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Association between myopia and sleep duration among primary school students in minority regions of Southwest China: a school-based cross-sectional research

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ABSTRACT

Objective To investigate the relationship between sleep duration and myopia among primary school students in minority regions of Southwest China.

Methods The school-based, cross-sectional study was conducted from October 2020 to January 2021. All participants underwent a comprehensive ocular examination and completed a questionnaire on demographic characteristics, ophthalmological history and major environmental factors for myopia. Spherical equivalent (SE) and ocular biometric parameters were measured after cycloplegia, with myopia being defined as SE ≤−0.5 D (Diopter). Multivariate regression models were used to examine the association of sleep duration with myopia, SE and axial length (AL).

Results A total of 857 students from grades 2 to 4 were included in the analysis, of which 63.6% were myopic and 62.0% belonged to ethnic minorities. Boys had a slightly higher prevalence of myopia compared with girls (66.7% vs 60.6%, p=0.06). Myopic students had longer AL, deeper anterior chamber depth and thinner central corneal thickness compared with non-myopic students (all p<0.05). There was no significant association between sleep duration and myopia in both boys and girls (p=0.319 and 0.186, respectively). Moreover, girls with a sleep duration of 8–9 hour/day had higher SE and shorter AL compared with those with less than 8 hour/day of sleep (β=0.41 and −0.32, respectively, all p<0.05).

Conclusion This cross-sectional study did not find a significant association between sleep duration and myopia. However, it suggests that 8–9 hours of sleep per day may have a protective effect on SE progression and AL elongation in girls. Future studies with objectively measured sleep duration are needed to validate the findings.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study utilized a random sample of multi-ethnic school-aged children in Southwest China, thereby addressing a research gap concerning marginalized populations.
⇒ The analyses included both visual acuity and ocular biological indicators, facilitating a comprehensive assessment of sleep duration and myopia.
⇒ Sleep data collected through questionnaire survey may be subjected to recall bias.
⇒ The cross-sectional design restricts the ability to establish the causal relationships between sleep duration and myopia.

INTRODUCTION

Myopia has emerged as a major public health issue in recent decades, becoming the leading cause of correctable visual impairment worldwide.[1] Striking evidence exists for rapid increase in the prevalence of myopia, especially in East and South Asia.[2] While myopia can be corrected through optical or surgical means, such as glasses, contact lenses and refractive surgery, its development increases the risk of high and pathologic myopia in children. Severe myopia-related ocular diseases like glaucoma, retinal detachment and myopic maculopathy can lead to irreversible vision loss, imposing a heavy burden both on personal quality of life and the society.[3] Therefore, early identification of risk factors for myopia could assist in pinpointing children who would benefit most from early interventions.[4]

Myopia is believed to result from a combination of genetic and environmental factors.[5] Previous epidemiological studies have extensively investigated the environmental risk factors for myopia.[6–11] Increasing evidence suggests that engaging in outdoor activities can help protect against myopia.[6–8] Additionally, known environmental risk factors include prolonged near work, excessive time on electronic devices, inappropriate light exposure, etc.[9–11] Modifying lifestyle habits can be an effective strategy for preventing the onset and progression of myopia. Therefore, it is crucial to further explore the modifiable risk factors associated with the development and progression of myopia.

In the field of public health, inappropriate sleep duration has recently been recognised as a modifiable risk factor for various eye disorders, such as cataract, glaucoma and diabetic retinopathy.[12 13] Recent studies have focused on investigating the link between sleep and myopia in children, aiming to find effective methods for myopia control. Despite extensive research, the correlation between sleep duration and myopia is still controversial. For instance, a negative association between sleep duration and risk of myopia has been found in Korean adolescents aged 12–19 years, with 0.1 diopters (D) increase in refractive error for each additional hour of sleep.[14] Another study on Japanese children aged 10–19 years indicated that shortest sleep duration and poorer sleep quality were significantly associated with high myopia.[15] Besides, no significant associations were found between sleep duration and myopia risk among Chinese and Singaporean school-aged children[16 17]. Remarkably, Lu *et al* suggested that longer sleep time (>8 hour/day) was associated with higher prevalence of myopia in elementary school students.[18] Given the uncertainty influence of sleep duration on myopia, further studies are warranted to verify the associations.

There has been no research conducted on the association between sleep duration and myopia among school-aged children in Chinese minority regions. Yunnan Province is a multiethnic and less developed region located in Southwest China. While Han ethnicity makes up about two-thirds of the population, there are 25 ethnic minority groups residing in Yunnan province according to the national census in 2020. This presents a unique opportunity to explore the ethnic variations in the patterns, predictors and burdens of myopia in China. The purpose of this study was to investigate the association between sleep duration and myopia in school-aged children through a large-scale school-based cross-sectional survey in Southwest China.

METHODS

Study design, setting and participants

The school-based, cross-sectional study was conducted from October 2020 to January 2021. Using a clustering sampling method, one primary school was selected from each of the multiethnic cities in Yunnan Province: Dali, Lijiang and Xishuangbanna. Students from grade 2 to 4 in each school were invited to participate in an ocular examination and a questionnaire survey. The sample size was calculated from careful power analysis considering the following four factors: a myopia prevalence of 35%,[19 20] a desired precision of 3.5%, a type I error of 0.05 and a non-response rate of 10%. The sample size required on this basis was a minimum of 785 participants. Altogether, 875 students completed the survey. The inclusion criteria were as follows: (1) students whose parents agreed to participate in this study; (2) completed both the questionnaire and ocular examination. The exclusion criteria were as follows: (1) with missing key variables; (2) suffering from serious ocular diseases or trauma; (3) having a history of ocular surgery or wearing contact lenses. Ultimately, 857 students were included in the final analysis.

Ocular examination

Trained ophthalmologists and optometrists conducted ocular examination on the participants. Refractive state was measured using auto-refractometry (AR-1, NIDEK, Japan) after cycloplegia (three drops of Mydrin with a 10 min interval; Mydrin is a combination eye drop of 0.5% tropicamide and 0.5% phenylephrine, Santen, Japan). Spherical equivalent (SE) was calculated as the sum of the sphere and half of the cylinder, with myopia was defined as an SE of ≤−0.50 diopters (D). Axial length (AL), central corneal thickness (CCT) and anterior chamber depth (ACD) were measured using AL-Scan (AL-Scan, NIDEK, Japan). All parameters for each eye were measured three times and then averaged.

Questionnaire survey

A self-administered questionnaire was completed by students and their parents. The questionnaire was developed in accordance with the recommendations of the National Health Commission, collecting information on age, sex, ethnicity, parental myopia, academic performance, outdoor activity, class recess, nap habits and duration of sleep. The duration of sleep was assessed by inquiring 'During the past week, how many hours each day did you usually sleep, including both daytime and night-time?'

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination of this research.

Statistical analysis

We double-entered and validated all data using Epidata V.3.1 (The Epidata Association, Odense, Denmark). Statistical analyses were performed using SPSS (IBM, SPSS 25.0, SPSS). Because SE and AL of the right and left eyes were highly correlated (Pearson correlation coefficient=0.93 for SE and 0.91 for AL, respectively, all p<0.05), data from the right eyes were used for analysis. Continuous variables were presented as means±SD and categorical variables as percentage. For comparisons, one-way analysis of variance and Pearson's χ^2 were used when appropriate. Multivariate logistic regression was used to examine the association between myopia and sleep duration categories, while multivariate linear regression was used to assess the association between SE and sleep duration categories as well as the association between AL and sleep duration categories. All tests were two sided and p value <0.05 was considered statistically significant.

RESULTS

Characteristics of the subjects stratified by myopia status are shown in table 1. The overall prevalence of myopia

Table 1 Characteristics of the subjects stratified by myopia status

Variable	Total	Non-myopia	Myopia	P value
Total, n (%)	857	312 (36.4)	545 (63.6)	
Age, mean (SD), years	9.26 (1.49)	8.88 (1.56)	9.49 (1.41)	< 0.001
SE, mean (SD), D	−1.57 (1.79)	−0.22 (1.16)	−2.33 (1.62)	< 0.001
AL, mean (SD), mm	23.93 (1.16)	23.37 (0.98)	24.25 (1.13)	0.040
CCT, mean (SD), mm	550.36 (34.73)	556.28 (33.17)	546.00 (35.17)	< 0.001
ACD, mean (SD), mm	3.68 (0.29)	3.59 (0.26)	3.74 (0.29)	< 0.001
Gender, n (%)				0.060
Boys	420 (49.0)	140 (33.3)	280 (66.7)	
Girls	437 (51.0)	172 (39.4)	265 (60.6)	
Grade, n (%)				<0.01
2	193 (22.5)	100 (51.8)	93 (48.2)	
3	437 (51.0)	265 (60.6)	172 (39.4)	
4	227 (26.5)	180 (79.3)	47 (20.7)	
Region, n (%)				< 0.001
Lijiang	132 (25.4)	64 (48.5)	68 (51.5)	
Dali	193 (22.5)	93 (48.2)	100 (51.8)	
Xishuangbanna	532 (52.1)	155 (29.1)	377 (70.9)	
Parental myopia, n (%)				0.060
None	537 (62.6)	208 (38.7)	329 (61.3)	
One	239 (27.8)	77 (32.2)	162 (67.8)	
Both	81 (9.6)	27 (33.3)	54 (66.7)	
Sleep duration, mean (SD), h/d	8.34 (1.11)	8.45 (1.02)	8.33 (1.15)	0.020

ACD, anterior chamber depth; AL, axial length; CCT, central corneal thickness; SE, spherical equivalent.

in our study was 63.6% (545/857), and the average age was 9.26±1.49 years. The mean SE was −1.57±1.79 D and the mean AL was 23.93±1.16 mm for all participants. Myopic children had lower SE, longer AL, thinner CCT and deeper ACD (all p<0.05). Sleep duration was lower in the myopia group than in the non-myopia group (8.33 vs 8.45 hour/day, p=0.02). Gender and parental myopia were not significantly associated with myopia (both p=0.06).

Table 2 presents the prevalence of myopia, SE and AL by ethnicity. Nearly two-thirds of the participants were from ethnic minorities, including Hani, Bai, Dai, Naxi and other ethnicities. Among the ethnicities, significant differences were found in myopia prevalence, SE and AL (all p<0.001).

SE and AL by myopia-related behaviours are presented in table 3. Children who slept 8–9 hour/d and engaged outdoor activities during breaks had less myopic SE and shorter AL (p<0.01). There was no significant statistical difference between SE and AL in terms of different academic performance, sleeping with the lights, noon break in this study.

Table 4 represents the prevalence of myopia, SE and AL stratified by sleep duration and gender. The myopia prevalence among boys (66.7%) was higher than girls (60.6%); the degree of myopia (SE: −1.69±1.83 D vs −1.45±1.75 D)

Table 2 The prevalence of myopia, spherical equivalent (SE) and axial length (AL) stratified by ethnicity

Ethnicity	n (%)	Prevalence of myopia % (n)	P value	SE (D) mean (SD)	P value	AL (mm) mean (SD)	P value
Total	857	63.6 (545)	< 0.001	−1.57 (1.79)	< 0.001	23.93 (1.16)	< 0.001
Han	326 (38.0)	63.5 (207)		−1.52 (1.76)		23.95 (1.16)	
Hani	160 (18.7)	70.6 (113)		−1.98 (1.92)		24.15 (1.05)	
Bai	81 (9.5)	49.4 (40)		−1.10 (1.43)		23.57 (1.13)	
Dai	171 (20.0)	70.8 (121)		−1.98 (1.78)		24.04 (1.03)	
Naxi	70 (8.2)	47.1 (33)		−0.66 (1.50)		23.48 (0.96)	
Others	49 (5.7)	63.3 (31)		−1.12 (1.85)		23.96 (1.76)	

Table 3 Spherical equivalent (SE) and axial length (AL) by myopia-related behaviours

Variable	n (%)	SE (D) mean (SD)	P value	AL (mm) mean (SD)	P value
Academic performance			0.825		0.752
Good	311 (36.3)	−1.60 (1.76)		23.97 (1.19)	
Medium	481 (56.1)	−1.56 (1.82)		23.91 (1.15)	
Bad	65 (7.6)	−1.45 (1.73)		23.93 (1.01)	
Sleep duration (h/d)			0.031		0.002
<8	215 (25.1)	−1.81 (1.78)		24.10 (1.07)	
8–9	443 (51.7)	−1.42 (1.79)		23.80 (1.04)	
≥–9	199 (23.2)	−1.62 (1.78)		24.06 (1.43)	
Sleep with lighting			0.062		0.195
Never	636 (73.6)	−1.64 (1.83)		23.97 (1.14)	
Occasionally	170 (19.8)	−1.34 (1.63)		23.86 (1.22)	
Frequently	30 (3.5)	−1.00 (1.89)		23.55 (1.01)	
Always	27 (3.1)	−1.83 (1.50)		24.08 (1.33)	
Noon break			0.200		0.257
Never	250 (29.2)	−1.49 (2.06)		23.94 (1.28)	
Occasionally	240 (28.0)	−1.42 (1.75)		23.81 (1.27)	
Frequently	151 (17.6)	−1.74 (1.68)		24.01 (1.06)	
Always	216 (25.2)	−1.69 (1.55)		24.00 (0.91)	
Activities during break times			0.006		0.005
Indoor activities	204 (23.8)	−1.57 (1.80)		23.94 (1.36)	
Outdoor activities	420 (49.0)	−1.40 (1.78)		23.81 (1.13)	
Studying	160 (18.7)	−1.75 (1.71)		24.17 (0.99)	
Snap	73 (8.5)	−2.12 (1.89)		24.08 (0.98)	
Outdoor activities time (h/d)			0.242		0.348
<1	156 (18.2)	−1.62 (1.97)		23.97 (1.18)	
1–2	311 (36.3)	−1.38 (1.69)		23.86 (1.04)	
2–3	176 (20.5)	−1.70 (1.70)		24.01 (1.24)	
≥3	161 (18.8)	−1.65 (1.94)		13.89 (1.03)	
Unknown	53 (6.2)	−1.77 (1.61)		24.14 (1.70)	

and AL (23.96±1.18 mm vs 23.91±1.14 mm) was higher among boys than girls. Although myopia was not associated with sleep duration in all genders, the prevalence of myopia in the group of 8–9 hour/day sleep duration was lower than the rest of the sleep duration group. Myopic SE and AL significantly decreased in the group with sleep duration 8–9 hour/day, and the same results were found among girls ($p<0.05$).

Online supplemental table 1 shows the regression analysis for sleep duration. After adjusting for potential confounders, no significant association was found between sleep duration and myopia. In multivariate linear regression model analysis, compared with sleep duration <8 hour/day, children with sleep duration of 8–9 hour/day had less myopic SE ($p=0.04$) and shorter AL ($p<0.01$). The same results were observed in the girls, while there was no statistically significant difference in the boys. However, no significant differences were found in SE and AL between the children with sleep duration less than 8 hour/day and those who slept more than 9 hour/day ($p=0.83$ and $p=0.68$, respectively).

DISCUSSION

The overall myopia prevalence was 63.6% in the present study, with a higher prevalence of myopia among boys compared with girls. Children who engaged in outdoor activities during breaks have less myopic SE and shorter AL. Our results suggest that there was no significant association between sleep duration and myopia among children aged 6–10 years in minority areas of Southwest China. However, statistically significant associations were observed between sleep duration and myopic SE.

The current study revealed a myopia prevalence of 63.6% among grade 2 to grade 4 students in minority areas of Yunnan province Southwest China. A study in

Table 4 The prevalence of myopia, spherical equivalent (SE) and axial length (AL) stratified by sleep duration and gender

Sleep duration (h/d)	Total n (%)	Prevalence of myopia % (n)	P value	SE (D) mean (SD)	P value	AL (mm) mean (SD)	P value
Total	857	63.6 (545)		−1.57 (1.79)		23.93 (1.16)	
< 8	215 (25.1)	69.8 (150)	0.058	−1.81 (1.78)	0.031	24.10 (1.07)	0.002
8–9	443 (51.7)	60.3 (267)		−1.42 (1.79)		23.80 (1.04)	
≥ 9	199 (23.2)	64.3 (128)		−1.62 (1.78)		24.06 (1.43)	
Boys	420	66.7 (280)		−1.69 (1.83)		23.96 (1.18)	
< 8	110 (26.2)	71.8 (79)	0.319	−1.79 (1.86)	0.716	24.02 (1.07)	0.350
8–9	217 (51.7)	63.6 (138)		−1.62 (1.87)		23.89 (1.03)	
≥ 9	93 (22.1)	67.7 (63)		−1.72 (1.68)		24.07 (1.55)	
Girls	437	60.6 (265)		−1.45 (1.75)		23.91 (1.14)	
< 8	105 (24.0)	67.6 (71)	0.186	−1.83 (1.68)	0.013	24.18 (1.08)	0.001
8–9	226 (51.7)	57.1 (129)		−1.23 (1.70)		23.72 (1.03)	
≥ 9	106 (24.3)	61.3 (65)		−1.53 (1.86)		24.04 (1.33)	

Guangzhou reported that the prevalence of myopia was 12.0% among first-grade students and 67.4% among seventh-grade students without cycloplegia.[19] Another school-based study conducted in Xi'an without cycloplegia has shown that the prevalence of myopia among 6–13-year-old students was 57.1%.[20] The relatively lower prevalence of myopia among school children probably because our research reduced the effect of regulation by using of the ciliary muscle paralysis agent. On the other hand, previous studies have demonstrated significant ethnic and regional variation in myopia prevalence.[21] While other studies have indicated higher myopia prevalence among the Han ethnic group compared with other ethnic groups,[22–24] our study found that the prevalence of myopia varied across the ethnic groups in Yunnan. The disparity might be attributed to geographic differences, air condition and genetic background.[25]

In our study, the prevalence of myopia was consistently higher among boys than girls in different sleep categories, and boys had a more myopic SE and longer AL than girls. However, majority epidemiological studies have identified that female sex as a risk factor for myopia.[26–28] Other research did not find a clear connection between myopia and gender.[20] The discrepancy might be due to variations in age distribution and differing definition of myopia. A longitudinal study conducted in China reported that age or education level was associated with a decrease in mean SE, which was equal to an increase in the prevalence of myopia[29]. Our study focused students from second to fourth grade and reflected the myopic ocular characteristics among children in the early education stage. Furthermore, the increased prevalence of myopia among girls during puberty may be related to the physiological changes caused by hormone levels. Previous studies demonstrated that girls grow faster in early puberty, while boys grow slower near or after the middle of puberty.[30 31] Xu *et al* also noted that menarche was associated with a higher risk of myopia among girls during puberty.[32] Furthermore, behavioural changes in girls during puberty, such as paying more attention to appearance and avoiding sun exposure during outdoor activities, may also contribute to the gender difference in myopia.[32] Overall, the complex aetiology if sex differences in myopia prevalence may involve factors such as age, educational level, biological aspects, outdoor activity time and other lifestyle risk factors, which should be further examined in future studies.

Previous studies have demonstrated that modifiable environmental risk factors play a crucial role in developing strategies of myopia control.[33 34] Consistent with previous studies,[9 35 36] children engaging outdoor activities during breaks have less myopic SE and shorter AL in our research. He *et al*'s randomised trial confirmed that the addition of 40 min of outdoor activity at school over 3 years resulted in a relative decline of 23% of myopia.[37] The lack of a significant association between outdoor time and myopia among primary school students in our study may be due to its cross-sectional design and small sample size. Future randomised controlled trials with a large sample size are needed to further explore the correlation between outdoor exercise time and myopia in minority areas. In addition, a few studies reported that nightlights exposure might increase the risk of myopia,[38 39] which contradicts our research findings. Theoretically, disruptions in the circadian cycle may impact eye growth in children, potentially increasing the likelihood of myopia.[40] Therefore, further study is warranted to explore the association and mechanisms between night sleep with light exposure and myopia.

Although myopic children in this study showed relatively shorter sleep duration than non-myopic children, there was no significant association found between sleep duration and myopia. Our findings align with several other studies that did not find a correlation between sleep duration and the prevalence of myopia.[17 41–43] For instance, Qu *et al* studied 1831 Chinese students aged

11–18 years and reported no statistically significant association between sleep time and myopia.[43] Similarly, the Anyang Childhood Eye Study reported that neither sleep duration nor bedtime was associated with the incidence of myopia, and there were no statistically significant association between sleep duration and bedtime with myopia progression and axial elongation over 4 years of follow-up.[17] In contrast, Lin *et al* found that longer sleep duration was associated with decreased risk of myopia among 9530 Chinese school-aged children[44]. Additionally, a population-based study conducted in Shenzhen city reported that not only insufficient sleep can increase the risk of myopia but also lack of daytime naps, and irregular sleep-wake pattern son weekdays were significantly associated with self-reported myopia among children and adolescents.[45] Ayaki *et al* also indicated that sleep quality was significantly correlated with myopic error among Japanese children, with high myopia group showing the most adverse effects.[15] In this cross-sectional study, children in the high myopia group exhibited the poorest Pittsburgh Sleep Quality Index scores, the least sleep time and the latest bedtime.[15] The varying results regarding sleep duration and its relationship with myopia may stem from differences in participant ages, sample size and variations in potential confounding factors in these studies, such as outdoor activities, light exposure and near-vision work.

Research on the relationship between sleep time and myopia indicators is limited. Li *et al* found that sleep quality, duration, timing and the consistency of specific sleep factors were not independently associated with myopia, SE or AL in a study of 572 multiethnic elementary school-aged children in Singapore.[16] Similarly, Huang *et al* reported that no independent relationship between sleep duration and myopia, cycloplegic SE and AL in 1140 Chinese children aged 6–18 years during the COVID-19 pandemic.[46] Children with sleep duration of 8–9 hour/day showed less myopic SE and shorter AL compared with those with less than 8 hours of sleep. On the other hand, children with a sleep duration of ≥9 hour/day did not show significant difference in cycloplegic SE and AL in our study. One hypothesis suggests that the impact of sleep on ocular structure may manifest early, while myopia develops as a result of long-term effects. It is proposed that disruption of the circadian rhythm might influence the critical emmetropisation process of myopic growth.[47] For instance, sleep deprivation may reduce the availability of dopamine receptors in the ventral striatum, leading to downregulation of retinal dopaminergic signalling and subsequent elongation of the AL.[48] Given the growing concern for myopia control, especially in areas with high prevalence, ensuring adequate sleep may be a key strategy in preventing and controlling myopia among school children.

The strengths of the study included the comprehensive myopia assessment such as the prevalence of myopia, SE and AL as well as the use of cycloplegic SE and AL, which minimised errors in measurement. Besides, the research focused on primary school students in second to fourth grade, capturing epidemiological characteristics in the early education stage and reducing selective bias by including a narrow sample range. Data on the association between sleep duration and myopia in Southwest China, with a significant number of ethnic minorities, were provided. However, there were several limitations that should be mentioned. First, sleep duration was collected from questionnaires, and the results may be affected by recall bias, leading to a decrease in accuracy. Second, cross-sectional design of the study could not determine a causal relationship between sleep duration and myopia. Our upcoming longitudinal cohort study will further explore the effect of sleep on myopia and the aetiology of myopia.

Conclusion

This study did not find a significant relation between sleep duration and myopia. However, children who slept for 8–9 hours per day had less SE and shorter AL compared with those who slept less than 8 hours or 9 hours or more. This suggests that sleep duration of 8–9 hours per day may be beneficial in preventing myopia. Future studies with objectively measured sleep duration are needed to validate these finding.

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Competing interests None declared.

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Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval The studies involving human participants were reviewed and approved by the Ethics Board of Kunming Medical University. Written informed consent to participate in this study was provided by the students' legal guardian/next of kin. Participants gave informed consent to participate in the study before taking part.

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