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Habitual sleep variability, not sleep duration, is associated with caloric intake in adolescents

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Abstract

Objective—To investigate the associations between objectively-measured habitual sleep duration (HSD), habitual sleep variability (HSV) and energy and snack intake in adolescents.

Methods—We used data from 324 adolescents participated in the Penn State Child Cohort follow-up examination. Actigraphy was used over 7 consecutive nights to estimate nightly sleep duration. The 7-night mean and standard deviation of sleep duration were used to represent HSD and HSV, respectively. Youth/Adolescent Food Frequency Questionnaire was used to obtain daily average total energy, protein, fat, carbohydrates intakes, and number of snacks consumed. Linear regression models were used to investigate the associations between habitual sleep patterns and caloric, protein, fat, and carbohydrates intakes. Proportional odds models were used to associate habitual sleep patterns and snack consumption.

Results—After adjusting for age, sex, race, BMI percentile, and smoking status, increased HSV was associated with higher energy intake, particularly from fat and carbohydrate. For example, with 1-hour increase in HSV, there was 170 (66) kcal increase in daily total energy intake. Increased HSV also related to increased snack consumption, especially snacks consumed after dinner. For instance, 1 hour increase in HSV was associated with 65% and 94% higher odds of

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consuming more snacks after dinner during school/work days and weekends/vacation days, respectively. Neither energy intake nor snack consumption was significantly related to HSD.

Conclusion—High variability in habitual sleep duration, not habitual sleep duration, is related to increased energy and food consumptions in adolescents. Maintaining a regular sleep pattern may decrease the risk of obesity in adolescents.

Keywords

Sleep Variability; Sleep Duration; Caloric Intake; Snack Consumption

1. Introduction

Pediatric obesity is becoming a global epidemic (1). In 2010, 43 million children were estimated to be overweight and obese worldwide. The worldwide prevalence of childhood overweight and obesity increased from 4.2% in 1990 to 6.7% in 2010, and is projected to reach 9.1% in 2020 (2). Not only is childhood obesity prevalent, but it is also a risk factor for increased morbidity and premature mortality in adulthood (3). Concurrent with the epidemic of childhood obesity is a marked increase in sleep disturbances and deprivation. Therefore, sleep duration has attracted attention as a potential novel risk factor for obesity in children. However, the majority of the previous studies reported the association between subjectively-reported sleep duration and obesity (4–7). Since subjectively-measured sleep duration is weakly correlated to objectively-measured sleep duration (8), it may not represent the actual sleep duration but serve as a surrogate marker of stress and depression (9). Therefore, the observed association between subjectively measured short sleep duration and obesity may be partially confounded by participants' psychological profiles (10, 11). On the other hand, previous literature reported an inconsistent relationship between objectively-measured sleep duration, a quantitative assessment of the actual sleep duration, and obesity (10–15).

Meanwhile, excessive food consumption is considered as a primary behavioral contributing factor to the pediatric obesity epidemic. As energy intake is in excess of energy expenditure, a positive energy balance occurs. The cumulative impact of sustained positive energy balance results in weight gain and may lead to obesity (16). In the last decade, several short-term interventional studies have consistently found a significant association between objectively-measured sleep duration and energy intake (17–19). However, these studies may not be generalized to real life.

With the increasing availability of actigraphy for multiple nights of sleep measurements, objectively-measured habitual sleep pattern, including both habitual sleep duration and sleep duration variability, has been used in observational sleep studies (20–23). Among which, Kjeldsen and coworkers reported that both habitual sleep duration and sleep duration variability were related to dietary risk factor for obesity in Danish school children (23). Therefore, it is plausible that increased variability in habitual sleep duration may contribute to unhealthy food consumption behavior. To date, it is the only study that examined the relationship between objectively-measured sleep duration variability and food intake.

Therefore, we carried out this study to investigate the association between objectively-measured habitual sleep duration (HSD) and habitual sleep variability (HSV) and energy intake and snack consumption in a population-based sample of healthy adolescents.

2. Methods

2.1. Population

We used available data from 421 adolescents who completed the follow-up examination of Penn State Child Cohort (PSCC) study. Recruitment methods and examination procedures for the PSCC baseline study have been published elsewhere (24). A total of 700 children aged 6–12 years participated in the baseline examination, conducted in 2002–2006. Among the 700 subjects, 421 returned and completed the follow-up examination during 2010–2013, yield a response rate of 60%. The loss to follow-up was mainly due to subjects moving out of the central Pennsylvania area. However, no major difference in the baseline demographic characteristics was observed between subjects who participated in the follow-up study examination and who did not. The participants were examined in the Clinical Research Center in Pennsylvania State University College of Medicine. After undergoing a whole-body dual-energy x-ray absorptiometry scan, a detailed physical exam and questionnaire-based data collection protocol were performed. An actigraph tri-axis accelerometer monitor (GT3X+, Actigraph LLC, Pensacola, FL) was used to measure the sleep duration. The participant stayed overnight in a sleep laboratory to complete a standardized PSG recording. After collecting morning blood, saliva and urine samples, the participants were released to proceed with their daily routine with the actigraphy and a set of questionnaires about their habitual behaviors, including food consumptions. The study protocol was approved by Penn State University College of Medicine Institutional Review Board. Written informed consents were obtained from participants and their parents or legal guardians if younger than 18 years.

2.2. Sleep Variables

The actigraphy worn on the wrist of non-dominant hand during bedtime was used to assess the sleep duration for 8 consecutive nights over the study period, in combination with the sleep diary that recorded “bed time” and “out of bed time” on a nightly basis. The actigraphy data were exported to a designated computer for analysis. After removing artifacts, the actual sleep duration were obtained by using ActLife 6 software (Actigraph LLC, Pensacola, FL). Sleep data for the first night was excluded from the calculation, as it was measured under a 9-hour sleep protocol in a laboratory environment. HSD and HSV were computed to assess participants habitual sleep patterns. The average of sleep duration across 7 nights in the free-living environment was used to represent HSD. The intra-subject standard deviation (SD) of the 7-night sleep duration was used to represent HSV. Participants with less than five (<5) nights, i.e. less than 70% of 7 nights, of sleep data were excluded from the analysis.

2.3. Food Intake Variables

A self-administered Youth/Adolescent Questionnaire (YAQ) was used to assess participants' daily nutrition and food intake behavior. Briefly, the participants were asked to

report the frequency of consumption of 152 food items over one year prior to the study. Frequencies for each of the 152 food items were analyzed and converted into a series of nutrient indices representing daily nutrition intake. The reproducibility and validity of the YAQ have been reported previously (25, 26). For this analysis, we used daily total energy, total fat, protein, and carbohydrate intake to represent the participants' energy and nutrition intake. Subjects with a daily total energy intake less than 500 kcal or greater than 5000 kcal were excluded from the analysis due to suspicion of implausible responses to the questionnaire.

To examine whether the association between habitual sleep pattern and nutrition intake can be attributed to snack eating behavior, the number of snacks consumed daily obtained from YAQ were used directly. To facilitate this analysis, participants were asked to report the number of snacks eaten on school/work days and weekends/vacation days for each of the three segments, including between breakfast and lunch, between lunch and dinner, and after dinner. 5 options, including "None", "1", "2", "3", and "4 or more", could be chosen for each segment.

2.4. Other Covariates

Subjects' demographic information, such as age, race, gender, smoking status, and medical history, was collected via a self-administered questionnaire. Subjects' height and weight were measured to calculate their body mass index (BMI) percentile. BMI percentile was adjusted for age and gender based on the formula and data from the 2000 CDC growth charts. Subjects with BMI percentile <85, 85 and <95, and 95 were categorized as "normal weight", "overweight", and "obese", respectively.

2.5. Statistical Analysis

Among 421 subjects who completed the follow-up examination, 97 individuals were excluded from the analysis due to insufficient nights of sleep data (n=94) and/or implausible daily total caloric intake (n=7). Thus, the effective sample size for this report is 324. Summary statistics of the demographics were calculated as mean (SD) for continuous variables and as proportions for categorical variables. No significant differences in demographic characteristics were observed between the analytical sample and those who were excluded. Analysis of variance and Cochran-Mantel-Haenszel tests were used to compare the distribution of demographic variables across the three BMI percentile groups. Linear regression models were used to assess the association between habitual sleep pattern and behavioral energy and nutrition intake. Initially, sleep variables were included in the models individually, in which only one sleep variable entered into the model as the independent variable to investigate the relationship between habitual sleep pattern and nutrition intake. We then included both HSD and HSV in the same model to control for each other. Major demographic confounding factors, including age, sex, race, BMI percentile, and smoking status were included in the adjusted models.

In order to avoid the loss in statistical power and retain interpretability of the analytic conclusions, the number of snacks consumed daily was used as an ordinal outcome, instead of arbitral dichotomization. Therefore, proportional odds models (POM) (27) were used to

evaluate the relationship between habitual sleep patterns and snack consumption. The advantage of POM is that the odds ratios (OR) can be interpreted as constant across all possible cutoff points of the outcome. In this case, we modelled the odds of consuming more snacks. Score tests for proportional odds assumption were used to test the validity of applying POM to our data. No major assumption violation was found in the analyses. Age, sex, race, BMI percentile, and smoking status were adjusted in the models. All analyses were performed using SAS statistical package (Version 9.3; SAS Institute, Cary, NC). A two-sided p value of 0.05 was used to determine statistical significance. All results are presented in units of 1 hour increase in HSD and HDV.

3. Results

3.1. Demographic characteristics of the sample

Demographic information of the study population has been summarized in Table 1. The mean (SD) age of this sample of adolescents was 16.7 (2.3) years. 53% of the subjects were male and 79% were white. 8.7% of the adolescents in our sample use tobacco products. The average HSD was 7.0 (0.8) hours, with an intra-subject variability of 1.2 hours. On average, the participants slept 0.3 hours longer during weekend/vacation days than school/work days. Such a difference in sleep duration between work days and weekends may serve as a major contributor of habitual sleep variability. The mean (SD) of daily caloric intake was 1765 (658) kcals. Among 324 participants, the proportion of normal weight, overweight, and obese were 66% (n=213), 18% (n=59), and 16% (n=52). A significant difference in racial identity was observed across three BMI groups. Specifically, there was a significantly lower percentage of whites in the obese group than in the other two groups. As shown in Table 1, we found a significant dose-response relationship between obesity status and carbohydrate intake. On average, subjects in the obese group consumed over 3 times more carbohydrates compared to those with normal weight. No significant differences were found in the intake of other macro nutrients intake or habitual sleep variables.

3.2. Snack consumption behavior of the sample

The daily snack consumption of the study sample is summarized in Table 2. There were 1/3 of the participants ate snacks before lunch on school/work days, whereas more than 60% of the subjects ate at least one snack before lunch on weekends/vacation days. More importantly, the majority of the adolescents in our study consume snacks after dinner each day. Specifically, 74% and 80% of the participants ate snacks after dinner on school/work days and weekends/vacation days, respectively. Among them, more than 6% consumed 4 or more snacks per night.

3.3. Association between habitual sleep patterns and macro nutrient intake

The associations between habitual sleep patterns and macro nutrients intake were presented in Table 3. The individual effects of HSD and HSV were examined in model 1. As shown in the table, HSV was significantly associated with increased caloric, total fat, and carbohydrates intake. For example, with 1 hour increase in HSV, there was an average increase in caloric intake of 173.49 (65.93) kcal. No association was found between any

sleep variable and protein intake. After we included HSD and HSV in the same model, the pattern of the associations remained unchanged.

3.4. Association between habitual sleep patterns and snack consumption behavior

Finally, the relationship between habitual sleep variables and snack eating behavior is presented in Table 4. As indicated in the table, HSV was significantly associated with snack consumption. For example, 1 hour increase in HSV was related to 65% higher odds of consuming more snacks after dinner, but not snack consumption during daytime, on school/work days. Higher HSV was consistently associated with increased snack consumption during weekends/vacation days, regardless time of the day. Specifically, with a 1-hour increase in HSV, the odds consuming more snacks increased by 57%, 57%, and 94% for morning, afternoon, and night snacks, respectively. On the contrary, HSD was not related to snack eating behavior in this sample of adolescent. These results suggest that high variability in sleep duration, not habitual sleep duration, is associated with more snack consumption, especially after dinner.

4. DISCUSSION

Although it has been documented in previous literatures that self-reported sleep deprivation is related to obesity in both adults and children (4–7, 10, 28, 29), inconsistent evidence was found between objectively-measured sleep duration and obesity (10–15). Two studies found significant associations (14, 15), but majority of the studies reported a lack of association between objectively-measured sleep duration (10–13). Thus, some investigators suspected that the link between short sleep duration and obesity may be overrated (30) and confounded by other factors, such as psychological profiles (9). Motivated by the discrepancy between subjectively and objectively measured sleep duration in association with obesity, we carried out this study to examine the relationship between objectively-measured habitual sleep pattern, including both sleep duration and duration variability, and food intake.

4.1. Sleep duration and energy intake

Previous interventional studies have reported objectively-measured short sleep duration is associated with altered caloric intake (17–19, 31, 32). For example, in a crossover study investigating the relationship between sleep deprivation and energy intake performed in 37 children, participants consumed significantly more calories during one week of restricted sleep (18). Other studies have suggested sleep behavior is also related to specific macronutrient content consumptions. For instance, Weiss et al. (31) reported that actigraphy-measured short sleep duration (<8 hours), was associated with an increased proportion of calories consumed from fat but a decreased proportion from carbohydrates in adolescents. On the contrary, results from another study suggested that PSG-recorded short sleep duration was related to higher carbohydrate intake, accompanied by increased consumption of snacks in healthy adults (17).

However, no significant association between actigraphy-measured sleep duration and food consumption behavior was observed in adolescents in our data. It should be noted that most of the previous interventional studies evaluated the relationship between objective sleep

duration and short-term food intake changes, as measured by 24-hour recall or 3-day dietary diary (18, 31, 32). More importantly, those studies were conducted under a fixed sleep protocol with a significant amount of sleep loss (4–5 hours' sleep/night) (17–19) and provided controlled diet (17, 19). However, our study was performed in a free-living environment, where the average sleep duration of the participants was 7 hours/night with a SD less than 1 hour. Meanwhile, we used the YAQ to capture the long-term food consumption habits by measuring the frequency of intakes on a wide-range of food items during one year prior to the study. Therefore, results from our study indicated that there is lack of association between habitual sleep duration and long-term food intakes. Even if there is an association between short sleep duration and food intakes, it only becomes apparent when sleep duration is extremely short.

4.2. Sleep variability and energy intake

The key finding of the present study, performed by using objectively-measured habitual sleep patterns, suggest HSV, as opposed to HSD, is related to energy intake and nutritional consumption of fat and carbohydrates. Specifically, high variability in habitual sleep duration was associated with increased energy consumption particularly from fat and carbohydrates. As we adjusted for HSD in our models, the observed associations are independent of average sleep duration. Therefore, instead of short sleep duration, it might be the large degree of fluctuations of sleep duration contributes to the energy overconsumption and obesity. To our knowledge, this is the first study to examine the relationship between the variability of habitual sleep duration and energy consumption behavior in a U.S. adolescent population.

4.3. Sleep variability and snack consumption

Another critical observation from the current study is that high HSV, not HSD, was associated with more snack consumption, especially after dinner. This result supported and extended the findings of Kjeldsen and colleagues, who have shown that high variability in objectively-measured sleep duration was related to increased consumption of nutrient-poor but energy-dense food, such as sweetened beverages (23). It indicated that the association between high sleep variability and energy overconsumption could be attributed to the unhealthy snack consumption behavior, especially at night. More importantly, high consumption of energy-dense snacks has been identified as a risk factor for developing metabolic syndrome in adults (33). Therefore, such an unhealthy snack eating behavior in adolescents may result in obesity and consequently contribute to higher metabolic syndrome risk in adulthood. Interestingly, we found a more consistent and stronger relationship between HSV and snack consumption during weekend/vacation days, when the participants sleep longer than weekdays. This result, again, suggested that the proposed popular yet simplistic theory that longer sleep duration related to less food intake and weight loss is debatable.

4.4. Possible mechanisms

To date, the underlying mechanisms, by which high variability in habitual sleep duration related to energy and food consumption, cannot be determined. Although it remains speculative, we cannot rule out the possibility that behavioral changes induced by irregular

sleep pattern may contribute to increased nutrition intake and snack consumption. For example, large night-to-night sleep duration variability, measured by actigraphy, is associated with subjective sleep disturbance, which is highly correlated to daytime fatigue (22). Thus, higher sleep duration variability may lead to daytime fatigue and consequently result in increased time spent in sedentary behavior, such as TV watching accompanied by snack consumption. It can be also speculated that the differences in the behavioral patterns and schedules during weekdays and weekend/vacations days may play a critical role. Specifically, individuals sleep less due to work burden and tight schedule on work days, resulting in a compensating and longer sleep during the weekend. Such an attempt to make up the sleep deficiency during weekend would contribute to the high variability of sleep duration. On the other hand, the relaxing and flexible schedule during weekends may lead to individuals spend more time to prepare and consume more food.

Besides, some investigators have postulated that appetite-regulating hormone imbalance (34–37), impaired glucose metabolism (38, 39), and reduced insulin sensitivity (40, 41) are underlying link between habitual sleep pattern and increased food intake. Therefore, it is plausible that the large fluctuation in sleep duration disrupt the rhythm of the hormone secretions, resulting in increased food intake. However, other investigators failed to replicate these results (17, 42–44). For example, Pejovic et al. (42) and Simpson et al. (44) both found increased leptin concentrations following sleep loss and suggested that previous observed association between decreased leptin level could be due to emotional stress. This hypothesis is supported by findings that sleep deprivation was related to stress, as measured by elevated sympathetic nervous activity (45). And sympathovagal imbalance was associated with increase food intake (46). Moreover, although the association between sleep duration and cortisol level remains inconsistent (47, 48), it has been suggested that chronic stress and glucocorticoids leads to increased consumption of palatable food (“comfort food”) (49, 50). Therefore, stress may serve as an intermediating link between habitual sleep patterns, especially sleep variability, and food consumption.

Lastly, habitual sleep pattern could influence neuronal activity in response to food stimuli. Recently, two studies (51, 52) showed significantly greater responses to food images, measured by functional magnetic resonance imaging, after sleep restrictions. Large variation in sleep duration may pose a similar impact on the neuronal system and stimulate the drive to consume food. However, more studies are needed to examine confirm these hypotheses.

4.5. Strength and Limitation

The leading strength of our study is that we captured habitual sleep pattern by using objectively-measured sleep duration over 7 consecutive nights. Therefore, not only can we investigate the effect of average sleep duration, but also the impact of night-to-night variability in habitual sleep duration. Most previous studies used subjectively-reported sleep duration, which is not capturing actual sleep duration and serving as a surrogate marker of the psychological domain. Among studies using objectively-measured sleep duration, most of them based on average sleep duration over a short time period. Secondly, the use of YAQ enabled us to investigate both overall energy intake over a relatively long period and specific food consumption during different periods of the day. Taking the advantage of these

data, we found HSV related only to nighttime, but not daytime, snack intake on school/work days. Moreover, the participants were practicing their daily routine over the study period. In contrast, most previous studies were conducted in controlled environment, in which the participants were asked to follow specific sleep protocols (17–19). Thus, the findings from those studies may not be reflecting the association between habitual sleep pattern and food intake in free-living environment. To increase the validity of our findings in describing the association with habitual sleep patterns, we purposely excluded the participants with less than 5 nights (70% of 7 nights) of sleep data.

Some limitations of the present study should be noted. Firstly, as a cross-sectional analysis of the data, we were not able to establish a temporal relationship between habitual sleep pattern and nutrition intake. Besides, there was a potential selection bias, given the response rate was 60% for our follow-up examination. But no significant differences were found in the demographic characteristics between respondents and those lost to follow-up. Moreover, recall bias in food intake and the lack of standardized definition of “snack” may lead to misclassification in energy and snack consumption and consequently result in the null findings between sleep duration and dietary behaviors. However, previous studies (25, 26) have concluded that the YAQ is a valid tool in assessing dietary and nutritional information in adolescents. Lastly, it is possible that the observed association was confounded by other unmeasured factors, such as chaotic home environment and neuropsychological conditions. For example, attention deficit hyperactivity disorder (ADHD) has been associated with both instability of sleep pattern (53) and “Western” dietary pattern (54).

5. Conclusions

In summary, we found increased HSV, but not HSD, was significantly associated with increased energy intake, particularly from fat and carbohydrates in this population-based sample of adolescents. Adolescents with high HSV were likely to consume more snacks, especially at nighttime. These relationships indicated that irregular habitual sleep pattern, consisting of nights shorter and longer sleep, is associated with an unhealthy behavior in energy and food intakes, especially after dinner. Such an association may overwhelm the energy equilibrium through excessive energy consumption, and consequently lead to obesity in adolescents. Clearly, further studies are needed to confirm these relationships and further elucidate the underlying mechanism.

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List of Abbreviations

BMI	body mass index
HSD	habitual sleep duration

HSV	habitual sleep variability
OR	odds ratio
POM	proportional odds models
PSCC	Penn State Child Cohort
PSG	Polysomnography
SD	standard deviation
YAQ	Youth/Adolescent Questionnaire

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Highlights

- The association between sleep pattern and energy intake in adolescents is unclear.
- Habitual sleep duration is not associated with caloric intake or food consumption.
- High sleep variability is related to higher energy intake and snack consumption.
- Maintaining a regular sleep pattern may reduce the risk of obesity in adolescents.

Table 1Descriptive characteristics of the study population[†]

	Overall N=324	Normal Weight N=213	Overweight N=59	Obese N=52	P value
Age (years)	16.72 (2.27)	16.69 (2.20)	16.89 (2.62)	16.58 (2.10)	0.76
Male (%)	51.85	52.58	49.15	51.92	0.90
White (%)	79.32	81.69	84.75	63.46	<0.01
Smoking (%)	8.67	7.55	11.86	9.62	0.45
HSD (hour)	7.00 (0.83)	7.04 (0.82)	7.06 (0.75)	6.80 (0.96)	0.17
HSV (hour)	1.18 (0.59)	1.18 (0.57)	1.13 (0.65)	1.30 (0.71)	0.30
Workday sleep duration (hour)	6.91 (0.90)	6.96 (0.88)	6.97 (0.87)	6.63 (1.00)	0.05
Weekend sleep duration (hour)	7.22 (1.37)	7.26 (1.27)	7.10 (1.27)	7.23 (1.81)	0.75
Total caloric intake (kcal)	1765.42 (658.42)	1814.95 (649.04)	1581.34 (654.54)	1841.52 (636.79)	0.61
Total fat intake (g)	63.65 (26.26)	66.12 (26.32)	57.80 (26.83)	63.66 (24.80)	0.25
Protein intake (g)	70.42 (27.72)	71.34 (27.95)	65.36 (26.16)	72.69 (26.30)	0.86
Carbohydrates intake (g)	232.42 (880.80)	183.75 (91.98)	368.75 (135.66)	578.23 (188.21)	<0.01

[†]The results were presented as mean (SD) and percentage for continuous and binary variables, respectively.

Table 2

Summary of snack consumption patterns in the PSCC population

	None	1	2	3	4
School/Work Days					
Before Lunch	67.55%	23.77%	3.40%	2.64%	2.64%
Lunch to Dinner	12.36%	47.94%	23.60%	9.74%	6.37%
After Dinner	15.91%	48.11%	21.21%	7.95%	6.82%
Weekends/Vacation Days					
Before Lunch	38.55%	39.31%	14.50%	1.91%	5.73%
Lunch to Dinner	9.77%	38.73%	32.33%	11.28%	7.89%
After Dinner	9.54%	41.22%	30.92%	10.31%	8.01%

Table 3

Regression coefficients (SE) and P value for associations between habitual sleep patterns and nutrition intakes¹

Nutrition variable	Sleep variable	Model 1 ²	Model 2 ³
Total calorie (kcal)	HSD	92.81 (48.16)	88.77 (47.76)
	HSV	173.49 (65.93) ** ⁴	169.48 (65.71) * ⁵
Total fat (g)	HSD	2.80 (1.86)	2.68 (1.84)
	HSV	4.95 (2.53) *	4.84 (2.53) *
Protein (g)	HSD	3.36 (2.03)	3.27 (2.03)
	HSV	3.87 (2.79)	3.73 (2.79)
Carbohydrates (g)	HSD	12.92 (6.61)	12.58 (6.52)
	HSV	28.76 (9.01) **	28.18 (8.79) **

¹ Results are presented in units of 1-hour increase in HSD and HSV. All models were adjusted for age, race, sex, and BMI percentile.

² Model 1: HSD and HSV were included in the model separately.

³ Model 2: HSD and HSV were included in the same model to control for each other

⁴ **: P<0.01

⁵ *: P<0.05

Table 4Odds ratios (95% CI) and P value for associations between habitual sleep pattern and snack consumption¹

	OR²	(95% CI)	P value
School/work days morning snack			
HSD	1.16	(0.81, 1.65)	0.42
HSV	1.30	(0.85, 2.00)	0.23
School/work days afternoon snack			
HSD	1.01	(0.74, 1.36)	0.99
HSV	1.07	(0.73, 1.58)	0.73
School/work days nighttime snack			
HSD	1.01	(0.74, 1.37)	0.83
HSV	1.65	(1.12, 2.43)	0.01
Weekends/vacation days morning snack			
HSD	0.95	(0.70, 1.29)	0.75
HSV	1.57	(1.06, 2.32)	0.02
Weekends/vacation days afternoon snack			
HSD	1.09	(0.81, 1.47)	0.57
HSV	1.57	(1.07, 2.30)	0.02
Weekends/vacation days nighttime snack			
HSD	1.17	(0.87, 1.59)	0.31
HSV	1.94	(1.32, 2.85)	<0.01

¹ HSD and HSV were included in the same model to control for each other. Results are presented in units of 1-hour increase in HSD and HSV. All models were adjusted for age, race, sex, and BMI percentile.

² The ORs represent the odds of consuming more snacks. e.g. An OR=1.16 indicates that with a 1-hour increase in HSD, there is a 16% increased odds of consuming more snacks.