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Sleep Health. Author manuscript; available in PMC 2017 August 16.

Published in final edited form as:
Sleep Health. 2017 August ; 3(4): 269–275. doi:10.1016/j.sleh.2017.05.005.

Sleep timing is associated with self-reported dietary patterns in 9- to 15-year-olds☆,,☆☆

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Abstract

Objective—To examine sleep timing differences in self-reported dietary patterns of children and adolescents.

Design—Cross-sectional.

Participants—Students aged 9–15 years (n = 119, 11.7 ± 1.3 years, 76% female) attending a summer program for the gifted. The upper and lower quartiles of reported midsleep time (weighted weekday-weekend average) were used to identify early (n= 28) and late (n= 27) sleep timing groups.

Methods—Sleep patterns were assessed via self-report. Participants also rated their likelihood to consume 9 different categories of food and drinks on a 5-point scale ranging from “no likelihood” to “high likelihood.” Foods were grouped as follows: (1) sugary and caffeinated beverages; (2) high-energy-dense, nutrient-poor foods (ie, sugary, salty, fatty foods); and (3) low-energy-dense, nutrient-rich foods (ie, vegetables, proteins, carbohydrates, fruits).

Results—Midsleep time was 02:11 ± 00:25 for the early and 06:14 ± 01:00 for the late sleep timing groups. Participants reporting later sleep timing were more likely to consume sugary/caffeinated beverages and high-energy-dense, nutrient-poor foods throughout the day compared with their early sleep timing peers. The late vs the early sleep timing group also had a higher likelihood of overall consumption of foods and drinks from all categories into the evening and nighttime hours.

Conclusion—Our findings indicate that children and adolescents who exhibit late sleep timing are more likely to make poorer dietary choices, which may have important implications for understanding pathways to adiposity and obesity risk during this sensitive period of development.

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☆☆Conflicts of interest: None.

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Keywords

Sleep timing; Diet; Nutrition; Obesity; Children; Adolescents

Introduction

The transition from late childhood to adolescence is a sensitive period in the development of eating habits.[1] Theoretical frameworks and a growing number of empirical findings suggest that the regulation of eating behavior across development is influenced by individual, cultural, physical, and societal factors.[2–5] At the individual level, sleep is emerging as an increasingly important factor in determining when, what, and how much children and adolescents eat[4–8] and thus may promote or protect the development of unhealthy eating habits and overweight/obesity. Both experimental and epidemiological research of sleep-obesity links have focused primarily on short sleep duration as a mechanism by which changes in feeding-related hormones and obesogenic eating preferences promote weight gain[7–13]; however, less is known about the timing of sleep in association with dietary habits, especially during development.[3,14–17]

One defining characteristic of the transition to adolescence is an increased preference for delayed sleep timing, which is promoted by the interaction between maturing biologically-based circadian and homeostatic sleep processes.[18,19] In the context of extracurricular activities, early school start times, electronic media, work, and family demands, many youth sleep too little during the week and delay bedtimes and wake times on weekends.[18] The emergence of this poor sleep health phenotype is associated with early school start times, age, and pubertal development and is generally more prevalent in fully mature adolescents than prepubertal children.[18–22] Although existing research on late sleep timing in children and adolescents has revealed associations with depression, poor school performance, substance use, and suicidal ideation,[23–25] a relatively large gap exists in understanding the influence of sleep timing on factors underlying overweight/obesity risk.[3]

Current knowledge of links between sleep timing and dietary patterns comes from only a handful of studies. Late bedtimes and/or a delayed sleep phase pattern in childhood and adolescence are associated with adiposity and weight status, even after controlling for sleep duration and a number of demographic and health factors.[15,26–28] Furthermore, youth self-reporting late sleep timing (bedtimes and wake times) are more likely to have higher BMI z scores and to consume more energy-dense, nutrient-poor food, whereas those reporting early sleep timing are more likely to eat more fruits and vegetables.[14] Later bedtimes and wake times in adolescence are also associated with the tendency to consume caffeinated drinks, eat more fast food and fewer dairy products, and show increased food preoccupation.[16,29] Finally, a recent experimental study used midpoint of sleep from multiple days during a baseline actigraphy assessment to categorize adolescents into early vs late sleep phase groups. Results showed that those exhibiting early sleep timing reduced their energy intake when following a strict sleep protocol with earlier bedtimes (10-hour time in bed), whereas the energy intake of late-type adolescents remained unchanged after adhering to a similar sleep schedule.[30] Collectively, these emerging data indicate that late sleep timing may be an

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independent risk factor (eg, over and above sleep duration) for a host of obesity-related behaviors and an important pathway in the emergence of poor dietary choices and obesity in youth.

This cross-sectional study extends current research on associations between sleep and dietary patterns in school-aged children and adolescents. Participants completed a questionnaire about usual weekday and weekend summer sleep patterns, as well as the likelihood of consuming different foods and beverages across a 24-hour day. Based upon average weekday/weekend midsleep time (MST), we discriminated between early and late sleeping participants and then examined group differences in dietary habits. We hypothesized that (1) the early vs the late sleep timing group would report an increased likelihood to eat low-energy-dense, nutrient-rich foods across the day; (2) the late vs the early sleep timing group would report an increased likelihood to eat high-energy-dense, nutrient-poor foods and sweet and caffeinated beverages across the day; and (3) the late vs the early sleep timing group would report an increased likelihood to eat foods and beverages from all groups into nighttime hours.

Methods

Participants

Participants included children and adolescents aged 9–15 years (n = 119; 11.7 ± 1.3 years; 76% female; 59% white, 30% African American, 11% other) attending a 1-week gifted summer program at the University of Southern Mississippi. Admittance to the program required either intelligence quotients ≥121 or achievement test scores ≥91 st percentile (no exclusion criteria). Parents signed an institutional review board–approved informed consent form before the start of the summer session, and students provided written assent. Participation was voluntary and anonymous with no compensation.

Protocol

During a single weekday group session at the beginning of the gifted summer program, a research assistant administered pencil-and-paper surveys, explained directions to all participants, and remained in the room while all surveys were completed. Item completion was checked as participants returned their surveys to reduce missing data and clock time errors.

Survey questions

Participants self-reported at-home eating behaviors by rating their likelihood of consuming 9 different categories of foods and beverages each hour across a 24-hour day on a 5-point scale (none, low, medium, high, or very high). The categories included carbohydrates, proteins, fatty foods, vegetables, fruits, salty foods, sweet foods, sugary beverages, and caffeinated beverages. Examples of foods and drinks were provided to ensure that participants were familiar with the specified categories. Regularity of eating breakfast, lunch, and dinner was assessed on a 5-point scale (never, rarely, sometimes, most of the time, nearly always). Participants also reported their usual at-home summer weekday and weekend bedtimes and wake times, as well as who set their bedtime (parent, self, other).

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Data processing and plan of analyses

Sleep timing was assessed from reported bedtimes and wake times. We computed both weekday and weekend MST; however, because these measures did not significantly differ in the overall sample we used an average (weighted) weekly MST [$MST^{average} = ((MST^{weekday} * 5) + (MST^{weekend} * 2)) / 7$] in this analysis. Lower and upper quartiles of this weekly MST were used to define early (n = 28; 02:11 ± 00:25) and late (n = 27; 06:14 ± 01:00) sleep timing groups (Table 1). Likelihood to consume foods and beverages from the different categories was categorized as “likely” if the response was *high* or *very high likelihood*.

Descriptive analyses compared early and late sleep timing participants on demographic and key study variables. Confirmatory factor analysis for complex data[31] tested whether reported likelihood of consumption could be grouped into the following 3 factors: (1) caffeinated and sweet beverages; (2) fatty, sweet, and salty foods; and (3) vegetables, proteins, carbohydrates, and fruits. Next, multivariate models examined how the probability of consumption in each of the 3 categories changed throughout the day for early- and late-sleeping adolescents. These models omitted data from 1:00 to 4:00, as the probability of food and beverage consumption was virtually zero for both groups during this time interval.

Results

Descriptive statistics

Sleep timing groups did not differ by sex or race; however, participants in the late sleep timing group were 0.66 year (~8 months) older than those in the early sleep timing group (Tables 1 and 2). We also observed group differences in who determined bedtimes (ie, parent vs student) and in the regularity of children and adolescents eating breakfast (Table 1).

Specifically, participants exhibiting early sleep timing were more likely to have a bedtime set by parents (74%), whereas only 22% of late-sleeping youth reported parent-determined bedtimes. The majority of early-sleeping students (96%) reported having breakfast “Most of the time/Always,” as compared with only 30% of those reporting late sleep timing. Very few early sleep timing group participants skipped breakfast (4%), whereas 37% of those who reported late sleep timing exhibited this pattern. We observed no significant group differences in the regularity of eating lunch or dinner.

Sleep variables

As expected, late-sleeping compared with early-sleeping students had delayed bedtimes, wake times, and MSTs on weekdays and weekends; however, the sleep duration of both groups was similar (Table 2). Further analyses investigated a 2-way interaction between weekday/weekend differences in early/late sleep timing for these variables. We found no interactions for bedtime ($F_{1,53} = 0.77$, $P = .38$) and sleep duration ($F_{1,53} = 0.19$, $P = .66$). The interaction term for wake time, however, was significant ($F_{1,53} = 4.37$, $P = .04$): wake times for the early sleep timing group was later on weekends than weekdays, whereas late-sleeping students had similar wake times across the week (Table 2).

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Total hours of food and beverage consumption across the day

We computed an aggregate "eating hours" variable that summed the total number of hours that students reported they were likely to consume the 9 food groups across the 24-hour day. As shown in Figure 1, early compared with late sleep timing group students had a high likelihood of consuming carbohydrate-rich (t[53] = 2.10, $P < .05$), fatty (t[53] = 4.19, $P < .001$), sweet (t[53] = 3.30, $P < .01$), salty (t[53] = 3.02, $P < .01$), and protein-rich foods (t[53] = 2.05, $P < .05$), as well as caffeinated (t[53] = 3.81, $P < .001$) and sweet beverages (t[55] = 3.98, $P < .001$).

Data reduction

Confirmatory factor analysis (CFA) tested whether the 9 food groups loaded onto 3 food factors: (1) caffeinated and sweet beverages; (2), fatty, sweet, and salty foods; and (3) carbohydrates, vegetables, proteins, and fruits. CFA was performed using the complex analysis type command in Mplus that accounts for within-individual item clustering (due to the repeated-measures nature of the data), thus providing accurate estimates of standard errors for clustered data.[31] Furthermore, robust weighted least squares estimator (WLSMV) was used to account for the binary nature of the food and beverage items. This approach grouped the 9 categories into high-energy-dense, nutrient-poor foods (ie, fatty, sweet, salty foods); low-energy-dense, nutrient-rich foods (ie, carbohydrates, vegetables, proteins, fruits); and beverages (ie, caffeinated and sweet beverages).[32,33]

The 3-factormodel had excellent fit to the data: χ^2 (24) = 40.66, $P = .018$; Confirmatory Fit Index (CFI) = 0.996, Root Mean Square Error of Approximation (RMSEA) = 0.016, and the 3-factor model had a significantly better fit than the 1-factor model: $\Delta\chi^2$ (3) = 104.70, $P < .001$. Furthermore, each food group loaded significantly to their appropriate factors. The 3 factors accounted for 76% of variance in carbohydrates, 66% of variance in vegetables, 87% of variance in fatty foods, 70% of variance in sweets, 71% of variance in salty foods, 79% of variance in proteins, 44% of variance in fruits, 75% of variance in caffeinated beverages, and 94% of variance in sweet beverages. Thus, subsequent analyses were performed for the 3 food subfactors.

Likelihood of food and beverage consumption across the day

The next set of analyses examined the effects of sleep timing differences on the likelihood of consumption of the 3 groups while controlling for age and sex. A multilevel model estimated the likelihood of consumption (in 1 of the 3 groups) over time of day and the effect of sleep timing on the likelihood of eating or drinking at each time point. The following set of formulas describes the model tested for sweet and caffeinated beverages for the person j at time i:

$$\mathrm{SweetCaffBev_{ij}}=\pi_{0j}+\pi_{1j}5\ \mathrm{am_j}+\pi_{2j}6\ \mathrm{am_j}+\ldots+\pi_{20j}\mathrm{Midnight_j}+\mathrm{e_j} \quad \text{Level 1}$$

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$$\pi_{0j}=\beta_{00}+\beta_{01}\ \text{Age}+\beta_{02}\ \text{Sex}+\beta_{03}\ \text{Early/Late}+r_0$$
$$\pi_{1j}=\beta_{10}+\beta_{11}\ \text{Early/Late}+r_1$$
$$\cdots\cdots\cdots\cdot$$
$$\pi_{20j}=\beta_{200}+\beta_{201}\ \text{Early/Late}+r_{20} \qquad \text{Level 2}$$

Thus, coefficients β_{10}–β_{20} correspond to differences in reported likelihood of drinking sweet and caffeinated beverages at each of the hours between 5:00 and 24:00, coefficient β_{03} corresponds to group differences in overall level of probability of consumption (ie, effects of eating preference on likelihood of consumption intercept), and coefficients β_{11}–β_{201} correspond to the effect of having a reported early (as opposed to late) sleep timing on hourly changes in probability of consumption. Table 3 presents model estimates for the effects of early (as compared with late) sleep timing on overall (intercept) and hourly reported likelihood to consume each of the 3 groups. Given that the likelihood of eating or drinking at each hour is a combination of its intercept and hourly changes, we present an easily interpreted visual summary of the data in Figure 2.

The pattern of reported likelihood to consume sweet and caffeinated beverages for youth with early vs late sleep timing was similar until 13:00 and then diverged drastically across the afternoon hours (Fig. 2A). For both groups, we observed a spike in reported probability of beverage consumption around mealtimes, but later-sleeping adolescents continued to consume sweet and caffeinated beverages at a relatively high rate between mealtimes and well into the late-night hours. Thus, as evident by separation of 95% confidence intervals, higher likelihood of consumption among late-sleeping than early-sleeping youth emerged after 13:00 and remained significant through midnight.

Reported likelihood of eating fatty, sweet, and salty foods for early and late sleeping adolescents was comparable in early- and late-sleeping students until 9:00 (Fig. 2B). Both groups experienced elevations in reported probability to eat these high-energy-dense, nutrient-poor foods between 9:00 and 13:00; however, this rise was more pronounced for late-sleeping vs early-sleeping youth. Students in the late-sleeping group continued to consume these foods at a higher rate throughout the afternoon and evening and into the late-night hours.

As illustrated in Figure 2C, reported likelihood to eat vegetables, proteins, carbohydrates, and fruits in youth reporting early and late sleep timing followed a similar pattern between 13:00 and 24:00, with peak eating times occurring around lunch and dinner and relatively lower likelihood of eating between mealtimes. Compared with late-sleeping youth, those exhibiting early sleep timing were more likely to consume these high-energy-dense, nutrient-poor foods at breakfast (8:00–9:00), whereas late-sleeping students showed a greater likelihood of consuming these foods after lunch (14:00–17:00) and at night (22:00–24:00).

Follow-up analyses examined whether results observed over time could be explained by group differences in sleep duration and time since awakening; however, controlling for the effects of these 2 variables produced statistically similar results.

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Discussion

The results of this study show that late sleep timing as measured by average weekly MST in children and young adolescents is associated with poorer dietary choices, such that late sleep timing students were more likely to consume high-energy-dense, nutrient-poor foods (ie, fatty, sugary, salty foods) and sweet or caffeinated beverages. We observed sleep timing differences for some but not all low-energy-dense, nutrient-rich food categories (ie, proteins and carbohydrates but not fruits and vegetables). No significant differences were observed in sleep duration between groups, suggesting that sleep timing may be an independent predictor of dietary patterns. Sleep timing group differences in dietary preferences remained after controlling for age and sex. These findings make important contributions to the field by showing sleep timing–dependent daily variations in the likelihood to consume different categories of foods and beverages.

Children and adolescents with late vs early sleep timing reported a greater likelihood of drinking sugary or caffeinated beverages throughout much of the 24-hour day. This result is consistent with and extends data from previous research showing an association between delayed sleep timing and higher consumption of caffeinated and/or sugary drinks.[16,25,29,34] Additionally, our observation of an increased likelihood of drinking caffeinated beverages in the late sleep timing group maps onto the findings of others suggesting that caffeine may be a compensatory mechanism for children and young adolescents to combat daytime sleepiness.[35–37] Interestingly, we observed a high likelihood of consumption of such beverages even at 21:00, 22:00, 23:00, and 24:00, which may further promote late sleeping tendencies in children and adolescents by prolonging sleep onset latency.[37]

In comparison to the early sleep timing group, youth reporting late sleep timing had a higher likelihood of eating food from the combined sugary, salty, and fatty food category, with the most striking differences in the afternoon and evening hours. These data are consistent with those from other studies showing associations between late sleep timing and increased consumption of fast-food[16] or foods high in fat, sugar, and/or salt,[14] as well as correlations between evening chronotype and increased consumption of fat, saturated fat, and sucrose in adults.[23] Furthermore, our findings complement those of Baron and colleagues,[17] who reported an association between energy intake after 20:00 with an increased body mass index in adults. Late childhood and adolescence are periods of increased developmental susceptibility to circadian misalignment,[18,34,38] which has been linked to dysregulation of satiety hormones such as leptin and ghrelin[39,40] and has implications for changes in energy balance and risk for adiposity and overweight status.

Both the early and late sleep timing groups showed peaks for the combined category of vegetables, fruits, proteins, and carbohydrates at 13:00, a typical lunchtime, and at 18:00, a typical dinnertime. The late sleep timing group reported higher likelihood of eating these foods than the early sleep timing group, notably in the afternoon and between 22:00 and midnight. In contrast, early sleep timing students reported a higher likelihood of eating food in this low-energy-dense, nutrient-rich group between 8:00 and 9:00, suggesting a healthier dietary profile.[41–43] Also, group differences in 24-hour eating patterns were only observed for carbohydrates and proteins and not for fruits and vegetables. These results are similar to

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those of Fleig and Randler,[16] who did not show sleep timing group differences in vegetable and fruit consumption; however, data from another study suggest the contrary, as youth with later sleep timing showed decreased consumption of fruits and vegetables.[44]

We also examined parental involvement in sleep schedules. About 75% of students in the early sleep timing group reported that their parents set their bedtimes, which was in striking contrast to the 22% of those in the late sleep timing group who had parent-determined bedtimes. This finding has important implications for sleep and overall health, as parental intervention may extend beyond establishing and enforcing sleep schedules. That is, children and adolescents who are going to bed earlier and waking up earlier may follow a stricter parent-set schedule, including a more rigid timing of meals and snacks. Children and adolescents who stay up and sleep in later may also have less overall parental regulation (ie, more freedom in choosing when and what foods and beverages they consume). Parental control of sleep timing may be an important consideration for pediatric health care professionals. Work done by Short et al[45] showed that children went to bed earlier and reported better daytime functioning when parents controlled bedtime. Furthermore, earlier bedtimes can help attenuate circadian misalignment (ie, phase delay, social jetlag) by gating light exposure at night[18] and thus promote healthier dietary patterns.

Although our results contribute to understanding associations between sleep timing and dietary patterns, a number of limitations should be noted. First, the generalizability of our study results is weak because of the use of a convenience sample from a gifted student summer program. Students were asked about their usual at-home sleep and dietary patterns during the summer, which may differ from the school year when they have less control over food choices and patterns. Thus, although these data may approximate “free” days as described by Roenneberg et al,[20] they may not be relevant for children and adolescents during the school year, when weekday eating patterns and especially wake times may be less variable. An interesting future line of investigation would assess the relationship between sleep timing and dietary patterns on both school and weekend days, as well as on “free” days. Second, our cross-sectional design limits the ability to understand developmental changes in sleep-dietary links. Third, although our food categories were based on current CDC guidelines[32] and supported by CFA, we did not distinguish between different types of carbohydrates. This limitation is important to note because carbohydrates can include a wide range of foods that vary in their energy density and nutrient profile. Finally, as we used only self-reports, our findings have limited utility for understanding pathways by which sleep timing may increase overweight/obesity. Self-report data on diet and sleep patterns are subject to recall and social desirability bias, especially in this age group.[46] Future well-controlled studies including biomarkers (eg, cortisol, melatonin, feeding-related hormones leptin and ghrelin) in a laboratory setting are needed to address this limitation and to control for differences in food availability, social factors, and physical activity.[47] Additional field-based work would also benefit from standardized measurement of sleep, dietary intake, electronic media use, and weight status.

In summary, we observed striking group differences in the likelihood of consuming different foods and beverages in children and adolescents who reported early vs late sleep timing under a relatively unrestricted summer interval. These differences remained even after

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controlling for age, sex, sleep duration, and time since awakening, which have implications for the development of individual- and school-based prevention and intervention programs targeting sleep and nutritional health. Late-sleeping children and adolescents reported a higher likelihood of consuming foods and caffeinated and sugary beverages across the day and into the night compared with those exhibiting early sleep timing. A higher likelihood of eating at night may promote weight gain in children and adolescents who regularly engage in late sleep timing, and thus increase their risk for chronic illnesses such as obesity and diabetes. Future studies are needed to accurately and reliably measure circadian biomarkers, food and beverage consumption, and weight status to determine mechanisms underlying associations between sleep timing, dietary patterns, and overweight/obesity risk across development.

Acknowledgments

We are most thankful to the students and their parents for their participation in this study. We also appreciate the support of Dr Frances Karnes, Director of the Center for Gifted Studies, and her associates at the University of Southern Mississippi.

References

1. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. Pediatrics. 1998; 101(3):539–549. [PubMed: 12224660]
2. Story M, Neumark-Sztainer D, French S. Individual and environmental influences on adolescent eating behaviors. J Am Diet Assoc. 2002; 102(3, Suppl):S40–S51. [PubMed: 11902388]
3. Miller AL, Lumeng JC, LeBourgeois MK. Sleep patterns and obesity in childhood. Curr Opin Endocrinol. 2015; 22(1):41–47.
4. Neumark-Sztainer D, Story M, Perry C, Casey MA. Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. J Am Diet Assoc. 1999; 99(8):929–937. [PubMed: 10450307]
5. Simon SL, Field J, Miller LE, DiFrancesco M, Beebe DW. Sweet/dessert foods are more appealing to adolescents after sleep restriction. PLoS One. 2015; 10(2):e0115434. [PubMed: 25706861]
6. Owens JA, Dearth-Wesley T, Lewin D, Gioia G, Whitaker RC. Self-regulation and sleep duration, sleepiness, and chronotype in adolescents. Pediatrics. 2016; 138(6):e20161406. pii. [PubMed: 27940688]
7. Beebe DW, Simon S, Summer S, Hemmer S, Strotman D, Dolan LM. Dietary intake following experimentally restricted sleep in adolescents. Sleep. 2013; 36(6):827–834. [PubMed: 23729925]
8. Chaput JP, Dutil C. Lack of sleep as a contributor to obesity in adolescents: impacts on eating and activity behaviors. Int J Behav Nutr Phys Act. 2016; 13(1):103. [PubMed: 27669980]
9. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. Sleep. 2010; 33(9):1201–1209. [PubMed: 20857867]
10. Nedeltcheva AV, Kilkus JM, Imperial J, Kasza K, Schoeller DA, Penev PD. Sleep curtailment is accompanied by increased intake of calories from snacks. Am J Clin Nutr. 2009; 89(1):126–133. [PubMed: 19056602]
11. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med. 2004; 1(3):e62. [PubMed: 15602591]
12. Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, et al. Meta-analysis of short sleep duration and obesity in children and adults. Sleep. 2008; 31(5):619–626. [PubMed: 18517032]

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13. Broussard JL, Kilkus JM, Delebecque F, Abraham V, Day A, Whitmore HR, et al. Elevated ghrelin predicts food intake during experimental sleep restriction. Obesity (Silver Spring). 2016; 24(1): 132–138. [PubMed: 26467988]
14. Golley RK, Maher CA, Matricciani L, Olds TS. Sleep duration or bedtime? Exploring the association between sleep timing behaviour, diet and BMI in children and adolescents. Int J Obes. 2013; 37(4):546–551.
15. Olds TS, Maher CA, Matricciani L. Sleep duration or bedtime? Exploring the relationship between sleep habits and weight status and activity patterns. Sleep. 2011
16. Fleig D, Randler C. Association between chronotype and diet in adolescents based on food logs. Eat Behav. 2009; 10(2):115–118. [PubMed: 19447353]
17. Baron KG, Reid KJ, Kern AS, Zee PC. Role of sleep timing in caloric intake and BMI. Obesity. 2011; 19(7):1374–1381. [PubMed: 21527892]
18. Carskadon MA. Sleep in adolescents: the perfect storm. Pediatr Clin N Am. 2011; 58(3):637–647.
19. Hagenauer MH, Perryman JI, Lee TM, Carskadon MA. Adolescent changes in the homeostatic and circadian regulation of sleep. Dev Neurosci. 2009; 31(4):276–284. [PubMed: 19546564]
20. Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, et al. Amarker for the end of adolescence. Curr Biol. 2004; 14(24):R1038–R1039. [PubMed: 15620633]
21. Laberge L, Petit D, Simard C, Vitaro F, Tremblay RE, Montplaisir J. Development of sleep patterns in early adolescence. J Sleep Res. 2001; 10(1):59–67. [PubMed: 11285056]
22. Crowley SJ, Van Reen E, LeBourgeois MK, Acebo C, Tarokh L, Seifer R, et al. A longitudinal assessment of sleep timing, circadian phase, and phase angle of entrainment across human adolescence. PLoS One. 2014; 9(11):e112199. [PubMed: 25380248]
23. Kanerva N, Kronholm E, Partonen T, Ovaskainen ML, Kaartinen NE, Konttinen H, et al. Tendency toward eveningness is associated with unhealthy dietary habits. Chronobiol Int. 2012; 29(7):920–927. [PubMed: 22823875]
24. Adan A. Chronotype and personality factors in the daily consumption of alcohol and psychostimulants. Addiction. 1994; 89(4):455–462. [PubMed: 8025504]
25. Giannotti F, Cortesi F, Sebastiani T, Ottaviano S. Circadian preference, sleep and daytime behaviour in adolescence. J Sleep Res. 2002; 11(3):191–199. [PubMed: 12220314]
26. Jarrin DC, McGrath JJ, Drake CL. Beyond sleep duration: distinct sleep dimensions are associated with obesity in children and adolescents. Int J Obes. 2013; 37(4):552–558.
27. Thivel D, Isacco L, Aucouturier J, Pereira B, Lazaar N, Ratel S, et al. Bedtime and sleep timing but not sleep duration are associated with eating habits in primary school children. J Dev Behav Pediatr. 2015; 36(3):158–165. [PubMed: 25607639]
28. Malone SK, Zemel B, Compher C, Souders M, Chittams J, Thompson AL, et al. Social jet lag, chronotype and body mass index in 14-17-year-old adolescents. Chronobiol Int. 2016; 33(9):1255–1266.
29. Ievers-Landis CE, Kneifel A, Giesel J, Rahman F, Narasimhan S, Uli N, et al. Dietary intake and eating-related cognitions related to sleep among adolescents who are overweight or obese. J Pediatr Psychol. 2016; 41(6):670–679. [PubMed: 26994854]
30. Beebe DW, Zhou A, Rausch J, et al. The impact of early bedtimes on adolescent caloric intake varies by chronotype. J Adolesc Health. 2015; 57(1):120–122. [PubMed: 25911162]
31. Asparouhov T. Sampling weights in latent variable modeling. Struct Equ Model. 2005; 12(3):411–434.
32. Centers for Disease Control (CDC). National Center for Chronic Disease Prevention and Health Promotion Division of Nutrition, Physical Activity, and Obesity; Low-energy-dense foods and weight management: cutting calories while controlling hunger. https://www.cdc.gov/nccdphp/dnpa/nutrition/pdf/r2p_energy_density.pdf
33. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, et al. Update of the healthy eating index: HEI-2010. J Acad Nutr Diet. 2013; 113(4):569–580. [PubMed: 23415502]
34. Wittmann M, Dinich J, Merrow M, Roenneberg T. Social jetlag: misalignment of biological and social time. Chronobiol Int. 2006; 23(1–2):497–509. [PubMed: 16687322]

Author Manuscript

35. Roehrs T, Roth T. Caffeine: sleep and daytime sleepiness. Sleep Med Rev. 2008; 12(2):153–162. [PubMed: 17950009]
36. Owens J, Group ASW. Committee on Adolescence. Insufficient sleep in adolescents and young adults: an update on causes and consequences. Pediatrics. 2014; 134(3):e921–e932. [PubMed: 25157012]
37. Bryant Ludden A, Wolfson AR. Understanding adolescent caffeine use: connecting use patterns with expectancies, reasons, and sleep. Health Educ Behav. 2010; 37(3):330–342. [PubMed: 19858312]
38. Roenneberg T, Allebrandt Karla V, Merrow M, Vetter C. Social jetlag and obesity. Curr Biol. 2012; 22(10):939–943. [PubMed: 22578422]
39. Nguyen J, Wright KP Jr. Influence of weeks of circadian misalignment on leptin levels. Nat Sci Sleep. 2010; 2:9–18. [PubMed: 23616693]
40. Scheer FAJL, Hilton MF, Mantzoros CS, Shea SA. Adverse metabolic and cardiovascular consequences of circadian misalignment. Proc Natl Acad Sci U S A. 2009; 106(11):4453–4458. [PubMed: 19255424]
41. St-Onge MP, Ard J, Baskin ML, Chiuve SE, Johnson HM, Kris-Etherton P, et al. Meal timing and frequency: implications for cardiovascular disease prevention: a scientific statement from the American Heart Association. Circulation. 2017; 135(9):e96–121. [PubMed: 28137935]
42. Ledikwe JH, Blanck HM, Khan LK, Serdula MK, Seymour JD, Tohill BC, et al. Low-energy-density diets are associated with high diet quality in adults in the United States. J Am Diet Assoc. 2006; 106(8):1172–1180. [PubMed: 16863711]
43. Rolls BJ, Bell EA. Intake of fat and carbohydrate: role of energy density. Eur J Clin Nutr. 1999; 53(suppl. 1):S166–S173. [PubMed: 10365994]
44. Rutters F, Lemmens SG, Adam TC, Bremmer MA, Elders PJ, Nijpels G, et al. Is social jetlag associated with an adverse endocrine, behavioral, and cardiovascular risk profile? J Biol Rhythm. 2014; 29(5):377–383.
45. Short MA, Gradisar M, Wright H, Lack LC, Dohnt H, Carskadon MA. Time for bed: parent-set bedtimes associated with improved sleep and daytime functioning in adolescents. Sleep. 2011; 34(6):797–800. [PubMed: 21629368]
46. Magarey A, Watson J, Golley RK, Burrows T, Sutherland R, McNaughton SA, et al. Assessing dietary intake in children and adolescents: considerations and recommendations for obesity research. Int J Pediatr Obes. 2011; 6(1):2–11.
47. Hearn MD, Baranowski T, Baranowski J, Doyle C, Smith M, Lin LS, et al. Environmental influences on dietary behavior among children: availability and accessibility of fruits and vegetables enable consumption. J Health Educ. 1998; 29(1):26–32.

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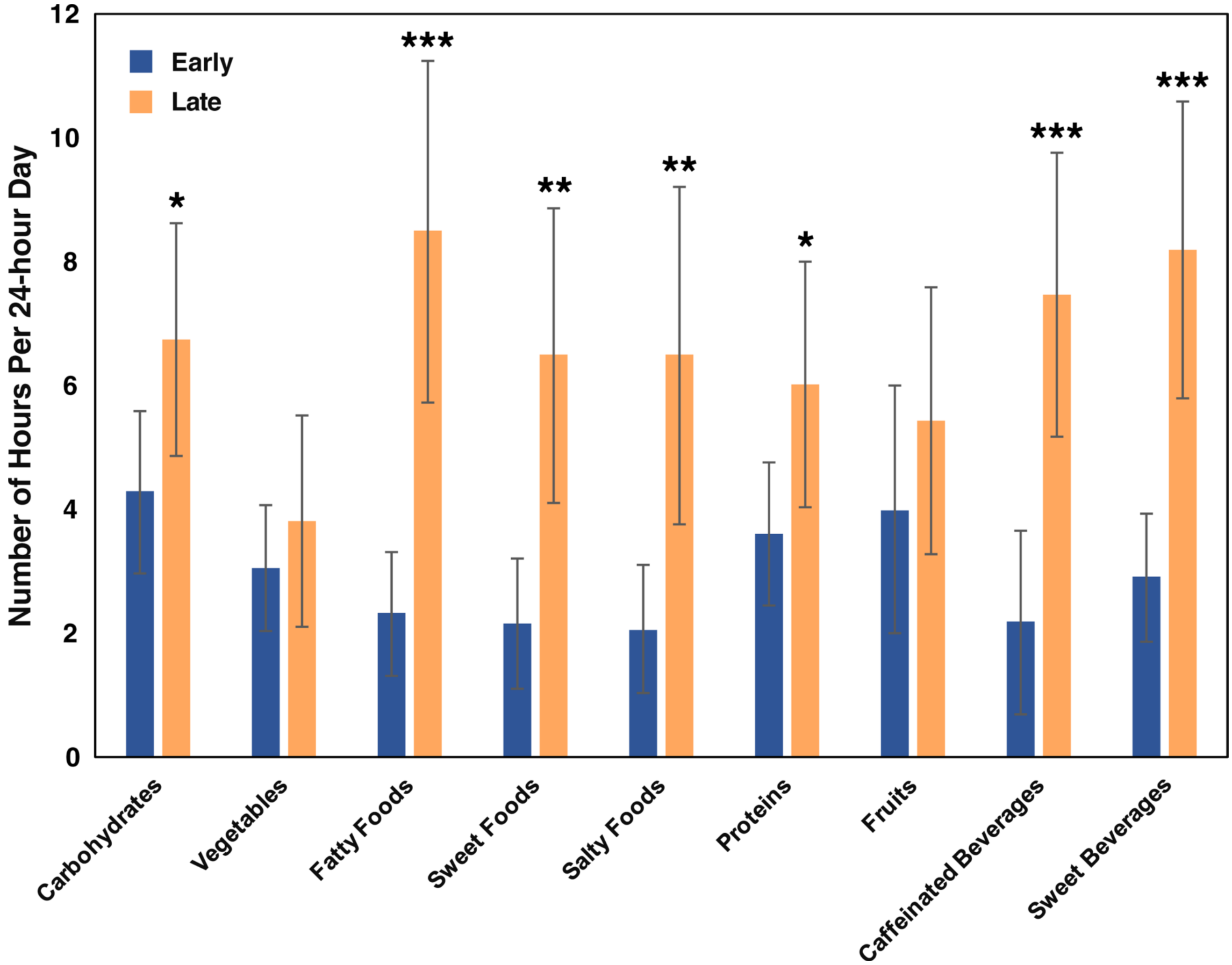

Fig. 1.

Average number of hours per 24-hour day that participants reported to be likely to consume food from the 9 food groups by early/late sleep timing groups. Data represent means and 95% confidence intervals of the mean. *$P < .05$, **$P < .01$, ***$P < .001$.

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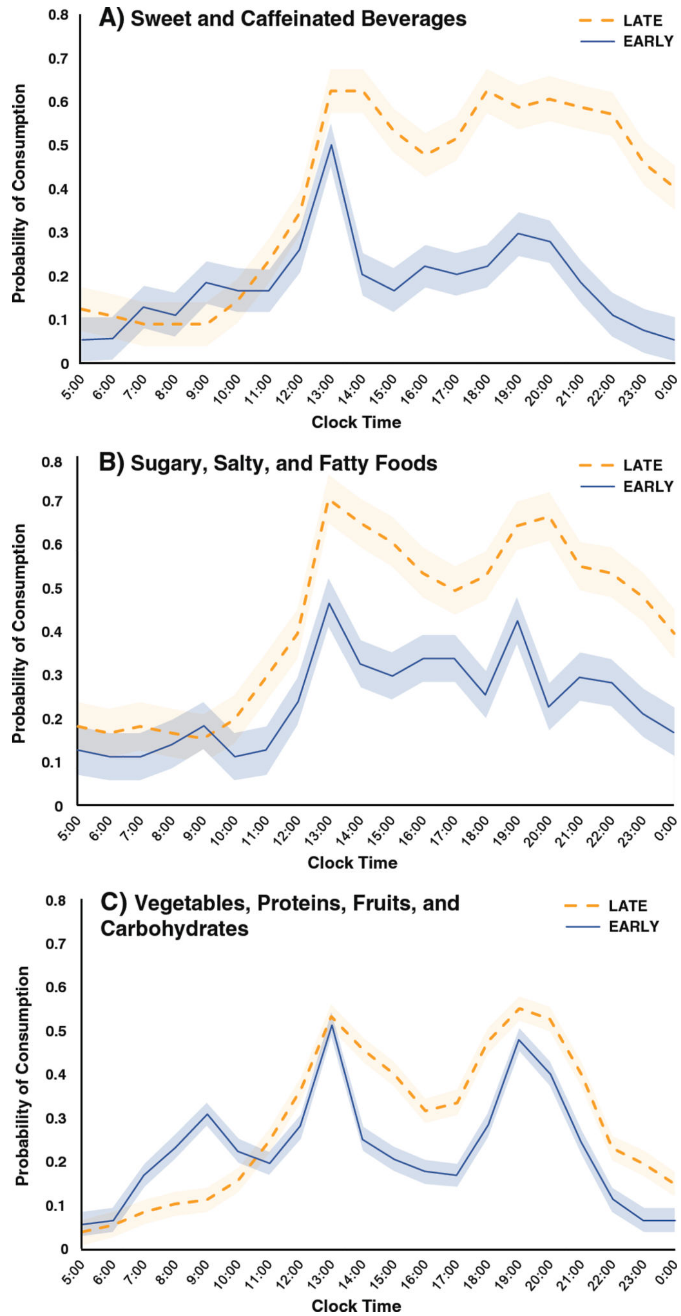

Fig. 2.

Probability of consumption of (A) sweet and caffeinated beverages; (B) high-energy-dense, nutrient-poor foods (ie, sugary, salty, fatty foods); and (C) low-energy-dense, nutrient-rich foods (ie, carbohydrates, vegetables, proteins, and fruits) throughout the day by early/late sleep timing groups. Average probabilities and their 95% confidence intervals (shaded).

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Table 1

Demographic variables for early and late sleep timing groups.

	Early (n = 27[a])		Late (n = 28[a])		Statistics
	n	**%**	**n**	**%**	χ^2 (*df*)
Sex					0.04 (1)
Female	19	68	19	70	
Male	9	32	8	30	
Race					3.64 (4)
White	20	71	14	52	
African American	6	21	9	33	
Asian American	1	4	1	4	
Native American	0	0	2	7	
Mixed/Other	1	4	1	4	
Who sets bedtime?					14.03 (2)**
My parents	20	74	5	22	
Myself	6	22	17	74	
Other	1	4	1	4	
Regularity of consuming breakfast					26.67 (2)**
Never/Rarely	1	4	10	37	
Sometimes	0	0	9	33	
Most of the time/Always	27	96	8	30	
Regularity of consuming lunch					4.53 (2)
Never/Rarely	0	0	4	15	
Sometimes	3	11	2	7	
Most of the time/Always	25	89	21	78	
Regularity of consuming dinner					0.39 (2)
Never/Rarely	0	0	0	0	
Sometimes	1	4	2	7	
Most of the time/Always	27	96	25	93	

* $P < .05$,

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** $P < .01$,

*** $P < .001$.

[a] Data from the “Who sets bedtime?” question were missing for 4 participants in the early sleep timing group and 1 participant in the late sleep timing group (n = 23 and n = 27; early and late groups, respectively).

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Table 2

Descriptive statistics for continuous variables (age, sleep) for early and late sleep timing groups (independent samples *t* tests [2-tailed])

	Early (n = 28[a])		Late (n = 27)		Statistics[b]		
	M	**SD**	***M***	**SD**	***t***	***d***	***P***
Age	11.19	1.04	11.85	1.29	−2.09	0.56	.042
Weekday							
Bedtime	21:24	0:48	1:24	1:59	−9.68	2.63	<.001
Wake time	6:36	1:03	11:03	1:02	−15.74	4.25	<.001
Sleep duration (h)	9.18	1.49	9.65	2.00	−0.98	0.26	.334
MST	2:00	0:34	6:14	1:13	−16.23	4.40	<.001
Weekend							
Bedtime	21:54	1:01	1:23	1:49	−8.69	2.35	<.001
Wake time	7:26	1:06	11:07	1:43	−9.47	2.54	<.001
Sleep duration (h)	9.51	1.30	9.72	2.08	−0.44	0.12	.666
MST	2:40	0:50	6:15	1:25	−11.25	3.05	<.001
Weekly average MST	2:11	0:25	6:14	1:00	−19.21	5.21	<.001

[a] Age data missing for 1 participant in the early sleep timing group (n = 27).

[b] *t* values adjusted for unequal variances based on the Levene test for inequality of variances.

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Table 3

Effects of early vs late sleep timing on food consumption throughout the day (time in left column) controlling for age and sex

	Sweet and caffeinated beverages			Sweet, fatty, and salty foods			Vegetables, fruits, proteins, and carbohydrates		
	B	SE	*B*/SE	B	SE	*B*/SE	B	SE	*B*/SE
Effect of early (1) vs late (0) type on eating intercept and eating at the following times:									
Intercept	−0.13	0.06	−2.08 *	−0.12	0.05	−2.51 *	−0.002	0.02	−0.08
5:00	0.06	0.03	2.18 *	0.07	0.04	1.87	0.02	0.02	1.27
6:00	0.08	0.03	2.48 *	0.07	0.03	2.21 *	0.01	0.04	0.31
7:00	0.17	0.06	3.08 **	0.06	0.03	2.11 *	0.09	0.05	1.61
8:00	0.15	0.06	2.57 *	0.09	0.04	2.55 *	0.13	0.06	2.12 *
9:00	0.23	0.07	3.18 **	0.14	0.05	2.83 **	0.20	0.06	3.14 **
10:00	0.15	0.08	2.05 *	0.04	0.04	1.11	0.07	0.06	1.17
11:00	0.06	0.08	0.75	−0.03	0.05	−0.63	−0.05	0.06	−0.79
12:00	0.04	0.10	0.41	−0.02	0.07	−0.27	−0.08	0.09	−0.95
13:00	0.01	0.13	0.04	−0.09	0.11	−0.89	−0.02	0.10	−0.16
14:00	−0.29	0.11	−2.72 **	−0.17	0.10	−1.70	−0.20	0.09	−2.34 *
15:00	−0.24	0.10	−2.28 *	−0.15	0.09	−1.72	−0.19	0.07	−2.68 **
16:00	−0.13	0.11	−1.17	−0.06	0.09	−0.59	−0.14	0.07	−1.99 *
17:00	−0.18	0.10	−1.78	−0.02	0.09	−0.21	−0.16	0.06	−2.57 *
18:00	−0.27	0.11	−2.61 **	−0.12	0.08	−1.54	−0.19	0.10	−1.85
19:00	−0.16	0.11	−1.46	−0.07	0.10	−0.78	−0.07	0.10	−0.67
20:00	−0.20	0.11	−1.85	−0.27	0.08	−3.33 **	−0.12	0.09	−1.41
21:00	−0.27	0.10	−2.85 **	−0.11	0.08	−1.32	−0.15	0.09	−1.71
22:00	−0.33	0.09	−3.76 ***	−0.11	0.08	−1.26	−0.12	0.06	−1.98 *
23:00	−0.26	0.07	−3.57 ***	−0.12	0.07	−1.60	−0.13	0.04	−3.01 **
24:00	−0.22	0.06	−3.50 ***	−0.08	0.05	−1.59	−0.08	0.04	−2.32 *

* $P < .05$,

** $P < .01$,

*** $P < .001$.

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