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SCIENTIFIC INVESTIGATIONS

The relationship between obesity and sleep timing behavior, television exposure, and dinnertime among elementary school-age children

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Study Objectives: The daily lifestyle behaviors of children have been shown to be associated with obesity. There are limited studies on the association of sleep timing behavior and body mass index (BMI), specifically in elementary school-age children. This study aimed to investigate the relationship between obesity and sleep timing patterns, television exposure time, and dinnertime among elementary school-age children.

Methods: Children (n = 169) aged 6 to 10 years who were residents of Alabama were recruited for this study. The questionnaires were used to determine the bedtime, wake-up time, television exposure time, and dinnertime of the participants. The participants were categorized into four groups depending on the bedtime and wake-up time behavior habits: early bed/early wake-up (EE); early bed/late wake-up (EL); late bed/early wake-up (LE); and late bed/late wake-up (LL) time. The BMI z-score, television exposure time, and dinnertime of these groups were compared.

Results: The LL group had a significantly higher BMI z-score compared to the EE group. The higher BMI z-score in the LL group may be associated with late bedtime and not late wake-up time. Approximately 71% of children with late bedtime (8:48 PM), 75% of children who watch television for more than 1 hour, and 54% of children who have dinner after 7:00 PM have obesity.

Conclusions: Daily behavior habits such as late bedtime, increased television exposure, and late dinnertime are associated with obesity.

Keywords: body mass index, childhood obesity, dinnertime, sleep timing, television exposure

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Short sleep duration has been shown to increase the risk of childhood obesity. There are limited studies on the association of sleep timing behavior, television exposure, and dinnertime with body mass index z-score, specifically in elementary school-age children.

Study Impact: We observed that children with late bedtime are more likely to have obesity, despite having a consistent sleep duration. The higher body mass index z-score is also related to prolonged television exposure and late dinnertime.

INTRODUCTION

Childhood obesity is a public health concern for a variety of reasons. In the United States, approximately 12.7 million children and adolescents are classified as obese.[1] The prevalence of obesity is 8.9% among children age 2 to 5 years, 17.5% for those age 6 to 11 years, and 20.5% for those age 12 to 19 years. The annual medical cost related to obesity is estimated to be $254 billion.[2] There are several known factors that could contribute to an increase in the prevalence of childhood obesity, including sedentary activities, media influence, socioeconomic status, food availability, parental influences, and cultural considerations. Children with obesity experience immediate and lasting consequences on physical, social, and emotional health. They have a higher likelihood of other chronic health conditions and diseases that affect physical health such as type 2 diabetes, cardiovascular disease, and cancer.[1,3,4]

The Centers for Disease Control and Prevention (CDC) suggest that approximately 35.5% of children are overweight and obese in Alabama, a state ranked as having the sixth highest rate of obesity in the United States. According to the CDC, an increase in the prevalence of childhood obesity in Alabama may be attributed to a lack of breastfeeding, unhealthy dietary habits, physical inactivity, and environmental conditions.

Short sleep duration has been shown to increase the risk of childhood obesity.[5,6] Sleep is essential for several biological processes that are necessary for providing optimal physical and mental health. Short sleep duration is a widespread problem across cultures.[7] However, studies have shown that the link between short sleep duration and obesity in children is more complicated than initially believed.[8,9] No association was found between sleep duration and body mass index (BMI) in a longitudinal study of United States adolescents.[10] Few studies have reported that sleep timing behavior (bedtime and wake-up time) rather than sleep duration is associated with obesity.[11] Children with a late bedtime and late wake-up time had a higher risk for obesity compared to those with early bedtime and wake-up routines in a study conducted in Australian children.[12] Children with early wake-up times have a lower BMI compared to children with late bedtimes.[13,14]

Children exposed to extended television viewing have a higher risk of obesity.[15,16] Television viewing reduces physical activity, increases unhealthy snacking, and also hampers sleep.[17] Children are also influenced by food-related TV ads, which promote low-nutrient foods and drinks with high calorie content.[18] The time of dinner consumption may also be associated with obesity.[19] The time of food intake has shown to regulate the circadian clock at behavioral, physiological, and molecular levels.[20]

The obesity-related lifestyle behavior factors are linked with each other, rather than distinct elements. Children's daily lifestyle behaviors are dependent on the family environment, especially in young children. In this study, we identified the relationship of the sleep timing pattern, television exposure time, and dinnertime with BMI in elementary school-age children.

METHODS

Participants

Approximately 169 children age 6 to 10 years were recruited from Lee County and Macon County, Alabama, by posting flyers at after-school programs and health fairs, on Facebook, and via participant referrals. Children with major health disorders such as diabetes, cardiovascular disease, or diagnosed sleep disorder based on initial phone survey with the parents were excluded. The parents brought their child to Auburn University to participate in this study. The written consents were obtained by the parents and participants. The study was approved by the Auburn University Institutional Review Board.

Anthropometry

Participants' body weight was measured without shoes and with light clothing to the nearest 4 ounces using a Tanita digital scale. Their height was measured to the nearest 0.1 cm on a calibrated scale attached to a stadiometer. In accordance with the CDC growth chart, BMI was calculated based on the body weight and height obtained. The recruited participants were classified as "underweight: less than the 5th percentile; normal weight: between 5th to 85th percentile; overweight: between 85th to 95th percentile; and obese: greater than the 95th percentile."[21] As children grow from age 2 to 20 years, not all such growth is body fat, so BMI z-scores are calculated using an SPSS (IBM Corp, Armonk, New York, United States) macro based on World Health Organization growth reference 2007 data adjusted for age and sex.[22]

Survey instrument

Parents completed questionnaires (on paper) on behalf of the participants about age, sex, annual family income ($25,000 or less, $25,001 to $50,000, $50,001 to $75,000, $75,001 or more), and child's mother's education (high school or less, some college or associate degree, bachelor's degree, graduate degree). In addition to these questions, we also asked the following: "What is the bedtime of your child?" "What time does your child wake up?" "How long does your child watch television per day?" and "What time does your child eat dinner?" Monetary compensation was provided to the participant as an appreciation for their time and support to this study.

Statistical analyses

Statistical analyses were performed using SPSS version 24. Continuous variables are expressed as mean ± standard error, except for television exposure time, which is expressed as mean ± standard deviation. The mean of the groups was evaluated by analysis of variance followed by Bonferroni *post hoc* test. Categorical variables were derived by calculating the frequencies and expressed as a percentage. The significant difference was then analyzed by either one-sample or two-sample *t* tests between the percentages. Unadjusted multinomial logistic regression was used to analyze the odds ratio and association between BMI z-score and sleep behavior categories. For adjusted analysis age, sex, television exposure, and dinnertime were used as covariables.

RESULTS

The characteristics of participants recruited for this study are shown in **Table 1**. The mean age of children was 8.42 years, 50.9% were female, and 49.1% were male. Of a total of 169 participants, 35.5% of children were considered overweight/obese. The demographic data, duration of television exposure, dinnertime, maternal education, and annual household income were also collected (**Table 1**).

A bedtime before 8:30 PM was considered as early bedtime and after 8:31 PM as late bedtime. Similarly, if the wake-up time was before 6:00 AM it was categorized as early wake-up time and after 6:01 AM as late wake-up time. Depending on the bedtime and wake-up time, the participants were classified into four groups: early bed/early wake-up (EE); early bed/late wake-up (EL); late bed/early wake-up (LE); and late bed/late wake-up (LL). The EE and EL groups went to bed 45 to 65 minutes earlier than the LE and LL groups, whereas the EE and LE groups woke up 40 to 65 minutes earlier than EL and LL groups. The sleep duration for EE (9 hours 56 minutes) and LL groups (9 hours 57 minutes) are very close. The EL group slept approximately 30 minutes longer (10 hours 23 minutes), whereas the LE group slept approximately 1 hour less. There were significant differences between the bedtime, wake-up time, and sleep duration, as shown in **Table 2**.

As the first step, we investigated whether bedtime or wake-up time is important for obesity. Therefore, we analyzed the differences in the BMI z-score based on only the bedtime, and the participants were separated according to early bedtime (EL and EE group) and late bedtime (LE and LL group). We observed a significantly higher ($P < .0001$) BMI z-score in the late bedtime group compared to the early bedtime group (**Figure 1A**). **Figure 1B** shows the proportion of normal weight, overweight,

Table 1—General characteristics of the study population.

	All (n = 169)	NW (n = 109)	OW (n = 32)	OB (n = 28)
Sex (n)				
Male	83	55	16	12
Female	86	54	16	16
Age (years)	8.42 ± 0.10	8.37 ± 0.14	8.28 ± 0.23	8.77 ± 0.28
Weight (kg)	32.22 ± 0.83	27.82 ± 0.64	34.12 ± 1.11 [a]	47.20 ± 2.69 [a b]
Height (cm)	132.37 ± 0.89	130.55 ± 1.09	132.47 ± 1.60	139.34 ± 2.45 [a]
BMI (kg/m^2)	17.96 ± 0.26	16.06 ± 0.15	19.31 ± 0.19 [a]	23.81 ± 0.59 [a b]
BMI z-score	0.70 ± 0.09	−0.02 ± 0.08	1.56 ± 0.05 [a]	2.56 ± 0.07 [a b]
Television time (%)				
0–30 minutes	20.09	33.94	15.63	10.71
30–60 minutes	24.79	25.69	34.38	14.29
> 60 minutes	55.12	40.37	50.00	75.00[c]
Dinnertime (%)				
Before 6:00 PM	32.34	38.53	40.63	17.86
6:00 to 7:00 PM	34.38	33.94	40.63	28.57
After 7:00 PM	33.28	27.52	18.75	53.57[d]
Maternal education (%)				
High school or less	23.67	23.85	15.63	32.14
Associate degree	24.85	23.85	21.88	32.14
Bachelor's degree	21.89	20.18	28.13	21.43
Graduate	29.59	32.11	34.38	14.29
Household income (%)				
< $25,000	30.18	33.03	18.75	32.14
$25,001–50,000	16.57	15.60	18.75	17.86
$50,001–75,000	14.20	15.60	18.75	3.57
> $75,001	39.05	35.78	43.75	46.43

Data expressed as mean ± standard error or as indicated. [a] $P < .001$ corresponds to NW versus OW or OB. [b] $P < .001$ corresponds to OW versus OB. [c] $P < .0001$ corresponds to < 30 minutes versus > 60 minutes and 30–60 minutes versus > 60 minutes in the obese group. [d] $P < .02$ corresponds to before 6:00 PM versus after 7:00 PM in obese group. BMI = body mass index, NW = normal weight, OB = obese, OW = overweight.

Table 2—Comparison of bedtime, wake-up time, and sleep duration across the sleep behavior categories.

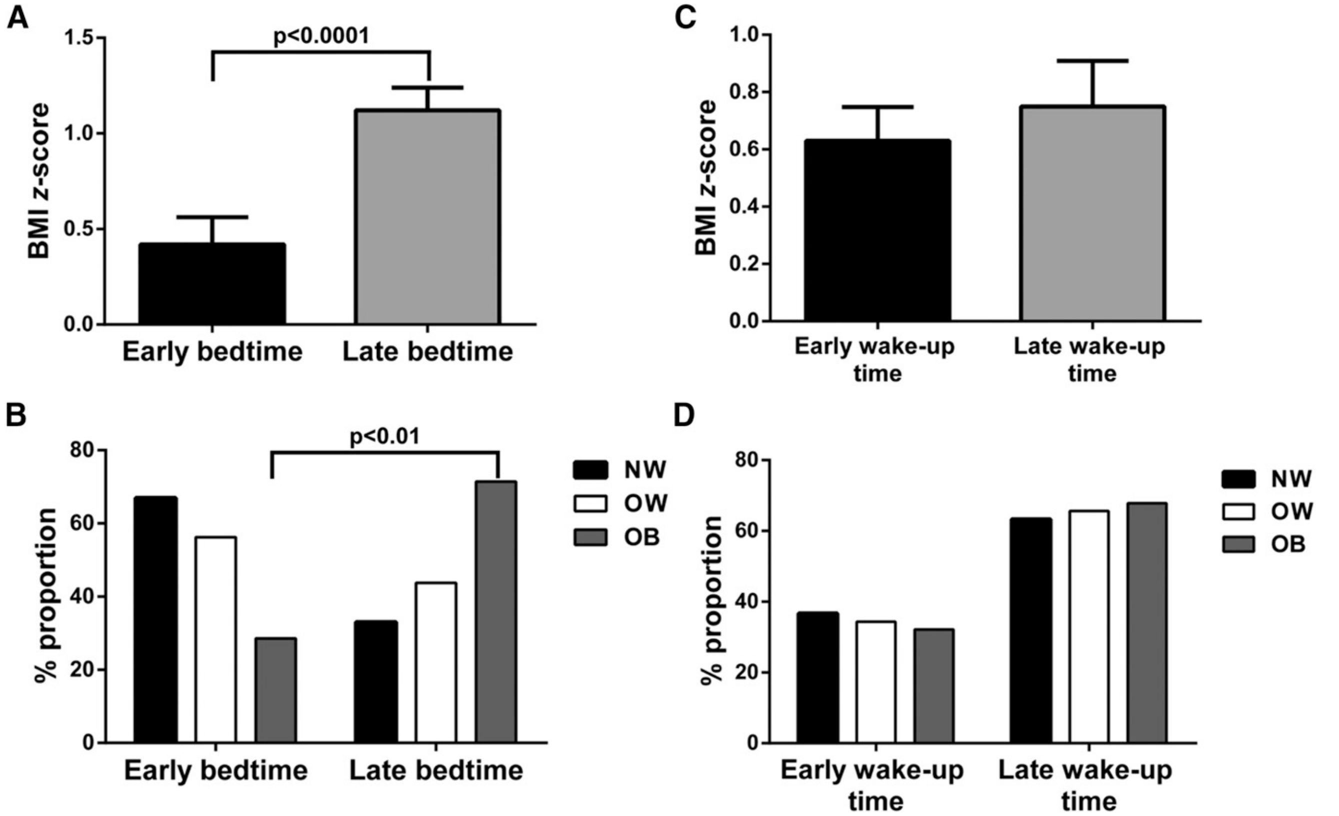
Characteristic	EE (n = 30)	EL (n = 69)	LE (n = 30)	LL (n = 40)
Bedtime	7:44 PM ± 27 [b c d]	8:01 PM ± 19 [a c d]	8:48 PM ± 9 [a b]	8:48 PM ± 10 [a b]
Wake-up time	5:40 AM ± 11 [b d]	6:24 AM ± 18 [a c d]	5:42 AM ± 9 [b d]	6:45 AM ± 18 [a b c]
Sleep duration	9:56 ± 31 [b c]	10:23 ± 23 [a c d]	8:54 ± 12 [a b d]	9:57 ± 22 [b c]

Data expressed as mean ± standard deviation. Bedtime and wake-up time are clock time ± minutes. Sleep duration is hours:minutes ± minutes slept in a 24-hour period. [a] $P < .0001$ versus EE. [b] $P < .0001$ versus EL. [c] $P < .0001$ versus LE. [d] $P < .0001$ versus LL. EE = early bed/early wake-up, EL = early bed/late wake-up, LE = late bed/early wake-up, LL = late bed/early wake-up time.

and obese children by early and late bedtime. Only 29% of participants were obese in the early bedtime group compared to 71% in the late bedtime group ($P < .01$). Similarly, the differences in the BMI z-score based on only the wake-up time were determined. The EE and LE groups were combined as early wake-up time, and EL and LL groups were combined as the late wake-up time. There was no significant difference in the BMI z-score between early wake-up and late wake-up times (**Figure 1C**). **Figure 1D** shows the proportion of normal weight, overweight, and obese children by early and late wake-up time. There was no significant difference in healthy and obese participants in early or late wake-up time groups. These results suggest that the participants with late bedtime after 8:30 PM tend to have a higher BMI z-score.

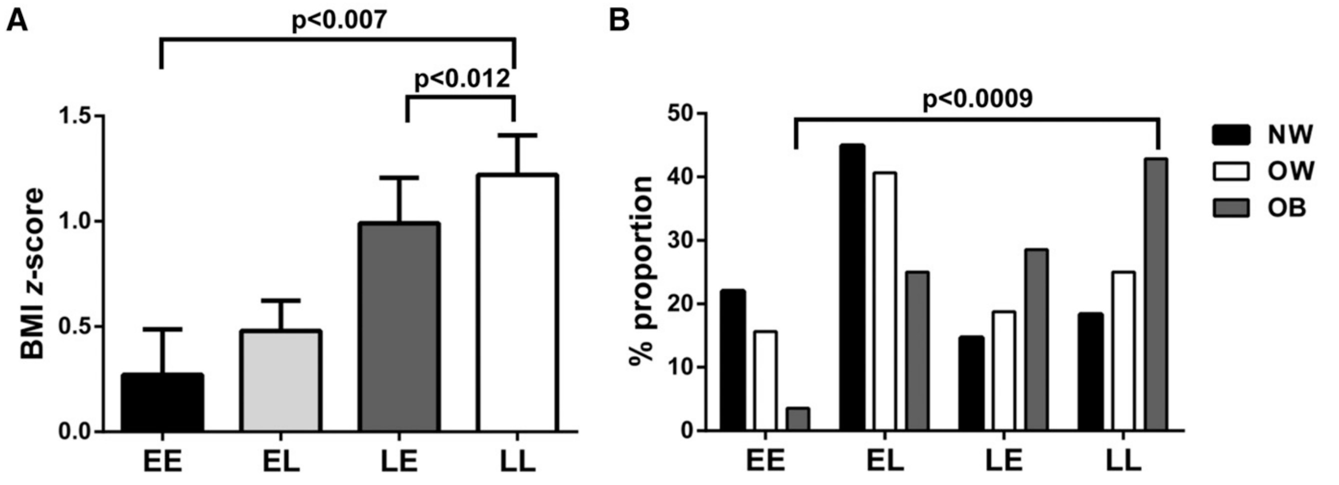
Next, we investigated the differences in the BMI z-score on the combination of both the bedtime and wake-up time. **Figure 2A** shows bar charts of the participants BMI z-score in EE, EL, LE, and LL groups. The BMI z-score is significantly

Figure 1—The relationship between bedtime and wake-up time with obesity.



(A) Early and late bedtime versus BMI z-score. **(B)** Percentage of normal weight, overweight, and obese participants in early and late bedtime category. **(C)** Early and late wake-up time versus BMI z-score. **(D)** Percentage of normal weight, overweight and obese participants in early and late wake-up time category. BMI = body mass index, NW = normal weight, OB = obese, OW = overweight.

Figure 2—The relationship between sleep behavior categories and obesity.



(A) Sleep categories versus BMI z-score. **(B)** Percentage of normal weight, overweight, and obese participants in four sleep categories. BMI = body mass index.

increased in the LL group ($P < .007$) compared to the EE group. The proportions of normal weight, overweight, and obese children according to sleeping habits are shown in **Figure 2B**. Approximately 4% of participants are obese in the EE group, 25% in the EL group, 28% in the LE group, and 43% in the LL group. Most importantly, the percentage of obesity (42.86% versus 3.57%, $P < .0009$) was significantly higher in the LL group compared to the EE group. The association between sleep timing behavior and BMI z-score is shown in **Table 3**. In unadjusted analysis, the LE ($P < .023$) and LL groups ($P < .002$)

Table 3—Association between sleep behavior categories and BMI z-score.

Sleep Category	Unadjusted					Adjusted				
	β	OR	*P*	95% CI		β	OR	*P*	95% CI	
				LB	UB				LB	UB
EL	0.149	1.16	.422	0.807	1.67	0.090	1.09	.65	0.739	1.62
LE	0.513	1.67	.023	1.073	2.60	0.222	1.25	.41	0.734	2.12
LL	0.689	1.99	.002	1.299	3.05	0.539	1.71	.03	1.053	2.79

Multinomial logistic regression was used to analyze the data, with EE group as reference category. The results were adjusted for age, sex, television exposure time and dinner time. CI = confidence interval, EE = early bed/early wake-up, EL = early bed/late wake-up, LB = lower bound, LE = late bed/early wake-up, LL = late bed/early wake-up time, OR = odds ratio, UB = upper bound.

had higher BMI z-scores compared with the EE group. After adjustment for age, sex, television exposure, and dinnertime, the LL group still had a significantly higher BMI z-score. We then analyzed the relationship between television exposure time with BMI z-score and sleep timing behavior. The participants were separated into three groups based on their television exposure time: less than 30 minutes of exposure, 30 minutes to 1 hour of exposure, and exposure for longer than 1 hour. The differences in the BMI z-score based on the television exposure time is shown in **Figure 3A**. BMI z-score is significantly higher in participants with more than 1 hour of television exposure ($P < .0001$) compared to participants with less than 30 minutes of exposure. The proportions of normal weight, overweight, and obese children by television exposure are shown in **Figure 3B**. Approximately 75% of participants with longer than 1 hour of television exposure are obese, 14% are obese with 30 minutes to 1 hour of television exposure, and 11% are obese with less than 30 minutes of television exposure. Children who watched television for more than 1 hour were more likely to have obesity in comparison with the other groups (75% versus 14.29% and 10.71%, $P < .0001$). **Figure 3C** shows the relationship between sleep timing behavior categories and television exposure. In the LL group, 30% of the participants watch television for more than 1 hour, whereas only 7% in the EE group do ($P < .02$).

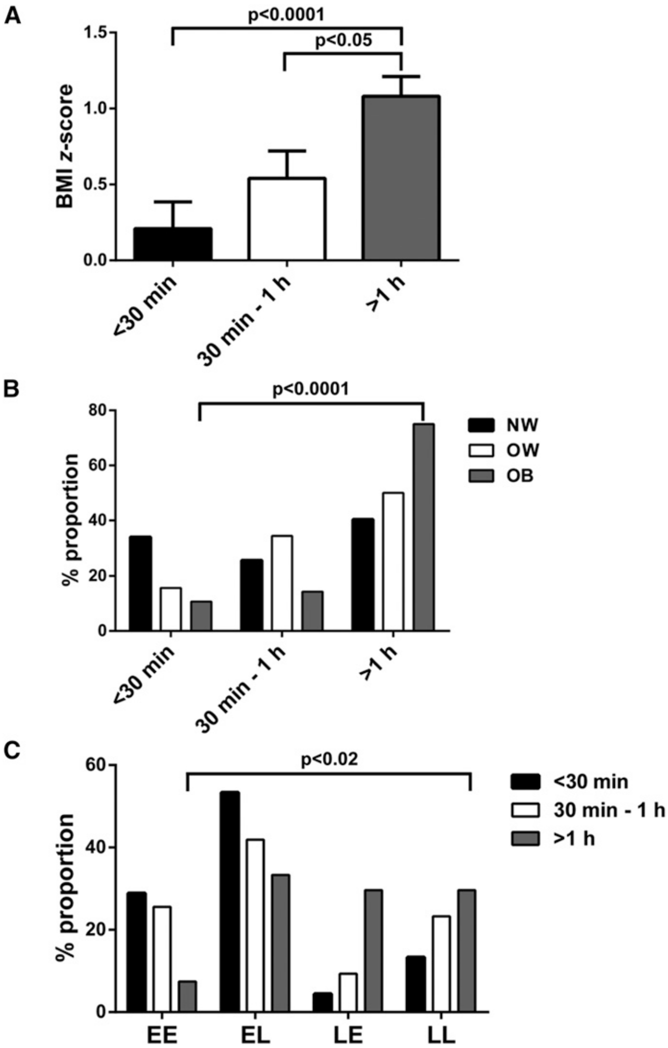
Also, the relationship of dinnertime with BMI z-score and sleep timing behavior was analyzed. The participants were separated into three groups based on dinnertime before 6:00 PM, between 6:00 to 7:00 PM, and after 7:00 PM. BMI z-score is significantly higher in participants with dinnertime at or after 7:00 PM ($P < .026$), compared to participants with earlier dinner- time, as shown in **Figure 4A**. Approximately 54% of participants with dinnertime after 7:00 PM are obese, compared to 18% with dinnertime before 6:00 PM who are obese ($P < .02$) as shown in **Figure 4B**. **Figure 4C** shows the relationship between sleep timing behavior categories and the dinnertime of the participants. The proportion of dinnertime with the sleep behavior categories shows that 35% of participants in the LL category and only 6% in the EE group have dinner after 7:00 PM ($P < .004$). The participants with late bedtime are more likely to have late dinnertime. The results suggest that longer television exposure time and late dinnertime are related to increased BMI and a late bedtime.

DISCUSSION

In the current study, we found a significant increase in the BMI of children with late bedtime/late wake-up time compared to early bedtime/early wake-up, despite having the same sleep duration. The CDC called insufficient sleep a public health epidemic. Several studies have reported that short sleep duration increases the risk of obesity,[23–27] diabetes,[28] and reduced quality of life.[29] Short sleep duration has been shown to have negative effects on endocrine functions such as increasing the secretion of cortisol and ghrelin, and reducing leptin secretion thereby affecting the glucose tolerance.[30] In addition, lack of sleep has been associated with anxiety, depression,[31] inability to focus[32] and to remember information[31] leading to poor academic performance, and a greater likelihood of injuries and accidents.[33] In this study, children with late bedtime/early wake-up time (LE group) had the shortest sleep duration compared to all other sleeping patterns. We may expect that this group will have the most significant BMI, but we found a significantly high BMI with late bedtime/late wake-up time (LL group), and the lowest BMI in early bedtime/early wake-up time (EE group), whereas both of these groups have the same sleep duration. This high BMI in late bedtime/late wake-up time is mainly associated with the late bedtime and not the late wake-up time, as we did not find a significant difference in the BMI between early and late wake-up time. The results suggest that the higher BMI is not dependent on the sleep duration but on bedtime. A similar study has shown that preschool children with an early bedtime were half as likely to be obese compared to children with late bedtimes.[34]

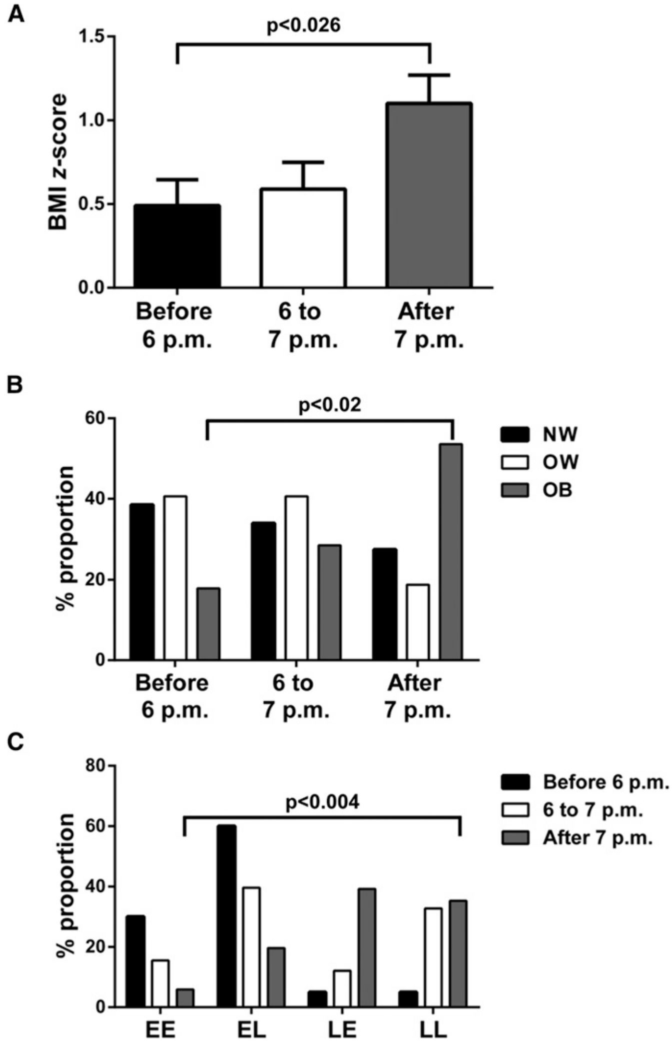
The late bedtime might not only be associated with the higher BMI, so we explored the relationship of the sleep timing pattern with television exposure time and the dinnertime of children. Children with late bedtime may tend to have a late dinner and watch television. In this study, we also found that the longer television exposure corresponds to a higher BMI z-score of children. Previous studies have shown that children exposed to longer television viewing time are more likely to become obese.[35,36] It has been demonstrated that children who have a television in their bedroom were more likely to be overweight compared to those who do not have a television in their bedrooms.[37] Television watching is one of the sedentary behaviors that induces a low metabolic rate and prevents other

Figure 3—The relationship between television exposure time and obesity.



(A) BMI z-score vs television exposure time. **(B)** Percentage of normal weight, overweight, and obese participants in different television exposure time categories. **(C)** Percentage of participants in EE, EL, LE, LL groups across the television exposure time categories. BMI = body mass index, EE = early bed/early wake-up, EL = early bed/late wake-up, LE = late bed/early wake-up, LL = late bed/early wake-up time.

Figure 4—The relationship between dinnertime and obesity.



(A) BMI z-score vs different dinnertimes. **(B)** Percentage of normal weight, overweight, and obese participants in different dinnertimes. **(C)** Percentage of participants in EE, EL, LE, LL groups across three different dinnertimes. BMI = body mass index, EE = early bed/early wake-up, EL = early bed/late wake-up, LE = late bed/early wake-up, LL = late bed/early wake-up time.

physical activities that consume the body's higher energy levels.[38] A study with Japanese preschool children has shown that those participants with shorter screen exposure, longer sleep duration, and an early dinnertime had the lowest percentage of overweight/obesity.[39] Late dinnertime has proved to be associated with higher BMI in adults.[40] Our results also suggest that children having dinner after 7:00 PM have a higher BMI z-score. Of the children who had a late bedtime (8:48 PM), approximately 60% of them watched television for longer than 1 hour, and 75% had dinner after 7:00 PM. The higher BMI z-score is not only in children with late bedtime but also with more prolonged television exposure and late dinnertime.

The limitations of this study are that the results are based on the small number of participants from the wide age range, low proportions of participants with obesity, and these results needed to be confirmed with a more extensive cohort study. The participants generally are highly educated and have moderate to high income. Other factors that could influence childhood obesity, such as socioeconomic status, food quality, parental influences, and physical activity, are not included. Also, bedtime is reported by the parents and there can be a difference in the time of a child going to bed and actual sleeping.

In this study, we explored the relationship of obesity in children with the sleep timing pattern, television exposure time, and dinnertime. We observed that children with late bedtime/late wake-up times are more likely to have obesity than children with early bedtime/early wake-up time, despite having the same sleep duration. The higher BMI in children with late bedtime/late wake-up time seems to be associated with late bedtime and not wake-up time. Bedtime, rather than sleep duration, is an essential factor for obesity in children. The higher BMI is also observed in children with more television exposure and late dinnertime.

ABBREVIATIONS

BMI, body mass index
CDC, Centers for Disease Control and Prevention
EE, early bed/early wake-up
EL, early bed/late wake-up
LE, late bed/early wake-up
LL, late bed/late wake-up

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