Association Between Sleep Status and Myopia in Children and Adolescents: A Cross-sectional Study in Shenzhen

Zhiqiang Zong
Anhui Medical University
Renjie Wang
Anhui Medical University
Yi Zhang
Anhui Medical University
Xiaoyan Wu
Anhui Medical University
Shaojun Xu (xushaojun@ahmu.edu.cn)
Anhui Medical University
Fangbiao Tao
Anhui Medical University

Research Article

Keywords: Sleep, social jet lag, circadian rythm, myopia, children, adolescents

Posted Date: September 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-912476/v1

Abstract

Purpose: The aim of this cross-sectional study was to assess the association between sleep status and myopia in children and adolescents.

Methods: Stratified cluster sampling a total of 30,188 schoolchildren from 14 schools located in 6 streets (Xinxiang, Songgang, Shiyan, Fuyong, Shajing and Xinan) of Baoan District in Shenzhen, China. The demographic characteristics of schoolchildren, information of self-reported myopia and their sleep status in the last 1 month were collected through using a standardized questionnaire. χ2-test was used to compare differences in myopia rates among children and adolescents in different sleep status. Logistic regression models were used to analyze the association of sleep status with myopia in children and adolescents.

Results: The self-reported myopia rates was 49.8% among children and adolescents in Shenzhen. In primary, junior high and senior high students, the myopia rates were 25.6%, 62.4%, and 75.7%, respectively. After controlling for confounders, the results of multiple logistic analysis showed that night sleep duration < 7h/d (OR = 2.02, 95%CI: 1.87-2.19), falling asleep at a fixed time (no) (OR = 1.14, 95%CI: 1.08-1.20), getting up at a fixed time in the morning (no) (OR = 1.28, 95%CI: 1.19-1.37), putting off sleeping on weekends ≥ 2 h/d (OR = 1.28, 95%CI: 1.17-1.41) and Putting off getting up on weekends ≥ 2 h/d were risk factors (OR = 1.23, 95%CI: 1.13-1.34). After stratified by grade, social jet lag was not associated with myopia among senior high students.

Conclusion: Insufficient sleep duration was positively associated with self-reported myopia, irregular patterns of sleep and social jet lag increased the risk of myopia among schoolchildren. Myopia prevention and control among children and adolescents should not only ensure adequate sleep, but also develop a habit of regular sleep.

Introduction

Myopia is a common disease that occurs mainly in childhood and early adulthood, and it is also known as short-sightedness or near-sightedness [1]. Because prevalence of myopia has rapidly risen globally over the past three decades, it has been described as an epidemic disease and has become an important public health problem [2]. A large number of studies have shown that myopia is associated with many factors, such as outdoor activities, near-work activities, educational pressure and parental myopia [3–6]. Considering the high incidence of myopia, there is an increasing need to explore other environmental factors that may influence the development of myopia.

Sleep is an important physiological process of the human body, and good sleep is a necessary condition to improve physical and mental health of children and adolescents. Several recent studies suggest that sleep may be potentially associated with myopia in children and adolescents. For instance, a cross-sectional study of 3, 625 Korean adolescents aged 12 to 19 years indicated that per 1 hour increase in sleep duration was associated with a 10% lower risk of myopia [7]. Difference, similar to jet lag between sleep pattern on weekends and school days are known as “social jet lag” [8, 9]. In children and adolescents, it is common that weekend sleep patterns are not as same as the study days [10, 11]. Objective measurements of sleep and light collected every 6 months for 14 days in Australian children aged 10 to 15 years revealed that non-myopic children had more regular sleep status (seldom staying up late and putting off getting up), while myopic children showed greater variability, whether it was the study day or weekend, summer or winter [12].

Therefore, we propose a hypothesis that poor sleep status, such as lack of sleep time, and social jet lag (mainly manifested in the inconsistency between weekend sleep status and study days in this study) may be associated with myopia in children and adolescents. we conducted a cross-sectional study in Shenzhen, China, with data on sleep duration, social jet lag and self-reported myopia obtained through a standardized questionnaire to examine the association between sleep status and myopia in children and adolescents.

Materials And Methods

From April 2019 to May 2019, 14 schools in 6 sub-districts including Xixiang, Songgang, Shiyan, Fuyong, Shajing and Xinan under the jurisdiction of Baoan District in Shenzhen, were selected by stratified cluster sampling, and 33, 801 primary and high school students were selected by cluster sampling in classes for student physical health survey. Excluding the questionnaires with ineffective missing filling, the exclusion criteria were that the questionnaire had significant logical errors or the missed filling rate was more than 5%, and a total of 30, 188 valid questionnaires were included, with a response rate of 84.4%. We abided by the guidelines of the Declaration of Helsinki and this study was approved by the biomedical ethics committee of Anhui Medical University (No. 2140104), and the investigation obtained the informed consent of the guardian of the respondents.

Based on literature search and expert consultation, a questionnaire was designed. The survey included sex, age (years), outdoor activity, academic record, study burden, family income, father’s education, mother’s education, father myopia, mother myopia, and sleep status in the last month (night sleep duration, whether to fall asleep at a fixed time, whether to get up at a fixed time, whether to put off falling asleep on weekends, and whether to put off getting up on weekends). Myopia was judged by parents (grades 1–4 in primary school) and students (grade 5 and above) who self-reported a history of optometry.

A detailed and feasible survey implementation plan was developed before the survey and the personnel participating in the survey were uniformly trained. Quality management personnel reviewed the returned questionnaires, performed data through classification and logical inspection before data analysis, and eliminated the samples lacking basic information.

EpiData 3.1 software was used to input the data, the database was verified after input, SPSS 17.0 software was used for statistical analysis, and ggplot 2 package in R tool 4.0.4 was used to make forest plots. The χ2 test and χ2-trend test were used to compare the differences in self-reported myopia rates among primary and middle school students with different characteristics. Self-reported myopia was used as the dependent variable, and confounding factors such as gender, school level, father and mother education level, parental myopia, and family economic status were adjusted using a binary logistic model to calculate

OR values and 95% CI, with $P < 0.05$ considered statistically significant, using nighttime sleep duration, falling asleep at a fixed time in the night, getting up at fixed time in the morning, putting off sleeping on weekends, and putting off getting up at weekends as independent variables.

Results

Table 1 showed the basic characteristics of this sampling. The self-reported myopia rate of children and adolescents (mean age = 12.44, SD = 3.47) in Shenzhen was 49.8% (15, 026/30, 188),,and the myopia rate of female students (54.2%) was higher than that of male students (46.3%), and the difference was statistically significant; the self-reported myopia rates among primary, junior high and senior high students were 25.6%, 62.4%, 75.7%, respectively, which increased with the grade, and the difference was statistically significant; the myopia rate of students with higher father and mother education level was lower, and the myopia rate of students with poor family economic level was lower, and the difference was statistically significant.

Table 1
Basic characteristics of the samples.

Variables	Number of participants	Myopia cases	Myopia rates (%)	χ^2 or χ^2-trend	P value
Sex				190.00[a]	< 0.001
Male	16,897	7,816	46.3		
Female	13,291	7,210	54.2		
Age (years)				5302.51[a]	< 0.001
≤ 12	14,484	4,049	28.0		
> 12	15,704	10,977	69.9		
Grade				5958.23[b]	< 0.001
Primary	13,420	3,431	25.6		
Junior high	8,232	5,137	62.4		
Senior high	8,536	6,458	75.7		
Family economic level				1127.34[b]	< 0.001
Under moderate	4,113	1,598	38.9		
Moderate	20,395	10,494	51.5		
Over moderate	5,680	2,934	51.7		
Father's education				52.49[b]	< 0.001
Junior high or below	9,641	5,025	52.1		
Senior high	11,387	5,712	50.2		
College or above	9,160	4,289	46.8		
Mother's education				119.86[b]	< 0.001
Junior high or below	12,203	6,448	52.8		
Senior high	11,184	5,554	49.7		
College or above	68,01	3,024	44.5		
Father myopia				444.10[b]	< 0.001
Yes	8,414	4,936	58.7		
No	20,791	9,503	45.7		
Unknown	983	587	59.7		
Mother myopia				164.62[b]	< 0.001
Yes	8,696	4,955	57.0		
No	2,0524	9,525	46.4		
Unknown	968	546	56.4		
Outdoor activity				26.66[b]	< 0.001
< 1h/d	12785	6661	52.1		
1-2h/d	10284	4873	47.4		
≥ 2h/d	7102	3479	49.0		
Screen time				140.73[b]	< 0.001
< 1h/d	15853	7492	47.3		
1-2h/d	7925	3918	49.4		
≥ 2h/d	6410	3616	56.4		

Note: [a] is for χ^2, [b] is for χ^2-trend

Variables	Number of participants	Myopia cases	Myopia rates (%)	χ^2 or χ^2-trend	P value
Academic record				148.18[b]	< 0.001
Bad	7,580	3,494	46.1		
Normal	11,573	8,627	49.1		
Good	5,035	2,905	57.7		
Study burden				397.40[b]	< 0.001
Light	2,451	1,035	42.2		
Normal	19,020	8,847	46.5		
Heavy	8,717	5,144	59.0		
Note: [a] is for χ^2, [b] is for χ^2-trend					

Table 2 showed the outcome of univariate analysis for sleep status and self-reported myopia. The self-reported myopia rates of students with night sleep duration ≥ 9, 8-9h/d, 7–8 and < 7h/d were 26.0%, 27.8%, 43.2%, and 68.6%, respectively, which increased with the decrease of night sleep duration (P < 0,001). And the effect of social jet lag on myopia was significant (all P value < 0.001). After subgroup analysis were performed by grade, in the primary school group, not falling asleep at a fixed time at night, not getting up at a fixed time in the morning, putting off falling asleep ≥ 2h/d on weekends, and putting off getting up ≥ 2h/d on weekend was associated with self-reported myopia (all P values < 0.001); in the junior high group, social jet lag was not associated with myopia (all P values > 0.05); in the senior high group, not getting up at a fixed time was related to self-reported myopia (P < 0.05).

Table 2
Comparison of self-reported myopia rates in children and adolescents with different sleep status stratified by grad

Variable	Total			Primary			Junior high		
	Number of participants	Myopia cases	Myopia rate (%)	Number of participants	Myopia cases	Myopia rate (%)	Number of participants	Myopia cases	Myopia rate (%)
Night sleep duration									
7 h/d	13,354	9,162	68.6	1,336	491	36.8	4,540	2,953	65.0
7–8 h/d	7,862	3,395	43.2	4,273	1,134	26.5	2,671	1,605	60.1
8–9 h/d	7,491	2,084	27.8	6,510	3,431	23.3	873	498	57.0
≥ 9 h/d	1,481	385	26.0	1,301	1,518	22.1	148	81	54.7
χ^2-trend		3695.82			94.22			32.32	
P value		< 0.001			< 0.001			< 0.001	
Fall asleep at a fixed time at night									
Yes	19,585	9,164	46.8	11,739	2,871	24.5	6,888	4,281	62.2
No	10,603	5,862	55.3	1,681	560	33.3	1,344	856	62.4
χ^2		198.58			60.61			1.14	
P value		< 0.001			< 0.001			0.287	
Get up at a fixed time in the morning									
Yes	25,515	12,352	48.4	9,773	2,263	23.2	8,232	5,137	62.4
No	4,673	2,674	57.2	3,647	1,168	32.0	4,345	2,726	62.7
χ^2		122.67			109.82			0.443	
P value		< 0.001			< 0.001			0.506	
Put off sleeping on weekends									
no	6,263	2,945	47.0	2,915	694	23.8	1,767	1,070	60.6
< 1 h/d	14,439	6,852	47.5	7,121	1,752	24.6	3,596	2,261	62.9
1–2 h/d	5,868	3,043	51.9	2,457	669	27.2	1,603	1,000	62.4
≥ 2 h/d	3,618	2,186	60.4	927	316	34.1	1,266	806	63.7
χ^2-trend		181.06			36.78			2.27	
P value		< 0.001			< 0.001			0.132	
Put off getting up on weekends									
no	5,610	2,400	42.8	3,092	756	24.5	1,501	885	59.0
< 1 h/d	11,793	5,519	46.8	5,918	1,454	24.6	3,044	1,947	64.0
1–2 h/d	6,881	3,507	51.0	3,011	783	26.0	1,767	1,095	62.0
≥ 2 h/d	5,904	3,600	61.0	1,399	438	31.3	1,920	1,210	63.0
χ^2-trend		424.31			20.46			2.20	
P value		< 0.001			< 0.001			0.138	

Table 3 and Fig. 1 showed the association between sleep status and the risk of self-reported myopia: Controlling of factors such as sex, age (years), outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia, the results of logistic analysis showed that the OR (95% CI) for myopia was 2.02 (1.87–2.19) in participants with night sleep duration < 7 h/d compared with students with night sleep duration 8–9 h/d; the ORs (95% CIs) for self-reported myopia were 1.14 (1.08–1.20) and 1.28 (1.19–1.37) in students who did not fall asleep at a fixed time at night and get up at a fixed time in the morning, respectively; the ORs (95% CIs) for self-reported myopia were 1.28 (1.17–1.41) and 1.23 (1.13–1.34) in students who put off sleeping ≥ 2 h/d and put off getting up ≥ 2 h/d on weekends, respectively.

Table 3
Multivariate logistic regression analysis of different sleep status and self-reported myopia in children and adolescents.

Variables	**Model 1**		**Model 2**					
	OR (95%CI)	**P value**	**Primary**		**Junior high**		**Senior high**	
	OR (95%CI)	P value	OR (95%CI)	P value	OR (95%CI)	P value		
Night sleep duration								
8–9 h/d	1.00		1.00		1.00		1.00	
< 7 h/d	2.02 (1.87–2.19)	< 0.001	1.60 (1.41–1.83)	< 0.001	1.18 (1.01–1.38)	0.033	1.63 (1.07–2.47)	0.022
7–8 h/d	1.30 (1.21–1.40)	< 0.001	1.14 (1.04–1.25)	0.005	1.05 (0.90–1.23)	0.573	1.34 (0.86–2.07)	0.208
≥ 9 h/d	0.92 (0.80–1.05)	0.202	0.89 (0.77–1.03)	0.126	0.95 (0.67–1.36)	0.786	0.66 (0.29–1.49)	0.313
Fall asleep at a fixed time at night								
Yes	1.00		1.00		1.00		1.00	
No	1.14 (1.08–1.20)	< 0.001	1.45 (1.33–1.58)	< 0.001	0.95 (0.86–1.04)	0.255	0.93 (0.84–1.03)	0.179
Get up at a fixed time int the morning								
Yes	1.00		1.00		1.00		1.00	
No	1.28 (1.19–1.37)	< 0.001	1.43 (1.27–1.60)	< 0.001	1.13 (0.99–1.28)	0.052	1.10 (0.97–1.25)	0.143
Put off sleeping on weekends								
no	1.00		1.00		1.00		1.00	
< 1 h/d	1.04 (0.97–1.11)	0.277	1.07 (0.97–1.19)	0.185	1.09 (0.96–1.23)	0.176	1.04 (0.90–1.19)	0.627
1–2 h/d	1.09 (1.01–1.18)	0.035	1.17 (1.03–1.33)	0.017	1.09 (0.94–1.25)	0.259	1.02 (0.87–1.20)	0.835
≥ 2 h/d	1.28 (1.17–1.41)	< 0.001	1.52 (1.29–1.80)	< 0.001	1.23 (1.06–1.44)	0.006	1.01 (0.85–1.20)	0.914
Put off getting up on weekends								
no	1.00		1.00		1.00		1.00	
< 1 h/d	1.05 (0.98–1.13)	0.181	1.05 (0.94–1.16)	0.412	1.13 (0.99–1.28)	0.071	0.92 (0.78–1.10)	0.362
1–2 h/d	1.10 (1.02–1.19)	0.017	1.12 (0.99–1.27)	0.057	1.08 (0.89–1.18)	0.748	1.03 (0.86–1.23)	0.780
≥ 2 h/d	1.23 (1.13–1.34)	< 0.001	1.36 (1.17–1.57)	< 0.001	1.12 (0.97–1.29)	0.129	0.95 (0.80–1.13)	0.539

Note. Model 1: adjusted for sex, age (years), outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.

Model 2: stratified by grade, adjusted for sex, age (years), outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.

After stratification by grade (Table 3, Fig. 2–4), for night sleep duration < 7h/d, the ORs (95%CIs) were respectively 1.60 (1.41–1.83), 1.18 (1.01–1.38) and 1.63 (1.07–2.47) among primary, junior and senior high students; in primary group, not falling asleep at night and not getting up at a fixed time in the morning, putting off sleeping ≥ 2h/d and getting up ≥ 2h/d on weekends had the most obvious effect among primary groups, and the ORs (95% CIs) were respectively

1.45 (1.33–1.58), 1.43 (1.27–1.60), and 1.52 (1.29–1.80), which indicated that social jet lag was significantly associated with myopia among primary students. In junior high group, putting off sleeping was significantly associated with myopia with ORs (95% CIs) 1.23 (1.06–1.44), while not falling asleep at a fixed time at night, not getting up at a fixed time in the morning and and getting up ≥ 2h/d on weekends were not risk factors. In senior high group, social jet lag was not associated with self-reported myopia (all P values > 0.05)

Discussion

Educational stress is an important cause of the myopia epidemic [13]. The self-reported myopia rate of 30, 188 primary and middle school students in Bao'an District, Shenzhen was 49.8%, and the self-reported myopia rates of primary, senior high, and junior high students were 25.6%, 62.4% and 75.7% respectively. This survey showed that students with a higher parental education level had a lower rate of self-reported myopia, and students with a poorer family economic status had a lower rate of self-reported myopia. Economic and social factors can affect parents' attitude towards myopia and their supervision and management of children's eye use behavior, and parents who pay attention to myopia will limit their children's video time [14]. Parental myopia has a certain predictive effect on myopia in children [15]. This survey also found that the self-reported myopia rate of students with myopia in one or both parents was significantly higher than that of students without myopia in both parents, and the shared environmental factors could not be ignored while family members shared genetic genes.

Early school hours in the morning and delayed time to bed at night caused by post-school homework and academic tasks resulted in reduced sleep length in children and adolescents. The results of this cross sectional study showed that the short sleep duration (< 7 h/d at night) was associated with myopia in children and adolescents with compared with students with sleep time ≥ 8–9 h/d at night. Late sleep allows children and adolescents to be exposed to artificial lighting for longer periods of time and spend more time indoors performing near tasks, such as reading or video screens, thus increasing the risk of myopia occurrence [16]. Blue light from smart phones, computers, and television also inhibits melatonin secretion and disturbs circadian rhythms, making it difficult for children and adolescents to fall asleep and enter a stable sleep state [17]. The use of artificial lighting and electronic screens in the dark at night can disturb the circadian clock and then affect circadian rhythms, which may be the underlying mechanism of myopia.

As in adults, children have significant circadian fluctuations in 24-hour corneal thickness and refractive rate, axial length, retinal thickness, choroidal thickness, intraocular pressure, and mean ocular perfusion pressure [18]. Animal experiments revealed that 2 hours of light exposure at midnight (0:00–2:00) could lead to changes in the circadian rhythm of axial length and choroidal thickness, and chicks showed “acute” axial growth lasting at least 6 hours after light exposure, suggesting that circadian rhythm disturbances may lead to myopia [19]. Circadian rhythm disorders can interfere with the normal development of the eyeball and affect the rate of eyeball growth, leading to the development of myopia[20]. Sleep deprivation can cause down-regulation of dopamine D_2 receptors in the ventral striatum of humans, resulting in reduced activation of retinal dopaminergic pathways, which in turn leads to axial elongation, triggering myopia [21].

This investigation also found that not getting up at a fixed time in the morning, not going to bed at night, putting off sleeping and getting up on weekends can increase the risk of myopia development among children and adolescents. Bright light in the morning will advance the circadian clock of body and converge to early skylarks (early morning type); while bright light at night will delay the circadian clock and converge to staying up late owls (night type). The results of Chakraborty R et al. showed that the urinary aMT6s melatonin level in the myopic group (29.17 ± 18.67) was significantly lower than that in the emmetropic group (42.51 ± 23.97, p = 0.04), and myopic patients showed a significant delay in falling asleep, prolonged sleep latency, shorter sleep duration, and a tendency to night-type [22]. The generation and maintenance of the circadian rhythm is the result of a series of gene regulations related to the circadian clock [23]. Animal experiments have confirmed that knockout of the circadian clock gene can lead to changes in ocular parameters. Specific knockout of the mouse retinal Bmal1 circadian clock gene can cause prolonged axial and intravitreal length and then induce myopia, and knockout of the Drosophila Cyc and Per circadian clock genes can cause pseudomorphic pyramidal cell lengthening and then induce myopia [24]. Further exploration of the association between sleep, social jet lag and myopia should be further strengthened. Sleep status may be an important entry point for the prevention and control of myopia in children and adolescents. The prevention and control of myopia not only needs to ensure adequate sleep time, but also develop good habits of regular.

Strengths of the cross-sectional study include a relatively large sample size that adjusted for potential confounders, as well as the fact that this is the first cross study investigating the effects of sleep duration and social jet lag on myopia incidence in children and adolescent. However, our study also had limitations. The main weakness of our investigation was that personal information about myopia was obtained by self-report through questionnaires instead of employing cycloplegic autorefraction for definitive diagnosis. In addition, causal inferences can not be made from cross-sectional studies, and more in-depth cohort studies should to be conducted to evaluate the effect of sleep status on myopia in children and adolescents.

Declarations

Acknowledgement

The authors thank all children, adolescents and their families for participating this study.

Author’s contributions

ZZ, YZ, SX and FT conceived and planned this study and take full responsibility for the paper. ZZ, YZ, RW and XW contributed to the analysis and interpretation of the data. ZZ took the lead in writing the manuscript. SX and FT supervised this study and contributed to revision of the paper. All authors read and approved the final manuscript.

Consent for publication

Not applicable

Competing interests

The authors report no conflicts of competing.

Ethics approval and consent to participate

We abided by the guidelines of the Declaration of Helsinki and this study was approved by the biomedical ethics committee of Anhui Medical University (No. 2140104), and the investigation obtained the informed consent of the guardian of the respondents.

Data available statement

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

References

1. Morgan IG, Ohno-Matsui KSaw S-M. Myopia. The Lancet 2012;379(9827): 1739–1748.
2. Baird PN, Saw SM, Lanca C, Guggenheim JA, Smith Iii EL, Zhou X, Matsui KO, Wu PC, Sankaridurg P, Chia A, et al. Myopia. Nat Rev Dis Primers 2020;6(1): 99.
3. Lim DH, Han J, Chung TY, Kang S, Yim HWEpidemiologic Survey Committee of the Korean Ophthalmologic S. Correction: The high prevalence of myopia in Korean children with influence of parental refractive errors: The 2008–2012 Korean National Health and Nutrition Examination Survey. PLoS One 2018;13(12): e0209876.
4. Morgan IG, French ANRose KA. Intense schooling linked to myopia. BMJ 2018;361(k2248).
5. Huang HM, Chang DSWu PC. The Association between Near Work Activities and Myopia in Children-A Systematic Review and Meta-Analysis. PLoS One 2015;10(10): e0140419.
6. Xiong S, Sankaridurg P, Naduvilath T, Zang J, Zou H, Zhu J, Lv M, He XXu X. Time spent in outdoor activities in relation to myopia prevention and control: a meta-analysis and systematic review. Acta Ophthalmol 2017;95(6): 551–566.
7. Jee D, Morgan IGKim EC. Inverse relationship between sleep duration and myopia. Acta Ophthalmol 2016;94(3): e204-210.
8. Sun W, Ling J, Zhu X, Lee TMLi SX. Associations of weekday-to-weekend sleep differences with academic performance and health-related outcomes in school-age children and youths. Sleep Med Rev 2019;46(27–53.
9. Cespedes Feliciano EM, Rifas-Shiman SL, Quante M, Redline S, Oken ETaveras EM. Chronotype, Social Jet Lag, and Cardiometabolic Risk Factors in Early Adolescence. JAMA Pediatr 2019;173(11): 1049–1057.
10. Fuligni AJ, Arruda EH, Krull JLGonzales NA. Adolescent Sleep Duration, Variability, and Peak Levels of Achievement and Mental Health. Child development 2018;89(2): e18-e28.
11. Lv Y, Cai L, Zeng X, Gui Z, Lai L, Tan WChen Y. Association between weekend catch-up sleep and executive functions in Chinese school-aged children. Journal of clinical sleep medicine: JCSM : official publication of the American Academy of Sleep Medicine 2020;16(8): 1285–1293.
12. Ostrin LA, Read SA, Vincent SJCollins MJ. Sleep in Myopic and Non-Myopic Children. Translational vision science & technology 2020;9(9): 22.
13. Mountjoy E, Davies NM, Plotnikov D, Smith GD, Rodriguez S, Williams CE, Guggenheim JAAtan D. Education and myopia: assessing the direction of causality by mendelian randomisation. BMJ 2018;361(k2022.
14. McCrann S, Flitcroft I, Lalor K, Butler J, Bush ALoughman J. Parental attitudes to myopia: a key agent of change for myopia control? Ophthalmic Physiol Opt 2018;38(3): 298–308.
15. Moon YLim HT. Relationship between peripapillary atrophy and myopia progression in the eyes of young school children. Eye (London, England) 2021;35(2): 665–671.
16. Liu XN, Naduvilath TJ, Wang J, Xiong S, He X, Xu XSankaridurg PR. Sleeping late is a risk factor for myopia development amongst school-aged children in China. Scientific reports 2020;10(1): 17194.
17. Kearney S, O'Donoghue L, Pourshahidi LK, Cobice DSaunders KJ. Myopes have significantly higher serum melatonin concentrations than non-myopes. Ophthalmic Physiol Opt 2017;37(5): 557–567.
18. Ostrin LA, Jnawali A, Carkeet APatel NB. Twenty-four hour ocular and systemic diurnal rhythms in children. Ophthalmic Physiol Opt 2019;39(5): 358–369.
19. Nickla DLTotonelly K. Brief light exposure at night disrupts the circadian rhythms in eye growth and choroidal thickness in chicks. Experimental eye research 2016;146(189–195.
20. Chakraborty R, Ostrin LA, Nickla DL, Iuvone PM, Pardue MTStone RA. Circadian rhythms, refractive development, and myopia. Ophthalmic Physiol Opt 2018;38(3): 217–245.
21. Volkow ND, Tomasi D, Wang GJ, Telang F, Fowler JS, Logan J, Benveniste H, Kim R, Thanos PKFerré S. Evidence that sleep deprivation downregulates dopamine D2R in ventral striatum in the human brain. The Journal of neuroscience: the official journal of the Society for Neuroscience 2012;32(19): 6711–6717.
22. Chakraborty R, Micic G, Thorley L, Nissen TR, Lovato N, Collins MJLack LC. Myopia, or near-sightedness, is associated with delayed melatonin circadian timing and lower melatonin output in young adult humans. Sleep 2021;44(3):
23. Greco CMSassone-Corsi P. Circadian blueprint of metabolic pathways in the brain. Nature reviews. Neuroscience 2019;20(2): 71–82.

24. Stone RA, McGlinn AM, Chakraborty R, Lee DC, Yang V, Elmasri A, Landis E, Shaffer J, Iuvone PM, Zheng X, et al. Altered ocular parameters from circadian clock gene disruptions. PloS one 2019;14(6): e0217111.

Figures

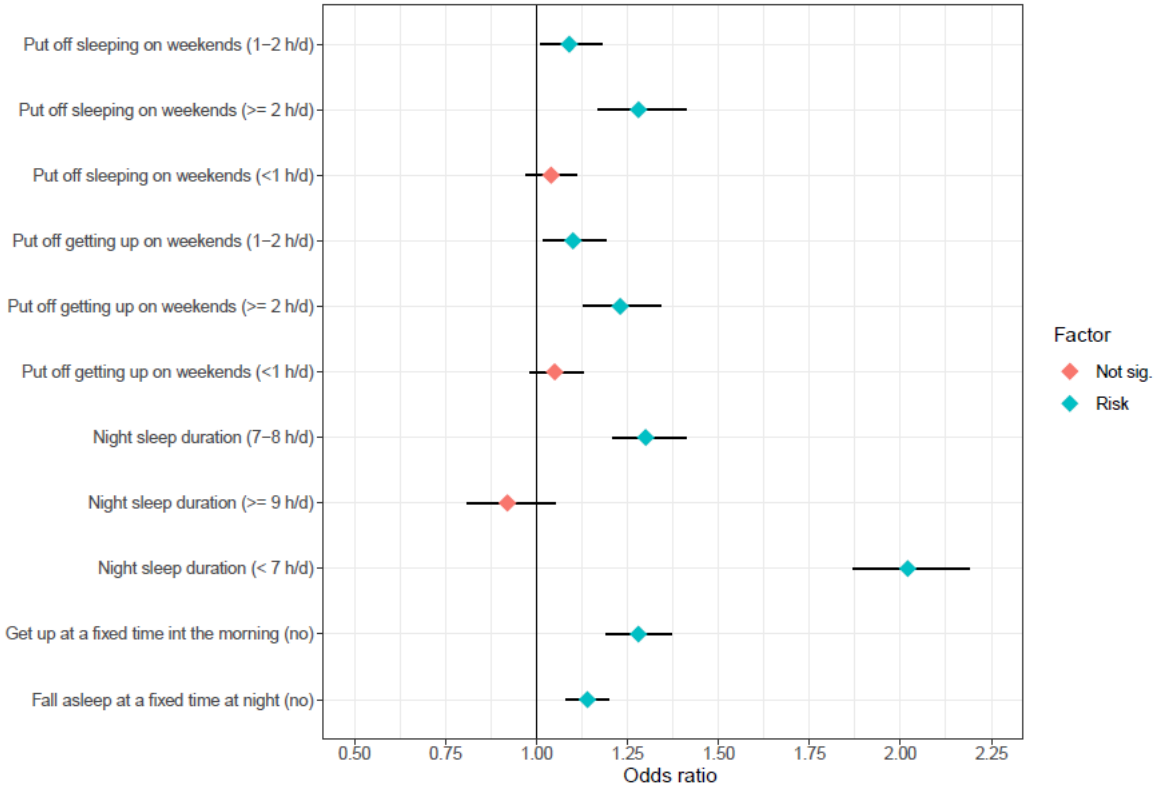

Figure 1

Forest plot of the association between sleep status and myopia in children and adolescence, adjusted for sex, outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.

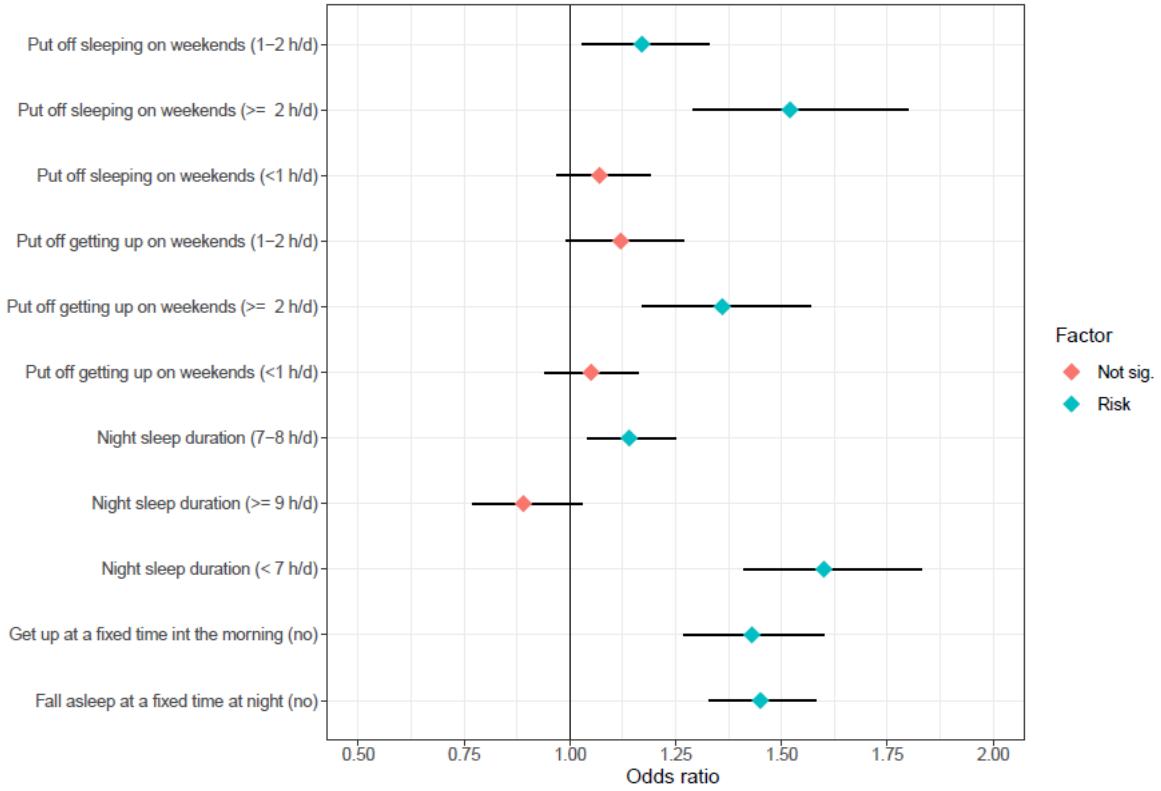

Figure 2

Forest plot of the association between sleep status and myopia in primary group, adjusted for sex, outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.

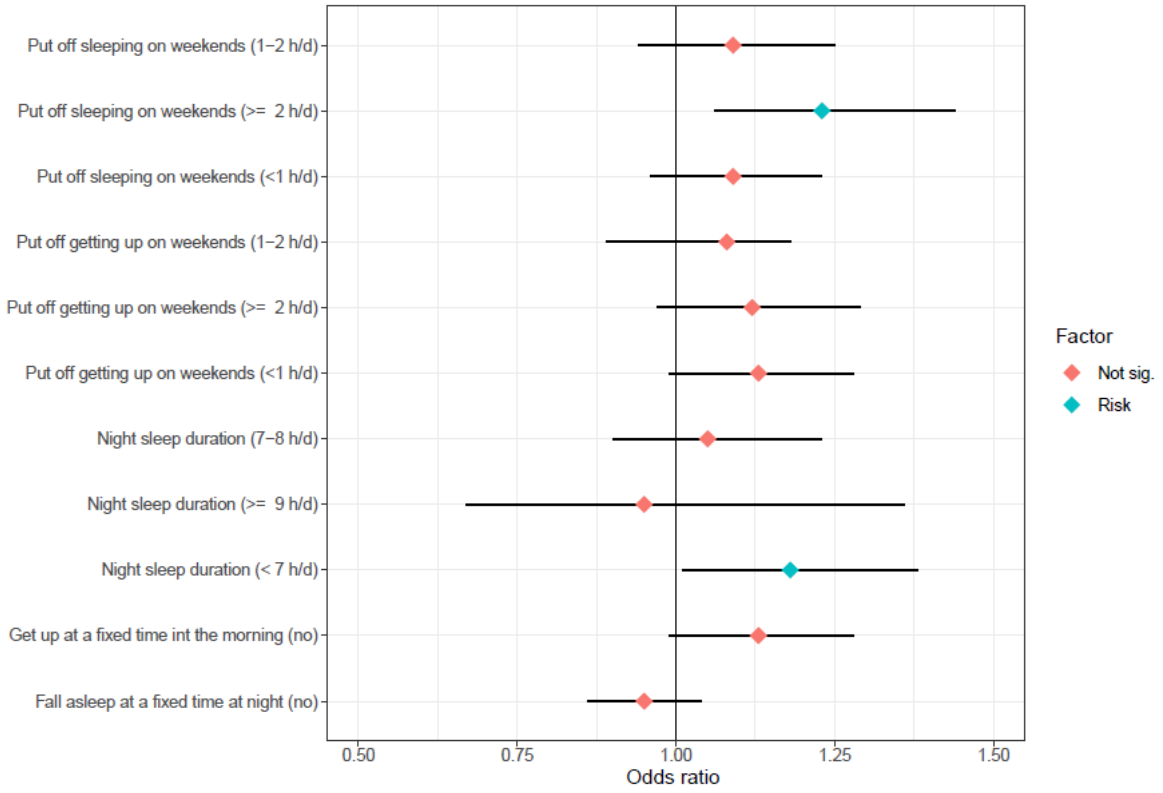

Figure 3

Forest plot of the association between sleep status and myopia in junior high group, adjusted for sex, outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.

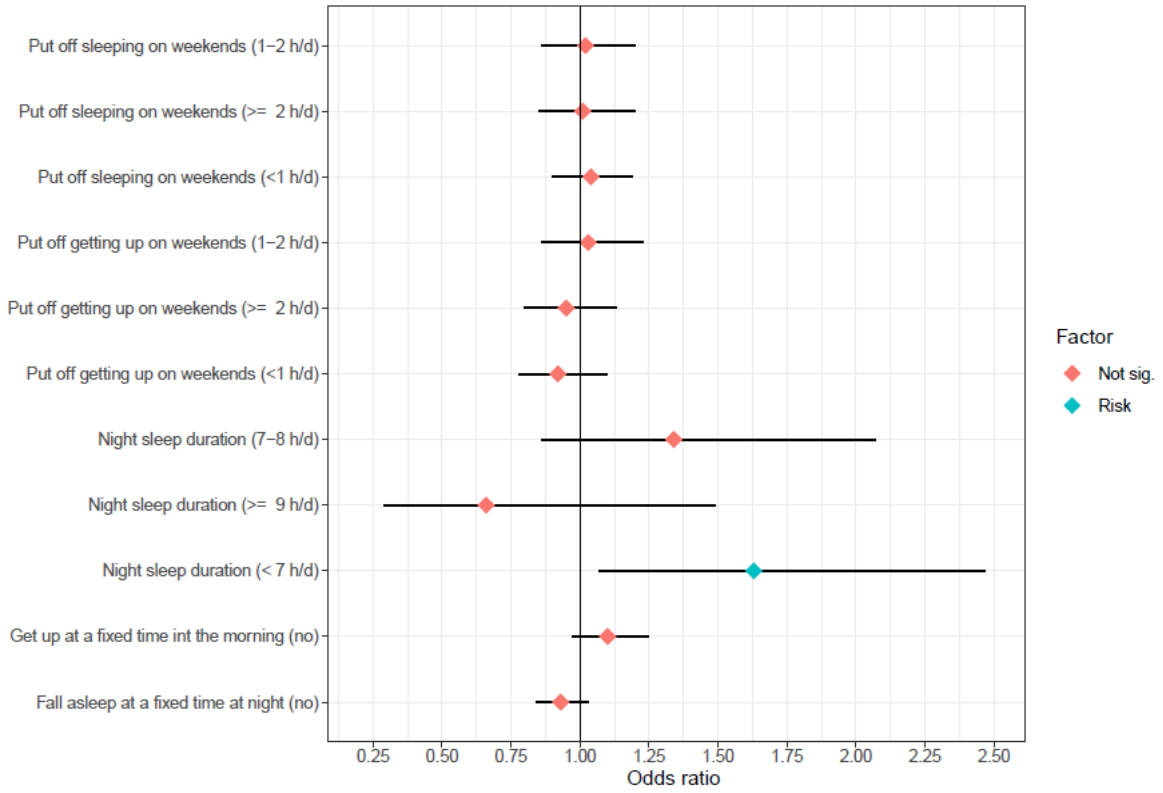

Figure 4

Forest plot of the association between sleep status and myopia in senior high group, adjusted for sex, outdoor activity, academic record, study burden, family economic level, father's education, mother's education, father myopia, mother myopia.