computer screen and eyes, less than one punch from the chest to the edge of the desk when reading and writing, number of in-school PE classes, and daily length of TV watching were all risk factors for myopia. It has been suggested that parental myopia is an important factor of myopia in Asian children, which means that children with one or both parents with myopia are more likely to develop early onset myopia [17]. Daily time spent outdoors, daily sleep time and number of in-school PE classes are considered "eye rest time", while daily TV watching time, on the contrary, is "eye working time". The longer the working time and the shorter the rest time, the easier it is to damage the eyes. The increased "rest time" can effectively slow down the myopic shift in refractive error, thus preventing the occurrence of myopia [18]. At the same time, adequate outdoor activities and PE classes increase children's exposure to sunlight and regulate the synthesis of vitamin D and dopamine in the human body, both of which are important factors to prevent myopia [19, 20]. Regarding sleep time, it was suggested [21] that circadian rhythm is closely related to eye growth and refractive development, and the light-dark cycle regulates retinal signal transduction, thereby affecting refractive development. Hence, parents are advised to pay attention to the daily time spent outdoors, sleep time, distance between computer screen and eyes, distance between the chest and the edge of the table when reading and writing, and length of TV watching of their children. For schools, it is necessary to properly maintain physical activity time to ensure that children have enough outdoor exercise time to reduce eye fatigue.

The limitations of this study are as follows: First, the limited research time makes it impossible to discuss the trend of the incidence of myopia in recent years. In the follow-up study, we plan to collect the incidence of myopia among children and adolescents in a certain period of time. For example, we can count the prevalence of myopia among children and adolescents in Liyang city from 2013 to 2022 and discuss the incidence of myopia and the changes of related influencing factors in the first 5 years and the latter 5 years. Second, this study only discussed the incidence of myopia among local children and adolescents without adjusting for other age groups. Future studies will also investigate the prevalence of myopia and related factors in adults. Thirdly, the epidemiological research scope only included the population of myopia among children and adolescents in Liyang City. We plan to expand the research scope in follow-up studies. For example, we will explore the epidemiology of

myopia among children and adolescents in larger area of China.

To sum up, myopia is still the most common type of refractive error among children and adolescents in Liyang City. Senior high school students, females and living in urban areas are associated with an increased possibility of developing myopia. Parental myopia, one inch between finger and pen tip when writing, daily time spent outdoors, daily sleep time, distance between computer screen and eyes, less than one punch from the chest to the edge of the desk when reading and writing, number of in-school PE classes and daily length of TV watching are all possible risk factors for myopia. In terms of mean SEQ, women and urban residents have a lower SEQ, and the value decreases gradually with age.

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Disclosure of conflict of interest

None.

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