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Original Article

Sleep duration in Chinese adolescents: biological, environmental, and behavioral predictors

Ting Chen [a,b], Zengqiang Wu [c], Zhifei Shen [c], Jun Zhang [a,b], Xiaoming Shen [a,b], Shenghui Li [a,b,*]

[a] MOE – Shanghai Key Laboratory of Children's Environmental Health, Xinhua Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai, China
[b] School of Public Health, Shanghai Jiao Tong University, Shanghai, China
[c] Shanghai Academy of Educational Sciences, Shanghai, China

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ABSTRACT

Objective: To examine sleep duration-related risk factors from multidimensional domains among Chinese adolescents.
Methods: A random sample of 4801 adolescents aged 11–20 years participated in a cross-sectional survey. A self-reported questionnaire was used to collect information about the adolescents' sleep behaviors and possible related factors from eight domains.
Results: In all, 51.0% and 9.8% of adolescents did not achieve optimal sleep duration (defined as <8.0 h per day) on weekdays and on weekends, respectively. According to multivariate logistic regression models, after adjusting for all possible confounders, 17 factors were associated with sleep duration <8 h. Specifically, 13 factors from five domains were linked to physical and psychosocial condition, environment, and behaviors. These factors were overweight/obesity, chronic pain, bedtime anxiety/excitement/depression, bed/room sharing, school starting time earlier than 07:00, cram school learning, more time spent on homework on weekdays, television viewing ≥2 h/day, physical activity <1 h/day, irregular bedtime, and shorter sleep duration of father.
Conclusion: Biological and psychosocial conditions, sleep environments, school schedules, daily activity and behaviors, and parents' sleep habits significantly may affect adolescents' sleep duration, indicating that the existing chronic sleep loss in adolescents could be, at least partly, intervened by improving adolescents' physical and psychosocial conditions, controlling visual screen exposure, regulating school schedules, improving sleep hygiene and daytime behaviors, and changing parents' sleep habits.

1. Introduction

Sleep is recognized as a major contributing factor to physical and mental health in children and adolescents [1,2]. It is generally believed that sleep is beneficial not only for energy conservation, neuronal recuperation, and brain plasticity, which are linked to daytime brain functioning and body homeostasis, but also for growth and cognitive and psychological development [3–7].

It has been demonstrated that despite the need for sleep in children and adolescents, sleep duration decreases with age and, as a result, sleep debt increases with age [8–14]. Therefore, the most marked reductions in sleep duration and the highest prevalence of sleepiness were thought to occur in adolescents [8–14]. In the context of elevated prevalence and negative consequences of sleep loss, increasing attention has been paid to the potential risk factors associated with short sleep duration in adolescents. These risk factors, or at least some of them, could be intervention targets.

Previous studies have suggested that the influential factors associated with sleep duration among adolescents included demographic factors, family environments, lifestyle patterns, sociocultural conventions, health status, and school schedules [15–21]. However, nearly all of these studies focused on a specific single perspective. Based on a strong tradition of Confucianism and intrinsic sociocultural values in China, Chinese adolescents may be most vulnerable to short sleep duration [8,22,23]. However, to the best of our knowledge, no study has yet specifically explored sleep duration and its related factors in this population. To fill these knowledge gaps, the present epidemiological study was designed to investigate sleep duration and its related factors in eight domains among Chinese adolescents: demographic characteristics, family

* Corresponding author at: School of Public Health affiliated with Shanghai Jiaotong University School of Medicine, 227 South Chongqing Road, 200127, China. Tel.: +86 21 63846590 ext. 776139; fax: +86 21 63846590.
E-mail address: Lsh9907@163.com (S. Li).

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structure and socioeconomic status, biological and psychosocial conditions, family history of sleep disorders, sleep environments, school schedules, routine activities and behaviors, and parents' sleep habits.

2. Methods

2.1. Ethics

The ethical application and consent procedure of this study were approved by the Ministry of Education of the People's Republic of China and Ethics Committee of Shanghai Jiaotong University School of Medicine.

2.2. Subjects and procedures

A cross-sectional study was conducted in Shanghai, which is located along the east coast of China with a total population of ~20.8 million in 2012 (State statistical bureau of the People's Republic of China, 2012). There are 17 districts in Shanghai, nine located in urban areas and eight in suburban/rural areas. From these districts, four located in urban areas and two located in suburban/rural areas were randomly selected. For every district, two junior high schools and two senior high schools were randomly selected. Study sample candidates were selected from the student population of these schools. Among 5159 students eligible for the study, 4966 (96.25%) returned completed questionnaires. One hundred and sixty-five children whose sleep duration was less than −3 standard deviations from the mean (SD) and/or greater than +3 SD were deleted. The final sample consisted of 4801 children (49.1% boys vs 50.9% girls). The mean age of the sample was 15.59 years (SD, 2.05; range, 11.0–20.0).

This study was conducted during November 2009. The research aims were explained to school principals and teachers in the target schools. Permission was obtained to carry out the study, which is the usual practice in China. The survey was implemented during a regular health education class. In the class, an anonymous questionnaire was delivered to the students. Researchers explained the study purpose to the students and emphasized that participation was voluntary. Students were requested to fill out the questionnaires. All students who did not attend the class were excluded from the survey.

2.3. Measures

2.3.1. Sleep duration

Sleep behaviors were assessed by a self-reported sleep inventory – the Adolescent Sleep Wake Scale (ASWS). ASWS is a five-subscale instrument which was designed and developed to screen for the most common sleep problems in adolescents [24]. A Chinese version of the ASWS was developed by translation and back-translation, and has excellent sensitivity and reliability (Cronbach's α coefficients for the internal consistency were 0.71 for the overall questionnaire and ranged from 0.61 to 0.73 for subscales; intraclass correlation coefficients for the test–retest reliability were 0.85 for the overall questionnaire and ranged from 0.64 to 0.82 for subscales).

The respondents were also requested to indicate their sleep habit during the previous month. Sleep habit information included bedtime, wake-up time, and sleep duration on weekdays (from Monday to Friday) and on weekends (Saturday and Sunday). For the statistical analysis, the number of minutes was divided by 60, multiplied by 100, and added to the number of hours to obtain a metric variable.

To determine the risk factors related to short sleep duration, the sleep duration was dichotomized into <8.0 h vs ≥8.0 h. Sleep duration <8.0 h was defined as less than optimal sleep duration. This cut-off point was chosen based on literature review and clinical evidence, where it has been shown that 8.0 h reflects the clinical importance of sleep restriction at the age of adolescence [8,15,25,26]. Two recently published papers emphasized that during pubertal development, the physiological needs for sleep do not decrease with increasing age [27,28]. Therefore, we adopted the same cut-off point for all of the sampled adolescents.

2.3.2. Possible risk factors regarding sleep duration

The 38 possible risk factors were grouped into eight domains: (1) demographic characteristic variables, (2) family structure and socio-economic status variables, (3) biological and psychosocial condition variables, (4) family history of sleep disorder variables, (5) sleep environment variables, (6) school schedule variables, (7) daily activity and behavior variables, and (8) parents' sleep habit variables.

Demographic characteristic variables included adolescents' age, gender, and class type (terminal class/general class).

Family structure and socio-economic status variables included household income [<1000, 1000–3000, and ≥3000 Renminbi (RMB; yuan)/person/month], family structure [single parent family, nuclear family, and large family (the family with family members of grandparents, parents, and child)], and parents' educational levels [middle school and below (low), high school (medium), and college and above (high)].

Adolescents' biological and psychosocial condition variables included overweight/obesity status [yes/no, defined by the standardized internationally referenced gender- and age-specific body mass index (weight in kg/height in m^2)] cut-offs [29]. Weight and height came from student physical health screening, which is conducted in September and October every year), chronic respiratory condition (yes/no, with the definition of being ever diagnosed with allergic rhinitis and bronchitis, asthma, or tonsil/adenoidal hypertrophy by pediatricians), chronic pain (yes/no), and history of attention deficit/hyperactivity disorder (ADHD) diagnosis (yes/no, with definition of being ever diagnosed with ADHD by pediatricians), bedtime anxiety (usually/often and occasionally/no, defined as feeling upset or worrying about something during bedtime), and bedtime excitement/depression (usually/often and occasionally/no, defined as feeling excited or feeling very sad during bedtime).

Family history of sleep disorder variables included parents' history of sleep disorders (yes/no) and grandparents' history of sleep disorders (yes/no).

Sleep environment variables included sleep arrangements (routine room/bed sharing vs sleeping alone; routine room/bed sharing was defined as sharing a bed/room with parents/caregivers five to seven nights per week), bedroom intrusive noise (usually/often and occasionally/no), bedroom intrusive light (usually/often and occasionally/no), and temperature too high or low (usually/often and occasionally/no).

School schedule variables included school starting time (before/after 07:00), school ending time (before/after 16:30), cram school learning (yes/no), and homework on weekdays and on weekends (<2 h/day and ≥2 h/day; the cut-off was based upon our previous study [30]).

Daily activity and behavior variables included psychotropic medications used during the previous month (yes/no; psychotropic medications include aspirin, Ritalin, caffeine, phenobarbital, etc.), active or passive smoking (yes/no), alcohol drinking (yes/no), television viewing (<2 and ≥2 h/day), computer game playing/computer using (usually/often and occasionally/no), physical activity on weekdays and weekends (<1 and ≥1 h/day), having drinks with caffeine or alcohol after 18:00 (usually/often and occasionally/no), doing exciting activities (for example, playing outside, playing video/internet games, and watching violent/stimulating television programs) around bedtime (usually/often and occasionally/no), and irregular bedtime (usually/often and occasionally/no).

Table 1
Biological and psychosocial condition and family history of sleep disorders regarding sleep duration <8.0 h by multivariate logistical regression models ($N = 4801$).

Variables	Model I		Model II		Model III	
	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Sleep duration on weekdays						
Biological and psychosocial condition						
Overweight/obesity vs none	1.18 (0.97–1.45)	0.103	1.15 (0.94–1.41)	0.181	1.08 (0.87–1.35)	0.474
Chronic respiratory condition vs none	1.08 (0.92–1.28)	0.335	1.02 (0.86–1.21)	0.794	0.97 (0.81–1.17)	0.749
Chronic pain vs none	1.43 (1.23–1.66)	<0.001	1.33 (1.14–1.56)	<0.001	1.29 (1.09–1.53)	0.003
History of ADHD diagnosis vs none	1.76 (1.03–3.01)	0.039	1.51 (0.87–2.64)	0.143	1.48 (0.83–2.63)	0.187
Bedtime anxiety		<0.001		<0.001		<0.001
Usually/often vs occasionally/no	1.64 (1.41–1.91)		1.54 (1.31–1.81)		1.44 (1.21–1.71)	
Bedtime excitement/depression		0.011		0.486		0.861
Usually/often vs occasionally/no	1.56 (1.11–2.19)		1.14 (0.79–1.64)		0.97 (0.65–1.43)	
Family history of sleep disorders						
Parents' history of sleep disorders vs none	1.39 (1.19–1.62)	<0.001	1.31 (1.10–1.55)	0.002	1.24 (1.03–1.49)	0.020
Grandparents' history of sleep disorders vs none	1.30 (1.05–1.61)	0.014	1.15 (0.91–1.46)	0.235	1.14 (0.89–1.46)	0.300
Sleep duration on weekends						
Biological and psychosocial condition						
Overweight/obesity vs none	1.49 (1.13–1.96)	0.005	1.47 (1.11–1.95)	0.007	1.45 (1.07–1.95)	0.015
Chronic respiratory condition vs none	1.13 (0.89–1.42)	0.320	1.08 (0.85–1.38)	0.511	1.05 (0.81–1.36)	0.727
Chronic pain vs none	1.25 (1.01–1.55)	0.039	1.15 (0.92–1.44)	0.210	1.09 (0.86–1.39)	0.475
History of ADHD diagnosis vs none	1.29 (0.66–2.49)	0.457	1.17 (0.60–2.30)	0.648	1.18 (0.59–2.35)	0.639
Bedtime anxiety		<0.001		0.007		0.027
Usually/often vs occasionally/no	1.53 (1.24–1.89)		1.37 (1.09–1.72)		1.32 (1.03–1.70)	
Bedtime excitement/depression		<0.001		0.003		0.046
Usually/often vs occasionally/no	2.35 (1.62–3.41)		1.86 (1.24–2.78)		1.57 (1.01–2.44)	
Family history of sleep disorders						
Parents' history of sleep disorders vs none	1.07 (0.86–1.33)	0.545	1.11 (0.87–1.41)	0.393	1.04 (0.80–1.35)	0.763
Grandparents' history of sleep disorders vs none	0.96 (0.70–1.32)	0.795	0.95 (0.67–1.35)	0.775	0.95 (0.66–1.37)	0.802

OR, odds ratio; CI, confidence interval; ADHD, attention deficit/hyperactivity disorder.
Model I adjusted for demographic characteristics, and family structure and socio-economic status.
Model II adjusted for demographic characteristics, family structure and socio-economic status, biological and psychosocial condition, and family history of sleep disorders.
Model III adjusted for demographic characteristics, family structure and socio-economic status, biological and psychosocial condition, family history of sleep disorders, sleep environments, school schedules, daily activity and behavior, and parents' sleep habits simultaneously.

Parents' sleep habit variables included bedtime (before 22:00, from 22:00 until midnight, later than midnight) and sleep duration (<6, 6–8, and ≥8 h/day).

The recording of each possible risk factor is demonstrated in Supplementary Table S1.

2.4. Statistical analysis

Statistical descriptions were made using the mean, standard deviation for continuous variables, and percentage for categorical variables. Independent-sample *t*-test, one-way analysis of variance, and χ^2-test were used to compare differences between groups where appropriate.

To identify related factors regarding sleep duration in our sampled adolescents, logistic regression analyses were performed, with '1' for sleep duration <8.0 h and '0' for sleep duration ≥8.0 h. Unadjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated by univariate logistic regression (Supplementary Table S2). Adjustments were also made by multivariate regression models following a three-step procedure. Each model included additional variables to assess increasingly proximate determinants of sleep duration: first, a simple model (model I) adjusted only for demographic and socio-economic characteristics (Tables 1–3 and Supplementary Table S3); second, variables regarding biological chronic health problems, psychosocial conditions, and family history of sleep disorders (Table 1) or sleep environments, school schedules (Table 2) or daily activity and behavior routine and parents' sleep habits (Table 3) were further included (model II); finally, a full model (model III) was established by adjusting socio-economic and environmental factors, biological chronic health problems and psychosocial conditions, family history of sleep disorders, sleep environments, school schedules, daily activity and behavior routine, and parents' sleep habits simultaneously. In addition, the multivariate linear regression analyses were also performed (Supplementary Tables S4–S6).

All analyses were performed using the Statistical Package for Social Sciences (SPSS) for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P < 0.05$ (two-tailed).

3. Results

3.1. Sleep duration and characteristics of the sample

The mean sleep duration in the sampled adolescents was 7.60 h (SD, 1.10) on weekdays and 9.23 h (SD, 1.42) on weekends, respectively. Compared with girls, boys' sleep duration on weekdays was somewhat longer (boys 7.68 h vs girls 7.53 h; $t = 4.81$, $P < 0.001$). The gender difference was not found on weekend sleep duration (boys 9.20 h vs girls 9.27 h; $t = -1.80$, $P = 0.072$). There was a significant tendency for shorter sleep duration with increasing age (weekday sleep duration: $F = 352.40$, $P < 0.001$; weekend sleep duration: $F = 23.07$, $P < 0.001$). Fig. 1 shows the sleep duration by age and gender.

It was shown that 51.0% of the sampled adolescents slept <8.0 h per day on weekdays (girls 54.8% vs boys 46.9%; $\chi^2 = 30.25$, $P < 0.001$). With increasing age, the prevalence of sleep duration <8.0 h increased ($\chi^2 = 1246.07$, $P < 0.001$). Compared to weekdays, the prevalence of sleep duration <8.0 h on weekends was much lower (9.8%). Fig. 2 shows the prevalence of sleep duration <8.0 h by age and gender.

3.2. Correlating factors of sleep duration by univariate logistical analyses

The unadjusted OR with 95% CI of possible risk factors for sleep duration less than 8.0 h on weekdays and on weekends are shown

Table 2
Sleep environments and school schedules regarding sleep duration <8.0 h by multivariate logistic regression models ($N = 4801$).

Variables	Model I		Model II		Model III	
	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Sleep duration on weekdays						
Sleep environments						
Sleep arrangements		0.524		0.595		0.858
Bed or room sharing vs sleeping alone	0.94 (0.77–1.14)		0.95 (0.77–1.16)		0.98 (0.78–1.23)	
Bedroom intrusive noise		0.022		0.026		0.843
Usually/often vs occasionally/no	1.34 (1.04–1.73)		1.36 (1.04–1.77)		1.03 (0.77–1.39)	
Bedroom intrusive light		0.107		0.400		0.747
Usually/often vs occasionally/no	1.23 (0.96–1.59)		1.12 (0.86–1.48)		0.95 (0.71–1.28)	
Temperature too high or low		0.220		0.573		0.675
Usually/often vs occasionally/no	1.39 (0.82–2.37)		1.17 (0.68–2.03)		0.88 (0.48–1.62)	
School schedules						
School starting time		0.069		0.137		0.067
Before 07:00 vs after 07:00	1.17 (0.99–1.39)		1.15 (0.96–1.37)		1.20 (0.99–1.45)	
School ending time		0.072		0.346		0.916
After 16:30 vs before 16:30	1.18 (0.99–1.40)		1.09 (0.91–1.31)		1.01 (0.83–1.24)	
Cram school learning vs none	1.08 (0.92–1.27)	0.334	1.07 (0.91–1.26)	0.397	1.03 (0.86–1.22)	0.777
Homework on weekdays		<0.001		<0.001		<0.001
≥2 vs <2 h/day	2.23 (1.92–2.59)		2.19 (1.86–2.56)		2.02 (1.70–2.40)	
Homework on weekends		0.003		0.727		0.559
≥2 vs <2 h/day	1.33 (1.10–1.61)		1.04 (0.85–1.27)		1.07 (0.86–1.32)	
Sleep duration on weekends						
Sleep environments						
Sleep arrangements		0.009		0.033		0.002
Bed or room sharing vs sleeping alone	1.58 (1.12–2.22)		1.47 (1.03–2.08)		1.85 (1.25–2.73)	
Bedroom intrusive noise		0.001		0.003		0.191
Usually/often vs occasionally/no	1.71 (1.25–2.33)		1.65 (1.19–2.31)		1.29 (0.88–1.87)	
Bedroom intrusive light		0.131		0.717		0.490
Usually/often vs occasionally/no	1.31 (0.92–1.87)		1.07 (0.73–1.57)		0.86 (0.57–1.31)	
Temperature too high or low		0.022		0.110		0.710
Usually/often vs occasionally/no	2.02 (1.11–3.68)		1.67 (0.89–3.12)		0.87 (0.40–1.86)	
School schedules						
School starting time		0.002		0.007		0.015
Before 07:00 vs after 07:00	1.46 (1.16–1.85)		1.40 (1.10–1.79)		1.39 (1.07–1.81)	
School ending time		0.058		0.170		0.245
After 16:30 vs before 16:30	1.33 (0.99–1.78)		1.23 (0.91–1.67)		1.21 (0.88–1.68)	
Cram school learning vs none	1.46 (1.15–1.87)	0.002	1.50 (1.17–1.93)	0.001	1.38 (1.06–1.80)	0.018
Homework on weekdays		0.068		0.162		0.517
≥2 vs <2 h/day	1.24 (0.98–1.57)		1.19 (0.93–1.53)		1.09 (0.84–1.43)	
Homework on weekends		0.339		0.661		0.185
≥2 vs <2 h/day	1.15 (0.86–1.55)		1.07 (0.79–1.46)		1.26 (0.90–1.77)	

OR, odds ratio; CI, confidence interval.
Model I adjusted for demographic characteristics, and family structure and socio-economic status.
Model II adjusted for demographic characteristics, family structure and socio-economic status, sleep environments, and school schedules.
Model III adjusted for demographic characteristics, family structure and socio-economic status, biological and psychosocial condition, family history of sleep disorders, sleep environments, school schedules, daily activity and behavior, and parents' sleep habits simultaneously.

in Supplementary Table S2. Almost all factors were statistically significant in the univariate regression models.

3.3. Correlating factors of sleep duration by multivariate regression analyses

3.3.1. Demographic characteristics, and family structure and socio-economic status

After controlling all potential factors, age, gender, and class type were found to be significantly associated with sleep duration <8.0 h on weekdays (Supplementary Table S3). For sleep duration on weekends, age and class type were independent influential factors.

3.3.2. Biological/psychosocial conditions, and family history of sleep disorders

The association of sleep duration on weekdays with biological/psychosocial conditions and family history is presented in Table 1. After adjusting only for demographic and socio-economic characteristics, six factors (chronic pain, history of ADHD diagnosis, bedtime anxiety, bedtime excitement/depression, parents' and grandparents' history of sleep disorders) were significantly associated with an increased likelihood of shorter sleep duration (model I). After further adjusting for biological/psychosocial conditions and family history of sleep disorders, three factors (chronic pain, bedtime anxiety, and parents' history of sleep disorders) remained statistically significant (model II). The associations were not found to be changed after adjusting for environmental and behavioral variables simultaneously (model III).

The association of weekend sleep duration with biological/psychosocial conditions and family history is demonstrated in Table 1. After controlling for all factors simultaneously, the full model indicated that overweight/obesity, bedtime anxiety, and bedtime excitement/depression were independent risk factors.

3.3.3. Sleep environments and school schedules

The association between sleep duration on weekdays and sleep environments and school schedules is given in Table 2. After adjusting only for demographic and socio-economic characteristics, three factors (bedroom intrusive sound, more time spent on homework on weekdays and on weekends) were significantly related to

Table 3
Daily activity and behavior and parents' sleep habits regarding sleep duration <8.0 h by multivariate logistic regression models ($N = 4801$).

Variables	Model I		Model II		Model III	
	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Sleep duration on weekdays						
Daily activity and behavior						
Psychotropic medications used in previous month vs none	1.25 (0.89–1.76)	0.195	1.17 (0.82–1.66)	0.393	1.04 (0.72–1.50)	0.853
Active or passive smoking vs none	1.15 (0.96–1.38)	0.138	1.04 (0.86–1.26)	0.653	1.04 (0.85–1.27)	0.693
Drinking vs none	2.68 (1.10–6.49)	0.029	2.22 (0.87–5.63)	0.095	1.96 (0.69–5.53)	0.204
Television viewing		0.737		0.834		0.587
≥2 vs <2 h/day	1.06 (0.76–1.49)		0.96 (0.68–1.37)		1.11 (0.77–1.61)	
Computer game playing/computer using		0.026		0.554		0.179
Usually/often vs occasionally/no	1.22 (1.02–1.45)		1.06 (0.88–1.28)		1.15 (0.94–1.39)	
Physical activity on weekdays		0.096		0.064		0.035
<1 vs ≥1 h/day	1.18 (0.97–1.43)		1.23 (0.99–1.52)		1.28 (1.02–1.60)	
Physical activity on weekends		0.022		0.173		0.246
<1 vs ≥1 h/day	1.21 (1.03–1.42)		1.13 (0.95–1.35)		1.12 (0.93–1.35)	
Having drinks with caffeine or alcohol after 18:00		<0.001		0.014		0.062
Usually/often vs occasionally/no	1.57 (1.24–1.97)		1.36 (1.07–1.75)		1.29 (0.99–1.69)	
Doing exciting activities around bedtime		0.001		0.255		0.740
Usually/often vs occasionally/no	1.32 (1.13–1.55)		1.11 (0.93–1.32)		1.03 (0.85–1.25)	
Irregular bedtime		<0.001		<0.001		<0.001
Usually/often vs occasionally/no	2.17 (1.78–2.64)		1.98 (1.61–2.45)		1.70 (1.36–2.13)	
Parents' sleep habits						
Mother's bedtime		<0.001		0.015		0.100
Later than midnight vs before 22:00	2.17 (1.46–3.23)	<0.001	1.61 (1.03–2.52)	0.036	1.35 (0.84–2.17)	0.218
22:00–midnight vs before 22:00	1.40 (1.20–1.62)	<0.001	1.25 (1.05–1.48)	0.013	1.21 (1.00–1.45)	0.045
Father's bedtime		<0.001		0.221		0.217
Later than midnight vs before 22:00	2.03 (1.53–2.68)	<0.001	1.32 (0.96–1.82)	0.087	1.35 (0.96–1.89)	0.081
22:00–midnight vs before 22:00	1.31 (1.12–1.53)	0.001	1.09 (0.91–1.31)	0.332	1.07 (0.89–1.30)	0.471
Mother's sleep duration		<0.001		0.227		0.126
<6 vs ≥8 h/day	1.76 (1.22–2.54)	0.002	1.10 (0.72–1.66)	0.664	1.03 (0.67–1.60)	0.895
6–8 vs ≥8 h/day	1.38 (1.18–1.62)	<0.001	1.18 (0.98–1.42)	0.086	1.22 (1.00–1.48)	0.050
Father's sleep duration		<0.001		0.005		0.031
<6 vs ≥8 h/day	2.34 (1.70–3.21)	<0.001	1.81 (1.26–2.60)	0.001	1.67 (1.14–2.44)	0.009
6–8 vs ≥8 h/day	1.29 (1.09–1.53)	0.004	1.20 (0.98–1.46)	0.073	1.15 (0.94–1.42)	0.180
Sleep duration on weekends						
Daily activity and behavior						
Psychotropic medications used in previous month vs none	0.99 (0.63–1.56)	0.960	0.86 (0.53–1.38)	0.520	0.86 (0.53–1.41)	0.552
Active or passive smoking vs none	1.25 (0.97–1.60)	0.087	1.18 (0.91–1.54)	0.214	1.19 (0.90–1.57)	0.216
Drinking vs none	1.95 (0.78–4.91)	0.155	1.42 (0.54–3.73)	0.479	0.89 (0.28–2.88)	0.851
Television viewing		0.020		0.057		0.018
≥2 vs <2 h/day	1.68 (1.08–2.59)		1.55 (0.99–2.43)		1.76 (1.10–2.81)	
Computer game playing/computer using		0.157		0.778		0.459
Usually/often vs occasionally/no	1.19 (0.94–1.52)		1.04 (0.80–1.35)		1.11 (0.84–1.46)	
Physical activity on weekdays		0.338		0.204		0.334
< 1 vs ≥1 h/day	0.87 (0.66–1.15)		0.82 (0.60–1.12)		0.85 (0.62–1.18)	
Physical activity on weekends		0.039		0.007		0.008
<1 vs ≥1 h/day	1.30 (1.01–1.67)		1.47 (1.11–1.95)		1.49 (1.11–1.99)	
Having drinks with caffeine or alcohol after 18:00		<0.001		0.013		0.097
Usually/often vs occasionally/no	1.71 (1.29–2.26)		1.46 (1.09–1.97)		1.31 (0.95–1.82)	
Doing exciting activities around bedtime		0.003		0.235		0.965
Usually/often vs occasionally/no	1.39 (1.12–1.74)		1.16 (0.91–1.48)		1.01 (0.77–1.32)	
Irregular bedtime		<0.001		0.001		0.014
Usually/often vs occasionally/no	1.74 (1.37–2.21)		1.52 (1.17–1.96)		1.42 (1.07–1.88)	
Parents' sleep habits						
Mother's bedtime		0.244		0.911		0.982
Later than midnight vs before 22:00	1.51 (0.92–2.47)	0.107	0.92 (0.52–1.64)	0.784	1.03 (0.57–1.86)	0.921
22:00–midnight vs before 22:00	0.99 (0.80–1.23)	0.932	0.95 (0.74–1.22)	0.690	1.03 (0.79–1.34)	0.851
Father's bedtime		0.070		0.534		0.330
Later than midnight vs before 22:00	1.48 (1.04–2.12)	0.029	1.26 (0.83–1.91)	0.276	1.32 (0.86–2.04)	0.204
22:00–midnight vs before 22:00	1.03 (0.82–1.30)	0.811	1.04 (0.79–1.36)	0.778	0.99 (0.74–1.31)	0.931
Mother's sleep duration		0.054		0.607		0.614
<6 vs ≥8 h/day	1.62 (1.03–2.55)	0.037	1.24 (0.74–2.09)	0.421	1.08 (0.62–1.88)	0.788
6–8 vs ≥8 h/day	0.95 (0.75–1.21)	0.691	0.97 (0.74–1.27)	0.814	0.89 (0.67–1.19)	0.440
Father's sleep duration		<0.001		0.021		0.014
<6 vs ≥8 h/day	2.02 (1.37–2.97)	<0.001	1.76 (1.13–2.74)	0.013	1.86 (1.17–2.96)	0.009
6–8 vs ≥8 h/day	0.98 (0.76–1.26)	0.879	1.02 (0.77–1.36)	0.890	1.02 (0.76–1.38)	0.889

OR, odds ratio; CI, confidence interval.
Model I adjusted for demographic characteristics, and family structure and socio-economic status.
Model II adjusted for demographic characteristics, family structure and socio-economic status, daily activity and behavior, and parents' sleep habits.
Model III adjusted for demographic characteristics, family structure and socio-economic status, biological and psychosocial condition, family history of sleep disorders, sleep environments, school schedules, daily activity and behavior, and parents' sleep habits simultaneously.

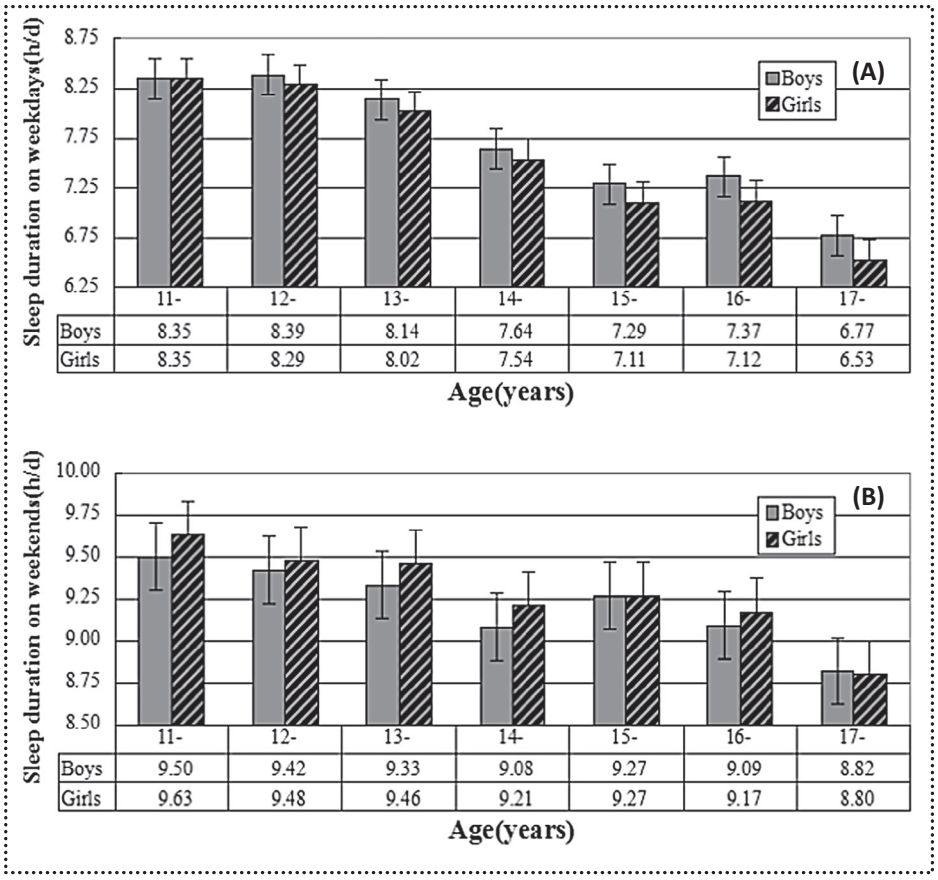

Fig. 1. Mean sleep duration by age and sex. (A) Sleep duration on weekdays; (B) sleep duration on weekends.

an increased likelihood of shorter sleep duration (model I). After controlling simultaneously for sleep environments and school schedules, except for more time on homework on weekends, two other factors remained statistically significant (model II). After adjusting further for all health problems, family history, and behavioral variables, only more time on homework on weekdays remained as risk factors for shorter sleep duration (model III). For sleep duration <8.0 h on weekends, bed/room sharing, school starting time earlier than 07:00, and cram school learning were found to be significant in the full model.

3.3.4. Daily activity and behavior routine and parents' sleep habits

The association of sleep duration on weekdays with behavior routine and parent's sleep habits is shown in Table 3. After adjusting only for demographic and socio-economic characteristics, 10 factors were significantly associated with an increased likelihood of sleep duration <8.0 h (model I). After controlling simultaneously for daily activity and behavior routine and parent's sleep habits, four factors (having drinks with caffeine/alcohol after 18:00, irregular bedtime, later bedtime of mother, and shorter sleep duration of father) remained statistically significant (model II). After further adjusting for all other health problems, family history and environmental variables, irregular bedtime, and shorter sleep duration of father remained statistically significant. Moreover, physical activity <1 h on weekdays, which was not significant in models I or II, was found to be related to weekday shorter sleep duration in model III.

For sleep duration on weekends, factors such as television viewing ≥2 h/day, physical activity <1 h on weekends, irregular bedtime, and shorter sleep duration of father were independent risk factors in the full model (model III).

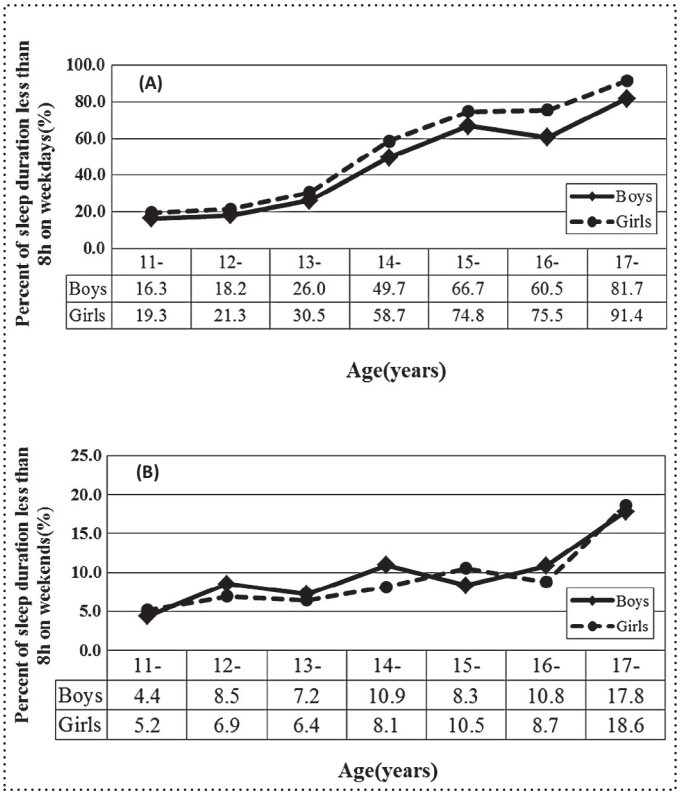

Fig. 2. Prevalence of sleep duration <8 h by age and sex. (A) Prevalence of sleep duration <8 h on weekdays; (B) prevalence of sleep duration <8 h on weekends.

3.4. Correlating factors of sleep duration by multivariate linear analyses

To provide more comprehensive information regarding sleep duration among Chinese adolescents, the standardized beta, along with 95% confidence interval, of possible risk factors, was calculated using multivariate linear regression models (Supplementary Tables S4–S6).

4. Discussion

This study demonstrated that insufficient sleep duration, defined as sleep duration <8.0 h per day, was widespread in Chinese adolescents, especially during weekdays. Biological and psychosocial conditions, sleep environments, school schedules, daily activity and behaviors, and parents' sleep habits were significant predictors.

4.1. Sleep duration in adolescents

In contrast to sleep duration on weekdays, adolescents slept approximately 1.5 hours longer on weekends (7.60 vs 9.23 h). Consistent with our previous finding among school-aged children, a similar phenomenon of sleep debt on weekdays and subsequent sleep compensation on weekends was found once again in adolescents [30]. Taken together, these studies suggest that the practice of insufficient sleep is widespread among school-aged children through high school adolescents. Statistical gender difference in weekday insufficient sleep duration was found (boys 46.9% vs girls 54.8%; $\chi^2 = 30.25$, $P < 0.001$), which is very similar to the results of a study in Spanish adolescents aged 13–18.5 years [31].

Compared with their peers in Australia (mean 8.28 h during school days) [32], Belgium (mean 10.00 h) [18], Chinese adolescents slept ~20 min to nearly 2 h and 30 min fewer. The difference in sleep duration could have physiological significance since previous research showed that modest change in sleep duration (~40 min on three consecutive nights) can improve (in the case of extension) or worsen (in the case of restriction) adolescents' neurobehavioral functioning [33]. Accordingly, efforts to examine factors related to sleep duration and to develop effective interventions to increase the duration of Chinese adolescents' sleep would seem necessary.

4.2. Factors regarding sleep duration

To the best of our knowledge, this is the first study to report influential factors of sleep duration from multidimensional perspectives. Our study included 38 potential influential factors elicited from eight domains: demographic characteristics, socioeconomic characteristics, biological and psychosocial conditions, family history of sleep disorders, sleep environments, school schedules, daily activity and behavior routine, and parents' sleep habits.

Taking all the potential confounding effects into account, 17 factors were found to be significant risk factors for sleep duration <8.0 h in our sampled adolescents. Among all these identified factors, 13 factors derived from five domains (biological/psychosocial conditions, sleep environments, school schedules, daily activity and behavior routine, and parents' sleep habits) should be given more attention, since these factors could be important targets for intervention.

Several studies have revealed that biological/psychosocial fitness could influence sleep duration [15,16,19]. Our present study further confirmed that, among six biological/psychosocial conditions, four were significantly associated with insufficient sleep duration.

Associations of obesity and chronic pain with sleep duration have been reported in other studies [20,30,34]. Our study provided new evidence for these associations among Chinese adolescents. Mental and psychosocial disability has been a major concern in modern competitive society [35]. Particularly, puberty is a very vulnerable stage for emotional and mental problems [36]. The present study demonstrated that more than one-third of Chinese adolescents frequently went through negative emotion during bedtime; it is the first study to establish the associations between negative mental condition and insufficient sleep duration among Chinese adolescents. By contrast, the associations were not established among our previous study in school-aged children [30].

Compared to other environment factors, such as noise, light, and temperature, bed/room sharing seemed to have greater impact on adolescents' sleep duration. In addition, we found that parents' sleep habits were associated with adolescents' sleep duration. Combined together, family environment and shared lifestyle should be taken into account in sleep research. Our previous study similarly indicated that co-sleeping potentially associated with negative effects on children's sleep hygiene and sleep problems [37]. Sleep arrangement, marked with ethnic, economic status, and socio-cultural background characteristics, was more prevalent in non-western countries. The implication of sleep arrangement on psychosocial and physical development has not been definitively determined. Another study in Chinese adolescents revealed that adolescents and their parents had correlations in sleep/wake patterns, perceived sleep need, and insomnia symptoms [38]. All these studies revealed a close linkage in sleep behaviors between adolescents and their parents, though the intrinsic underlying mechanisms have not been clearly interpreted.

The present study found that school starting time earlier than 07:00 and more time spent on homework were significant predictors for insufficient sleep duration, a finding similar to our previous study conducted among school-aged children [30]. Our study also showed, for the first time, that cram school learning was a significant predictor among Chinese adolescents. School schedules reflect certain cultural attributes and traditions of a nation. It is well known that Chinese students, especially high school students, are burdened with tremendous academic pressure even to the extent of sacrificing sleep time. Outwith the regular school academic schedule, many students have an extra learning plan. The present study demonstrated that as high a proportion as 63.9% of Chinese adolescents attended extracurricular learning classes.

In our study, associations between sleep duration and daily activity and behavior routine were examined. Many studies have suggested that media exposure such as computer game playing, Internet use, and television viewing may contribute to the increase in sleep loss among adolescents [17,30,39], which were consistent with our finding. Furthermore, our data provided evidence that physical activity was related to sleep duration among adolescents. The literature on this topic is scarce and worthy of further research [31]. In addition, our study supported previous findings that poor bedtime hygiene practices (e.g. irregular bedtime) were strong predictors for insufficient sleep duration [30,40,41]. There has been a general understanding of the importance of sleep hygiene for optimal sleep duration [17,40,41].

4.3. Limitations

There are several limitations that should be considered when interpreting the results. We collected information on adolescents' biological chronic health problems through self-reported questionnaire, but not clinical measures (a more rigorous method, unfortunately unavailable for large samples). Moreover, although we presented the findings from a rich data-set of possible risk factors, other factors may be significantly associated with adolescents' sleep duration.

5. Conclusions

This report provides information about influential factors of sleep duration in Chinese adolescents. Biological and psychosocial condition, sleep environments, school schedules, daily activity and behaviors, and parents' sleep habits had significant impact on adolescents' sleep duration. The findings of our study have important clinical significance, as the results indicate that the existing chronic sleep loss in adolescents could be, at least partly, intervened. A more recent study in adolescents found that school-based intervention was effective in addressing adolescents' sleep problems [42]. Based on our results, we advocate the combination of school- and family-oriented intervention, which should be more effective.

Our analyses have two major strengths. This is the first population-based study to examine influential factors associated with sleep duration among Chinese adolescents. We also extended previous findings by presenting results from a richer array of potential risk factors covering eight domains. Therefore, the present study has extended the information for understanding the correlates of chronic sleep loss in adolescents.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.05.018.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.sleep.2014.05.018.

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