Association between short sleep duration and overweight/obesity 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 short sleep duration and its association with overweight or obesity in adolescents from middle school in Fuzhou, China.

Methods: A total of 13,063 students (male: 6,500; female: 6,553) from 18 different schools in Fuzhou city were included in this study. Questionnaires focusing on short sleep duration and overweight or obesity related factors were collected. The sleep duration was self-reported by the subjects. The body weight and height were measured by the qualified personnel. Logistic regression analysis was used to evaluate the effects of short 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 short sleep duration among students was 82.8%. The majority of high school students (92.5%) showed a short sleep duration. Compared with male children with a sleep duration of 8-10 h per day, the odds ratios (ORs) of overweight/obesity for those with a sleep duration of less than 6 h or 6-8 h per day were 1.60 (1.22-2.09) and 1.07 (0.90-1.29) after adjusting social and demographic status, mental health and lifestyle factors. The homologous ORs of female children were 1.45 (1.04-2.04) and 1.11(0.85-1.45), respectively.

Conclusions: A large number of adolescents suffered from short sleep duration. Short sleep duration is associated with a higher OR of overweight/obesity in middle-school children, especially in the male adolescences.

Background

Overweight and obesity, with an increased trend in the past few decades, have been considered 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 capital city of Fujian Province localized in the southeast of China. In 2010, Lin et al reported the body development of the students in middle school in Fuzhou city [3], however, few studies focused on the incidence of overweight/obesity and the relationship between overweight/obesity and the sleep duration in these students.

Obesity is considered to be associated with the genetic and environmental factors [4, 5]. Nowadays, more and more attention has been paid to sleep duration among the individuals with obesity [6]. Short sleep duration is regarded to be related to increased risk of obesity, injuries, behavior problems, attention-deficit disorder, poor academic performance and psychological problems in students [7-9]. In adulthood, short sleep duration is a risk factor of cardiovascular diseases [10]. Until now, short sleep duration has been acknowledged to affect metabolism, endocrine function and immune systems [11]. However, there are still some controversies on the relationship between short sleep duration and overweight or obesity. Some

studies proposed a U-shaped [12, 13] or linear inverse correlation [14] between sleep duration and obesity, however, some studies proposed no correlation between them [15, 16]. Meanwhile, the association between short sleep duration and the overweight/obesity was somehow affected by sex [17], in which the sex was considered a specific trait for short sleep duration in these with overweigh/obesity [18, 19]. In this study, we aimed to investigate the prevalence of short sleep duration among students in Fuzhou. In addition, we explored the relationship between short sleep duration and overweight or obesity.

Methods

Survey design

Cluster random sampling method was utilized in our survey. Firstly, five representative cities and four rural areas were selected from Fuzhou City. Secondly, the adolescents from two selected middle schools were enrolled randomly from the selected counties. Thirdly, all students in the selected classes were invited to participate in the study by the qualified teachers in their school after informing about the potential benefits and risks by our staff. All the subjects were invited to participate in this study at their wills, and those not willing to participate in this survey were excluded. A total of 15,025 students from 18 different schools were invited, and finally 14,499 students (96.5%) participated in the survey. After exclusion of subjects with missing key variables (e.g. sex, height, weight and sleep duration), 13,063 eligible subjects (male: 6,500; female: 6,553) were included in the final analyses. Existing investigation was modeled from the questionnaire including the Youth Risk Behavior Survey, performed by the Centers for Disease Control and Prevention [20], and the international Global School-based Student Health Survey conducted with the support of WHO [21]. Questionnaires distributed to the respondents included the demographic characteristics (e.g. age and sex), athletic activity, screen-time, nutrient supplements, 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 was 12-year old. 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 (approval No. 2019-117).

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% confidential interval (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.

Definition of the variables

The key schools were defined as these supported by the local government and the education bureau, with more high quality teachers and students. The ordinary schools were those supported less by the local government and the education bureau, and lower in the quality of the teachers and students compared

with the key schools. The environment for the learning and capacity of the key schools was much better than that of the ordinary schools.

Overweight and obesity screening

The body weight and height of each subject were measured by the qualified staff annually in the routine physical examination. 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) [22]. Overweight was defined as increase of one standard deviation (SD) of BMI compared with the normal children of the same sex at the same age, and obesity was defined as increase of two standard deviations (SDs) of BMI. The disease history was inquired by the staff, followed by physical examination to exclude the secondary obesity induced by severe diseases, endocrine or metabolic disorders.

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. 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) [23]. Sleep duration was subdivided into 3 groups: “<6h”,“6-8 h”, and “8-10 h”, as a categorical variable in the multivariable logistic regression.

Co-variates

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

Statistical analysis

SPSS 26.0 software was used for the statistical analysis. Continuous variables were described by mean±SD. Chi square test was utilized to analyze the differences in overweight and obese rates of different groups. For the analysis of the correlation between short sleep duration and the overweight or obesity, the generalized linear mixed model was utilized with the school and district as the variables for the random effects and other factors as the fixed effect variables. Adjusted ORs and 95% CI were evaluated through three logistic regression models. $P < 0.05$ was considered to statistical significance. In this study, obesity and overweight was classified as one group based on the following aspects: (i) The sample size for obesity was small, which may hamper the confidence of the data. (ii) The effects of short sleep duration on overweight and obesity were similar. There was a relationship between sleep duration and overweight. Short sleep duration may lead to overweight in children [24, 25]. Besides, short sleep duration may increase the risk of obesity in children [26-28]. Meanwhile, many studies classified the

overweight and obesity as the same group, in order to analyze the effects of sleep duration on overweight and obesity [13, 29-31].

In order to further validate whether the sex would modulate the effects of overweight on the short sleep duration, we analyzed the correlation between short sleep duration and overweight/obesity among the male and female adolescence. In the Logistics regression analysis, no additional variable was given in Model 0. The Model 1 of total subject involved adjustment for sex, age. For the Model 1 of male and female, we adjusted sex, region, and types of school. For the Model 2 of the three aspects, we additionally adjusted for utility of electronic product daily during school or in bedroom, 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, taking nutrient supplements in the past 12 months. Besides, they were further adjusted for feeling annoy, sad or lonely in the Model 3 of the three aspects.

Results

Respondent characteristics

Finally, 13,063 subjects (male: 6,500; female: 6,553) were included in this study. The respondents with short sleep duration had longer screen-time than that of the counterparts with short sleep duration, (P<0.001, Table 1). Meanwhile, compared with those with long sleep duration, these with a short sleep duration were less likely to participate in physical activity (P<0.001) or have breakfast (P<0.001). Instead, short sleep duration was significantly linked to consuming night snack (P<0.001), irritation (P<0.001), sad (P<0.001) and lonely (P<0.001).

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

aracteristics	Total (n=13063)	<6 h (n=1762)	6-8 h (n=9051)	8-10 h (n=2250)	F/c2	*P* value
e (years)	14.44±1.64	14.94±1.65	14.53±1.64	13.66±1.36	369.68	<0.001
nder					103.26	<0.001
Boys	6520(49.9)	802(45.5)	4381(48.4)	1337(59.4)		
Girls	6543(50.1)	960(50.1)	4670(51.6)	913(40.6)		
pes of school					3.86	0.145
Key school	7817(59.8)	1092(62.0)	5386(59.5)	1339(59.5)		
Ordinary school	5246(40.2)	670(38.0)	3665(40.5)	911(40.5)		
eas					57.41	<0.001
Urban	5924(45.3)	860(48.8)	3910(43.2)	1154(51.3)		
Rural	7139(54.7)	902(51.2)	5141(56.8)	1096(48.7)		
reen time per y					210.20.	<0.001
ring school						
30minute	5386(41.2)	596(33.8)	3659(40.4)	1131(50.3)		
0-60minute	3949(30.2)	469(26.6)	2814(31.1)	666(29.6)		
>60minute	3728(28.5)	697(18.7)	2578(28.5)	453(20.1)		
ing electronic oducts	8422(64.5)	1254(71.2)	5898(65.2)	1270(56.4)	99.70	<0.001
bedroom						
neone smoking home	7163(55.4)	1015(58.2)	4954(55.2)	1194(53.6)	8.69	0.013
ing strenuous ercise	8362(65.4)	1032(59.8)	5749(65.0)	1581(71.8)	64.95	<0.001
spare time						
ercise at derate intensity	7057(55.8)	837(49.0)	4896(55.8)	1324(60.9)	55.43	<0.001
spare time						
ys for consuming eakfast	6.13±1.56	5.52±1.99	6.17±1.48	6.40±1.36	163.74	<0.001
ys for nsuming ht snack	2.10±2.34	2.39±2.51	2.09±2.29	1.91±2.35	19.44	<0.001
ving fried food en in the past 12 nths	7468(70.9)	950(70.2)	5279(71.6)	1239(68.7)	6.17	0.046
ving pastry en in the past 12 nths	8342(80.6)	1035(78.5)	5880(81.1)	1427(80.3)	5.16	0.076
trition oplements in the	4982(51.3)	612(49.6)	3518(51.6)	852(51.7)	1.64	0.441

st 12 months						
equency of ling lonely					316.78	<0.001
Never	4760(36.7)	443(25.3)	3255(36.2)	1062(47.7)		
Sometimes	6397(49.4)	888(50.8)	4584(51.0)	925(41.5)		
Always	1803(13.9)	417(23.9)	1145(12.7)	241(10.8)		
equency of ling sad					245.29	<0.001
Never	4795(37.0)	489(28.0)	3291(36.7)	1015(45.5)		
Sometimes	6877(53.1)	945(54.1)	4919(54.8)	1013(45.5)		
Always	1283(9.9)	314(18.0)	768(8.6)	201(9.0)		
equency of ling irritated					425.93	<0.001
Never	2084(16.3)	207(12.0)	1281(14.4)	596(27.1)		
Sometimes	8771(68.5)	1054(61.1)	6353(71.5)	1364(62.1)		
Always	1946(15.2)	463(26.9)	1246(14.0)	237(10.8)		

Overweight and obesity

The prevalence of overweight and obesity were 12.1% and 7.1%, respectively (Table 2). They were statistically differences different 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 [n(%)]

Characteristics	Normal	Overweight/ obesity	Overweight	Obesity	Total	c^2	*P* value
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 short sleep duration was 82.8%. The prevalence of short sleep duration 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 short sleep duration 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 short 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 short 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

As shown in Model 1, compared with all the subjects and male children who slept 8-10h per day, those who slept for less than 6 hrs a day showed a higher possibility of overweight/obesity after adjusting socio-demographic status [OR=1.32 (95%CI: 1.12-1.56) and 1.23 (95%CI: 1.00-1.51)] (Table 3 and Table 4). After additionally adjusting life-style factors in Model 2, all the subjects and male children who slept for less than 6 hrs a day showed a significantly higher association for overweight/obesity in comparison with the reference group [OR=1.55 (95%CI: 1.27-1.90) and 1.60 (95%CI: 1.23-2.07)]. The Ors were 1.53 (1.24-1.88) and 1.60 (1.22-2.09), after further adjustment for mental health such as feeling irritation, sad or lonely. Similarly, there were significant differences among the female children. The homologous ORs for female children were 1.44 (1.10-1.89) in Model 1, 1.51 (1.08-2.11) in Model 2 and 1.45 (1.04-2.04) in Model 3, respectively. Nevertheless, the lower CI was very close to significance.

Table 3 Odds ratios of overall overweight/obese based on sleep duration

Characteristics	<6h	6-8h	8-10h
Total (n)	1762	9051	2250
Overweight/obese (n)	376	1669	465
Model 0	1.07(0.92-1.26)	0.91(0.81-1.02)	1.00
Model 1	1.32(1.12-1.56)**	1.05(0.93-1.89)	1.00
Model 2	1.55(1.27-1.90)**	1.09(0.94-1.27)	1.00
Model 3	1.53(1.24-1.88)**	1.09(0.94-1.27)	1.00

Model 0, no additional variables

Model 1, adjustment for gender, age.

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

*$P < 0.05$; **$P < 0.01$

Table 4 Odds ratios of overweight/obese based on sleep duration in different gender

Characteristics	<6 h	6-8 h	8-10 h
Female			
Total (n)	960	4670	913
Overweight/obese (n)	152	568	119
Model 0	1.36(1.04-1.77)**	0.98(0.79-1.22)	1.00
Model 1	1.44(1.10-1.89)**	1.02(0.82-1.27)	1.00
Model 2	1.51(1.08-2.11)*	1.11(0.85-1.44)	1.00
Model 3	1.45(1.04-2.04)*	1.11(0.85-1.45)	1.00
Male			
Total (n)	802	4381	1337
Overweight/obese (n)	224	1101	346
Model 0	1.10 (0.90-1.35)	0.99(0.86-1.14)	1.00
Model 1	1.23(1.00-1.51)	1.07(0.92-1.23)	1.00
Model 2	1.60(1.23-2.07)**	1.07(0.80-1.29)	1.00
Model 3	1.60(1.22-2.09)**	1.07(0.90-1.29)	1.00

Model 0, no addition variables
Model 1, adjustment for age.
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 investigated the link between short sleep duration and overweight/obesity in adolescents of Fuzhou, China. After adjusting socio-demographic status, lifestyle factors, and mental health, there was a negative correlation between short sleep duration and overweight/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 sex, age and region, which were similar with the Report on Childhood Obesity in China [32]. 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[33, 34].

The prevalence of obesity in male children was significantly higher than that of female children. In addition, the prevalence of short sleep duration in adolescents showed strike increase with age. About

92.4% of adolescents in high school showed a short sleep duration, which is possibly related to the study pressure, especially pressure from the college entrance examination.

Sleep deficiency was associated with increased prevalence of obesity[35]. Consistently, our study revealed that short sleep duration was negatively related to overweight/obesity. Meanwhile, it could be an independent risk factor for obesity[10, 36, 37]. One study provided causal evidence on the relationship between short sleep duration and weight gain in the population-level [38]. Moreover, Krietsch et al reported that there was a U-shaped correlation between those with short sleep duration and obesity only in the female children [39]. These differences may be related to the physiology between female and male adolescence.

To date, little is known about the relationship between sleep and obesity. Sleep duration was reported to involve in the regulation of cerebral function (e.g. appetite), which could lead to over-eating in an obesogenic environment [40]. The homeostatic control of appetite was achieved by complex interactions among numerous neuroendocrine hormones [41]. Many pivotal hormones (e.g. insulin, leptin, cortisol and ghrelin) [42] may involve in the association between sleep and obesity. Even after adjusting the BMI, sleep duration was negatively correlated with circulating leptin [43]. The leptin pathway could explain the key mechanism via modificatory effects [44]. Under some circumstances, the short sleep duration could lead to disruption of insulin, leptin, cortisol and ghrelin expression [45, 46]. After a period of sleep loss, people could experient a 24% increase in hunger with largely whetting the appetite for high carbohydrate foods [45]. 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 short sleep duration may result in reduction in the physical activity, which subsequently promoted the weight gain [47, 48]. In this study, adolescents with adequate sleep did more exercise of moderate-intensity than those with short sleep duration.

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 [49]. The variants of *CLOCK* gene was related to sleep duration [50], calorie intake [51], metabolic syndrome [52], and obesity [53]. Meanwhile, methylation of *CLOCK* gene was associated with carbohydrate intake, total energy intake, insulin resistance, and BMI [54]. *REV-ERBα* rs2071570 and rs2071427 were related to BMI and sleep duration in male children, which indicated that there was an association between the *REV-ERBα* gene and human obesity, especially in males [55]. In line with our findings, there was a negative correction between sleep duration and overweight/obesity among male children [56].

Obesity is related to biology and behavior, and the social context [57]. Social support from friends and awareness/internalization of thinness ideals were significantly related to odds of overweight/obesity in youth. Such association varied by age and sex, and persisted after control for intra-familial factors such as overall family support/function, diet and activity specific support [58]. A cross-sectional study on social risk factors for overweight and obesity in women in Zimbabwe showed that the key social factors associated with overweight and obesity were older age, wealthy and the use of hormonal contraception.

Besides, a higher education and being Christian also increased the risk of obese and overweight, respectively [59]. Some home environment related factors may increase the incidence of overweight/obesity among children, such as sleeping too late that may lead to inadequate sleeping and increased opportunity for taking food in night [60]. Less daytime care by mothers and shorter sleep duration were associated with increased risk of overweight in the childhood [61].

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 determination of sleep duration was reported by the students themselves, which was a limiting factor. Indeed, the facilities may contribute to the reduction of the errors, however, it was a challenge for the promotion of the facility as the sample size was too large. In the subsequent study, representative samples will be selected for the monitor of the sleep duration of the subjects including sleep quality. Third, the impact of prolonged sleep duration on overweight or obesity among adolescents was not investigated in our study, as we laid emphasis on the risk of overweight or obesity induced by short sleep duration in middle-school students. Then we will focus on the effects of long sleep duration on the overweight and obesity in the students. Fourth, the psychologic status of the subjects when self-reporting may lead to some bias of the results. In the follow-up study, qualified mental scales will be required to evaluate the psychologic status including depression and sorrow, which can correct the effects of psychologic variables on overweight and obesity.

Conclusion

Adolescents suffered from short sleep duration. Short sleep duration is associated with higher odds of overweight/obesity in middle-school children, especially in the male adolescences. Attention should be paid to ensure the sleeping duration of these students, in order to control the overweight and promote the healthy development. 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

Ethics approval and consent to participate

The study was approved by the Ethical Committee of Fujian Medical University.

Consent for Publication

Written parental consent was obtained on behalf of participants below the age of 16.

Availability of data and material

All the data were available upon appropriate request.

Competing interests

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

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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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