Association between Sleep Duration and Overweight/Obesity risk among middle-school students: a cross-sectional study in Fuzhou, China

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Abstract

Background: This study was designed to investigate the prevalence of sleep deprivation and explore the association between sleep duration and overweight or obesity in adolescents from middle school in Fuzhou, China.

Methods: Questionaires focusing on sleep duration and overweight or obesity related factors were collected. A generalized linear hybrid model was used to evaluate the effects of sleep duration on overweight or obesity in school students.

Results: The overall rates of overweight and obesity were 12.1% and 7.1%, respectively. The prevalence of sleep deprivation among students was 82.8%. The majority of high school students (92.5%) suffered from insufficient sleep. Compared with male children with a sleep duration of over 8 hrs a day, the odds ratios (95% *CI*) of overweight/obesity for those with a sleep duration of less than 6 h or 6 - 8 h, were 1.63 (1.25-2.13) and 1.06 (0.88-1.27). After adjusting social and demographic status, mental health and lifestyle factors, the odds ratios of female children were 1.38(0.99-1.93) and 1.04 (0.79-1.35), respectively.

Conclusions: A large number of adolescents suffered from insufficient sleep. Sleep duration was negatively correlated with overweight or obesity among male children.

Background

Overweight and obesity, with an increased trend in the past few decades, is becoming a threat to the public health worldwide. In a recent survey, about 711.4 million individuals were diagnosed with obesity, among which 107.7 million were children [1]. Meanwhile, a large proportion of adolescents (19.4%) aged 7–18 yrs presented overweight and obesity in a national survey [2]. In China mainland, the number of obese children is very huge because of alternations in the diet compared with the previous decades [1]. Fuzhou is the provincial capital of Fujian Province localized in the southeast of China. Previously, studies have been conducted on the corpulent middle-school students in Fuzhou, but the incidence of overweight and/or obesity has not been investigated.

Obesity is considered to be associated with the genetic and environmental factors. Nowadays, more and more attention has been paid to sleep duration among the individuals with obesity [3]. Sleep deprivation among students is regarded to be related to increased risk of obesity, injuries, behavior problems, attention-deficit disorder, poor academic performance and psychological problems [4–6]. In adulthood, sleep deprivation is a risk factor of cardiovascular diseases [7]. Insufficient sleep duration mainly affects metabolism, endocrine function and immune systems [8]. However, there are still some controversies on the relationship between sleep deprivation and overweight or obesity. Some studies proposed a U-shaped [9, 10]or linear inverse correlation [11] between sleep duration and obesity, while others proposed no associations [12, 13]. In this study, we aimed to investigate the prevalence of short sleep duration among students in Fuzhou. In addition, we explored the relationship between sleep duration and overweight or obesity.

Methods

Survey design

In this survey, we utilized the multistage stratified random cluster sampling method. Sampling was randomly selected from 5 urban areas and 4 rural areas from the total 13 areas. Then the adolescents from 2 selected middle schools were sampled randomly from the selected counties. Existing investigation was modeled from the questionnaire including the Youth Risk Behavior Survey, performed by the Centers for Disease Control and Prevention **[14]**, and the international Global School-based Student Health Survey conducted with the support of WHO **[15]**. Questionnaires distributed to the respondents included the demographic characteristics (e.g. age and gender), athletic activity, screen-time, diet, as well as sleep and mental health (e.g. sadness, annoyance and loneliness). This survey was conducted between May and June in 2019. The age of the youngest participants included in the study was 12 years. Written parental consent was obtained on behalf of participants below the age of 16. The study was approved by the Ethical Committee of Fujian Medical University.

The sample size was calculated using the following formula: $N=deff\times\mu^2\times P\times(1-P)/d^2$. In addition, the 95% CI (2-sided for μ=1.96) was determined, and the measure of probability (*P*) was the obese rate (8.6%) of China **[2]**. The design effect (deff) value was set to 2 and the relative error (d value) was d=r×0.01 (r=15%). On this basis, the sample size was 2,680 for each stratum. After taking 4 strata (i.e. boy and girl, urban and rural area) and an assumed potential non-response rate of 10% into consideration, the final sample size was 11,929.

Outcome variables

Body mass index (BMI) was the result of measured weight (kg) divided by the square of height in meters. The diagnostic criteria for overweight and obesity among adolescents were conducted based on the guidelines proposed by the Chinese Working Group on Obesity for Children (WGOC) **[16]**.

Sleep duration

Sleep duration was calculated by self-administered questionnaires by recalling the average time of falling asleep and getting up in the preceding 7 days. The average time of using electronic products each day was also self-administered. A short sleep duration was defined as a sleep duration less than 8 hrs a day for teenagers aged ≥13 according to the recommendation of American Academy of Sleep Medicine (AASM) **[17]**. Sleep duration was subdivided into 3 groups: “<6h”,“6-8 h”, and “>8h”, as a categorical variable in the multivariable logistic regression.

Co-variates

The questionnaire also investigated other factors related to obesity, including the gender and age, days for consuming breakfast and night snack, physical activity, homework time, high-energy snacks and fast food intake.

Statistical analysis

SPSS21 was used for the statistical analysis. Continuous variables were described by mean±standard deviation. Chi square test was utilized to analyze the differences in overweight and obese rates of different groups. Logistic regression analysis was conducted to investigate the relationship between sleep duration and obesity. Adjusted odds ratios (ORs) and 95% CI were evaluated through three logistic regression models. $P< 0.05$ was considered to statistical significance.

Results

Respondent characteristics

The respondents with short sleep duration had longer screen-time than that of the counterparts with sufficient sleep, ($P< 0.001$, Table 1). Meanwhile, compared with those with sufficient sleep duration, they less frequently participated in physical activity ($P< 0.001$) or consuming breakfast ($P< 0.001$). Instead, sleep deprivation was significantly linked to consuming night snack ($P< 0.001$) and feeling irritated ($P< 0.001$), sad ($P< 0.001$) and lonely ($P< 0.001$).

Table 1
Sleep duration of middle school students in Fuzhou, China

Characteristics	Total (n = 13063)	Non-short sleep duration (n = 2250)	Short sleep duration (n = 10813)	*P* value
Age (years)	14.44 ± 1.64	13.66 ± 1.36	14.61 ± 1.65	< 0.001
Gender				< 0.001
Boys	6520(49.9)	1337(59.4)	5183(47.9)	
Girls	6543(50.1)	913(40.6)	5630(52.1)	
Types of school				0.726
Key school	7817(59.8)	1339(59.5)	6478(59.9)	
Ordinary school	5246(40.2)	911(40.5)	4335(40.1)	
Areas				< 0.001
Urban	5924(45.3)	1154(51.3)	4770(44.1)	
Rural	7139(54.7)	1096(48.7)	6043(55.9)	
Screen time per day during school				< 0.001
30minute	5386(41.2)	1131(50.3)	4255(39.4)	
30-60minute	3949(30.2)	666(29.6)	3283(30.4)	
≥ 60minute	3728(28.5)	453(20.1)	3275(30.3)	
Using electronic products in bedroom	8422(64.5)	1270(56.4)	7152(66.1)	< 0.001
Someone smoking at home	7163(55.4%)	1194(53.6)	5969(55.7)	0.064
Doing strenuous exercise in spare time	8362(65.4)	1581(71.8)	6781(64.1)	< 0.001
Exercise at moderate intensity in spare time	7057(55.8)	1324(60.9)	5733(54.7)	< 0.001
Days for consuming breakfast	6.13 ± 1.56	6.40 ± 1.36	6.07 ± 1.60	< 0.001

Characteristics	Total (n = 13063)	Non-short sleep duration (n = 2250)	Short sleep duration (n = 10813)	*P* value
Days for consuming night snack	2.10 ± 2.34	1.91 ± 2.35	2.14 ± 2.33	< 0.001
Having fried food often in the past 12 months	7468(70.9)	1239(68.7)	6229(71.3)	0.024
Having pastry often in the past 12 months?	8342(80.6)	1427(80.3)	6915(80.7)	
Frequency of feeling lonely				< 0.001
Never	4760(36.7)	1062(47.7)	3698(34.46)	
Sometimes	6397(49.4)	925(41.5)	5472(50.99)	
Always	1803(13.9)	241(10.8)	1562(14.55)	
Frequency of feeling sad				< 0.001
Never	4795(37.0)	1015(45.53)	3780(35.2)	
Sometimes	6877(53.1)	1013(45.45)	5864(54.7)	
Always	1283(9.9)	201(9.02)	1082(10.1)	
Frequency of feeling irritated				< 0.001
Never	2084(16.3)	596(27.1)	1488(14.0)	
Sometimes	8771(68.5)	1364(62.1)	7407(69.9)	
Always	1946(15.2)	237(10.8)	1709(16.1)	

Overweight and obesity

The prevalence of overweight and obesity were 12.1% and 7.1%, respectively (Table 2). They were statistical differences in the rate of obesity and overweight among various regions ($P < 0.001$). No statistical differences were noticed in the rate of obesity and overweight between the students in the key schools and ordinary schools ($P = 0.566$). The prevalence of obesity rate of among the male children was significantly higher than that of female counterparts ($P < 0.001$).

Table 2
Prevalence of overweight and obesity among different groups

Characteristics	Normal	Overweight/ Obesity	Overweight	Obesity	Total	χ^2	*P*
Gender						365.53	< 0.001
Boys	4849(74.4)	1671(25.6)	1106(17.0)	565(8.7)	6520		
Girls	5704(87.2)	839(12.8)	473(7.2)	366(5.6)	6543		
Area						48.51	< 0.001
Urban	4635(78.2)	1289(21.8)	789(13.3)	500(8.4)	5924		
Rural	5918(82.9)	1221(17.1)	790(11.1)	431(6.0)	7139		
Age(y)						94.38	< 0.001
≤ 13	3866(78.3)	1071(21.7)	592(12.0)	479(9.7)	4937		
14–15	3133(81.3)	721(18.7)	470(12.2)	251(6.5)	3854		
≥ 16	3559(83.3)	713(16.7)	517(12.1)	196(4.6)	4272		
Types of School						1.14	0.566
Key school	6335(81.0)	1482(19.0)	939(12.0)	543(6.9)	7817		
Ordinary school	4218(80.4)	1028(19.6)	640(12.2)	388(7.4)	5246		
Total	10553(80.8)	2510(19.2)	1579(12.1)	931(7.1)	13063		

Short sleep duration

The total prevalence of sleep deprivation was 82.8%. The prevalence of sleep deprivation among the female children was significantly higher than that in male counterparts (86.0% vs. 79.5% $P < 0.001$). There were statistical differences among the prevalence of sleep deprivation in the students aged ≤ 13 yrs (67.7%), those aged 14–15 yrs (77.8%) and those aged ≥ 16 yrs (92.5%, $P < 0.001$). The prevalence of sleep duration in the students lived in the urban was significantly lower than those lived in the rural areas (80.5% vs. 84.6%, $P < 0.001$). No statistical difference was noticed in the prevalence of sleep duration in the students of the key schools and ordinary schools (82.9% vs. 82.6%, $P = 0.726$).

Relationship between sleep duration and overweight/obesity

Model 1 showed that, compared with male children who slept more than 8 hrs per day, those who slept for less than 6 hrs a day showed higher risk for overweight or obesity after adjusting socio-demographic status (OR = 1.25, 95%CI: 1.02–1.54, Table 3). After additionally adjusting life-style factors in Model 2, male children who slept for less than 6 hrs a day showed a significantly higher risk for overweight/obesity by comparing to the reference group (OR = 1.65, 95%CI:1.27–2.13). The odds ratios were 1.63 (1.25–2.13), after further adjustment for mental health such as feeling irritation, sad or lonely. Nevertheless, there were no significant differences among the female children. The homologous odds ratios (95%CI) for female children were 1.41 (1.02–1.96) in Model 2 and 1.38 (0.99–1.93) in Model 3, respectively.

Table 3
Adjusted odds ratios of Overweight/obese based on sleep duration

Characteristics	≤6 h	6–8 h	> 8 h
Overall			
Total	1762	9051	2250
Overweight/obese	376	1669	46
Model 1	1.32(1.12–1.55)*	1.04(0.92–1.17)	1.00
Model 2	1.55(1.27–1.89)**	1.06(0.92–1.23)	1.00
Model 3	1.53(1.24–1.87)*	1.06(0.91–1.23)	1.00
Female			
Total	960	4670	913
Overweight/obese	152	568	119
Model 1	1.38(1.06–1.81)*	0.99(0.80–1.23)	1.00
Model 2	1.41(1.02–1.96)*	1.04(0.80–1.35)	1.00
Model 3	1.38(0.99–1.93)	1.04(0.79–1.35)	1.00
Male			
Total	802	4381	1337
Overweight/obese	224	1101	346
Model 1	1.25(1.02–1.54)*	1.07(0.92–1.23)	1.00
Model 2	1.65(1.27–2.13)**	1.06(0.89–1.27)	1.00
Model 3	1.63(1.25–2.13)**	1.06(0.88–1.27)	1.00
Model 1, adjustment for gender, age, region, types of school.			
Model 2, additionally adjusted for whether using electronic product daily during school, electronics in bedroom, someone smoking at home, strenuous physical activity, moderate physical activity, days of consuming breakfast and night snack per week, having fried food or pastry in the past 12 months, having taken nutrient supplements in the past 12 months.			
Model 3, further adjusted for feeling annoy, sad or lonely			
*P< 0.05; **P< 0.01			

Discussion

This study revealed the link between sleep duration and overweight or obesity in adolescents of Fuzhou, China. After adjusting socio-demographic status, lifestyle factors, and mental health, there was a negative correlation between sleep duration and overweight or obesity among male children.

The prevalence of overweight or obesity in our study was 19.2%, which was higher than the national average [2]. Moreover, our findings demonstrated the differences among gender, age and region, which were similar with the Report on Childhood Obesity in China [18]. The prevalence of obesity showed decline with the elevation of the ages, which may be possibly related to physical development and attention to their appearances. The prevalence of obesity in male children was significantly higher than that of female children. In addition, the prevalence of sleep deprivation in adolescents showed strike increase with age. About 92.4% of adolescents in high school suffered from sleep deprivation. Study pressure, especially pressure from the college entrance examination, may contribute to such a high prevalence.

Our study revealed that sleep duration was negatively related to obese risk, which was consistent with previous study showing that sleep deficiency seemed to parallel the increased prevalence of obesity[19]. Meanwhile, it could be an independent risk factor for obesity[7, 20, 21]. One study provided causal evidence on the relationship between sleep deprivation and weight gain in the population-level [22]. Moreover, Krietsch et al reported that there was a U-shaped correlation between those with insufficient sleep and obesity only in the female children [23]. These differences may be related to the physiology of adolescence between female and male.

To date, little is known about the relationship between sleep and obesity. Sleep duration involved in the regulation of cerebral function such as controlling the appetite, which could lead to over-eating in an obesogenic environment [24]. The homeostatic control of appetite was achieved by complex interactions among numerous neuroendocrine hormones [25]. Many pivotal hormones (e.g. insulin, leptin, cortisol and ghrelin) [26] may involve in the correlation between sleep and obesity. Even after adjusting the BMI, sleep duration was negatively correlated with circulating leptin [27]. Eptin pathway could explain the key mechanism via a modification effect [28]. Under some circumstances, the sleep deprivation could lead to disruption of insulin, leptin, cortisol and ghrelin expression [29, 30]. After a period of sleep loss, people could experience a 24% increase in hunger with largely whetting the appetite for high carbohydrate foods [29]. In our study, students with short sleep duration spent more time on night snack than those with adequate sleep, which may lead to weight gain. Fatigue caused by insufficient sleep may result in reduced physical activity, which then promoted the weight gain [31, 32]. In this study, adolescents with adequate sleep did more exercise of moderate-intensity than those with insufficient sleep.

Circadian Locomotor Output Cycles Kaput (CLOCK) genes involved in regulation of diurnal rhythm, and their effects on neuroendocrine systems might have an impact on obesity [33]. The variants of *CLOCK* gene was related to sleep duration [34], as with calorie intake [35], metabolic syndrome [36], and obesity [37]. Meanwhile, methylation of *CLOCK* gene was associated with carbohydrate intake, total energy intake, insulin resistance, and BMI [38]. *REV-ERBα* rs2071570 and rs2071427 were related to BMI and sleep duration in male children, confirming the association of the *REV-ERBα* gene with human obesity, mainly in

males [39]. In line with our findings, this theory supported a negative correction between sleep duration and overweight/obesity only among male children [40].

A large and representative sample was included in the survey. Meanwhile, we analyzed a wide range of covariance to verify the relationships between sleep duration and overweight or obesity by adjusting potential confounding factors correlated with overweight or obesity. Nevertheless, there are some limitations in our study. First, causal inference will be limited in the cross-sectional design, although there are several theories supporting our findings. Second, the impact of prolonged sleep duration on overweight or obesity among adolescents was not explored in our study, as we laid emphasis on the risk of overweight or obesity induced by sleep deprivation in middle-school students.

Conclusion

Adolescents suffered from insufficient sleep. There was a negative correlation between sleep duration and overweight or obesity in male children other than in female children. In future, further researches are required to investigate the relationship between sleep duration and specific hormones in adolescents, in order to explore the potential mechanisms of overweight or obesity.

Abbreviations

Body mass index (BMI)

Chinese Working Group on Obesity for Children (WGOC)

American Academy of Sleep Medicine (AASM)

Odds ratios

Circadian Locomotor Output Cycles Kaput (CLOCK)

Declarations

Ethical approval and consent to participate

Written parental consent was obtained on behalf of participants below the age of 16. The study was approved by the Ethical Committee of Fujian Medical University.

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Not applicable.

Authors' contributions

Designed and modified the manuscript: WSC and WSY; Designed the research and participated in the experimental design, coordinated and drafted the manuscript: LGB, ZFH, XXY, CYY; Data collection, achievement interpretation and manuscript writing: LGB, ZFH, XXY, CYY; Analysed the data: LGB, XXY, CYY. All of the authors have given final approval of the version to be published.

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Availability of data and materials

All the data were available upon appropriate request.

Competing interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Consent for publication

Not available.

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