

PEDIATRICS

Sleep Duration and Overweight/Obesity in Preschool-Aged Children: A Prospective Study of up to 48,922 Children of the Jiaxing Birth Cohort

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Study Objectives: To examine the association between sleep duration and overweight/obesity in preschool-aged children.

Methods: A total of 48,922 3-year old children enrolled in the Jiaxing Birth Cohort, who provided sleep information and anthropometric data, were included in the present study as baseline and were followed up to 5 years of age. Sleep duration was categorized as ≤ 10 hours, 11–12 hours, and ≥ 13 hours. Overweight and obesity were defined according to the cut point criteria in China. Prevalence ratios and risk ratios were used to assess the association between sleep duration and risk of overweight/obesity.

Results: In cross-sectional analyses at baseline, the adjusted prevalence ratios (95% confidence interval) of overweight (with 11–12 h of sleep being considered the reference group) for children sleeping ≤ 10 h and ≥ 13 h were 1.13 (1.06–1.20) and 1.16 (1.09–1.24), respectively, whereas the adjusted prevalence ratios (95% confidence interval) of obesity were 1.25 (1.11–1.40) and 1.25 (1.11–1.42). In longitudinal analyses, the adjusted risk ratios (95% confidence interval) of overweight for children sleeping ≤ 10 h and ≥ 13 h were 1.48 (1.26–1.74) and 1.13 (0.96–1.34), while adjusted risk ratios (95% confidence interval) of obesity were 1.77 (1.30–2.40) and 1.19 (0.85–1.66). Restricted cubic splines regression supported U-shaped curvilinear associations between sleep duration and overweight/obesity in both cross-sectional and longitudinal analyses.

Conclusions: Both short and overlong sleep duration are associated with a higher risk of overweight/obesity in preschool-aged children. Optimizing sleep duration may be an important modifiable intervention for overweight and obesity.

Keywords: childhood, sleep duration, overweight, obesity

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Significance

The present study observed U-shaped curvilinear associations between sleep duration and overweight/obesity in preschool-aged children for the first time, suggesting that there may be an “optimum range” of sleep duration for preschool-aged children. We believe our findings will increase awareness of the importance of proper sleep duration for preschool-aged children. Further studies are needed to explore the causality between sleep duration and overweight/obesity among children.

INTRODUCTION

The prevalence of childhood overweight and obesity has been rising at an alarming rate in both developed and developing countries during past few decades.¹ It is estimated that nearly 41 million children under the age of 5 were affected by overweight and obesity in 2014.² Overweight and obese children are more likely to stay obese into adulthood and obesity itself is a direct cause of many non-communicable diseases such as cardiovascular diseases and diabetes.³ Additionally, childhood obesity can also affect children’s mental health and psychosocial development, leading to poor socialization and reduce educational attainment.^{4,5}

Conventionally, the high prevalence of obesity is attributed to increased intake of energy-dense food and reduced physical activity.⁶ However, in recent years, sleep duration has been proposed as a possible modifiable factor of obesity,⁷ and many previous epidemiologic studies have reported the associations between sleep duration and obesity in different age groups.^{8–12} A large-scale 3-year cohort study involving 21,469 healthy individuals aged 20 years or older observed an increased risk of becoming obese among those sleeping ≤ 5 hours per night, compared with those sleeping 7 hours, but no significant difference was seen between those sleeping ≥ 8 hours and those sleeping 7 hours.¹² Another cohort study assessed the longitudinal association between sleep duration and obesity among adolescents transitioning to adulthood, finding that short sleep duration in adolescence was associated with incident obesity

in young adulthood.⁸ However, except for a few cross-sectional studies,^{13,14} no large prospective studies have examined the relationship between sleep duration and obesity in preschool-aged children, especially the relationship between overlong sleep duration and obesity, which may also be associated with increased risk of obesity.¹⁵

Against these backgrounds, we used the data obtained from the Jiaxing Birth Cohort to explore both the cross-sectional and longitudinal association between sleep duration and overweight/obesity in preschool-aged children. We hypothesized that short sleep duration and overlong sleep duration would both be associated with increased risk of overweight/obesity in preschool-aged children.

METHODS

The ethical application and consent procedure of this study were approved by the Ethics Committee of the College of Biosystem Engineering & Food Science at Zhejiang University (Approval Number 2013013).

Study Participants

All the children for this study were participants in the Jiaxing Birth Cohort, which was part of a large population-based health surveillance system initiated in 1993 in China. Detailed information has been described previously.^{16,17} Briefly, pregnant women were enrolled in local clinics or maternity and child health care hospitals in Jiaxing, a prefectural city with a

middle-level socioeconomic development in China. Then they were invited to visit the local clinics or hospital on a regular basis until their children were 6 years of age. Besides the general information obtained at their first visit, follow-up information regarding their children's behavioral and anthropometric data were collected at each visit.

During the period of 1999 to 2009, 54,989 children enrolled in the Jiaying Birth Cohort had detailed general and sleep duration information and anthropometric data at 3 years of age. Among the 54,989 children, 4,663 were excluded because of abnormal birthweight (< 2,500 or > 3,999 g) and children with abnormal gestational periods (< 37 or > 42 weeks; $n = 1,404$) were also excluded. Thus, in the cross-sectional analyses of relationship between sleep duration and childhood overweight/obesity, 48,922 children were included as baseline. Of the 48,922 children, 19,580 had follow-up information at the age of 5. After excluding those who were overweight at baseline ($n = 3,552$), 16,028 children were included in the longitudinal analyses.

Sleep Duration and Key Study Variables

Parents were asked about their children's average sleep duration during a "typical" recent week at each visit when children were 3 and 5 years of age. The current sleep recommendations for preschool-aged children range between 11 and 12 h of sleep per night.¹⁶ Based on this recommendation, sleep duration in preschool children was categorized as ≤ 10 h, 11–12 h, and ≥ 13 h.

In addition to sleep duration, other covariates were also collected according to previous studies.^{13,17} Among these, continuous covariates included child's birth weight, maternal age at delivery and body mass index (BMI); categorical covariates included child's gender, breastfeeding status (never breastfed or ever breastfed), appetite (more than peers or the same as or less than peers), physical activity (≤ 2 , or > 2 h/day), maternal education (< high school, high school, and > high school), and maternal occupation (farmer or other). Appetite data was collected by qualitatively asking parents whether their children ate more compared with peers.

Outcome Measures and Overweight/Obesity Definition

Children's body weight and height were measured to the nearest 0.1 kg and 0.1 cm by trained nurses, using a digital weighing scale and a wall-mounted stadiometer. BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). Overweight and obesity were defined by age- and gender-specific cutoff points according to the latest Chinese criteria (overweight: 16.8, 16.9, 16.5, and 16.6 for 3-year old boys, 3-year old girls, 5-year old boys, and 5-year old girls; obesity: 18.1, 18.3, 17.9, and 18.2 for 3-year old boys, 3-year old girls, 5-year old boys, and 5-year old girls), which were more suitable for Chinese children than the 2006 WHO Child Growth Standards.¹⁸

Statistical Analyses

Child and maternal characteristics by sleep duration were summarized with means and standard deviations and assessed by one-way ANOVA for continuous variables, while

proportions were described and χ^2 test was adopted for categorical variables. Prevalence ratios (PRs) and risk ratios (RRs) were used to assess the cross-sectional and longitudinal association between sleep duration and risk of overweight/obesity. Crude PRs and RRs of overweight/obesity for children with different sleep duration were estimated by univariate logistic regression. Adjusted PRs and RRs were then estimated using multivariate logistic regression after adjustment for child's age, gender (boy or girl), birth weight (2,500–2,999, 3,000–3,499, and 3,500–3,999 g), breastfeeding status (never or ever), appetite (more than peers and the same as or less than peers), physical activity (≤ 2 , and > 2 h/day), maternal age at delivery (< 25, 25–29, and ≥ 30 years), BMI (< 18.5, 18.5–24.9, and ≥ 25 kg/m^2), education (< high school, high school, and > high school), and occupation (farmer or other). As a remarkably different prevalence and incidence of overweight/obesity between boys and girls was observed, stratified analysis based on gender was performed to examine the sleep-overweight/obesity association according to different gender. Stratified analysis based on children's appetite was also conducted to evaluate whether there was effect modification of appetite. To further explore the possible non-linear relationship between sleep duration and overweight/obesity risk, a logistic regression model with restricted cubic splines in which sleep duration was treated as a continuous variable was fitted.^{19,20} Three knots at 9, 11.5, and 13 h of sleep were specified, corresponding to the 3 categories used in logistic regression. Relationship between children's BMI and continuous sleep duration was also assessed via restricted cubic splines method with same knots. Percentage of missing data on child's appetite, physical activity, maternal education, and occupation were 0.2%, 0.1%, 0.1%, and 0.2% at baseline, and < 0.1%, < 0.1%, 0.1%, and 0.2% in the longitudinal data. To examine the impact of missing data on final results, a sensitivity analysis was conducted by omitting those children with these missing data. All statistical analyses were carried out using SAS (version 9.3) for Windows. Except where otherwise specified, a two-tailed P value < 0.05 was considered significant.

RESULTS

Child and Maternal Characteristics According to Sleep Duration

Of 48,922 children aged 3 years, 68.2% children had the recommended sleep duration with 11–12 hours. Children with better appetites and more physical activity had a higher proportion of sleeping ≥ 13 h, whereas children born to mothers having a higher education or whose occupation was not farmer more likely to have an appropriate sleep duration (11–12 h) (Table 1). In addition, children's breastfeeding status and mother's age at delivery also varied between different sleep duration categories. Among 16,028 children having follow-up information at 5 years of age, the 77.9% of children were sleeping 11–12 hours. Similarly, children's breastfeeding status, appetite, physical activity, maternal education, occupation, and age at delivery were different between the 3 sleep category groups (Table 2).

Table 1—Child and maternal characteristics according to sleep duration in cross-sectional analyses.

	n	Sleep Duration			P value
		≤ 10 hours	11–12 hours	≥ 13 hours	
Age (month)	48,922	38.2 ± 3.7	37.6 ± 3.2	37.4 ± 2.9	< 0.001
Gender (%)					0.48
Boy	24,826	4,163 (16.8)	16,979 (68.4)	3,684 (14.8)	
Girl	24,096	4,139 (17.2)	16,410 (68.1)	3,547 (14.7)	
Birth weight (g, %)					0.50
2,500–2,999	8,040	1,320 (16.4)	5,509 (68.5)	1,211 (15.1)	
3,000–3,499	25,445	4,372 (17.2)	17,355 (68.2)	3,718 (14.6)	
3,500–3,999	15,437	2,610 (16.9)	10,525 (68.2)	2,302 (14.9)	
Breastfeeding status (%)					0.03
Never	2,686	446 (16.6)	1,886 (70.2)	354 (13.2)	
Ever	46,236	7,856 (17.0)	31,503 (68.1)	6,877 (14.9)	
Appetite (%)					< 0.001
More than peers	39,422	6,382 (16.2)	26,881 (68.2)	6,159 (15.6)	
The same as or less than peers	9,418	1,904 (20.2)	6,460 (68.6)	1,054 (11.2)	
Physical activity (%)					< 0.001
≤ 2 hours/day	3,915	400 (10.2)	3,263 (83.3)	252 (6.4)	
> 2 hours/day	44,944	7,889 (17.6)	30,090 (66.9)	6,965 (15.5)	
Mother's age at delivery (year, %)					< 0.001
< 25	29,346	4,883 (16.6)	19,690 (67.1)	4,773 (16.3)	
25–29	13,976	2,432 (17.4)	9,870 (70.6)	1,674 (12.0)	
≥ 30	5,600	987 (17.6)	3,829 (68.4)	784 (14.0)	
BMI at first screening (kg/m ² , %)					0.26
< 18.5	9,522	1,587 (16.7)	6,468 (67.9)	1,467 (15.4)	
18.5–24.9	36,582	6,253 (17.1)	24,992 (68.3)	5,337 (14.6)	
≥ 25	2,818	462 (16.4)	1,929 (68.5)	427 (15.2)	
Maternal education (%)					< 0.001
< High school	35,028	5,873 (16.8)	23,319 (66.6)	5,836 (16.7)	
High school	9,414	1,662 (17.7)	6,729 (71.5)	1,023 (10.9)	
> High school	4,448	761 (17.1)	3,318 (74.6)	369 (8.4)	
Maternal occupation (%)					< 0.001
Farmer	31,612	5,598 (17.7)	20,793 (65.8)	5,221 (16.5)	
Other	17,231	2,696 (15.6)	12,534 (72.7)	2,001 (11.6)	

Data are presented as number (row percentage) of children unless otherwise indicated. BMI, body mass index.

Cross-Sectional Association between Sleep Duration and Overweight/Obesity in Children at 3 Years of Age

Among the children aged 3 years, 18.1% were overweight and 4.1% were obese. The prevalence of overweight and obesity were higher in boys (11.1% and 2.7%, respectively) than that in girls (6.7% and 1.4%, respectively). In crude analyses, both sleeping < 10 h and sleeping > 13 h were significantly associated with the prevalence of overweight and obesity (Table 3). After adjustment for potential covariates, associations of sleep duration and overweight/obesity remained almost unchanged. The adjusted PRs (95% confidence interval [CI]) of overweight (with 11–12 h of sleep being considered the reference group) for children sleeping ≤ 10 h were 1.13 (1.06–1.20) and ≥ 13 h were 1.16 (1.09–1.24), whereas the adjusted PRs (95% CI) of obesity for children sleeping ≤ 10 h were 1.25 (1.11–1.40) and ≥ 13 h were 1.25 (1.11–1.42) compared with those sleeping 11–12 h. In the stratified analysis, based on children's gender, no significant modification effect of gender on the association of sleep duration and overweight/obesity was observed (P for interaction were 0.57 and 0.44, respectively) (see Table S1 in

supplemental material), while there was a significant modification effect of appetite (P for interaction were 0.02 and 0.004, respectively) (Table S1). However, the significance of the association between sleep duration and overweight/obesity still remained. Results of logistic regression model with restricted cubic splines indicated that associations for sleep-overweight/obesity were curvilinear and their shapes were similar, a U-shape with the bottom at around 11–12 h of sleep (Figure 1A and 1B). Similarly, continuous splines regressions also supported non-linear U shape association between sleep duration and children's BMI (see Figure S1A in supplemental material).

Longitudinal Association between Sleep Duration and Overweight/Obesity in Children from 3 to 5 Years of Age

The incidence of overweight and obesity among children from 3 to 5 years of age were 9.3% and 2.1%, respectively. Higher incidence of overweight and obesity were also found in boys. In both crude analyses and analyses adjusted for potential covariates, sleeping less than 10 h was remarkably associated with a higher risk of overweight (adjusted RR [95% CI]: 1.48,

Table 2—Child and maternal characteristics according to sleep duration in longitudinal analyses.

	n	Sleep Duration			P value
		≤ 10 hours	11–12 hours	≥ 13 hours	
Age (month)	16,028	65.1 ± 3.7	34.6 ± 4.0	64.8 ± 3.4	< 0.001
Gender (%)					0.58
Boy	7,712	758 (9.8)	6,033 (78.2)	921 (11.9)	
Girl	8,316	840 (10.1)	6,448 (77.5)	1,028 (12.4)	
Birth weight (g, %)					0.46
2,500–2,999	2,845	285 (10.0)	2,204 (77.5)	356 (12.5)	
3,000–3,499	8,512	819 (9.6)	6,654 (78.2)	1,039 (12.2)	
3,500–3,999	4,671	494 (10.6)	3,623 (77.6)	554 (11.9)	
Breastfeeding status (%)					0.03
Never	806	74 (9.2)	656 (81.4)	76 (9.4)	
Ever	15,222	1,524 (10.0)	11,825 (77.7)	1,873 (12.3)	
Appetite (%)					< 0.001
More than peers	12,855	1,262 (9.8)	9,945 (77.4)	1,648 (12.8)	
The same as or less than peers	3,166	336 (10.6)	2,532 (80.0)	298 (9.4)	
Physical activity (%)					< 0.001
≤ 2 hours/day	1,315	137 (10.4)	1,063 (80.8)	115 (8.7)	
> 2 hours/day	14,711	1,461 (9.9)	11,417 (77.6)	1,833 (12.5)	
Mother's age at delivery (year, %)					< 0.001
< 25	9,263	847 (9.1)	7,155 (77.2)	1,261 (13.6)	
25–29	4,681	542 (11.6)	3,698 (79.0)	441 (9.4)	
≥ 30	2,084	209 (10.0)	1,628 (78.1)	247 (11.9)	
BMI at first screening (kg/m ² , %)					0.78
< 18.5	3,142	330 (10.5)	2,426 (77.2)	386 (12.3)	
18.5–24.9	12,011	1,186 (9.9)	9,372 (78.0)	1,453 (12.1)	
≥ 25	875	82 (9.4)	683 (78.1)	110 (12.6)	
Maternal education (%)					< 0.001
< High school	11,552	1,115 (9.7)	8,812 (76.3)	1,625 (14.1)	
High school	2,977	333 (11.2)	2,431 (81.7)	213 (7.2)	
> High school	1,487	146 (9.8)	1,230 (82.7)	111 (7.5)	
Maternal occupation (%)					< 0.001
Farmer	10,397	1,002 (9.6)	7,861 (75.6)	1,534 (14.8)	
Other	5,605	593 (10.6)	4,598 (82.0)	414 (7.4)	

Data are presented as number (row percentage) of children unless otherwise indicated. BMI, body mass index.

1.26–1.74) and obesity (adjusted RR [95% CI]: 1.77, 1.30–2.40) compared with sleeping 11–12 h (Table 4); while sleeping more than 13 h was not found to be associated with overweight/obesity. No significant modification effect of gender and appetite on the sleep-overweight/obesity association was observed in the stratified analyses (gender: P for interaction were 0.35 and 0.39; appetite: P for interaction were 0.61 and 0.61, respectively) (see Table S2 in supplemental material). Nevertheless, logistic regression model with restricted cubic splines showed a U-shaped curvilinear association between sleep duration and overweight/obesity, with a bottom at 11–12 h of sleep (Figure 1C and 1D). Sleep duration was also found to be nonlinearly associated with children's BMI (see Figure S1B in supplemental material).

DISCUSSION

The present result showed a U-shaped curvilinear association between sleep duration and overweight/obesity in preschool-aged children. Children sleeping shorter than 10 hours and children sleeping more than 13 hours had a higher risk of

being overweight and obese than those sleeping 11–12 hours. No modification effect of gender on sleep-overweight/obesity association was noted.

The result that short sleep duration was associated with higher risk of overweight and obesity in preschool-aged children is consistent with previous cross-sectional studies.^{13,14} Furthermore, these associations were stronger with the decrease of sleep duration in logistic model with restricted cubic splines. This result is in line with an earlier study conducted in Germany, in which a dose-dependent decrease in the prevalence of overweight and obesity by duration of sleep in 5- and 6-year-old children was found.¹³ The additional and important new insight from the present study is that prolonged sleep duration was also associated with overweight and obesity. The association between prolonged sleep duration and overweight/obesity was examined in adolescents and adults in previous studies,^{21,22} while it was seldom assessed in preschool-aged children.

Several possible explanations have been put forward to explain the biological plausibility of the associations between short sleep duration and overweight/obesity. Growth hormone,

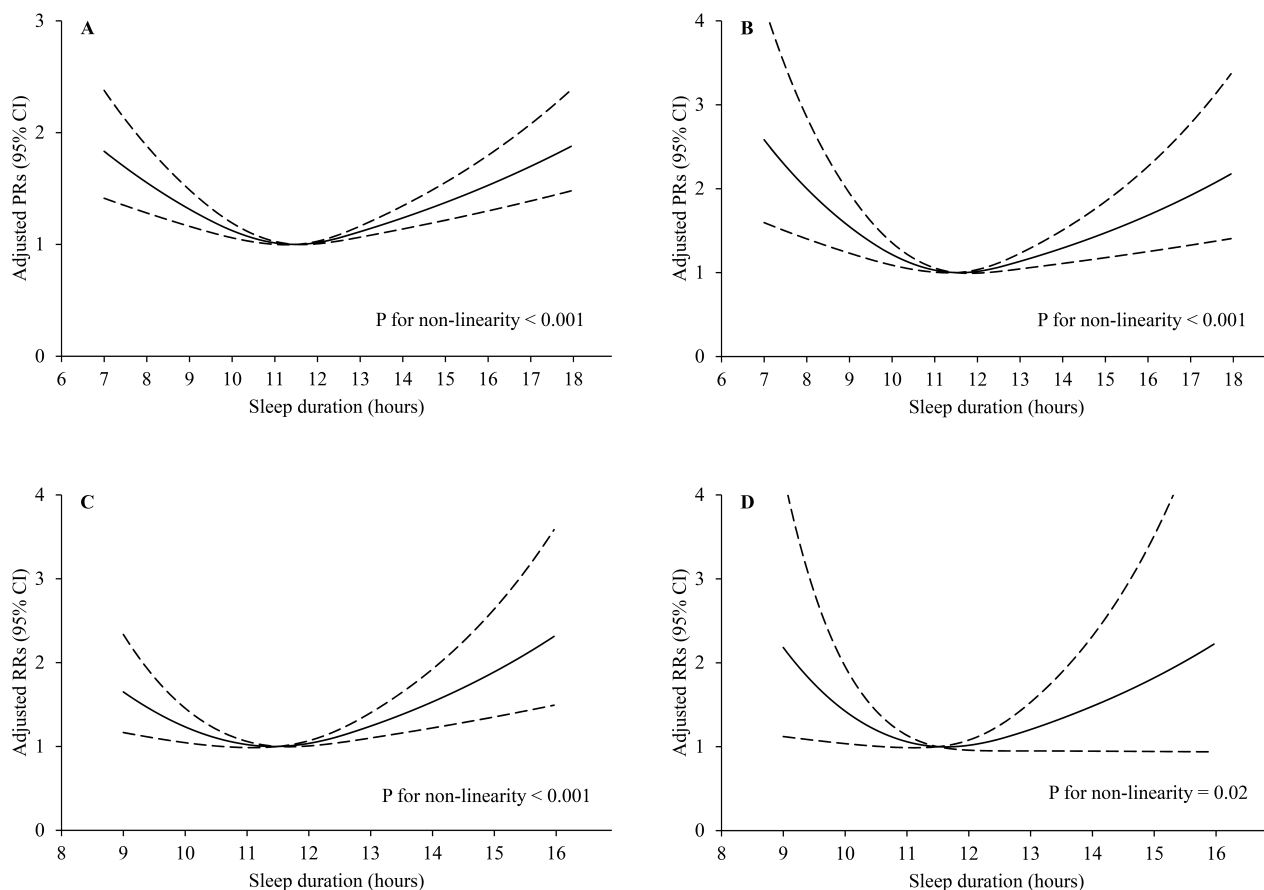


Figure 1—Curvilinear associations between sleep duration and overweight/obesity in cross-sectional and longitudinal analyses. **(A)** overweight in cross-sectional analyses; **(B)** obesity in cross-sectional analyses; **(C)** overweight in longitudinal analyses; **(D)** obesity in longitudinal analyses. All analyses were adjusted for child's age, gender, birth weight, breastfeeding status, appetite and physical activity, maternal age at delivery, maternal body mass index, education, and occupation. PRs, prevalence ratios; RRs, risk ratios; CI, confidence interval.

Table 3—Cross-sectional association between sleep duration and overweight/obesity at baseline.

Sleep Duration	Risk of Overweight			Risk of Obesity		
	Case/Study Participants	Crude PRs	Adjusted PRs*	Case/Study Participants	Crude PRs	Adjusted PRs*
≤ 10 hours	1,572/8,302	1.11 (1.04–1.18)	1.13 (1.06–1.20)	389/8,302	1.23 (1.10–1.38)	1.25 (1.11–1.40)
11–12 hours	5,820/33,389	1.00	1.00	1,283/33,389	1.00	1.00
≥ 13 hours	1,455/7,231	1.19 (1.12–1.27)	1.16 (1.09–1.24)	347/7,231	1.26 (1.12–1.42)	1.25 (1.11–1.42)

Values presented as prevalence ratios (PRs) and 95% confidence interval (CI). *PRs were adjusted for child's age, gender, birth weight, breastfeeding status, appetite and physical activity, maternal age at delivery, maternal body mass index, education and occupation.

Table 4—Longitudinal association between sleep duration and overweight/obesity.

Sleep Duration	Risk of Overweight			Risk of Obesity		
	Case/Study Participants	Crude RRs	Adjusted RRs*	Case/Study Participants	Crude RRs	Adjusted RRs*
≤ 10 hours	200/1,598	1.46 (1.24–1.71)	1.48 (1.26–1.74)	53/1,598	1.70 (1.26–2.30)	1.77 (1.30–2.40)
11–12 hours	1,115/12,481	1.00	1.00	247/12,481	1.00	1.00
≥ 13 hours	181/1,949	1.04 (0.88–1.23)	1.13 (0.96–1.34)	42/1,949	1.09 (0.78–1.52)	1.19 (0.85–1.66)

Values presented as risk ratios (RRs) and 95% confidence interval (CI). *RRs were adjusted for child's age, gender, birth weight, breastfeeding status, appetite and physical activity, maternal age at delivery, maternal body mass index, education and occupation.

which could increase growth hormone-mediated lipolysis and reduce the risk of overweight/obesity, was hypothesized to play a role in sleep-overweight/obesity associations, as short sleep duration may result in a lower excretion of growth hormone.²³ This concept was supported by a study in which growth hormone secretion was shown to be diminished in patients with sleep disorder.²⁴ In addition, short sleep duration was found to be associated with reduced leptin and elevated ghrelin, which may increase hunger and appetite, contributing to an increased BMI.^{22,25} Short sleep may also disrupt circadian rhythms, leading to abnormal timing of adipocyte differentiation and release of adipokines,²⁶ which were reported in obese human subjects.²⁷

The mechanism behind the association between prolonged sleep duration and overweight/obesity is not clear. Children sleeping for a long duration always have an increased time in bed and a reduced energy expenditure, which may affect their weight status. This hypothesis was supported by a study showing that long sleepers have a lower physical activity levels.²⁸ However, in the present study, children with an overlong sleep duration were more likely to be physically active, and the associations between overlong sleep duration and overweight/obesity still existed after adjustment for physical activity in restricted cubic splines regression analysis. Another possibility raised in a sleep cohort study is that patients with sleep disordered breathing (a medical condition associated with increased BMI) may spend a longer time in bed to compensate for fragmented sleep.²²

Some previous studies have noted gender-related differences in the association between sleep duration and overweight/obesity.^{29–31} Among these, most observed associations between short sleep duration and overweight/obesity only in boys rather than in girls,^{30,31} whereas in a cohort study, the associations were found among both boys and girls in longitudinal analysis and no interactions by gender were noted.⁸ Similarly, in the present study, though there were significant difference in prevalence and incidence of overweight/obesity among boys and girls (all P values for χ^2 test < 0.001), the sleep-overweight/obesity associations were found in both groups and no modification effect of gender was observed. The gender difference in prevalence and incidence of overweight/obesity might due to the difference in body composition, hormone biology, and the susceptibility to certain social, genetic, and environmental factors.³²

The present study has several strengths. Firstly, both cross-sectional and longitudinal association between sleep duration and overweight/obesity were assessed. Longitudinal investigation of incident overweight/obesity could provide stronger causal evidence than do cross-sectional analyses. Secondly, the present study also examined the association between longer than the recommended sleep duration and overweight/obesity, which was seldom performed in previous studies. Furthermore, information on maternal obese status, children's appetite and physical activity levels, which may have an effect on children's weight status, were collected and adjusted in the statistical model, making the results more robust. Additionally, sleep duration was modeled continuously with restricted cubic splines when exploring the possible non-linear relationship

between sleep duration and risk of overweight/obesity. This would prevent the loss of information resulting from the categorization of continuous variables.³³ Finally, because of the low percentage of missing data, almost identical results were observed in the sensitivity analysis that omitting children with incomplete covariate data (data not shown).

Nevertheless, a few important potential limitations should be taken into consideration in the present study. Firstly, sleep duration was based on parental report, which may have bias because parents may have reported when they place their child in bed, rather than when the child fell asleep; thus the sleep time may have been overestimated. However, sleep time in children 1 to 5 years old reported by parents has been reported to closely related with that measured by actigraph.³⁴ Secondly, daytime nap duration, which was very common in preschool-aged children in China, was not recorded. However, studies conducted in China¹⁴ and Netherlands³⁵ found no association between daytime sleep duration and the development of childhood obesity. Thirdly, the questionnaire used in the present study has not been statistically validated and tested for reliability. Especially qualitative questions about children's physical activity with peers may not accurately reflect the time spent playing outdoors; thus, potential bias cannot be excluded. Fourthly, socioeconomic status other than maternal education and maternal occupation were not collected. Nevertheless, all the participants in the present study were recruited from Jiaying city, a small region in Southeast China where people shared similar social patterns, which could minimize the influence of these factors. In addition, sleep-overweight/obesity association was also found in developed regions with a higher socioeconomic status than Jiaying.²² Hence, the influence of socioeconomic status on sleep-overweight/obesity association might be limited. Finally, loss to follow-up did exist. However, comparison between children included in the longitudinal analyses and those not included indicated that they did not differ much in the characteristics (see Table S3 in supplemental material). Furthermore, selection bias from loss to follow-up may be limited, since the main reason of loss to follow-up lay on the difficulty of contacting all the participants as they were spread out geographically.

In summary, both short and long duration of sleep were associated with a higher risk of overweight/obesity in preschool-aged children and the sleep-overweight/obesity association assumed a U-shape with the bottom at around 11–12 hours of sleep. These findings suggested that optimizing sleep duration may be an important modifiable intervention for overweight/obesity in preschool-aged children. More studies are required to explore the causality between sleep duration and overweight/obesity among children.

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