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ORIGINAL CONTRIBUTION

Association between weekday sleep duration and nonmedical use of prescription drug among adolescents: the role of academic performance

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Abstract

Nonmedical use of prescription drug (NMUPD) among adolescents has increased substantially over the last 2 decades, and evidence suggests that sleep duration may impact upon drug use and academic performance. This study aimed to estimate the prevalence of sleep duration, NMUPD, and academic performance among Chinese adolescents, to test the independent associations of sleep duration with NMUPD, and to investigate whether these associations vary by academic performance. Data were from the 2015 School-based Chinese Adolescents Health Survey using a multi-stage, stratified-cluster, random-sampling method to collect information from 162,601 high school students [mean age (SD) = 15.2 (1.9) years; 47.4% were male] from 42 cities in China. The weighted prevalence of sleeping ≤ 5 h/weekday was 1.1% (95% CI, 1.0–1.1%), and the weighted prevalence of sleeping > 9 h/weekday was 7.6% (95% CI 7.4–7.7%). After adjusting for significant covariates and academic performance, the results showed that compared with those with 7–9 h/weekday sleep duration, students reporting ≤5 h/weekday were more likely to misuse opioids (AOR = 2.12, 95% CI 1.73–2.59), sedatives (AOR = 2.00, 95% CI 1.65–2.42), and any prescription drug use (AOR = 1.89, 95% CI 1.60–2.23); students with>9 h/weekday sleep duration were also at a higher risk of opioids use, sedative use, and any prescription drug misuse; the U-shaped association of sleep duration with NMUPD was found. Moreover, there exist significant associations between weekday sleep duration and NMUPD among Chinese adolescents, and academic performance plays a moderating role in the aforementioned associations. The efforts to prevent NMUPD should be focused on adolescents who report abnormal sleep duration or poor academic performance.

Keywords Sleep duration · Sleep · Academic performance · Nonmedical use of prescription drug · Moderating effect · Adolescent

Introduction

Adolescence refers to the period of transition between childhood and adulthood, and is characterized by increased imitation and exploration along with a range of risky behaviors, including drug use [1]. During this period, adolescents may be responsible for their own medication management and especially vulnerable to the damaging effects of drug use for their still developing brains [2]. Non-medical use of prescription drugs (NMUPD) is defined as prescription drug use without a doctor's prescription or solely for the experience or feeling caused by the drug [3]. NMUPD has increased substantially over the last 2 decades, which is growing at a faster rate than that of most illicit drugs [4]. However, compared with illicit drugs, prescription drugs are more easily available to most adolescents from peers or home [5], and are commonly misperceived as safer [6].

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Results from the 2014 National Survey on Drug Use and Health (NSDUH) in the United States demonstrated that prescription drugs were the second most popular type of drugs among adolescents [7], and the latest 2016 NSDUH report showed that the prevalence of past-year opioid use among adolescents was approximately 3.6% (corresponding to 891,000 adolescents) [8]. Our previous studies in China also demonstrated that 3.2% of adolescents reported the misuse of any prescription drugs, and the most common non-medically used prescription drugs among students were sedatives (2.0%), followed by opioids (1.6%) [9]. NMUPD has become a growing public health problem, and Chinese adolescents are no exception.

Sleep is necessary for physical and mental health across adolescence, and insufficient sleep can be harmful [10]. The National Sleep Foundation (NSF) recommends a sleep range of 8–10 h per day for teenagers (14–17 years) and a sleep range of 7–9 h per day for young adults (18–25 years) [11], and the American Academy of Sleep Medicine (AASM) mentions that teenagers (13–18 years) should sleep 8–10 h per day on a regular basis to promote optimal health. However, prior studies have illustrated that sleep duration tends to decrease during adolescence, despite the need for sleep remaining constant, and irregular and insufficient sleep among adolescents has been a major public health concern [12]. A number of adolescents reported that they slept less than 7 h/weekday, with an estimated prevalence of 29.0–39.0% [13, 14]. Our previous studies also demonstrated that among Chinese adolescents, sleep disturbance was not rare (with a prevalence of 39.6%) [15], and the weighted prevalence of sleeping ≤5 h/day was 5.6% [14]. Evidence has suggested that short sleep duration (less than 7 h on school nights) is associated with an increased risk behavior factors among middle school students [16]. Poor sleep quality is associated with substance use [17, 18], and sleep deprivation is related to low self-control, which has been found to be associated with a range of behaviors including substance use among adolescents [19]. Moreover, sleep duration and quality also can affect hormonal function which may cause psychological and physiological impairments to occur along with NMUPD [20]. Although some studies reported the significant association between sleep and substance use [18, 21], little is known about which sleep duration is concurrently related to prescription drug use problems among the Chinese adolescents.

Additionally, it has also been reported that lack of sleep can have negative effects on cognitive functions and academic performance [22, 23]. Furthermore, previous studies have demonstrated that poor academic performance was more common among adolescents involved in substance use behaviors [24, 25]. Recently, regarding education inequality in China, academic stress has become a serious social problem. To compete for resources (i.e., to outperform their competitors in average student academic performance), most Chinese high schools start earlier than 07:00 a.m., keep students in classes for long hours, assign a mass of homework, and organize countless exams [26]. School schedules may also reflect certain cultural attributes, and it is well known that Chinese high school students are burdened with tremendous academic stress even to the extent of sacrificing sleep to achieve better academic performance [27, 28]. Therefore, in the association between sleep duration and NMUPD among Chinese adolescents, academic performance may play a potential moderating role.

Prior studies reported that circadian characteristics (e.g., age, gender), school dynamics (e.g., relationships with classmates or teachers), and family status (e.g., living arrangement and family socioeconomic status) were also associated with sleep duration, academic performance, or NMUPD among adolescents [29–31]. However, there is also a paucity of studies considering the effects of the above-mentioned covariates on the association between sleep duration, academic performance, and NMUPD. Confucianism has been the major cultural influence in China for more than 2000 years, and the principles of Confucianism are emphasizing education, family system, hierarchical relationships, and benevolence [32]. The traditional Confucianism and intrinsic sociocultural values may make Chinese adolescents differ from their peers in Western countries on the association between sleep duration, academic performance, and NMUPD.

Aims

The aims of this nationally large-scale study among Chinese adolescents were twofold. First, to estimate the prevalence of sleep duration, NMUPD, and academic performance. Second, to test the hypotheses that weekday sleep duration may be independently associated with NMUPD, and the association of sleep duration with NMUPD may be moderated by academic performance.

Methods

Data collection

The present study used the data collected from the 2015 School-based Chinese Adolescents Health Survey (SCAHS). SCAHS is an ongoing study about the health-related behaviors among Chinese adolescents (7–12th grades; conducted every 2 years since 2007) [9, 33]. A multi-stage, stratified cluster, random sampling method was utilized in the 2015 SCAHS. The procedures for data collection were as follows: in stage 1, seven large provinces of China were randomly

selected in this study. According to per capita gross domestic product (GDP), we divided the selected provinces into three economic stratifications (high economic level, middle economic level, and low economic level), and two representative cities (or primary sampling units) were randomly selected from each stratification. The selected provinces and cities were: (1) Eastern China including Shandong province (Zibo city, Yantai city, Binzhou city, Taian city, Linyi city, and Heze city); (2) Southern China including Guangdong province (Shenzhen city, Zhongshan city, Yangjiang city, Qingyuan city, Jieyang city, and Heyuan city); (3) Southwestern China including Guizhou province (Guiyang city, Liupanshui city, Qiannan city, Anshun city, Qiandong city, and Bijie city) and Chongqing municipality (Yuzhong district, Fuling district, Beibei district, Yongchuan district, Youyang county, and Yunyang county); (4) Northern China including Liaoning (Dalian city, Shenyang city, Yingkou city, Liaoyang city, Dandong city, and Chaoyang city) and Shanxi (Taiyuan city, Jincheng city, Lvliang city, Jinzhong city, Datong city, and Xinzhou city); (5) Central China including Hunan (Zhuzhou city, Yueyang city, Changde city, Chenzhou city, Jishou city, and Shaoyang city). In stage 2, there were four general and four vocational high schools that were randomly chosen from each representative city. In stage 3, two classes were randomly selected from each grade within the selected schools. All students who were available in the selected classes were invited to participate in this study voluntarily. Of the students invited, 162,601 students' questionnaires were completed and qualified, resulting in a response rate of 94.1%. To protect the privacy of the students, a rigorously anonymous method was utilized to collect information from the self-reported questionnaires. These questionnaires were completed by students during the normal class period (45 min), and were administered by our research assistants without the presence of teachers (to avoid any potential information bias). Written informed consent letters were obtained from each participant who was at least 18 years of age. If the student was under 18 years of age, a written informed consent letter was obtained from one of the student's parents (or legal guardian). The study obtained the ethical approval from the Sun Yat-Sen University, School of Public Health Institutional Review Board.

Measures

Outcome variable

NMUPD was assessed by asking students the following question: 'during the 12 months, have you taken the following medications not to treat sickness but just for the purpose of experiencing or getting high without a doctor's prescription (responses were coded as No=0 and Yes=1)?' In this study, the three measures of NMUPD included non-medical use of opioids, sedatives, and any of the above-mentioned prescription drugs. The list of prescription drugs was reported to be widely used by adolescent drug abusers in rehabilitation centers of China, and provided by the Center for Adverse Drug Reaction (ADR) Monitoring of Guangdong. Opioids included compounded liquorice tablets (opium), compounded cough syrup with codeine (codeine), tramadol hydrochloride, and diphenoxylate. Sedatives included compounded aminopyrine phenacetin tablets (barbiturates), diazepam or triazolam (benzodiazepines), and scopolamine hydrobromide tablets (barbiturates).

Independent variable

Sociocultural conventions and school schedules have impacts on sleep duration among adolescents [34]. Most Chinese high schools start earlier than 07:00 a.m., keep students in classes for long hours, and assign a mass of homework [26]. Based on literature review and the practical situations about the sleep duration of Chinese adolescents [13, 14, 35–37], weekday sleep duration was measured by the item ('how many hours of sleep do you get on a weekday [a normal school day]?'). Considering it is common that Chinese adolescents are burdened with high academic stress even to the extent of sacrificing sleep time [27, 28], the responses of the total sleep time (TST) were divided into '≤ 5 h', '5–7 h', '7–9 h', or '>9 h'. The response of '7–9 h' was labeled as moderate rather than optimal, and students choosing this answer were treated as our reference group.

Moderating variable

Regarding the Chinese education system, almost all of the high schools run final exams at the end of each academic semester [38]. Although the final exams (may contain different types or numbers of courses) may vary in relation to school type and grade level, high schools in China get used to rank students based on the total test scores (or GPA) of the final exam at the end of each academic semester, and each grade in each school has the ranking of the final exam [26]. Actually, all the high schools recruited in this study run final exams at the end of each academic semester, each grade in each school has the recorded ranking of the final exam, and this record is always distributed to students to make sure they know their place in academic performance. In this study, academic performance was captured by asking the students their ranking in the final exam at the academic semester closest to the survey period. The responses were categorized into "good/above average=1", "average=2", and "poor/below average=3″ according to school and grade level. The "average" means the median level of the ranking.

Covariates

Depressive symptoms were measured by the Center for Epidemiologic Studies Depression Scale (CES-D) in Chinese, which has been validated and extensively utilized in Chinese adolescents with a satisfactory psychometric properties [39, 40], and the Cronbach's α for CES-D scale was 0.89 in this study. The students were asked to rate the frequency of 20 symptoms of depression by choosing one of four response options that ranged from 'rarely or none of the time' to 'most or all of the time'. Higher scores were indicative of more severe depressive symptomatology, with a maximum score of 60 [41]. Other substance use (including smoking and drinking) was evaluated by asking students the question: 'have you smoked a cigarette (or drunk alcohol) in your lifetime (responses were coded as No =0 and Yes=1)?'.

Demographic characteristics were also assessed, including age, gender (1 = boys, 2 = girls), living arrangement, household socioeconomic status (HSS), classmate relations, and relationships with teachers. Students' living arrangement (including living with two biological parents = 1, living with only father or mother = 2, and living with others = 3) was measured by asking students who lived in their primary home. HSS (categorized into excellent or very good = 1, good = 2, and fair or poor = 3) was assessed by asking students about their perception of the family economic status. Classmate relations and relationships with teachers were measured by asking the student's perception of their relationships with classmates and teachers (responses ranged from good = 1 to poor = 3).

Statistical analysis

First, descriptive analyses stratified by NMUPD were utilized to describe the sample characteristics, and categorical and continuous data were reported in the form of proportions and means (SD). Second, appropriate sampling weights and estimation procedures that accounted for the complex sampling design were utilized in the prevalence estimates and logistic regression analyses [42]. For the outcome with low event rate, logistic regression models used the Firth's penalized likelihood approach [43]. Univariate logistic regression models were first conducted to explore the potential associations of sleep duration and academic performance with NMUPD. Next, multivariate logistic regression analyses were performed to evaluate the independent associations between sleep duration and NMUPD, and those variables that were significant in the chi-square tests (or t tests) or widely reported in the literature were simultaneously incorporated in the multivariate logistic regression models. To investigate whether the associations of sleep duration with NMUPD varied by students' academic performance, we tested the interaction item between sleep duration and academic performance. Third, if the interaction item was significantly related to NMUPD, stratification analyses would be performed to evaluate the association of sleep duration with NMUPD in students with different academic performance. Regarding the logistic regression analyses, observation with missing data was eliminated. All statistical analyses were conducted using Stata SE 12.0 (StataCorp, Houston, Texas, USA). All statistical tests were two sided, and a P value of less than 0.05 was considered statistically significant.

Results

The sample characteristics are shown in Table 1. Of 162,601 eligible participants, 47.4% were male. The mean (SD) age of the total students was 15.2 (SD: 1.9) years. The majority of students lived with two biological parents (72.0%), and 19.6% reported their HSS as fair or poor. The proportion of students with depressive symptoms was 10.4%. There were statistically significant differences between students involved or not involved in NMUPD in the distribution of gender, age, grade, living arrangement, HSS, relationships with teachers, classmate relations, smoking, drinking, depressive symptoms, academic performance, and sleep duration ($P < 0.05$).

The weighted prevalence of sleeping ≤5 h/weekday was 1.1% (95% CI, 1.0–1.1%), the weighted prevalence of sleeping 5–7 h/weekday was 29.7% (95% CI 29.4–29.9%), the weighted prevalence of sleeping 7–9 h/weekday was 61.7% (95% CI 61.5–61.9), and the weighted prevalence of sleeping>9 h/weekday was 7.6% (95% CI 7.4–7.7%). Overall, 35.6% (95% CI 35.4–35.9%) of the students reported good academic performance, 34.0% (95% CI 33.7–34.2%) reported average academic performance, and 30.4% (95% CI 30.2–30.7%) reported poor academic performance. A total of 3.1% (95% CI 3.0–3.2%) students admitted opioid use, 3.7% (95% CI 3.6–3.8%) reported sedatives misuse, and 5.6% (95% CI 5.4–5.7%) reported nonmedical use of any prescription drug.

Table 2 presents the associations of sleep duration and academic performance with NMUPD. Without adjusting for any covariates, Model 1 demonstrated that a self-reported TST ≤5 h/weekday, 5–7 h/weekday, and >9 h/weekday was positively associated with nonmedical use of opioids, sedatives, and any prescription drug, respectively. Additionally, self-reported academic performance was also significantly associated with NMUPD ($P < 0.05$). After adjusting for age, gender, grade, living arrangement, HSS, relationships with teachers, classmate relations, smoking, drinking, and depressive symptoms, Model 2 illustrated that students who reported average or poor academic performance were more likely to be involved in opioid misuse, sedative misuse, and nonmedical use of any prescription drug ($P < 0.05$).

Table 1 Sample characteristics among 162,601 adolescents

Variables	Total, *n* (%)	Opioid use		Sedative use		APDU	
		n (%)	*P* value[a]	*n* (%)	*P* value[a]	*n* (%)	*P* value[a]
Total	162,601 (100.0)	5010 (3.1)	NA	6039 (3.7)	NA	9044 (5.6)	NA
Gender							
Boys	74,837 (47.4)	2535 (3.4)	< 0.001	2548 (3.4)	< 0.001	4157 (5.6)	0.596
Girls	82,896 (52.6)	2287 (2.8)		3269 (3.9)		4554 (5.5)	
Missing data	4868	NA		NA		NA	
Age, mean (SD)	15.2 (1.9)	15.0 (1.8)	< 0.001	15.2 (2.0)	0.693	15.1 (1.9)	< 0.001
Grade							
7th	25,675 (15.8)	788 (3.1)	< 0.001	816 (3.2)	< 0.001	1320 (5.1)	< 0.001
8th	27,652 (17.0)	1012 (3.7)		1221 (4.4)		1833 (6.6)	
9th	27,573 (17.0)	983 (3.6)		1081 (3.9)		1684 (6.1)	
10th	31,809 (19.6)	994 (3.1)		1292 (4.1)		1871 (5.9)	
11th	29,604 (18.2)	792 (2.7)		1074 (3.6)		1519 (5.1)	
12th	20,285 (12.5)	441 (2.2)		555 (2.7)		818 (4.0)	
Missing data	3	NA		NA		NA	
Living arrangement							
Two biological parents	116,639 (72.0)	3224 (2.8)	< 0.001	3869 (3.3)	< 0.001	5861 (5.0)	< 0.001
Only father or mother	19,701 (12.2)	722 (3.7)		831 (4.2)		1264 (6.4)	
Others	25,752 (15.9)	1042 (4.0)		1310 (5.1)		1877 (7.3)	
Missing data	510	NA		NA		NA	
Household socioeconomic status							
Excellent or very good	32,380 (20.0)	1023 (3.2)	< 0.001	1141 (3.5)	< 0.001	1767 (5.5)	< 0.001
Good	97,827 (60.4)	2803 (2.9)		3318 (3.4)		5031 (5.1)	
Fair or poor	31,821 (19.6)	1156 (3.6)		1553 (4.9)		2200 (6.9)	
Missing data	573	NA		NA		NA	
Relationships with teachers							
Good	88,165 (54.4)	2267 (2.6)	< 0.001	2668 (3.0)	<0.001	4059 (4.6)	< 0.001
Average	68,401 (42.2)	2374 (3.5)		2940 (4.3)		4371 (6.4)	
Poor	5490 (3.4)	341 (6.2)		402 (7.3)		572 (10.4)	
Missing data	545	NA		NA		NA	
Classmate relations							
Good	117,984 (72.8)	3260 (2.8)	< 0.001	3926 (3.3)	< 0.001	5924 (5.0)	< 0.001
Average	41,300 (25.5)	1539 (3.7)		1907 (4.6)		2813 (6.8)	
Poor	2819 (1.7)	190 (6.7)		184 (6.5)		273 (9.7)	
Missing data	499	NA		NA		NA	
Smoking							
No	148,052 (93.3)	4152 (2.8)	< 0.001	5065 (3.4)	< 0.001	7619 (5.1)	< 0.001
Yes	10,676 (6.7)	720 (6.7)		808 (7.6)		1187 (11.1)	
Missing data	3874	NA		NA		NA	
Drinking							
No	81,866 (51.5)	3294 (4.0)	< 0.001	3966 (4.8)	< 0.001	5921 (7.2)	< 0.001
Yes	77,166 (48.5)	1605 (2.1)		1946 (2.5)		2935 (3.8)	
Missing data	3569	NA		NA		NA	
Depressive symptoms							
No	137,416 (89.6)	4163 (3.0)	0.004	5103 (3.7)	0.463	7617 (5.5)	0.930
Yes	15,900 (10.4)	547 (3.4)		572 (3.6)		884 (5.6)	
Missing data	9285	NA		NA		NA	
Academic performance							
Good	57,669 (35.6)	1312 (2.3)	< 0.001	1589 (2.8)	< 0.001	2421 (4.2)	< 0.001

Table 1 (continued)

Variables	Total, *n* (%)	Opioid use		Sedative use		APDU	
		n (%)	*P* value[a]	*n* (%)	*P* value[a]	*n* (%)	*P* value[a]
Average	55,029 (34.0)	1660 (3.0)		2083 (3.8)		3059 (5.6)	
Poor	49,266 (30.4)	2022 (4.1)		2338 (4.7)		3525 (7.2)	
Missing data	637	NA		NA		NA	
Sleep duration (h/night)							
≤ 5	1772 (1.1)	126 (7.1)	< 0.001	143 (8.1)	< 0.001	197 (11.1)	< 0.001
5–7	48,227 (29.7)	1480 (3.1)		1872 (3.9)		2774 (5.8)	
7–9	100,323 (61.7)	2924 (2.9)		3484 (3.5)		5261 (5.2)	
> 9	12,279 (7.6)	481 (3.9)		540 (4.4)		812 (6.6)	

APDU any prescription drug use, *SD* standard deviation, *NA* not applicable or no data available

[a]Chi-square tests were used for categorical variables, *t* tests were used for age data

Table 2 Association of sleep duration and academic performance with NMUPD

Variables	Model 1, OR (95% CI)			Model 2, AOR (95% CI)			Model 3, AOR (95% CI)		
	Opioid use	Sedative use	APDU	Opioid use	Sedative use	APDU	Opioid use	Sedative use	APDU
Sleep duration (h/night)									
≤ 5	2.54 (2.11–3.05)	2.44 (2.05–2.91)	2.26 (1.95–2.63)	2.13 (1.75–2.61)	2.02 (1.67–2.44)	1.91 (1.62–2.25)	2.12 (1.73–2.59)	2.00 (1.65–2.42)	1.89 (1.60–2.23)
5–7	1.06 (0.99–1.13)	1.16 (1.09–1.23)	1.13 (1.07–1.19)	1.10 (1.02–1.19	1.11 (1.04–1.19)	1.12 (1.06–1.19)	1.09 (1.01–1.18)	1.11 (1.03–1.18)	1.15 (1.09–1.21)
7–9	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
> 9	1.35 (1.23–1.49)	1.28 (1.16–1.40)	1.28 (1.18–1.38)	1.20 (1.07–1.34)	1.24 (1.12–1.37)	1.19 (1.09–1.30)	1.19 (1.06–1.33)	1.23 (1.11–1.36)	1.18 (1.08–1.28)
Academic performance									
Good	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)	NA	NA	NA
Average	1.34 (1.24–1.44)	1.40 (1.30–1.48)	1.34 (1.27–1.42)	1.23 (1.13–1.33)	1.25 (1.16–1.34)	1.23 (1.16–1.30)	NA	NA	NA
Poor	1.84 (1.71–1.97)	1.76 (1.65–1.88)	1.76 (1.67–1.86)	1.48 (1.37–1.60)	1.43 (1.33–1.54)	1.44 (1.35–1.53)	NA	NA	NA

NMUPD nonmedical use of prescription drug, *OR* odds ratio, *AOR*=adjusted odds ratio, *CI* confidence interval, *APDU* any prescription drug use

Model 1 were unadjusted models; the Firth's penalized likelihood approach was utilized for the low event rate

Model 2 adjusted for age, gender, grade, living arrangement, household socioeconomic status, relationships with teachers, classmate relations, smoking, drinking, and depressive symptoms; the Firth's penalized likelihood approach was utilized for the low event rate

Model 3 adjusted for age, gender, grade, living arrangement, household socioeconomic status, relationships with teachers, classmate relations, smoking, drinking, depressive symptoms, and academic performance; the Firth's penalized likelihood approach was utilized for the low event rate

Moreover, after adjusting for the above-mentioned significant covariates and academic performance, Model 3 demonstrated that compared with those with 7–9 h/weekday sleep duration, students reporting ≤5 h/weekday were more likely to misuse opioids (adjusted odds ratio [AOR] =2.12, 95% CI 1.73–2.59), sedatives (AOR=2.00, 95% CI 1.65–2.42), and any prescription drug use (AOR=1.89, 95% CI 1.60–2.23); students with>9 h/weekday sleep duration were also at a higher risk of opioid use (AOR=1.19, 95% CI 1.06–1.33), sedative use (AOR=1.23, 95% CI 1.11–1.36), and any prescription drug misuse (AOR=1.18, 95% CI 1.08–1.28). The U-shaped association of sleep duration

with nonmedical use of opioids, sedatives, and any prescription drug was found, respectively (please see the Fig. 1).

First, the results of the multivariate logistic regression models demonstrated that the interaction item (between sleep duration and academic performance) was significantly associated with nonmedical use of opioids, sedatives, and any prescription drug ($P < 0.05$). Next, Table 3 shows that the results of the stratification analyses conducted separately for students with different academic performance. Among students with self-reported good academic performance, our adjusted models showed that students with ≤5 h/weekday sleep duration were at a higher risk of opioid use (AOR = 2.48, 95% CI 1.69–3.63), sedative use (AOR = 2.46, 95% CI 1.71–3.52), and any prescription drug use (AOR = 2.21, 95% CI 1.62–3.03) than those with 7–9 h/weekday sleep duration. A self-reported TST of 5–7 h/weekday was significantly related to nonmedical use of sedatives (AOR = 1.16, 95% CI 1.02–1.32) and any prescription drug (AOR = 1.13, 95% CI 1.02–1.26). Among students with self-reported poor academic performance, the results of multivariate logistic

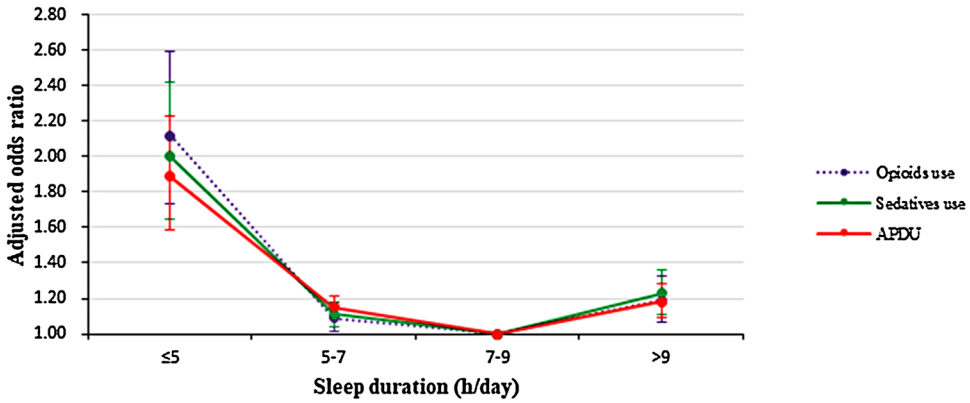

Fig. 1 Adjusted association of weekday sleep duration with nonmedical use of prescription drug among adolescents

Table 3 Associations between sleep duration and NMUPD stratified by academic performance

Variables	Opioid use[a]		Sedative use[a]		APDU[a]	
	AOR (95% CI)	*P* value	AOR (95% CI)	*P* value	AOR (95% CI)	*P* value
Good academic performance group						
Sleep duration (h/night)						
≤ 5	2.48 (1.69–3.63)	< 0.001	2.46 (1.71–3.52)	< 0.001	2.21 (1.62–3.03)	< 0.001
5–7	1.11 (0.96–1.29)	0.155	1.16 (1.02–1.32)	0.026	1.13 (1.02–1.26)	0.023
7–9	1.00 (reference)		1.00 (reference)		1.00 (reference)	
> 9	1.18 (0.94–1.48)	0.161	1.23 (0.99–1.53)	0.054	1.15 (0.96–1.37)	0.123
Average academic performance group						
Sleep duration (h/night)						
≤ 5	1.41 (0.90–2.21)	0.131	1.57 (1.06–2.31)	0.023	1.35 (0.96–1.91)	0.088
5–7	1.07 (0.93–1.22)	0.349	1.13 (1.01–1.27)	0.040	1.14 (1.03–1.25)	0.010
7–9	1.00 (reference)		1.00 (reference)		1.00 (reference)	
> 9	0.96 (0.78–1.19)	0.729	1.01 (0.84–1.22)	0.919	0.97 (0.83–1.14)	0.732
Poor academic performance group						
Sleep duration (h/night)						
≤ 5	2.35 (1.77–3.11)	< 0.001	2.03 (1.54–2.68)	< 0.001	2.07 (1.64–2.62)	< 0.001
5–7	1.10 (0.98–1.25)	0.117	1.05 (0.94–1.18)	0.385	1.10 (0.99–1.19)	0.061
7–9	1.00 (reference)		1.00 (reference)		1.00 (reference)	
> 9	1.37 (1.16–1.61)	< 0.001	1.40 (1.20–1.64)	< 0.001	1.37 (1.20–1.56)	< 0.001

NMUPD nonmedical use of prescription drug, *APDU* any prescription drug use, *AOR* adjusted odds ratio, *CI* confidence interval

[a]Model for opioids use, sedatives use, and APDU adjusted for age, gender, grade, living arrangement, household socioeconomic status, relationships with teachers, classmate relations, smoking, drinking, and depressive symptoms, separately; the Firth's penalized likelihood approach was utilized for the low event rate

regression models demonstrated that compared with those reporting 7–9 h/weekday sleep duration, students reporting ≤5 h/weekday were more likely to be involved in opioid misuse (AOR = 2.35, 95% CI 1.77–3.11), sedative misuse (AOR = 2.03, 95% CI 1.54–2.68), and any prescription drug misuse (AOR = 2.07, 95% CI 1.64–2.62). The associations of reporting sleep>9 h/weekday with opioid use (AOR = 1.37, 95% CI 1.16–1.61), sedative use (AOR = 1.40, 95% CI 1.20–1.64), and any prescription drug use (AOR = 1.37, 95% CI 1.20–1.56) were only statistically significant in students with self-reported poor academic performance. These results suggested that academic performance may play a significant moderating role in the associations between sleep duration and nonmedical use of opioids, sedatives, and any prescription drugs, respectively.

Discussion

NMUPD and abnormal sleep duration have been of great concern, and tend to increase among adolescents [7–9]. This study demonstrated that the weighted prevalence of opioid misuse, sedative misuse, and any prescription drug misuse during the past year was 3.1% (95% CI 3.0–3.2%), 3.7% (95% CI 3.6–3.8%), and 5.6% (95% CI 5.4–5.7%). These rates were similar with results from the 2016 NSDUH report indicating that 3.6% and 2.3% of adolescents admitted nonmedical use of opioids and sedatives in the past year, respectively [8]. In line with prior studies [9, 44], our study also reported that there existed significant differences between students with and without NMUPD in the distribution of gender, age, grade, living arrangement, HSS, relationships with teachers, classmate relations, smoking, drinking, depressive symptoms, academic performance, and sleep duration.

The present study also showed that the proportion of students who reported a TST of 7–9 h/weekday was the largest (accounting for 61.7%), and 1.1% and 7.6% of the students reported sleeping ≤ 5 h/weekday and > 9 h/weekday, respectively. The prevalence of short (or long) sleep duration was lower than that described in a previous study from the Youth Risk Behavior Surveillance System (YRBSS) suggesting the distribution of sleep duration among middle school students was 5.9% for ≤4 h/weekday, 6.0% for 5 h/weekday, 17.2% for 9 h/weekday, and 10.0% for ≥10 h/weekday [45]. One possible explanation for these differences may be in the nature of the samples (e.g., age and gender), females were more likely to report a long sleep duration than male, and older adolescents reported less sleep than younger adolescents [27]. Additionally, other environmental factors (such as school start time, academic stress, and electronic devices use) may also have impacts on adolescent sleep duration. Earlier school start time and higher academic stress were common among Chinese high schools and students [26–28], and these may explain the lower prevalence of sleeping>9 h/weekday in the present study. The higher prevalence of sleeping ≤5 h/weekday in the prior study using the data from the YRBSS might be related to that American adolescents were more easily exposed to gaming or social media [46], and American parents did not exert more control over their children than do Chinese parents (e.g., the control of electronic devices use) [47].

Adolescence is marked by profound changes in circadian rhythms and sleep [34], academic performance [25], and the increased likelihood of drug use [1]. Consistent with prior studies [18, 24, 25], after adjusting for demographics and depressive symptoms, our study first found that self-reported average and poor academic performers were at an elevated risk of past-year nonmedical use of opioids, sedatives, and any prescription drugs. A possible explanation for these results is that existing evidence has found that class attendance is positively associated with academic performance, and compared with good academic performers, students reporting poor academic performance may be more likely to be absent from schools and have a negative attitude toward school [48, 49]. Moreover, school is one of the main social institutions of adolescence and plays an important role in constraining problem behaviors. School absenteeism is considered as an important marker of a student's disengagement from school, and may increase the risk of substance use [50]. Moreover, after adjusting for the above-mentioned covariates and academic performance, a novel finding of this study is that compared with those reporting 7–9 h/weekday sleep duration, students who reported a TST of ≤5 h/weekday, 5–7 h/weekday, and>9 h/weekday were more likely to misuse opioids, sedatives, and any prescription drug, indicating that there was a U-shaped association of sleep duration with NMUPD. Similarly, Fakier et al. reported that adolescents having sleep problems were more likely to use tobacco, alcohol, cannabis, and other substance [18]; Tang et al. found a significant association between nonmedical use of opioids and poor sleep quality among Chinese adolescents [51]; Terry-McElrath et al. found that as the frequency of sleeping at least 7 h/weekday elevated, substance use frequency significantly decreased and vice versa among US secondary students [21]. These results might be related to that the deprivation of sleep may cause mood and impulse control dysregulation [52], and then it may result in substance use behaviors through negative moods or the impairment of impulsivity to drug self-administration [53]. For individuals with long sleep duration, prolonged sleep might be related to depression, social isolation, or chronic medical diseases [54], and social isolation has been reported to be associated with the onset and development of substance use [55]. Previous studies have proposed that 5-hydroxytriptamine system may play an important role in both sleep

and NMUPD [56, 57], and maturational changes at adolescence may influence the circadian timing system (leading to delayed sleep onset or later waking times) and health-risk behaviors (e.g., NMUPD). Although the mechanism of the association between sleep duration and NMUPD is still unclear, our findings recommend that (1) schools should educate students, parents, and teachers about the healthy sleep needs and patterns of adolescents, and increase their awareness of the adverse effects of NMUPD; (2) schools should provide earlier risk assessment and intervention strategies to students who have experienced abnormal sleep duration or NMUPD; (3) considering earlier school start time was common among high schools in China [26], schools should structure the school schedule to accommodate the sleep needs of adolescents (e.g., properly delaying school starting time); (4) students should avoid taking nicotine, caffeine, alcohols, and other chemical products that interfere with sleep; (5) government should strengthen the regulations to limit sales of prescription drugs to adolescents.

As the association between sleep problems and academic performance has been developed in prior studies [22, 23], and evidence also suggests that academic performance may be related to NMUPD [24, 25]. Our study first investigated the interaction effects between academic performance and sleep duration on NMUPD among adolescents, and the results indicated that this interaction item was significantly associated with nonmedical use of opioids, sedatives, and any prescription drug. Moreover, another novel finding of this study is that the results of the stratification analyses found that after adjusting for significant covariates, among students with self-reported good academic performance, short sleep duration was positively associated with nonmedical use of opioids, sedatives, and any prescription drug; among students with self-reported poor academic performance, students reporting a long sleep duration were at a higher risk of opioid use, sedative use, and any prescription drug use. These results suggested that academic performance may have moderating effects on the association of sleep duration with NMUPD, and we hypothesized a possible reason for these associations is that academic stress is high among Chinese high school students, and students with good academic performance may sacrifice sleep time to study [27, 28]. Students with poor academic performance may sleep longer than their corresponding groups, and those with abnormal sleep duration may lead to negative moods or reduction in impulse control [52, 58], which might be positively associated with NMUPD. Overall, our study findings highlighted the effects of sleep duration on NMUPD among students with different academic performance, and suitable and effective strategies which are helpful to develop proper sleep patterns might be important components in decreasing NMUPD in adolescents with abnormal sleep duration.

In general, the strengths of this study include the large sample size of Chinese adolescents, the first known moderating role of academic performance on the association between sleep duration and NMUPD. Moreover, our study also had several limitations that should be noted when interpreting the results. First, only school students were sampled in this study, and those adolescents who had dropped out of school or were not present in school on the day the survey was administered were not covered. However, abnormal sleep duration and NMUPD may be more common among adolescents who were absent. Second, because this study is the cross-sectional design, the interpretation of the direction of the observed associations is limited. Third, although depressive symptoms and other covariates have been incorporated in the model for evaluating the association between sleep duration and NMUPD, other psychiatric disorders (e.g., anxiety of bipolar disorder) were not considered in the current study. Fourth, the use of the structured self-report questionnaires to collect data may subject our results to recall bias, and some sensitive data (e.g., NMUPD) in this study may be underreported due to social desirability. However, the anonymity of the questionnaires is assured, and this method may have helped to collect accurate information from adolescents. Fifth, pubertal status (e.g., sexual maturity rating) may have influences on adolescents' reaction to their perceptions of the bodily changes and adolescent behavior (such as sleep) [59]. However, the measure of pubertal status is not included in the present study, but our future studies are suggested to consider this issue.

Conclusion

The present study found that short sleep duration and long sleep duration were independently associated with NMUPD, indicating the associations between sleep duration and NMUPD were U shaped. Moreover, the interaction between sleep duration and academic performance was significantly related to NMUPD. The results of stratification analyses indicated that among students reporting good academic performance, short sleep duration was associated with an increased risk of NMUPD; among those admitting poor academic performance, long sleep duration was positively associated with NMUPD, suggesting that academic performance played a moderating role in the association between sleep duration and NMUPD. Sleep duration and NMUPD among adolescents are public issues of concern, and our study recommended that a surveillance system like NSDUH in the United States should be established in China to monitor the sleep and NMUPD among adolescents, and parents and teachers should pay close attention to the adolescents who report abnormal sleep duration or are involved in NMUPD.

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Compliance with ethical standards

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