Original Article

Report on Childhood Obesity in China (10): Association of Sleep Duration with Obesity*

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Abstract

Objectives To explore the association of sleep duration with obesity among children in urban areas of China.

Methods A total of 6 576 children (3 293 boys and 3 283 girls) aged 7-11 years were randomly selected from 36 primary schools in 6 metropolitan cities in China. A 7-day Physical Activity Recall was used to assess the sleep duration and physical activity level. The height, weight, waist circumference (WC) and percentage of body fat (%BF, as determined by bioelectrical impedance analysis technique) were measured by following the standardized operation procedures. The information on demography, lifestyle and eating habits was collected with a self-administered questionnaire from participants and their parents.

Results The average sleep duration per night in the children was 9.7 h with the decreasing trends along with the increase of age (P<0.05). The sleep duration was negatively associated with body mass index (BMI) and WC in both boys and girls after adjustment for confounders (β value -0.23 and -0.82 for boys, -0.24 and -0.91 for girls, respectively, P<0.01). However, no significant association of sleep duration with %BF was found. Children who slept less than 9.0 h per night had a higher risk for overweight and obesity (OR=1.29, 95% CI: 1.01, 1.64) and abdominal obesity (OR=1.38, 95% CI: 1.04, 1.83) as compared with those who slept for 10.0-10.9 h.

Conclusions Short sleep duration is associated with obesity. It is important to ensure adequate sleep duration of children and foster their healthy lifestyle at an early stage of life.

Key words: Sleep duration; Obesity; Children; China

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INTRODUCTION

The increasing prevalence of childhood obesity has become a major public health problem in both developed and developing countries. In China, there is an alarming increase in the proportion of overweight and obesity among children. The data from the China National Nutrition Survey (1982) and the China National Nutrition and Health Survey (2002) have shown that

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the prevalence of overweight and obesity increased from 1.7% in 1982 to 5.3% in 2002 among children aged 7-12 years[1]. The rapid increase in childhood obesity is mainly due to China's ongoing nutritional and lifestyle transition. During the past two decades, a 10-fold increase in the per capita gross domestic product was parallel with an increase in the energy-dense foods consumption and leisure time inactivity, and a decrease in transport related physical activity[2-5].

Childhood obesity brings immediate negative impact on the current health of children; moreover, it can last to adulthood and influence their future health[6]. Therefore, effective and comprehensive efforts to prevent childhood obesity should be required. The most effective way of tackling obesity is to identify risk factors and then develop appropriate control strategies[7]. Among the numerous risk factors, an increasing attention has been paid to inadequate and poor-quality sleep over recent years for both children and adolescents[8-11]. Reilly et al. followed up 8 234 children in UK and found that short sleepers (<10.5 h/night) at age of 30 months had a 45% greater risk for developing obesity at age of 7 years than those who slept longer (>12 h/night)[8]. However, the information on the association of sleep duration with childhood obesity was limited in China[12]. The purpose of the present study was to explore the association of sleep duration with obesity among children in urban areas of China and provide scientific evidence for policy makers.

MATERIALS AND METHODS

Sampling Method and Study Population

Six metropolitan cities in China, including Harbin, Beijing, Jinan, Shanghai, Chongqing, and Guangzhou were selected in this study. The multistage random clustering sampling procedure was applied to recruit the participants. Firstly, two urban districts from each selected city were randomly chosen. Then, three primary schools were randomly selected from each selected district. Finally, two classes from each grade were randomly selected from grade 2-5 of each selected school. All the students in the selected classes who were free from physical disability, congenital diseases and any diagnosed medical condition that might potentially interfere with metabolism were invited to participate in the study.

The study protocol was approved by the Ethical Review Committee of the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Signed consent forms were obtained from both the children and their parents or guardians.

General Information

A self-administered questionnaire was used to collect the information on demography, lifestyle and eating habit (the frequency of having breakfast per week, whether overate for most meals, etc.) from the participants. Moreover, the information on family socioeconomics, birth weight and feeding pattern (whether exclusive breastfeeding is provided to the child within 4 months after birth) was collected by a questionnaire from the parents.

Sleep Duration

The type, frequency, duration of each physical activity at school and outside school, sleep duration, sedentary activities including watching TV, using computer (playing games, using internet, chatting, etc.) and doing homework during the last week were collected by using a validated 7-day Physical Activity Recall, which was interview-administered for students of Grade 2, and self-administrated for students of Grade 3-5. Sleep duration was assessed based on the question "What time do you usually go to bed in the evening" and "What time do you usually get up in the morning". These two questions were asked for weekdays and weekends separately. The average sleep duration for each participant was calculated as the sum of hours for sleep in the five weekdays and in two weekend days divided by 7 days.

Anthropometric Measurements

Height was measured to the nearest 0.1 cm with a freestanding stadiometer mounted on a rigid tripod (GMCS-I, Xindong Huateng Sports Equipment Co. Ltd., Beijing, China). Fasting body weight was measured to the nearest 0.1 kg by using a balance-beam scale (RGT-140, Weighing Apparatus Co. Ltd. Changzhou Wujin, China) with participants wearing only underwear. Body mass index (BMI, kg/m^2) was calculated as weight (kg) divided by the square of height (m). Waist circumference (WC) was measured by using an inelastic tape to the nearest 0.1 cm midpoint between the lower costal border and the top of the iliac crest and the measurement was taken at the end of normal expiration. WC was measured twice. If the variation between the two measurements was greater than 2.0 cm, a third measurement would be taken and the mean of the two closest measurements was used.

Body composition was measured by using a single frequency (50 Hz) hand to foot bioelectrical impedance device (ImpDF50; Impedimed Pty Ltd., Qld, Australia). Resistance (R) and reactance (Xc) were read directly from the device. Fat-free mass was calculated by using the prediction equation suggested by Deurenberg et al.[13]. Percentage of body fat (%BF) was then derived based on the two-component model.

Quality Control

The same devices were employed in the six sites and all the measurements were conducted by trained investigators following the standardized operation procedures. The duplicate measurements in subgroups showed high reproducibility (with correlation coefficients of duplicate measurements being 0.99 for height and 0.98 for weight).

Definition of Obesity

Overweight was defined as BMI between the 85th and the 95th percentile, whereas obesity was defined as BMI ⩾95th percentile by using age- and sex-specific BMI cutoff points developed by the Working Group for Obesity in China (WGOC)[14]. Abdominal obesity was defined as age- and sex-specific WC ⩾90th percentile proposed by Ji et al.[15].

Statistical Analysis

Continuous variables were described as mean±standard deviation and one way analysis of variance (ANOVA) was used to compare the difference among age groups. Wald chi-square test was used to compare the difference in the prevalence of overweight, obesity and abdominal obesity among age groups. General Linear Model (GLM) was used to calculate the mean and 95% CI of BMI, WC and %BF by sleep category after adjustment for covariates such as age, sex, maternal BMI, paternal BMI and birth weight. Considering the clustered design of the current study, a multilevel mixed linear model (PROC MIXED) was employed to explore the association of BMI and WC with sleep duration. School was treated as the random effect. BMI/WC was used as dependent variable and sleep duration and 12 potential confounders were treated as fixed effects in the model, including seven continuous variables (age, birth weight, breakfast frequency per week, time in leisure physical activities per day, time in sedentary activities per day, maternal BMI and paternal BMI) and five categorical variables (whether overeating for most meals usually, whether exclusive breastfeeding is praticed within the first four months, per capita annual income of households classified as low, middle and upper class (dummy indicator), maternal and paternal education (dummy indicator, low, middle and upper level)). A generalized linear mixed model (PROC GLIMMIX) was used to explore the association of sleep duration with overweight and obesity, and abdominal obesity. Overweight and obesity or abdominal obesity (dichotomous) was used as the dependent variable. According to the recommended sleep duration for children in a meta-analysis study[16] and a cross-sectional study in China[17], sleep duration was classified into 4 categories (<9.0 h/d, 9.0-9.9 h/d, 10.0-10.9 h/d, ⩾11.0 h/d) and used as indicator variable with the category of 10.0-10.9 h as the reference. All statistical analyses were performed with SAS 9.1.3 for Windows (SAS Institute Inc, Cary, NC, USA). A two-tailed $P<0.05$ was considered significant.

RESULTS

The Characteristics of the Subjects

Finally, a total of 6 576 children (3 293 boys and 3 283 girls) were included in our analyses. For the multivariable analysis, 4 985 observations with completed information for all variables remained. No significant differences were found in the characteristics between the whole and subgroup sample. Table 1 described the characteristics of the participants. The average sleep duration per night of the children was 9.7 h, which decreased with the increase of age ($P<0.05$). No significant differences were found in the prevalence of overweight, overweight and obesity, and abdominal obesity among the age groups.

The Association of Sleep Duration with BMI, WC, and %BF

No significant differences in BMI, WC and %BF were found among the four sleep categories in both boys and girls (Table 2). However, when the clustered design of the study was taken into account, sleep duration was inversely associated with BMI and WC for both genders (β value -0.23, $P=0.017$ and β value -0.82, $P=0.003$ in boys, β value -0.24 $P=0.006$ and β value -0.91, $P<0.001$ in girls, respectively) after adjustment for potential confounders by using the multilevel mixed linear model analysis, while no significant association of sleep duration with %BF was found in either gender (Table 3).

Table 1. The Characteristics of the Participants[1]

	Age (yr)					Total	F/χ^2	P^2
	7-	8-	9-	10-	11-11.9			
n	608	1777	1780	1613	798	6576	-	-
Height (cm)	128.3±5.4[e]	131.9±6.0[d]	136.7±6.3[c]	142.1±7.0[b]	146.6±7.2[a]	137.1±8.6	1248.9	<0.0001
Weight (kg)	26.8±5.4[e]	29.0±6.5[d]	32.0±7.2[c]	36.4±9.0[b]	39.1±9.1[a]	32.6±8.6	436.0	<0.0001
BMI (kg/m^2)	16.2±2.4[c]	16.6±2.7[b]	17.0±2.8[b]	17.9±3.3[a]	18.0±3.2[a]	17.1±3.0	78.2	<0.0001
WC (cm)	54.4±6.5[e]	56.2±7.6[d]	57.9±7.9[c]	61.0±9.4[b]	62.1±9.0[a]	58.4±8.6	148.5	<0.0001
%BF (%)	24.3±4.6[b]	24.1±4.8[b]	24.0±4.9[b]	24.2±5.0[a]	23.6±5.1[b]	24.1±4.9	2.7	0.028
Overweight	77 (12.7)	206 (11.6)	207 (11.6)	204 (12.6)	98 (12.3)	792 (12.0)	1.4	0.836
Obesity	71 (11.7)	181 (10.2)	168 (9.4)	179 (11.1)	57 (7.1)	656 (10.0)	12.0	0.017
Overweight and obesity	148 (24.4)	387 (21.8)	375 (21.0)	383 (23.7)	155 (19.4)	1448 (22.0)	8.8	0.065
Abdominal obesity (%)	84 (13.8)	242 (13.6)	232 (13.0)	255 (15.8)	102 (12.8)	915 (13.9)	7.0	0.137
Average sleep duration (h/d)	10.0±0.8[a]	9.9±0.8[b]	9.8±0.8[c]	9.6±0.8[d]	9.5±0.8[e]	9.7±0.8	50.3	<0.0001
Sleep duration category								
<9.0 h/d	57 (9.4)	213 (12.0)	238 (13.4)	281 (17.4)	173 (21.7)	962 (14.6)	151.1	<0.0001
9.0-9.9 h/d	224 (36.8)	749 (42.2)	863 (48.5)	829 (51.4)	447 (56.0)	3112 (47.3)	491.8	<0.0001
10.0-10.9 h/d	269 (44.2)	702 (39.5)	590 (33.2)	437 (27.1)	159 (19.9)	2157 (32.8)	461.3	<0.0001
⩾11.0 h /d	58 (9.6)	113 (6.4)	89 (5.0)	66 (4.1)	19 (2.4)	345 (6.2)	83.8	<0.0001

Note. [1]Mean±standard deviation for continuous variables and N (%) for overweight, obesity, overweight and obsity, abdominal obesity, and sleep duration category. [2] Comparison among age groups with ANOVA analysis for continuous variables ('F' was shown as a statistic) and chi-square test for category variables ($x^2$was shown as a statistic). [a,b,c,d,e]Sharing the same letter indicates no significant difference between age groups.

Table 2. The Mean and 95% CI of BMI, WC, and %BF by Gender and Sleep Duration Category[1]

Sleep duration	*n*	BMI (kg/m^2)	WC (cm)	%BF (%)
Boys				
<9.0 h/d	503	17.8 (17.5, 18.1)	61.0 (60.2, 61.8)	22.9 (22.5, 23.4)
9.0-9.9 h/d	1 513	17.6 (17.4, 17.8)	60.1 (59.6, 60.6)	22.7 (22.5, 23.0)
10.0-10.9 h/d	1 067	17.5 (17.3, 17.7)	59.7 (59.1, 60.3)	22.8 (22.5, 23.1)
⩾11.0 h/d	210	17.7 (17.3,18.2)	60.3 (58.9, 61.6)	22.9 (22.2, 23.7)
P		0.252	0.085	0.896
Girls				
<9.0 h/d	459	16.8 (16.5, 17.0)	57.1 (56.5, 57.8)	25.4 (25.0, 25.8)
9.0-9.9 h/d	1 599	16.6 (16.4, 16.7)	56.4 (56.1, 56.8)	25.2 (25.0, 25.4)
10.0-10.9 h/d	1 090	16.7 (16.5, 16.8)	56.6 (56.2, 57.0)	25.3 (25.0, 25.6)
⩾11.0 h/d	135	16.8 (16.3, 17.3)	56.7 (55.4, 57.9)	24.8 (24.1. 25.6)
P		0.399	0.327	0.566

Note. [1]General Linear Model corrected for age, maternal BMI, paternal BMI and birth weight.

The Association of Sleep Duration with Obesity

The mean and 95% CI of sleeping hours in different body weight groups were shown in Figure 1. No significant difference in sleep duration among non-overweight, overweight and obese groups was found in both boys and girls, as well as between groups of non-abdominal obesity and abdominal obesity.

Considering the disability of GLM model to fit the results for boys and girls separately due to excessive strata (including the strata for control variables), and the coherence of the association between boys and girls based on results in Table 3 and Figure 1, we presented the association between sleep duration and obesity for the whole subjects (Table 4). Children who slept <9.0 h per night had a higher risk for overweight and obesity as compared with those with sleep duration of 10.0-10.9 h (reference group) (OR 1.29, 95% CI 1.01, 1.64, *P*=0.045). However, no association was found between the children with 9.0-9.9 h or ⩾11.0 h sleep duration compared with the reference group. Similar results were found in the association of sleep duration with abdominal obesity. The OR for the group with sleep duration less than 9.0 h per night was 1.38 (95% CI 1.04, 1.83, *P*=0.028).

Table 3. Association of Sleep Duration with BMI, WC, and %BF[1] (*n*=4 985)

Dependent Variable	Standardized Estimate[5]	Error	*P*-value
Boys			
BMI	-0.23	0.10	0.017
WC	-0.82	0.27	0.003
%BF	-0.07	0.16	0.635
Girls			
BMI	-0.24	0.09	0.006
WC	-0.91	0.24	0.000
%BF	0.10	0.14	0.500

Note. [1]Multilevel mixed linear model was performed by taking the clustered design of the study into account and adjusting for age, leisure time activities, sedentary activities, birth weight, maternal BMI, paternal BMI, usually overeating, breakfast frequency, family income, exclusive breatfeeding within first 4 months after birth and parents' education level.

DISCUSSION

The prevalence of obesity is increasing worldwide and the causes of this epidemic are not fully explained by the changes in traditional dietary pattern and decreases in physical activity[18]. In the 1990s, it was proposed that shorter habitual sleep time may also be on the causal pathways[19]. The present study showed that sleep duration was inversely associated with BMI and WC after being controlled for potentially confounding variables among children from the urban areas of China, which was consistent with the previous cross-sectional and longitudinal studies[16, 20-26]. For example, in a study conducted by Snell et al, children with less sleep duration at baseline had higher BMIs 5 years later and were more likely to be overweight after baseline BMI and other confounders were controlled[26]. One study conducted in Swedish adults showed that sleep duration remained inversely related to WC after it was adjusted for potential confounders[25].

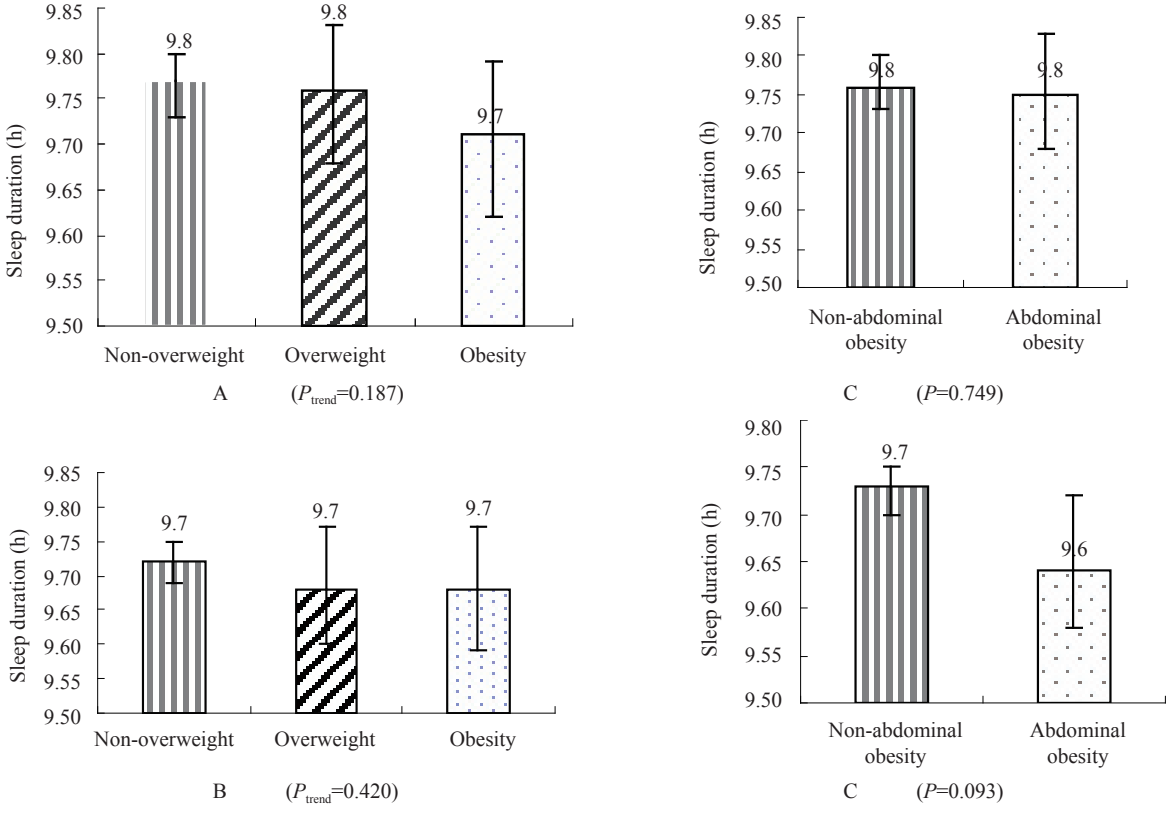

Figure 1. The mean and 95% CI of sleep duration by weight group. Sleep duration in groups of non-overweight, overweight and obesity in boys (a) and in girls (b). Sleep duration in groups of non-abdominal obesity and abdominal obesity in boys (c) and in girls (d).

Table 4. The Association of Sleep Duration with Overweight and Obesity and Abdominal Obesity

	n	Estimate	Standard Error	Crude OR (95% CI)	Adjusted OR[1] (95% CI)	*P*-value
Overweight and obesity						
Sleep < 9.0 h/d	723	0.25	0.13	1.21 (0.95, 1.54)	1.29 (1.01, 1.64)	0.045
Sleep 9.0-9.9 h/d	2393	0.04	0.09	1.02 (0.85, 1.22)	1.04 (0.87, 1.25)	0.688
Sleep 10.0-10.9 h/d (reference)	1621	-	-	1.00	1.00	-
Sleep ⩾11.0 h/d	248	0.18	0.19	1.12 (0.78, 1.62)	1.20 (0.83, 1.73)	0.341
Abdominal obesity						
Sleep < 9.0 h/d	723	0.32	0.15	1.36 (1.03, 1.79)	1.38 (1.04, 1.83)	0.028
Sleep 9.0-9.9 h/d	2393	0.05	0.11	1.05 (0.85, 1.30)	1.05 (0.84, 1.30)	0.674
Sleep 10.0-10.9 h/d (reference)	1621	-	-	1.00	1.00	-
Sleep ⩾11.0 h/d	248	0.27	0.22	1.27 (0.83, 1.94)	1.31 (0.85, 2.01)	0.219

Note. [1]Adjusted for age, gender, leisure time activities, sedentary activities, birth weight, maternal BMI, paternal BMI, usually overeating, breakfast frequency, family income, exclusive breastfeeding within 4 months after birth and parents' education level.

Another study conducted in 5 358 Turkish children aged 6 to 17 years found that WC was significantly higher in boys sleeping ⩽8.0 h compared with those sleeping ⩾10.0 h[24]. Limited studies have explored the relationship between %BF and sleep duration due to the limitation of body composition measurement in large-scale studies. In the current study, no significant relationship between sleep duration and %BF was found in both boys and girls, which was inconsistent with the two previous studies[27-28], where a significant inverse association of body fat mass as determined by DEXA[27] or skinfold thickness[28] with sleep duration was found among female adolescents and children, respectively. The inconsistency might be, in part, due to the different measurement for the body fat. In our study, BIA was used to assess %BF, which is less accurate compared with the DEXA. Moreover, as shown in Yu's study, central adiposity is more strongly associated than BMI with sleep duration[27], which can partly explain the significant association of sleep duration with WC, rather than with %BF in our study.

Our study also showed that children with sleep duration less than 9.0 h per night had a higher risk for both overweight and obesity and abdominal obesity compared with their counterparts with sleep duration of 10.0-10.9 h per night. The association of short sleep duration with obesity has been indicated in both children[8,17,26,29-30] and adults[31-34]. Similar to our findings, a recent study in Quebec children reported that short sleep duration was independently associated with overweight and obesity after adjustment for potential confounders[30]. A large scale cross-sectional study in Chinese children and adolescents from Beijing also showed that less sleep was associated with overweight (OR=1.18, 95% CI: 1.04, 1.33) and obesity (OR=1.36, 95% CI: 1.19, 1.56)[17]. There are some possible pathways to interpret the relationship between short sleep duration and obesity. Firstly, the sleep-curtailment condition might disrupt hormones that regulate appetite and metabolism associated with increased hunger and appetite for carbohydrate-rich foods[35]. Secondly, more calorie intake is needed by the body to counterbalance additional energy expenditures from increased wake time. Moreover, the metabolic regulatory system could overcompensate for additional energy expenditures and lead to obesity over time[29]. Finally, sleep deprivation has also been linked to decreased glucose tolerance, which is also a risk factor for obesity[36].

Some previous studies indicated the sex difference in the association between sleep duration and obesity[20,27,37-38]. This difference may be due to the differences in the physiology of puberty between boys and girls. Puberty is a period characterized by increased muscle mass and reduced fat mass in males, whereas in females, there is an increase in fat mass[39]. However, the gender difference in association between sleep duration and adiposity indices was not seen in the present study. Generally, Chinese girls start their puberty at age of 11-12 years and boys at age of 13-14 years[40]. The proportion of girls aged 11 years in our sample was only 5.6%, which can explain the non-gender difference in the current study.

It should be noted that our study has several limitations. Firstly, the current study, as a cross-sectional study, precludes causal inferences regarding the relationship between sleep duration and obesity. Additional experimental and longitudinal studies are needed. Secondly, energy intake, which is a main contributor to obesity, was not evaluated in the present study. However, 12 potential control variables including dietary pattern and lifestyle were included into the regression model to reduce the bias in explaining the relationship between sleep and obesity. Finally, information on sleep duration was self-reported by the children, which might have memory bias. Moreover, calculation of sleep duration based on the time they went to bed and got up was not very accurate for estimating sleep duration because the duration in bed was not exactly the sleep duration. Though a study has shown that a self-report assessment of sleep is a valid measure compared with quantitative sleep assessments with actigraph[41], the assessment of the sleep duration still needs to be improved.

In conclusion, short sleep duration is associated with obesity and abdominal obesity among children from the urban areas of China. In order to improve the health of children, adequate sleep time should be ensured for the children, and a healthy lifestyle should be fostered.

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