Refractive errors and visual impairment among children and adolescents in southernmost China

Li Peng
Department of Ophthalmology, Central South University Xiangya School of Medicine Affiliated Haikou Hospital
Ling Gao
Department of Neurosurgery, Central South University Xiangya School of Medicine Affiliated Haikou Hospital, Haikou, Hainan, 570208, China.
Yunyan Zheng
Department of Ophthalmology, Central South University Xiangya School of Medicine Affiliated Haikou Hospital
Yanan Dai
Department of Ophthalmology, Changsha Central Hospital, University of South China, Changsha, Hunan, 410004, China
Qing Xie (opht_xq@163.com)
Department of Ophthalmology, Central South University Xiangya School of Medicine Affiliated Haikou Hospital

Research Article

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Abstract

Background: Refractive errors and visual impairment in southernmost China have not been reported previously. We aim to investigate and determine the age-specific prevalence of myopia, hyperopia, astigmatism, and visual impairment based on a large population cross-sectional study in Hainan area of southernmost tropical province in China.

Methods: A population-based sample of 31,524 children aged 6-15 years from Hainan was assessed. Non-cycloplegic autorefraction and visual acuity (VA) analyses were performed on all participants and a subgroup of participants undergoing cycloplegia.

Results: Of all participators, 22.986% presented uncorrected VA (UCVA) decreased worse than 0.3logMAR, 17.206% presented UCVA decreased worse than 0.5logMAR and 46.95% presented abnormal UCVA [worse than 0.1logMAR (≥6, <8 years old) and worse than 0logMAR(≥8years and older)] at least in one eye. The overall prevalence of myopia [spherical equivalent (SE) ≤−0.50 D] and high myopia (SE≤−6.00 D) were 45.97%, 0.96% respectively. Hyperopia [SE ≥+1.00 D (≥7 years old) and SE ≥+2.00 D (≥6, <7 years old)] and significant hyperopia (SE≥+3.00 D) were 4.21% and 0.62%, respectively. Astigmatism [cylinder≥1.00 D (≥7 years old) and ≥+1.75 D (≥6, <7 years old)] was found in 31.87%.

Conclusions: Myopia was the most common refractive error in southernmost province in China (Hainan). Its prevalence increased with age, while hyperopia prevalence showed a decreasing trend. However, myopia, especially high myopia prevalence was much lower than in other urban regions across China, as residents of Hainan may benefit from more ultraviolet B (UVB) radiation during daylight exposure.

Background

Refractive errors (RE) are the most common cause of visual impairment and disability in children and adolescents worldwide (1). They can be classified into myopia, hyperopia and astigmatism (2). Approximately 12.8 million children are estimated to have visual impairment from uncorrected refractive errors worldwide (3). Refractive errors represent an excessive increase in myopia which has huge social, educational, and economic consequences to society, especially for those suffering from high myopia (4, 5). Currently, the prevalence of myopia is increasing worldwide. Studies have been performed to excavate the possible factors related to refractive errors. Environmental and genetic factors have both been implicated (6, 7). Some researchers confirmed that time spent outdoors playing is an important environmental factor for preventing myopia (8), although there is no unanimous agreement on whether different outdoor activities affect the progression of myopia. Previous studies have suggested that daylight exposure holds a dose-response relationship with ocular axial elongation, which plays a vital role in reducing myopia (9).

As is well-known, the highest rates of myopia occur in China with over 80% of the younger generation impacted at present (10), making it a major current concern. Hainan, the only tropical island and province in China, stretches from 3.30°N~20.07°N latitude with the longest daylight exposure in China. Like in other areas of China, Hainan children proceed to primary school education at age 6 years and fulfill 9 years of compulsory education. The analysis of visual refractive errors in this isolated island has not been reported to date. Therefore, it is important to identify the prevalence in Hainan children and adolescents.

To date there are no reports of refractive errors and visual impairment published for the Hainan population. This report focuses on the age prevalence of myopia, hyperopia and astigmatism in children and adolescents in Hainan province in China. It aims to contribute new data on refractive errors and visual acuity for this population.

Methods

This large population cross-sectional study was approved by the research ethics committees of Central South University Xiangya School of Medicine, Affiliated Haikou Hospital and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from their parent or legal guardian of all participants.

Prior to enrolling school children and adolescents, the purpose and methods of this study were explicated by the investigators. This was a cross-sectional study conducted from May 2018 to July 2018. Participating children and adolescents were from 12 primary schools and 7 junior middle schools. All students from different grades were invited to participate. Of 31,780 eligible students, 31,524 students took part in this study (99.20% participation rate). The reasons for exclusion from the analysis of refraction were failure to complete the examination, previous ophthalmic surgery, wearing intraocular lenses and eye diseases including ocular trauma, cataracts and glaucoma. Uncorrected visual acuity (UCVA) was tested for each eye by trained doctors under bright daylight with a measured distance of five meters. UCVA was measured using the Chinese standard logarithm visual chart and logMAR UCVA was performed for subsequent analyses.

All the participants accepted the UCVA testing, computer optometry, slit lamp microscope examination, the cover-uncover test, the alternate cover test and pupil fundus examination. The children and adolescents underwent all examinations by two trained ophthalmologists and auto-refractometry was conducted by two experienced senior optometrists. Each eye was measured without cycloplegia at least three times to obtain a mean value via performing a NIDEK RM (NIDEK, ARK-1, Japan). Repeated measurements were performed if one measured outcome deviated from the other two by more than 0.50 D. Measurements of three reliable examinations were averaged for analysis.

Population subgroup for a cycloplegic autorefraction study

The refractometric results were considered to be influenced by active accommodation responses in children with non-cycloplegic autorefraction (1). A small fraction of these participants with accepting parents were assigned to cycloplegia measurement with no other strict inclusion or exclusion criteria. Cycloplegia assessment was performed using 1% cyclopentolate eye drops. Refractive error measurements were the same as above before and after cycloplegia.

Definitions of Myopia, Hyperopia and Astigmatism

Spherical equivalent refractive errors were counted as the sphere power plus 1/2 of the cylinder power (SER=sphere+½ cylinder). Myopia was defined as spherical equivalent (SE) ≤−0.50 diopter (D) in at least one eye. Non-myopia was defined as follows, logMAR visual acuity ≤0.1 in both eyes, no glasses or ophthalmic history (11). Since UCVA was a study factor to consider in all children, UCVA 0 log MAR in both eyes was not used for study exclusion. Hyperopia was defined as SE ≥+1.00 D (≥7 years old) and SE ≥+2.00 D (≥6, <7 years old) in at least one eye for the primary analysis. Cylindrical refractive error was classified as positive correcting cylinder form. Astigmatism was defined as cylindrical refractive error in at least one eye: ≥1.00D (≥7 years old) and ≥+1.75 D (≥6, <7 years old). When one eye was myopic and the other hyperopic, the participant was considered both as a myope and as a hyperope. If a refractive error was present only in one eye, the participant was still categorized into the appropriate eye group for each condition in the analysis. Meanwhile, myopia (SE≤-1.00D, ≤-5.00D, ≤-6.00D) and Hyperopia (SE≥+0.50D, ≥+3.00D) were also calculated and presented in this study for further research.

Definition of decreased visual acuity visual impairment

Abnormal UCVA was defined as UCVA worse than 0.1 logMAR (≥6, <8years old) and worse than 0 logMAR (≥8years and older) in at least one eye for its clinical diagnosis. Conversely, in all other conditions it was defined as normal UCVA. Decreased visual acuity (VA) was defined as presenting with worse than 0.3 logMAR in at least one eye. Low vision (LV) was defined as decreased UCVA, worse than 0.5 logMAR in at least one eye.

Statistical Analysis

Prevalence was calculated as the percentage of participants with the particular type of refractive error to the total number of children who successfully completed refraction for at least one eye. Results are showed for 3 age groups from 6 years to 15 years old. R statistical analysis package (version 3.5.3) was used to statistically analyze the data with a 0.05 significance level for probability (p). Confidence intervals (CI) presented for proportions are exact binomial 95% confidence intervals. No missing data were found.

Results

Population Characteristics

31,524 children and adolescents participated in this study and completed all the clinical eye examinations. 17,794 were boys and 13,730 were girls. The proportion of male participants was a little higher than that of female participants (56.446% vs.43.554%, P<0.0001). Mean age of the participants was 9.73±2.42 years (range 6 to 15 years). The participants were grouped into three according to their ages≥6, <9years old for group6-8; ≥9, <12years old years for group9-11≥12; and ≤15years old for group12-15). The number of children were 11,277, 12,292, 7,955 for the three groups, respectively. The demographic characteristics of the participants are demonstrated in Figure. 1AB.

UCVA visual acuity independently reduces with age in left or right eyes

The overall mean logMAR was 0.145 (±0.279) for the right eyes and 0.140 (±0.274) logMAR for the left eyes. Each group's overall mean logMAR is presented in Table1. There were no statistically significant differences between left and right eye groups (p<0.001). Eyesight got worse with increasing age. (Figure. 1CD).

22.99% participants had decreased UCVA in at least one eye (7246/31,524), 2.15% of group6-8(677/31,524), 10.60% of group9-11 (3349/31,524) and 10.21% of group12-15 (3,220/31,524). LV was seen in 17.21% of all the participators (5424/31,524), 1.30% of group6-8(408/31,524), 7.92% of group9-11(2495/31,524) and 8.00% of group12-15(2,521/31,524). Abnormal UCVA was observed in 46.95% (14,799/31,524) of all the participants, 9.20% of group6-8 (2,901/31,524), 21.59% of group9-11 (6,806/31,524) and 16.15% of group12-15 (5,092/31,524). (Table1), (Figure. 2).

Refractive Error varies with age

The overall mean SE was -1.16D (±1.43), for right eyes and -1.13D (±1.56) for left eyes. The mean SE was -0.98 D (±1.37) in group6-8, -1.16 D (±1.42) in group9-11, and -1.39D (±1.50) in group12-15 for the right eyes. The mean SE differences between the three age groups were statistically significant p1,2,3<0.001which indicated negative SE increase with age. (Table1) (Figure. 3).

Prevalence of Myopia, Hyperopia and Astigmatism

Table 2 summarizes the prevalence of myopia, hyperopia, and astigmatism determined in each age group between 6 to 15 years. The overall prevalence rates of myopia (≤-0.50D D) and hyperopia were 45.97 % (CI: 45.4-46.5%) and 4.21% (CI:4.0-4.4). Moreover, myopia and hyperopia prevalence rates were 31.21% (CI: 30.4-32.1%) and 5.60% (CI: 5.2-6.0%) in group6-8, 50.08% (CI: 49.2-51.0%) and 3.61% (CI: 3.3-3.9%) in group9-11, 60.54% (CI:59.5-61.6%) and 3.18% (CI:3.4-4.3%) in group12-15, respectively. Differences were seen in myopia and hyperopia prevalence between groups. Both were associated with age. The overall prevalence of high myopia (SE≤−6.00 D) was 0.96% (CI: 0.9-1.1%); 0.19% (CI: 0.1-0.3%) in group6-8, 0.93% (CI: 0.8-1.1%) in group9-11 and 2.10% (CI: 1.8-2.4%) in group12-15. The overall prevalence of significant high hyperopia (SE ≥+3.00 D) was 0.62% (CI: 0.5-0.7 %); 0.67% (CI: 0.5-0.8 %) in group6-8, 0.59% (CI: 0.5-0.7%) in group9-11 and 0.58% (CI: 0.4-0.7%) in group12-15. The overall prevalence of astigmatism was 31.87% (CI: 31.4-32.4%); 29.88% (CI: 29.0-30.7%) in group6-8, 32.70% (CI: 31.9-33.5%) in group9-11 and 33.43% (CI: 32.4-34.4%) in group12-15.

Figure. 4 illustrates the prevalence of myopia, hyperopia and astigmatism by year of age in 6 to 15-year-olds. Myopia and high myopia prevalence appeared increased across the age range with a significant trend, but this contrasted with hyperopia prevalence. Results for astigmatism revealed that prevalence appeared relatively stable with no significant trend. Different SE statuses were also calculated. (Table2, Figure. 4).

Cycloplegic autorefraction subgroup study results

1,003 children and adolescents included in the subgroup of participants 546 were boys and 457 were girls with a mean age of 9.90±2.30. (median:10 years; range: 6–15 years). The overall mean SE was -1.27±1.43 D , -0.90±1.66 D for right eyes and -1.24±1.51D,-0.84±1.75D for left eyes before and after cycloplegia respectively. The average difference of SE was -0.37±0.85D for right eyes and -0.40±0.84 D for left eyes before and after cycloplegia.

Discussion

Based on the data from large population-based multi-age group studies, we presented

prevalence estimations for myopia, hyperopia and astigmatism in Hainan, the tropical island of China with children aged 6 to 15 years old. This is the first report about refractive errors in this emblematic population of children and adolescents in farthest south China. It has revealed myopia to be the most common type of refractive error.

In our study, we found that prevalence of myopia, high myopia and uncorrected visual acuity impairment was lower in the first 3 years of primary school, but increased with age and grade as intensive continuing education increased. However, hyperopia prevalence declined with age. The average SE results were -0.98 D (±1.37), -1.16 D (±1.42), and -1.39D (±1.50) in the above three age groups respectively. In addition, low myopia is the most common form of myopia, but the prevalence of high myopia increased with advancing age.

Therefore, compared with recently published 5 year child and adolescent myopia data from other countries, the prevalence of myopia in our sample was significantly higher than Netherlands (2.4%) (7), Saudi Arabia (2.**7**%) (12), Norway(13.0%) (10)**,** Colombia (14.9%) (13), North India (21.1%) (14), Denmark (17.9%), Spain (20.0%) (9) and Poland (16.33%) (15). However, it is similar to France (42.7%) (16), but lower than in Korea (51.9%) (3) (see Table 3). Compared with different regions across China, the prevalence of myopia in our study within the same age range of children was lower than that of Feng Hua (87.65%, Eastern China) (17)，Guangzhou (69.9%, Southern China) (17)，Beijing (70.9%, Northern China) (18)，Qingdao (52.02%, Eastern China）(18), Chongqing (54.9%, Western China), and Tianjin (53.9%, Northern China) (19), but higher than Mangshi (35.9%,Western Rural China) (20) and Tibet（28.51%, Plateau of China）(20). (Table 3)(Figure. 5).

The overall prevalence of high myopia was very low (0.96%), lower than many studies with a similar age group，such as studies from Korea (5%) (3), Spain (3.6%)(9)，Indonesia (8.54%) (9, 21), and the aforementioned Chinese cities. The overall prevalence of hyperopia (SE$\geq$+0.50 D) (13.80%) is significantly higher than Indonesia (0.73%) (9), America(5%)(22) and Chongqing (3%, Western China) (23); Significantly lower than Norway (57.0%) (10)**,** Brazil (59.8%) (24), and Colombia (32.3%) (13). However, it is similar to Korea (13.4%) (3). A thorough comparison of refractive error based on studies published during the last 5 years is summarized in Table3.

Mean SE in our study was better than Guangzhou (-1.7± 1.9)(17) ,Tianjin (-0.99 ± 1.69 D) (19) in 6-12 year-olds, and Yiwu (-2.61 ±2.01)(25) in 12 year-olds. It was however worse than Poland (+0.55±1.23) (15) and Norway (+0.51 ±1.29) (10)**.** In this study, the trends of different SE were also calculated. The trends showed a close ratio between SE$\leq$-0.5 and SE$\leq$-1.00, a low ratio of SE$\leq$-5.00 and SE$\leq$-6.00. This indicated another feature that although myopia was common, it could develop into high myopia slowly. (Figure.5).

The exact mechanism associated with myopia was undetermined, but could be explained by many related factors, such as genetic factors, environment, lower refractive status at baseline, shorter reading distance, outdoor exposure and so on. Overall, increased incidence of myopia remains a global public health challenge, which necessitates novel therapeutic methods to curb its progression.

Even though genetic factors are considered to be important in myopia development, especially high myopia (7, 26), a multitude of studies on the large increase in incidence propose a much stronger effect of environmental factors in younger students. Some researchers hold the view that intensive continuing education and limited time outdoors are major risk factors (18). However, little evidence of the relationship between time spent at work and myopia was reported in Norway (10). This is important as Norway has a low myopia prevalence and being outdoors is a part of growing up. Many of the studies on myopia suggest that longer outdoor light exposure time correlated with a significant reduction in myopia prevalence and incidence among school students (9). High levels of daylight exposure were considered to be the environmental factor of greatest importance in preventing myopia (9). Haikou City, as the capital of Hainan Province, located in low-latitude tropical regions in China, experiences China's longest hours of sunshine and great radiant energy. The average sunshine hours are more than 2000 hours per year. The hypothesis that daylight exposure explains why prevalence of myopia in our study was lower than other regions of China cannot explain why it was higher than other countries at the same latitude, such as North India (14). In addition, at the same latitude, the incidence rate of myopia was higher than in other Asian children of the same age, but with lower high myopia prevalence (3)Therefore, daylight exposure may be an influential factor, but it does not fully explain myopia development.

Results of another study showed that increased computer use is related to myopia development before children reach 10 years of age. outdoor exposure may be important for intervention against myopia because it could mitigate near work activities, including computer use, reading time and distance (27).A systematic review of several studies has indicated an association between screen time and myopia, but Meta-analysis suggested that screen time was not related with prevalent and incident myopia. So, there is still a debate whether digital screen time would induce the higher risk of myopia (28). However, there is no question that more near work and less time spent outdoors would be affected by the increased use of digital devices.

As mentioned in the literature review, previous studies have noted the importance of UVB exposure in myopia. Increased UVB exposure reduces myopia, especially in adolescence (29). Violet light suppressed the axial length elongation in the chick myopia model, and myopia suppressive gene EGR1 was upregulated as revealed by expression microarray analyses (30). Several reports have shown that the increasing quartile of total UVB can contribute to decreased prevalence of myopia (31).

Hainan, with the longer time of UV exposure, is the smallest and southernmost province of China. As compared to many studies conducted in other provincial capital cities of China, low overall myopia prevalence (45.97%) and low overall high myopia prevalence (0.96%) were found in our screening population. In addition, numbers of nonmyopic students newly developing myopia annually are lower. The possible reasons for this difference may be associated with environmental influences. It is likely that the UVB exposure is one of the important factors in myopia development.

Our study contributes new knowledge to the field attributed to the latest and large population-based screening methods. When we defined refractive errors, monocular myopia, hyperopia and astigmatism were taken into consideration rather than performing statistical analyses on one of two eyes. Our approach thus represents the overall data unlike reports in other published papers. Our calculated myopia prevalence would therefore be artificially lower than now reported if we simulated the alternative approach from such studies.

Although myopia was defined as combined spherical equivalent with normal UCVA to reduce over-measuring of myopic magnitude, there is still a notable limitation of the present study. There is lack of cycloplegic refraction that might lead to over-estimation of myopia and under-estimation of hyperopia due to accommodation. The difference in refractive error prior to, and after cycloplegia was about 0.37 diopters in a small sample; consistent with other research findings (32). Regardless, the difference between pre- and post-cycloplegia was small and may not impose a significant clinical influence under real-world conditions in a large sample population. We also need further investigations to acquire data on ocular biometry and more detailed information about students. We certainly aim for this to be our next research focus.

Genetic and environmental risk factors may be taken into consideration to explain how refractive errors develop differently. Our results presented a higher myopia prevalence than European countries, which indicated the potential presence of a genetic predisposition to myopia in Asian populations. All in all, myopia in Asians is a serious health problem. Genetic heterogeneity, variation in circannual adaptation and environmental factors including timing and behavior patterns of exposure to myopia-generation are related to greater shift towards myopia. Therefore, it is important to dedicate effective control methods to slow myopia progression.

Conclusions

Myopia was the most common refractive error in southernmost province in China (Hainan). Its prevalence increased with age, while hyperopia prevalence showed a decreasing trend. However, myopia, especially high myopia prevalence was much lower than in other urban regions across China, as residents of Hainan may benefit from more ultraviolet B (UVB) radiation during daylight exposure.

Abbreviations

VA: visual acuity, UCVA: uncorrected visual acuity, UVB: ultraviolet B, RE: refractive errors, SE: spherical equivalent

Declarations

Ethics approval and consent to participate

This study was approved by the research ethics committees of Central South University Xiangya School of Medicine, Affiliated Haikou Hospital and adhered to the tenets of the Declaration of Helsinki (Ethical Approval Number: SC20200141). Informed consent was obtained from their parent or legal guardian of all participants.

Consent for publication

Not applicable

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Authors' contributions

LP, LG, and QX were primarily responsible for study design. LP and LG performed data acquisition and analysis, as well as drafting of the manuscript. YYZ and YND were also involved in data analysis. All authors reviewed and approved the final manuscript.

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Tables

Table1: Table of presenting visual acuity. Mean SE (standard deviation, SD) in diopters [D] and mean logMAR for the right eye.

Age groups	n	Low vision	Decreased UCVA	Abnormal UCVA	Mean SE[D]	Mean logMAR
6-8	11277	408 (1.29%)	677 (2.15%)	2901 (9.20%)	-0.981±1.37	0.054±0.15
9-11	12292	2495 (7.92%)	3349 (10.62%)	6806 (21.59%)	-1.16±1.42	0.167±0.29
12-15	7955	2521 (8.00%)	3220 (10.21%)	5092 (16.15%)	-1.39±1.50	0.241±0.35
Total	31524	5424 (17.21%)	7246 (22.99%)	14799 (46.95%)	-1.16±1.43	0.145±0.28

Low vision: Worse than 0.5logMAR; Decreased UCVA: Worse than 0.3LogMAR; Abnormal UCVA: worse than 0.1 logMAR (≥6, <8years old) and worse than 0 logMAR (≥8years and older) in at least one eye.

Table2: Prevalence of Myopia, Hyperopia, Astigmatism and the distribution of different SE.

Age groups		n	Myopia % (CI) （SE≤-0.50D）	Myopia % (CI) （SE≤-1.00D）	Myopia % (CI) （SE≤-5.00D）	Myopia % (CI) （SE≤-6.00D）	%(CI) （SE≥+0.50 D）	Hyperopia% (CI) (CI) （SE*）	Hyperopia% (CI) （SE≥+3.00 D）	Stigmatism% (CI) （Cyl*）
6-8	All	11277	31.21 (30.4-32.1)	23.99 (23.2-24.8)	0.62 (0.5-0.8)	0.19 (0.1-0.3)	19.90 (19.2-20.6)	5.60 (5.2-6.0)	0.62 (0.5-0.8)	29.87 (29.0-30.7)
	Femal	5078	32.69 (31.4-34.0)	24.62 (23.4-25.8)	0.57 (0.4-0.8)	0.20 (0.1-0.3)	19.57 (18.5-20.7)	5.56 (4.9-6.2)	0.67 (0.4-0.9)	28.59 (27.4-29.8)
	Male	6199	30.00 (28.9-31.1)	23.47 (22.4-24.5)	0.66 (0.5-0.9)	0.18 (0.1-0.3)	20.16 (19.2-21.2)	5.63 (5.1-6.2)	0.68 (0.5-0.9)	30.92 (29.8-32.1)
9-11	All	12292	50.08 (49.2-51.0)	44.82 (43.9-45.7)	3.05 (2.7-3.4)	0.93 (0.8-1.1)	11.57 (11.0-12.1)	3.61 (3.3-3.9)	0.59 (0.5-0.7)	32.70 (31.9-33.5)
	Femal	5366	55.09 (53.8-56.4)	49.24 (47.9-50.6)	3.07 (2.6-3.5)	1.10 (0.8-1.4)	10.53 (9.7-11.4)	3.35 (2.9-3.8)	0.56 (0.4-0.8)	31.81 (30.6-33.1)
	Male	6926	46.20 (45.0-47.4)	41.39 (40.2-42.6)	3.03 (2.6-3.4)	0.79 (0.6-1.0)	12.37 (11.6-13.1)	3.81 (3.4-4.3)	0.62 (0.4-0.8)	33.40 (32.3-34.5)
12-15	All	7955	60.54 (59.5-61.6)	57.12 (56.0-58.2)	6.78 (6.2-7.3)	2.10 (1.8-2.4)	8.57 (8.0-9.2)	3.18 (2.8-3.6)	0.58 (0.4-0.7)	33.43 (32.4-34.4)
	Femal	3286	69.14 (67.6-70.7)	65.70 (64.1-67.3)	7.97 (7.0-8.9)	2.71 (2.2-3.3)	8.98 (8.0-10.0)	5.37 (3.1-4.4)	0.76 (0.5-1.1)	32.87 (31.3-34.5)
	Male	4669	54.49 (53.1-55.9)	51.08 (49.6-52.5)	5.93 (5.3-6.6)	1.67 (1.3-2.0)	8.29 (7.5-9.1)	2.80 (2.3-3.3)	0.45 (0.3-0.6)	33.75 (32.4-35.1)
Total		31524	45.97 (45.4-46.5)	40.47 (39.9-41.0)	3.12 (2.9-3.3)	0.96 (0.9-1.1)	13.80 (13.4-14.2)	4.21 (4.0-4.4)	0.62 (0.5-0.7)	31.86 (31.4-32.4)

SE*：SE ≥+1.00 D (≥7 years old) and SE ≥+2.00 D (≥6, <7 years old)

Cyl*：Cylinder≥1.00D(≥7 years old) and ≥+1.75 D(≥6, <7 years old)

Table3: Summary of myopia prevalence (%) from this study and from other studies published in recent 5 years, matched on myopia definition and best matched on age.

Country	Age（years）	n	Myopia%(≤-0.50D）	High Myopia (≤-6.00D）	Hyperopia% (≥+0.50 D）	Latitude	Cycl-oplegia
Norway(10)	16-19	393	13	0.5	57	60.4° N	YES
North India(33)	9-12	516	27	NA	NA	16.4° N	YES
Brazilian(34)	9–11	266	6.4	NA	67.1	22.9° S	YES
	13–15	167	12.6		59.8		
Poland (15)	9–13	4875	14.01	NA	NA	52.1° N	YES
Denmark (35)	9.7-15.4	307	17.9	NA	NA	55.8° N	YES
France(16)	10-19	8289	42.7	1.8	NA	48.7° N	NO
Korea (36)	5-19	7486	51.9	5.0	13.4	37.3° N	NO
Netherlands.(37)	6	5711	2.4	NA	NA	53.2° N	YES
Saudi Arabia(12)	3-10	1,893	2.7	NA	1.5	24.3° N	NO
Colombia (13)	15	NA	14.7	NA	32.3	5.1° N	NO
Spain(9)	5-7	6152	20	3.6	NA	43.4° N	NO
Indonesia(38)	8-12	410	32.68	8.54	0.73	6.1° S	NO
Eastern China (17)	18	43858	87.65	16.6	NA	29.4° N	NO
Eastern China(39)	10-15	4890	52.02	5.7	NA	36.0° N	YES
Northern China(40)	6-18	35745	70.9	19.4	NA	40.2° N	NO
Southern China(41)	7.2-12.2	1669	69.9	3.1	NA	23.2° N	NO
Western China(32)	6-15	1858	54.9	2.42	3.0	29.0 N	YES
Northern China (19)	6-12	527	53.9	NA	NA	38° N	YES
Eastern China (25)	5-19	4801	63.1	9.4	NA	29.02° N	NO
Our study	6-15	31524	45.97	0.96	13.80	20° N	NO

Figures

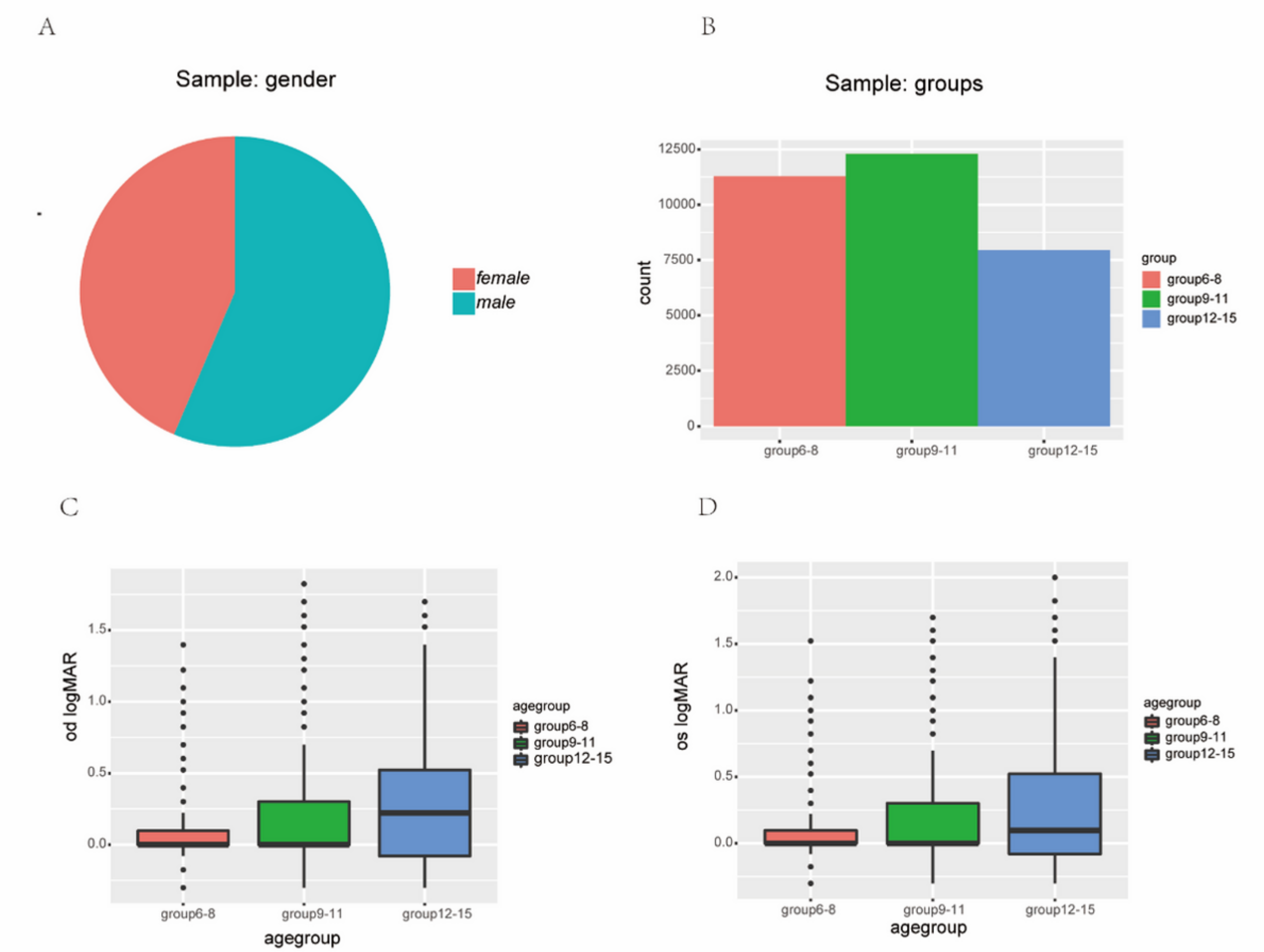

Figure 1

Distribution of sample by gender(A), age group(B), and visual acuity（logMAR）of the right and left eyes (C and D).

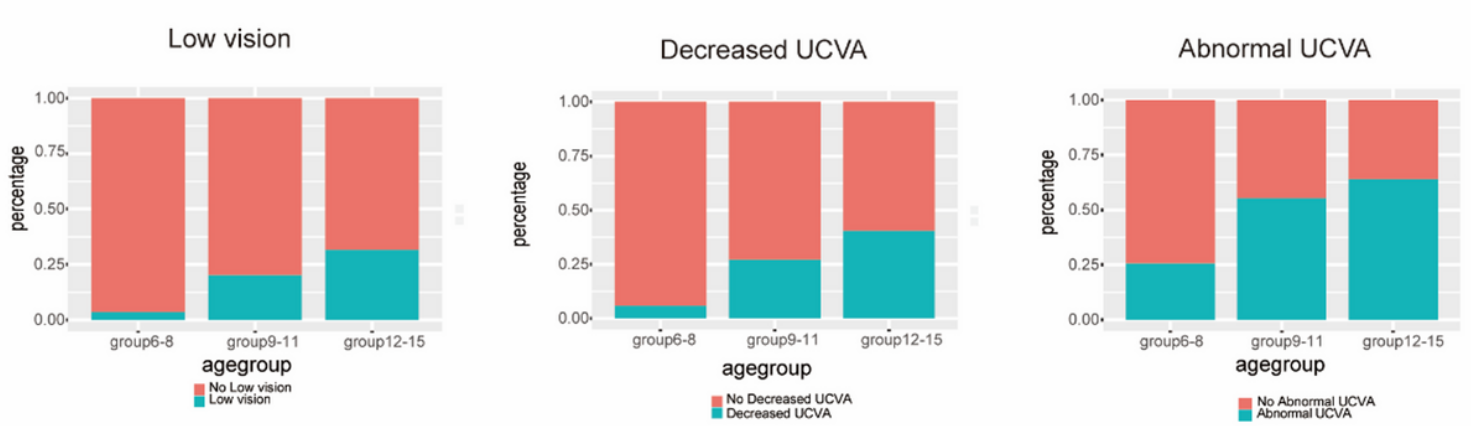

Figure 2

Distribution map of three visual acuity groups. Low vision：Worse than 0.5 logMAR; Decreased VA: Worse than 0.3 logMAR; Abnormal UCVA: worse than 0.1 logMAR (≥6, ≤7years old) and worse than 0 logMAR(≥8years and older)] at least in one eye.

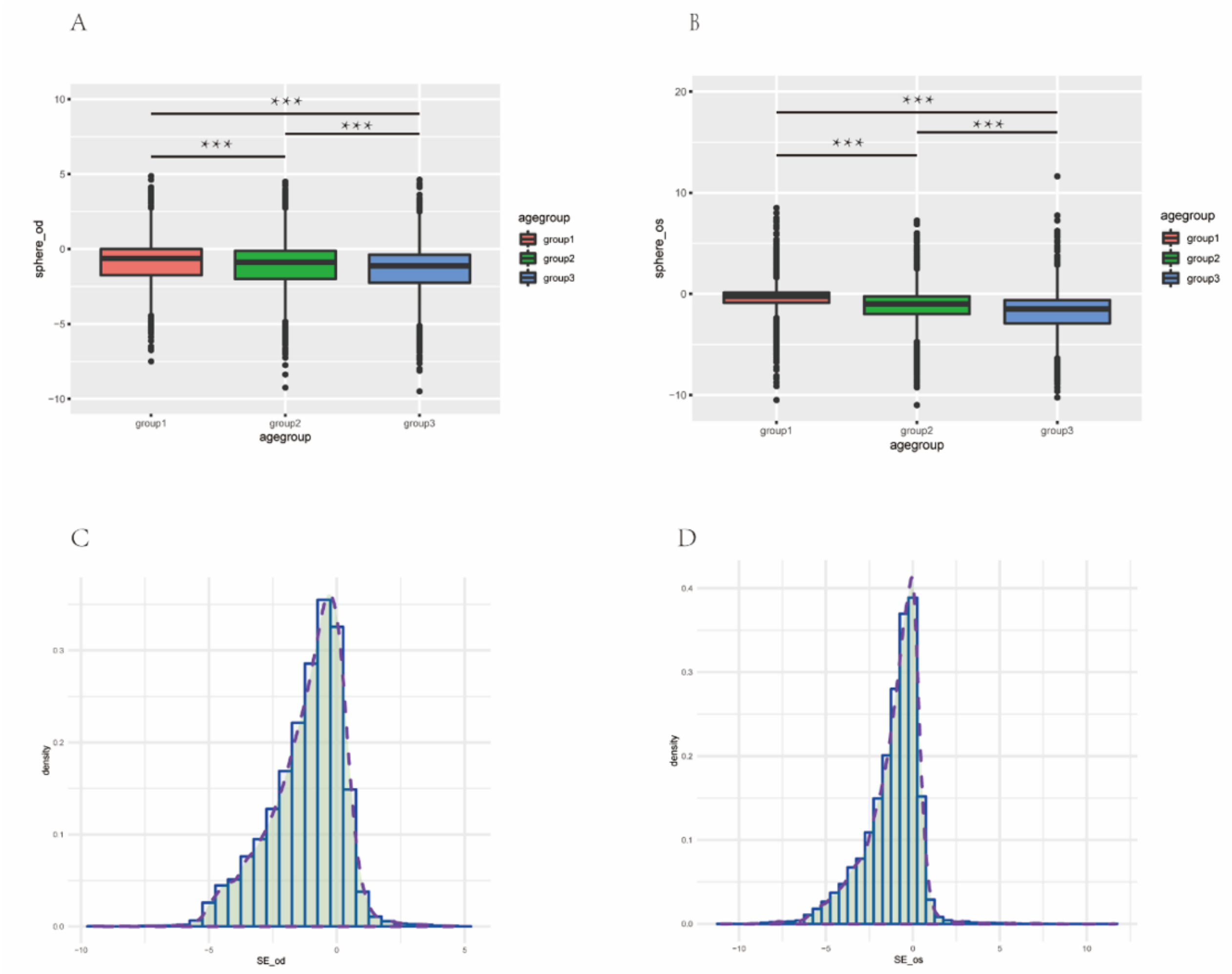

Figure 3

Distribution map of mean SE in the right(A, C) and left eyes(B,D).

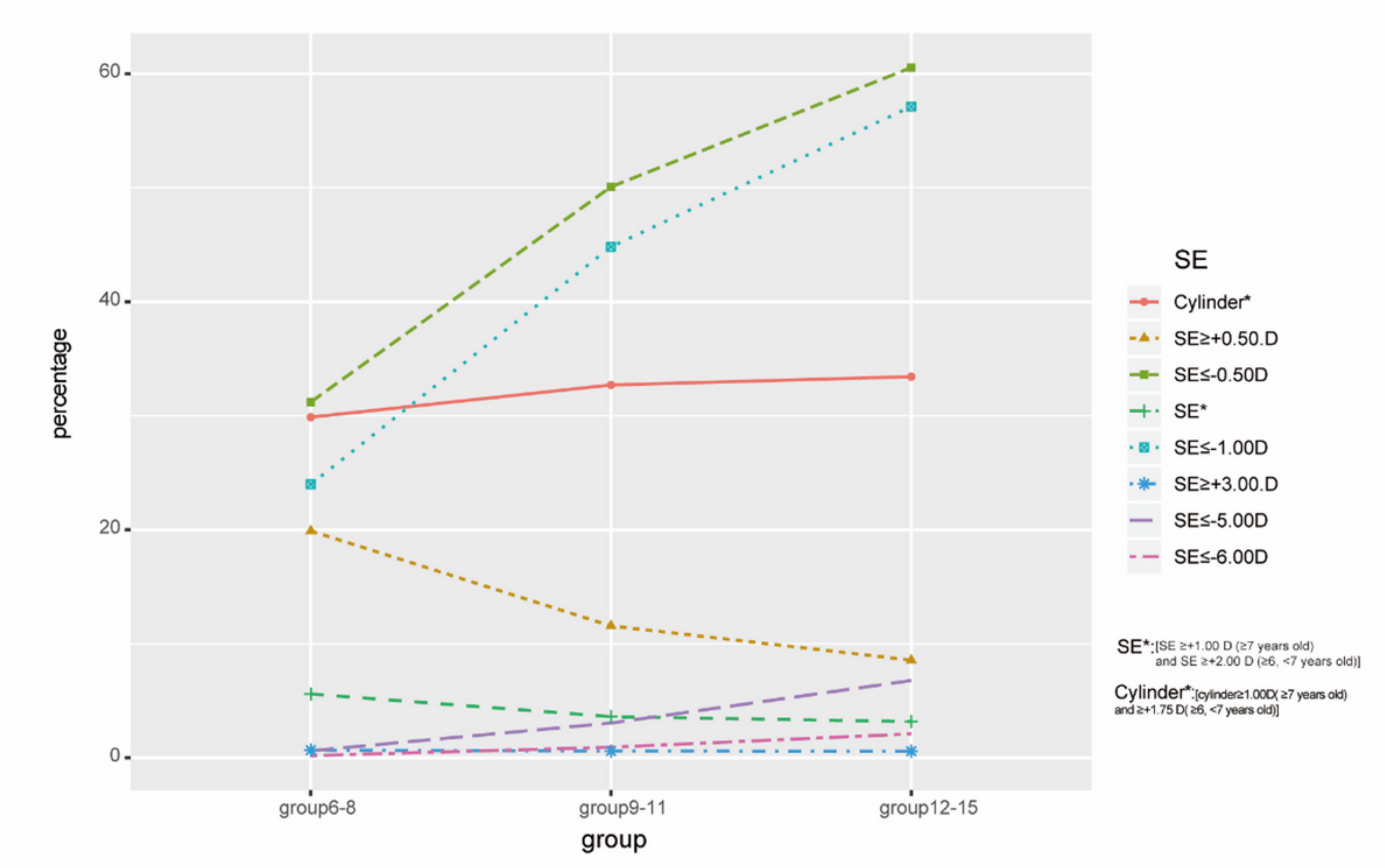

Figure 4

Changes of distribution lines of myopia, hyperopia, astigmatism and the distribution of different SE with age groups. Locally weighted regression lines derived for prevalence of myopia(SE≤-0.50D, ≤-1.00D, ≤-5.00D, ≤-6.00D), hyperopia(SE≥+0.50D and SE*), Significant hyperopia(SE≥+3.00 D)and astigmatism (cylinder*) as a function of age group for Hainan children and adolescents.

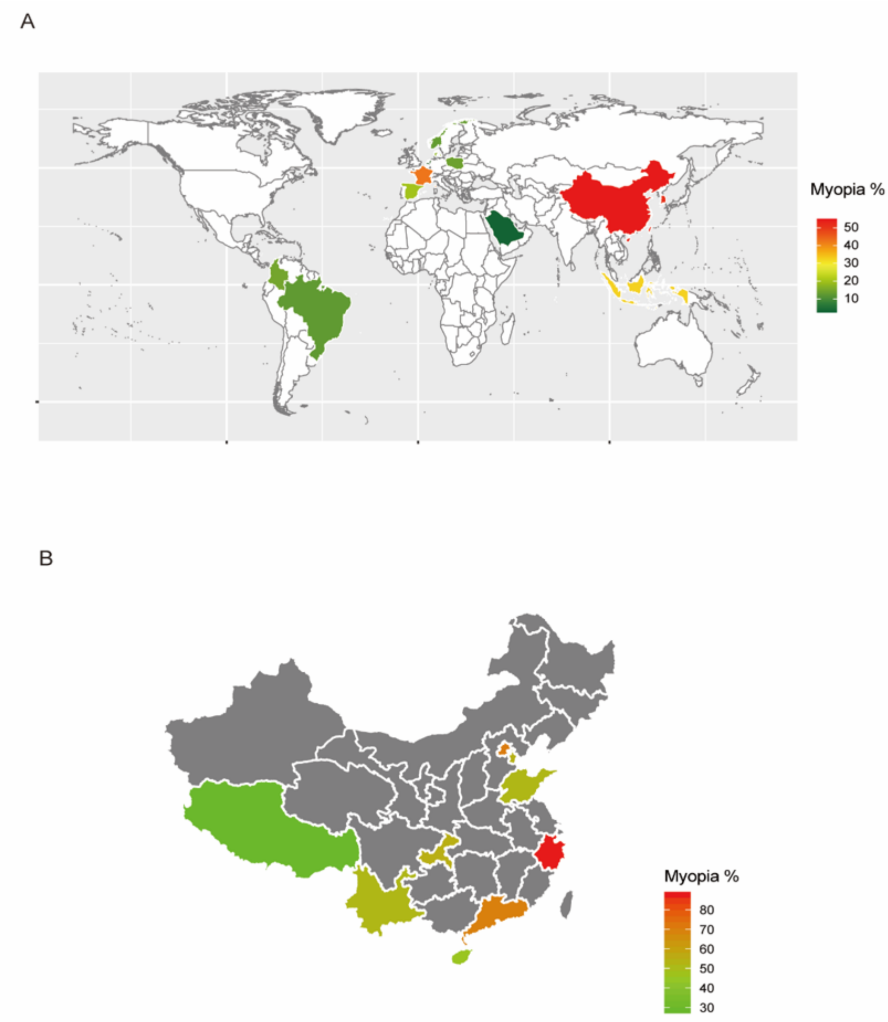

Figure 5

Map of World (A) and China (B) showing the data of myopia prevalence from other studies published in recent 5 years, matched on myopia definition and age. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.