Short Communication

Is late bedtime an overlooked sleep behaviour? Investigating associations between sleep timing, sleep duration and eating behaviours in adolescence and adulthood

Anna H Grummon[1,2,]* [iD], Rebeccah L Sokol[3] and Leslie A Lytle[4,5]

[1]Center for Population and Development Studies, Harvard TH Chan School of Public Health, Cambridge, MA 02138, USA: [2]Carolina Population Center, University of North Carolina Chapel Hill, Chapel Hill, NC 27514, USA: [3]Department of Health Behavior & Health Education, University of Michigan School of Public Health, Ann Arbor, MI 48109, USA: [4]Department of Health Behavior, Gillings School of Global Public Health, University of North Carolina Chapel Hill, Chapel Hill, NC 27599, USA: [5]Department of Nutrition, Gillings School of Global Public Health, University of North Carolina Chapel Hill, Chapel Hill, NC 27599, USA

Abstract

Objective: To examine whether bedtime is associated with usual sleep duration and eating behaviour among adolescents, emerging adults and young adults.
Design: Cross-sectional multivariable regression models, stratified by developmental stage, to examine: (1) association between bedtime and sleep duration and (2) associations between bedtime and specific eating behaviours at each developmental period, controlling for sleep duration. All models adjusted for socio-demographic characteristics, depressive symptoms and screen time behaviours.
Setting: National Longitudinal Study of Adolescent to Adult Health, waves I–IV, USA.
Participants: A national probability sample surveyed in adolescence (aged 12–18 years, wave I: 1994–1995, *n* 13 048 and wave II: 1996, *n* 9438), emerging adulthood (aged 18–24 years, wave III: 2001–2002, *n* 9424) and young adulthood (aged 24–34 years, wave IV: 2008, *n* 10 410).
Results: Later bedtime was associated with shorter sleep duration in all developmental stages, such that a 1-h delay in bedtime was associated with 14–33 fewer minutes of sleep per night (*P*s < 0·001). Later bedtime was also associated with lower odds of consuming healthier foods (i.e. fruits, vegetables; range of adjusted OR (AOR), 0·82–0·93, *P*s < 0·05) and higher odds of consuming less healthy foods and beverages (i.e. soda, pizza, desserts and sweets; range of AOR, 1·07–1·09, *P*s < 0·05). Later bedtime was also associated with more frequent fast-food consumption and higher sugar-sweetened beverage consumption (*P*s < 0·05).
Conclusions: Later bedtime was associated with shorter sleep duration and less healthy eating behaviours. Bedtime may be a novel behaviour to address in interventions aiming to improve sleep duration and dietary intake.

More than two-thirds of adolescents[1,2] and one-third of adults[3] do not get the recommended amount of sleep. Poor sleep behaviours increase the risk for a variety of negative outcomes, including poor dietary quality[4–16] and obesity[17–20]. Although research has traditionally focused on *sleep duration* as a key contributor to poor diet and diet-related chronic diseases, there is growing interest in understanding the role of *sleep timing*, in particular late

bedtime[16,21–24]. Later bedtime could affect dietary behaviours and diet-related health outcomes through several pathways. For example, later bedtimes may be a driver of shorter sleep duration: individuals who go to bed later may not be able to compensate by sleeping later the next morning due to work, school and social schedules[25,26]. In turn, shorter sleep duration has been associated with worse dietary quality[4–16]. Later bedtime may also worsen

Corresponding author: Email agrummon@hsph.harvard.edu

dietary quality independently of its effects on sleep duration[23], as eating late at night is associated with higher energetic intake and lower dietary quality compared with eating at other times of day[16,27,28].

While evidence suggests that later bedtime could contribute to both shorter sleep duration and less-healthy dietary choices, these questions remain understudied. Research has not investigated whether later bedtime is associated with shorter sleep duration. Likewise, only a handful of studies have examined the relationship between bedtime and dietary behaviours in adolescents[23,29–31] or adults[28,32,33], and none has been conducted in probability samples of the US population. These relationships are particularly important to assess in adolescence, emerging adulthood and young adulthood, as these are three key developmental stages for changing sleep patterns[34] and for the development of dietary behaviours and obesity[35–38]. Understanding these associations will shed light on whether sleep timing is a potentially promising target for interventions aiming to improve sleep duration, dietary quality and weight.

To address these gaps, we examined cross-sectional associations between bedtime, sleep duration and eating behaviours using a large national probability sample followed in adolescence, emerging adulthood and young adulthood. Our objectives were to: (1) investigate the association between usual bedtime and sleep duration and (2) examine the association between usual bedtime and eating behaviours, independent of sleep duration. We examined cross-sectional associations within developmental stages, rather than longitudinal associations across these stages, because sleep behaviours are expected to exert relatively immediate impacts on eating behaviours. We hypothesised that: (1) later bedtimes would be associated with shorter sleep duration, and (2) later bedtimes would independently be associated with less healthy eating behaviours.

Methods

Study sample

We used data from the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative sample of approximately 20 000 individuals recruited from middle and high schools in 1994–1995 and followed into adulthood[39]. We used data from wave I (collected in 1994–1995), wave II (1996), wave III (2001–2002) and wave IV (2008). Wave V did not assess sleep timing.

We examined participants in three developmental stages: adolescence (waves I and II, including participants age ≥12 and ≤18 years), emerging adulthood (wave III, age >18 and ≤24 years) and young adulthood (wave IV, age >24 and ≤34 years) (see online supplementary material, Supplemental Figs. 1–4), following previous studies[40].

Measures

Usual bedtime

The main exposure variable was participants' self-reported usual bedtime. In waves I and II, participants reported their usual bedtime on 'weeknights' during the school year (see online supplementary material, Supplemental Table 1 provides details on key study variables). In waves III and IV, participants reported their usual bedtimes for days when they go to work, school or similar activities ('weekdays') and for days when they do not have to wake up at a certain time ('weekends'). We calculated a weighted average of these variables, following previous studies[41,42]. In all waves, we converted bedtimes to decimal hours after 12.00 hours (e.g. we coded a bedtime of 21.30 hours as 9·5), such that larger values indicated later bedtime.

Usual sleep duration

In waves I and II, participants self-reported usual sleep duration in hours/night. In waves III and IV, participants reported their usual bedtime and wake time for weekdays and weekends, as described above. We used responses to those items to calculate usual sleep duration in decimal hours (e.g. 30 min equals 0·5 decimal hours), again calculating a weighted average of sleep duration on weekdays and weekends.

Eating behaviours

We examined participants' self-reported eating behaviours (online supplementary material, Supplemental Table 1). Different behaviours were assessed in each wave; for each wave, we identified eating behaviours that could be easily defined as 'healthier' or 'less healthy.' In wave I, data were available on whether the participant had consumed fruits, vegetables and sweets in the past day (coded as yes/no). In wave II, we examined consumption of fruits, vegetables, soda, pizza, desserts and sweets, and French fries in the past day (coded as yes/no), as well as on the frequency of fast-food consumption (days in past week ate fast food). In wave III, we examined frequency of fast-food consumption (days in past week ate fast food). Finally, in wave IV, we examined frequency of fast-food consumption (times in past week ate fast food) and amount of sugar-sweetened beverage consumption (number of sugar-sweetened beverages consumed in the past week).

Covariates

Covariates included potential confounders of the relationship between bedtime, sleep duration and eating behaviours, including sociodemographic characteristics (e.g. age, parental education and income to reflect socio-economic status, nativity), screen time behaviours and depressive symptoms[12,18,23,29–32] (online supplementary material, Supplemental Table 1).

Table 1 Sample characteristics by developmental stage, National Longitudinal Study of Adolescent to Adult Health*

| | Adolescents ≥12 and ≤18 years | | | | Emerging adults >18 and ≤24 years | | Young adults >24 and ≤34 years | |
| | Wave I (n 13 048) | | Wave II (n 9438) | | Wave III (n 9427) | | Wave IV (n 10 410) | |
Characteristics	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Sleep duration (h)	7·8	1·2	7·7	1·2	8·1	1·5	8·9	2·0
Bedtime, decimal hours after noon	10·7	1·2	10·5	1·0	12·1	1·8	10·5	2·5
Eating behaviours (%)†								
Ate fruit yesterday	79		66		–		–	
Ate vegetables yesterday	69		80		–		–	
Ate sweets/desserts yesterday	55		65		–		–	
Drank soda yesterday	–		71		–		–	
Ate pizza yesterday	–		26		–		–	
Ate French fries yesterday	–		33		–		–	
Fast food, number of days in last week	–		2·1	1·7	2·4	2·0	–	
Fast food, number of times in last week	–		–		–		2·4	3·2
SSB, number of drinks in last week	–		–		–		12·3	13·9
Age (years)	15·3	1·7	15·7	1·4	21·5	1·6	28·2	1·8
Female (%)	49		50		49		49	
Race/ethnicity (%)								
White	69		69		69		69	
Hispanic	11		11		11		11	
Black	14		14		14		14	
Other	6		6		6		6	
Born in the USA (%)	95		95		95		97	
Parental education (%)								
Less than a high school diploma	10		10		10		10	
High school diploma or GED	26		26		25		27	
Some college	32		32		31		32	
College or more	31		32		33		32	
Parental income, logged	3·49	0·96	3·48	1·0	3·50	0·97	3·49	0·97
Usual television viewing (%)‡§								
Low (0–14 h/week)	50		54		54		68	
Medium (15–28 h/week)	28		27		28		22	
High (≥29 h/week)	22		19		17		9	
Usual video/computer games (%)§‖								
Low (0–14 h/week)	96		96		91		94	
Medium (15–28 h/week)	3		3		6		4	
High (≥29 h/week)	1		1		3		2	
Depressive symptoms¶	7·0	3·8	7·0	3·8	6·2	3·8	7·0	3·8

*Means, SD and % adjusted for complex survey features of Add Health. Eating behaviours listed as '–' were not assessed in this survey wave.
†See online Supplementary material, Supplemental Table 1 for information on measurement of eating behaviours in each wave.
‡Participants reported on the usual number of hours per week they spent watching television during the past 30 d.
§We trichotomised screen time variables using the categories reported in Kruger et al.[12].
‖Participants reported on the usual number of hours per week they spent playing video or computer games during the past 30 d.
¶Sum score on the nine items from Center for Epidemiological Studies Depression Scale[55] that were assessed in all four waves. Score on each item ranged from 0 to 3 yielding a possible sum scores of 0–27, where higher scores indicate more depressive symptoms.

Statistical analysis

Analytic samples included participants with complete information on key variables and valid sampling weights. To reduce the influence of outliers, we decided *a priori* to remove outlying observations with implausible values on sleep duration and bedtime, excluding from analyses respondents further than 2·576 SD from sample means on these variables (online supplementary material, Supplemental Figs. 1 through 4), similar to previous studies[40]. Participants excluded from analysis due to missing or extreme data were similar to included participants in their average sleep duration, bedtime and eating behaviours, but differed slightly in some demographic characteristics (online supplementary material, Supplemental Table 2).

To evaluate the relationship between bedtime and sleep duration within each developmental stage, we estimated multivariable ordinary least squares models stratified by developmental stage, regressing sleep duration on bedtime and covariates. To examine the relationship between bedtime and each eating behaviour within each developmental stage, we regressed each eating behaviour variable on bedtime, stratifying by developmental stage and controlling for both sleep duration and covariates. We used logistic regression for dichotomous eating behaviour variables (e.g. ate fruit yesterday) and negative binomial regression for count variables (e.g. fast food times/week). We report adjusted OR and unstandardised coefficients/marginal effects (Bs).

Table 2 Association of later bedtime with usual sleep duration, by developmental stage, National Longitudinal Study of Adolescent to Adult Health*

	Adolescents ≥12 and ≤18 years						Emerging adults >18 and ≤24 years			Young adults >24 and ≤34 years			P for differences across waves†
	Wave I (n 13 048)			Wave II (n 9438)			Wave III (n 9427)			Wave IV (n 10 410)			
	B	95 % CI	P	B	95 % CI	P	B	95 % CI	P	B	95 % CI	P	
Bedtime, decimal hours after noon	−0·23	−0·27, −0·19	<0·001	−0·50	−0·53, −0·46	<0·001	−0·27	−0·31, −0·24	<0·001	−0·55	−0·58, −0·52	<0·001	<0·001

*Table shows the association between bedtime and usual sleep duration in hours/night from regressions of sleep duration on bedtime, controlling for age, sex, race/ethnicity, nativity, parental educational attainment, logged parental income, usual time spent watching television, usual time spent playing video/computer games and depressive symptoms. Bedtime was calculated in decimal hours after 12.00 hours, such that larger values indicate later bedtimes. Bs reported are unstandardised regression coefficients. All analyses accounted for complex survey features of Add Health.
†P value reported is for an adjusted Wald test examining whether all coefficients were equal in seemingly unrelated estimation, $F(3,126) = 82·12$.

All analyses accounted for Add Health's complex sampling design.

We conducted analyses using Stata version 15.1 (StataCorp LLC). The University of North Carolina Institutional Review Board granted human subjects' research approval for this study.

Results

The analytic samples included 9427–13 048 individuals per wave (Table 1). Average sleep duration increased somewhat across waves. Average bedtime was similar in waves I, II and IV (22.30–22.42 hours), and later in wave III (24.06 hours).

In all developmental stages, later bedtime was associated with shorter sleep duration, independently of demographic characteristics, screen time behaviours and depressive symptoms (range of Bs: –0·55 to –0·23 h/night, all Ps < 0·001, Table 2). Associations between bedtime and sleep duration significantly differed across the four waves (adjusted Wald test F (3,126) = 82·12, P < 0·001). The negative association was strongest among young adults, for whom going to bed 1 h later was associated with a reduction in usual sleep duration of 0·55 h (~33 min) per night.

Generally, later bedtime was also associated with less healthy eating behaviours in each development stage, even after controlling for usual sleep duration (Fig. 1). Of the thirteen associations tested, all but two were statistically significant (Ps < 0·05) and all the significant associations were in the expected direction, with later bedtime being associated with less healthy eating behaviours. Only eating sweets yesterday as reported by adolescents in wave 1 (adjusted OR: 0·06, P = 0·08) and eating French fries yesterday as reported by adolescents in wave 2 (adjusted OR: 1·06, P = 0·08) were not significantly associated with bedtime, though the associations were in the expected directions. Stronger associations were seen between bedtime and consumption of fruits and vegetables in adolescents, bedtime and the frequency of fast-food consumption in adolescents, and bedtime and sugar-sweetened beverage consumption in young adults.

Discussion

In this cross-sectional study with a large national sample, bedtime was negatively associated with sleep duration among adolescents, emerging adults and young adults. Going to bed 1 h later was associated with 14–33 fewer minutes of usual sleep duration per night. This reduction could be clinically meaningful: previous studies have found that a 1-h reduction in usual sleep duration is associated with an 80 % increase in odds of obesity among adolescents[43] and a 0·35 kg/m^2 increase in BMI among adults[18].
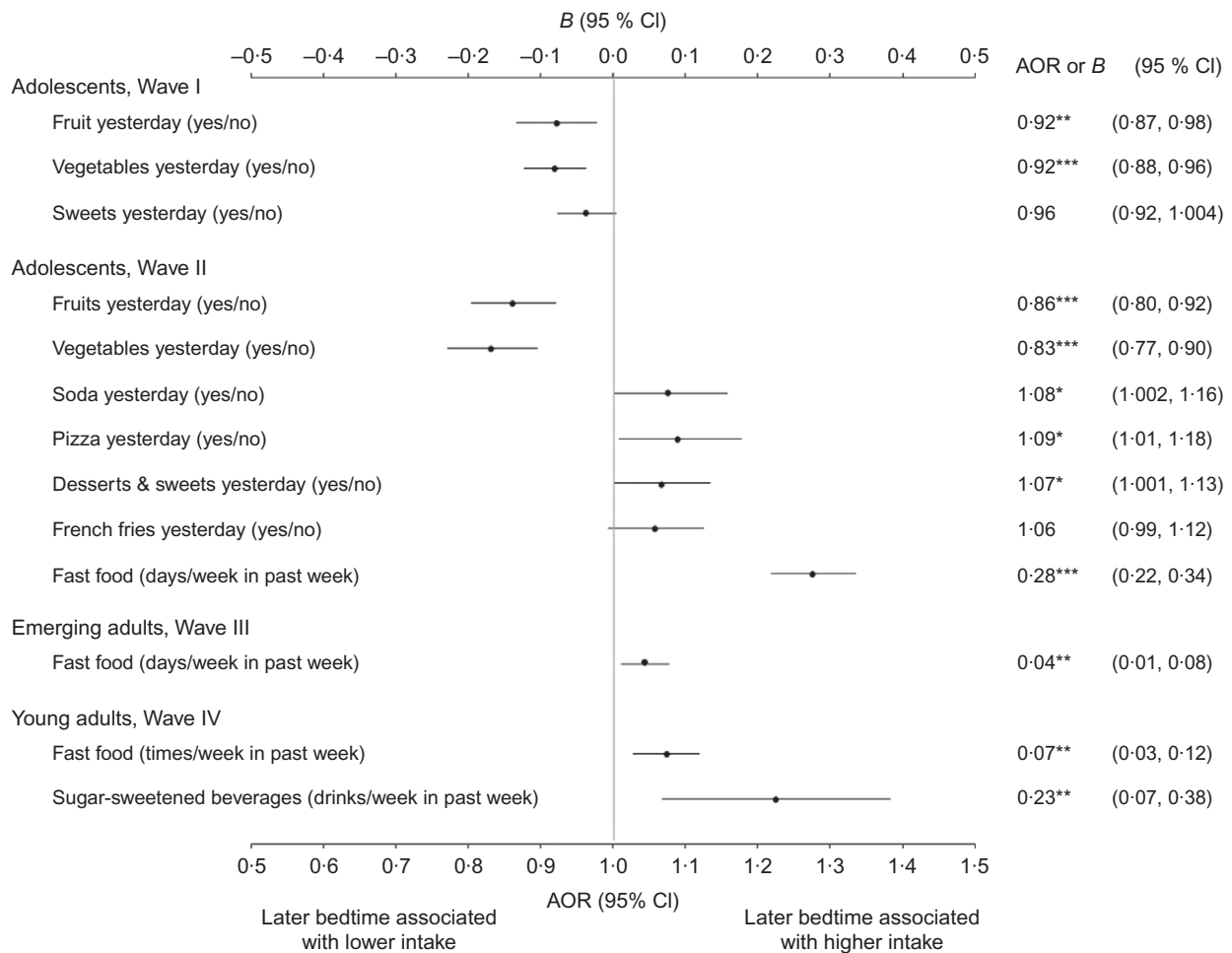
Fig. 1 Associations of later bedtime with eating behaviours, controlling for sleep duration, National Longitudinal Study of Adolescent to Adult Health. Figure shows associations between bedtime and eating behaviours. Bedtime was calculated in decimal hours after 12.00 hours, such that larger values indicate later bedtimes. Figure shows unstandardised regression coefficients (Bs) for continuous outcomes (top horizontal axis) and adjusted OR (AOR) for binary outcomes (bottom horizontal axis), controlling for usual sleep duration, age, sex, race/ethnicity, nativity, parental educational attainment, logged parental income, usual time spent watching television, usual time spent playing video/computer games and depressive symptoms. All analyses accounted for complex survey features of Add Health. *P < 0·05, **P < 0·01, ***P < 0·001

Across developmental stages, later bedtimes were generally associated with reporting lower consumption of healthier foods and higher consumption of less healthy foods. For example, adolescents who reported later bedtimes had lower odds of fruit and vegetable consumption and higher odds of consuming soda, desserts and pizza. Likewise, later bedtime was associated with greater frequency of fast-food consumption in all developmental stages. These findings are consistent with studies examining bedtime and eating behaviours in non-national samples[23,29,31,32]. While some of the observed associations were small, the consistent pattern of results suggests that these small associations could add up to meaningful differences in overall dietary quality and diet-related health outcomes. For example, fruit and vegetable consumption[44] and fast-food intake[45] have been found to be associated with health outcomes such as heart disease and insulin resistance.

Several mechanisms could underlie the observed associations between bedtime and eating behaviours. For example, those who go to bed later may be eating more energy-dense snacks that are convenient for late night eating, contributing to higher energetic intake and lower dietary quality compared with eating during other times of day[16,27,28]. Another possibility is that poorer sleep behaviours are a marker for a general profile of riskier behaviours, rather than later bedtime being a driver of less healthy dietary choices, though research on this question is mixed[42,46–49]. Additional research should also explore the complex interplay of sleep behaviours, diet, adiposity, and hunger, satiety, and growth hormones[50–52].

Strengths of our study include its use of a large population-based national sample, examination of three developmental stages critical to the development of eating behaviours and obesity[35–38], and inclusion of important potential confounders in analyses, particularly screen

time[16] and depressive symptoms[53]. By examining the cross-sectional relationships over three developmental periods, we demonstrate that the behaviours co-vary during each developmental stage and that some behavioural patterns are stable across developmental stages.

Limitations of our study include the inconsistency of eating behaviour questions used across the four waves and our inability to examine overall dietary quality. Another limitation is that sleep behaviours were self-reported. While self-reported and objectively measured sleep variables are significantly correlated[54], future research should examine these associations using gold standard measures of sleep whenever possible. Third, we used complete case analysis to account for missing data. While participants included in analysis had similar sleep and eating behaviours as those excluded from analysis, we cannot rule out sample selection bias. Finally, we cannot rule out alternate explanations for the observed associations, including residual confounding and reverse causality (i.e. eating certain foods causes individuals to go to bed later).

Conclusions

In a national probability sample, later bedtime was associated with shorter sleep duration during adolescence, emerging adulthood and young adulthood. Further, later bedtime was generally associated with less healthy eating behaviours, even after controlling for sleep duration. Given the cross-sectional design of this study, future research using longitudinal and experimental designs is needed to clarify the relationships between bedtime, sleep duration and eating behaviours. If bedtime is causally related to eating behaviours and sleep duration, encouraging earlier bedtimes could be a promising strategy to incorporate into interventions aiming to improve eating behaviours, increase sleep duration or prevent obesity.

Acknowledgements

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980020002050

References

1. Eaton DK, McKnight-Eily LR, Lowry R *et al.* (2010) Prevalence of insufficient, borderline, and optimal hours of sleep among high school students: United States, 2007. *J Adolescent Health* **46**, 399–401.
2. Wheaton AG, Jones SE, Cooper AC *et al.* (2018) Short sleep duration among middle school and high school students: United States, 2015. *Morb Mortal Wkly Rep* **67**, 85.
3. Liu Y (2016) Prevalence of healthy sleep duration among adults: United States, 2014. *Morb Mortal Wkly Rep* **65**, 137–141.
4. Córdova FV, Barja S & Brockmann PE (2018) Consequences of short sleep duration on the dietary intake in children: a systematic review and metaanalysis. *Sleep Med Rev* **42**, 68–84.
5. Kjeldsen JS, Hjorth MF, Andersen R *et al.* (2013) Short sleep duration and large variability in sleep duration are independently associated with dietary risk factors for obesity in Danish school children. *Int J Obes* **38**, 32.
6. Chaput J-P, Tremblay MS, Katzmarzyk PT *et al.* (2018) Sleep patterns and sugar-sweetened beverage consumption among children from around the world. *Public Health Nutr* **21**, 2385–2393.
7. Sampasa-Kanyinga H, Hamilton HA & Chaput J-P (2018) Sleep duration and consumption of sugar-sweetened beverages and energy drinks among adolescents. *Nutrition* **48**, 77–81.
8. Franckle RL, Falbe J, Gortmaker S *et al.* (2015) Insufficient sleep among elementary and middle school students is linked with elevated soda consumption and other unhealthy dietary behaviors. *Prev Med* **74**, 36–41.
9. Rangan A, Zheng M, Olsen NJ *et al.* (2017) Shorter sleep duration is associated with higher energy intake and an increase in BMI z-score in young children predisposed to overweight. *Int J Obes* **42**, 59.
10. Weiss A, Xu F, Storfer-Isser A *et al.* (2010) The association of sleep duration with adolescents' fat and carbohydrate consumption. *Sleep* **33**, 1201–1209.
11. Martinez SM, Tschann JM, Butte NF *et al.* (2016) Short sleep duration is associated with eating more carbohydrates and less dietary fat in Mexican American children. *Sleep* **40**, zsw057.
12. Kruger AK, Reither EN, Peppard PE *et al.* (2014) Do sleep-deprived adolescents make less-healthy food choices? *Br J Nutr* **111**, 1898–1904.
13. Cespedes EM, Hu FB, Redline S *et al.* (2016) Chronic insufficient sleep and diet quality: contributors to childhood obesity. *Obesity* **24**, 184–190.

14. Prather AA, Leung CW, Adler NE *et al.* (2016) Short and sweet: associations between self-reported sleep duration and sugar-sweetened beverage consumption among adults in the United States. *Sleep Health* **2**, 272–276.

15. Dashti HS, Ordovás JM, Jacques PF *et al.* (2015) Short sleep duration and dietary intake: epidemiologic evidence, mechanisms, and health implications. *Adv Nutr* **6**, 648–659.

16. Chaput J-P (2014) Sleep patterns, diet quality and energy balance. *Physiol Behav* **134**, 86–91.

17. Magee L & Hale L (2012) Longitudinal associations between sleep duration and subsequent weight gain: a systematic review. *Sleep Med Rev* **16**, 231–241.

18. Cappuccio FP, Taggart FM, Kandala N-B *et al.* (2008) Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* **31**, 619–626.

19. Chen X, Beydoun MA & Wang Y (2008) Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. *Obesity* **16**, 265–274.

20. Li L, Zhang S, Huang Y *et al.* (2017) Sleep duration and obesity in children: a systematic review and meta-analysis of prospective cohort studies. *J Paed Child Health* **53**, 378–385.

21. Fleig D & Randler C (2009) Association between chronotype and diet in adolescents based on food logs. *Eat Behav* **10**, 115–118.

22. Thind H, Davies SL, Lewis T *et al.* (2015) Does short sleep lead to obesity among children and adolescents? Current understanding and implications. *Am J Lifestyle Med* **9**, 428–437.

23. Golley RK, Maher CA, Matricciani L *et al.* (2013) Sleep duration or bedtime? Exploring the association between sleep timing behaviour, diet and BMI in children and adolescents. *Int J Obes* **37**, 546.

24. Jarrin DC, McGrath JJ & Drake CL (2013) Beyond sleep duration: distinct sleep dimensions are associated with obesity in children and adolescents. *Int J Obes* **37**, 552–558.

25. Gibson M & Shrader J (2018) Time use and labor productivity: the returns to sleep. *Rev Econ Stat* **100**, 783–798.

26. Giuntella O & Mazzonna F (2016) *If You Don't Snooze You Lose Health and Gain Weight: Evidence from a Regression Discontinuity Design*. Bonn, Germany: IZA.

27. Spaeth AM, Dinges DF & Goel N (2013) Effects of experimental sleep restriction on weight gain, caloric intake, and meal timing in healthy adults. *Sleep* **36**, 981–990.

28. Baron KG, Reid KJ, Kern AS *et al.* (2011) Role of sleep timing in caloric intake and BMI. *Obesity* **19**, 1374–1381.

29. Thellman KE, Dmitrieva J, Miller A *et al.* (2017) Sleep timing is associated with self-reported dietary patterns in 9- to 15-year-olds. *Sleep Health* **3**, 269–275.

30. Adamo KB, Wilson S, Belanger K *et al.* (2013) Later bedtime is associated with greater daily energy intake and screen time in obese adolescents independent of sleep duration. *J Sleep Disord Ther* **2**, 2167–0277.

31. Agostini A, Lushington K, Kohler M *et al.* (2018) Associations between self-reported sleep measures and dietary behaviours in a large sample of Australian school students (*n* = 28,010). *J Sleep Res* **27**, e12682.

32. Ogilvie RP, Lutsey PL, Widome R *et al.* (2018) Sleep indices and eating behaviours in young adults: findings from Project EAT. *Public Health Nutr* **21**, 689–701.

33. Mossavar-Rahmani Y, Weng J, Wang R *et al.* (2017) Actigraphic sleep measures and diet quality in the Hispanic Community Health Study/Study of Latinos Sueno ancillary study. *J Sleep Res* **26**, 739–746.

34. Maslowsky J & Ozer EJ (2014) Developmental trends in sleep duration in adolescence and young adulthood: evidence from a National United States sample. *J Adoles Health* **54**, 691–697.

35. Lawlor DA & Chaturvedi N (2006) Treatment and prevention of obesity: are there critical periods for intervention? *Int J Epidemiol* **35**, 3–9.

36. Dietz WH (1994) Critical periods in childhood for the development of obesity. *Am J Clin Nutr* **59**, 955–959.

37. Nelson MC, Story M, Larson NI *et al.* (2008) Emerging adulthood and college-aged youth: an overlooked age for weight-related behavior change. *Obesity* **16**, 2205–2211.

38. Alberga A, Sigal R, Goldfield G *et al.* (2012) Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes* **7**, 261–273.

39. Harris K, Halpern C, Whitsel E *et al.* (n.d.) The National Longitudinal Study of Adolescent to Adult Health: Research Design. The National Longitudinal Study of Adolescent to Adult Health. http://www.cpc.unc.edu/projects/addhealth/design (accessed March 2018).

40. Sokol RL, Grummon AH & Lytle LA (2020) Sleep duration and body mass: direction of the associations from adolescence to young adulthood. *Int J Obes* **44**, 852–856. doi: 10.1038/s41366-019-0462-5.

41. Krueger PM, Reither EN, Peppard PE *et al.* (2015) Cumulative exposure to short sleep and body mass outcomes: a prospective study. *J Sleep Res* **24**, 629–638.

42. Larson N, Dewolfe J, Story M *et al.* (2014) Adolescent consumption of sports and energy drinks: linkages to higher physical activity, unhealthy beverage patterns, cigarette smoking, and screen media use. *J Nutr Educ Behav* **46**, 181–187.

43. Gupta NK, Mueller WH, Chan W *et al.* (2002) Is obesity associated with poor sleep quality in adolescents? *Am J Hum Biol* **14**, 762–768.

44. Aune D, Giovannucci E, Boffetta P *et al.* (2017) Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality: a systematic review and dose-response meta-analysis of prospective studies. *Int J Epidemiol* **46**, 1029–1056.

45. Pereira M, Kartashov A, Ebbeling C *et al.* (2005) Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* **365**, 36–42.

46. Dumuid D, Olds T, Lewis LK *et al.* (2017) Health-related quality of life and lifestyle behavior clusters in school-aged children from 12 countries. *J Pediatr* **183**, 178–183.e2.

47. Ding D, Rogers K, Macniven R *et al.* (2014) Revisiting lifestyle risk index assessment in a large Australian sample: should sedentary behavior and sleep be included as additional risk factors? *Preven Med* **60**, 102–106.

48. Nuutinen T, Lehto E, Ray C *et al.* (2017) Clustering of energy balance-related behaviours, sleep, and overweight among Finnish adolescents. *Int J Public Health* **62**, 929–938.

49. Kaar JL, Schmiege SJ, Vadiveloo M *et al.* (2018) Sleep duration mediates the relationship between health behavior patterns and obesity. *Sleep Health* **4**, 442–447.

50. Beccuti G & Pannain S (2011) Sleep and obesity. *Curr Opin Clin Nutr Metab Care* **14**, 402–412.

51. Prinz P (2004) Sleep, appetite, and obesity – what is the link? *PLoS Med* **1**, e61. Public Library of Science.

52. Spiegel K, Tasali E, Leproult R *et al.* (2009) Effects of poor and short sleep on glucose metabolism and obesity risk. *Nat Rev Endocrinol* **5**, 253–261.

53. Chang PP, Ford DE, Mead LA *et al.* (1997) Insomnia in young men and subsequent depression: the Johns Hopkins Precursors Study. *Am J Epidemiol* **146**, 105–114.

54. Lauderdale DS, Knutson KL, Yan LL *et al.* (2008) Self-reported and measured sleep duration: how similar are they? *Epidemiology* **19**, 838–845.

55. Eaton WW, Smith C, Ybarra M *et al.* (2004) Center for epidemiologic studies depression scale: review and revision (CESD and CESD-R). In *The Use of Psychological Testing for Treatment Planning and Outcomes Assessment: Instruments for Adults*, pp. 363–377 [ME Maruish, editor]. Mahwah, NJ: Lawrence Erlbaum.