Title: Sleep duration or bedtime? Exploring the association between sleep timing behaviour, diet and BMI in children and adolescents

Running title: Sleep habits and diet quality.

Article Type: Original Research

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Sources of support: RKG was supported by a National Health and Medical Research Council Public Health Postdoctoral Fellowship (478115). CAM is supported by an Australian Research Council Postdoctoral Fellowship. The collection of data used in study was supported by the Australian Commonwealth Department of Health and Ageing; the Department of Agriculture, Fisheries and Forestry; and by the Australian Food and Grocery Council.

Conflict of interest statement: There is no financial support or relationships which pose a conflict of interest.

Abstract

Objective: To determine whether sleep timing behaviour is associated with energy intake and diet quality in children and adolescents.

Design: Cross-sectional analysis of nationally representative survey data.

Sample: 2200 participants of the 2007 Australian National Children's Nutrition and Physical Activity Survey aged 9-16 years with two days of food intake data, four days of use of time data and complete anthropometry. Participants were grouped into one of four sleep-wake behaviour categories: Early Bed/Early Rise (EE); Early Bed/Late Rise (EL); Late Bed/Early Rise (LE), and Late Bed/Late Rise (LL). The four categories were compared for BMI z score, energy intake and diet quality assessed using the Dietary Guideline Index for Children and Adolescents. Analyses were adjusted for survey design, socio-demographic characteristics, sleep duration and physical activity level.

Results: In adjusted multi-variate regression models with sleep timing behaviour group as the independent variable, the 'Late Bed/Late Rise' category compared to the 'Early Bed/Early Rise' category had a higher BMI-z score (β=0.20 95% CI 0.06 to 0.34, p=0.007), and lower diet quality (-4.0 95% CI -5.7 to -2.3, p<0.001). Children and adolescents who went to bed late also had a higher intake of extra foods (i.e. energy-dense, nutrient-poor foods) while those whom went to bed early consumed more fruit and vegetables. Energy intake was associated with sleep duration (β=-4.5kJ 95% CI -6.7 to -2.4, p<0.001), but not sleep timing behaviour.

Conclusion: Late bedtimes and late wake up times are associated with poorer diet quality, independent of sleep duration, physical activity level and child and socio-demographic characteristics.

Keywords

adolescent, child, sleep, bedtime, food intake, obesity

Introduction

The identification of modifiable factors associated with excess weight gain is important to inform child obesity prevention and treatment interventions. Sleep is among the factors hypothesised to play a role in child overweight and obesity. Evidence from both cross-sectional[1-5] and longitudinal[6, 7] studies suggests that children with short sleep durations are at an increased risk of being overweight or obese[1, 2, 8].

While the exact mechanism(s) remains unclear, short sleep duration has been hypothesised to modulate weight gain by altering processes related to energy balance. Experimental studies[9-11] suggest short sleep duration might contribute to weight gain via hormonal responses involving reciprocal changes in leptin and ghrelin levels, leading to reduced energy expenditure and increased appetite and energy intake. Studies have also shown that short sleep duration is associated with altered food intake, specifically, increased snack consumption [12] and foods high in fat [13, 14], with[9-11, 15] and without [12, 16] hormonal changes. While experimental studies are limited for children, cross-sectional studies show that children with short sleep duration tend to be less physically active[17, 18] and consume greater quantities of high-energy foods [14, 19]. These findings support the hypothesis that sleep may facilitate weight gain by altering energy expenditure and food intake in children.

Although research on sleep and obesity has predominantly focused on sleep duration, it has recently been suggested that sleep timing behaviour (i.e. the combination of a child's bedtime and wake up time) may be a better predictor of obesity than sleep duration alone [19]. Indeed, the link between short sleep duration and obesity may not be as strong as initially thought [20, 21]. For example, a recent longitudinal study [22] of 13,568 US adolescents showed no association between sleep duration and body mass index (BMI).

While it is difficult to disentangle the independent effects of sleep timing and sleep duration, as shorter sleep duration can frequently be linked to a delay in bedtime [23, 24], evidence for an association between sleep timing behaviour and children's weight status is emerging. For example, in a recent study on Australian 9-16 year olds, it was shown that despite a similar sleep duration, a later bedtime/later wake up time combination was associated with a 1.5 times higher risk of obesity compared to an early bedtime/wake up time pattern [25]. These findings are consistent with other studies that show an association between BMI and sleep timing preference, with early risers having a lower BMI than later retiring children [26, 27].

It is plausible that a delayed bedtime and wake up time may be related to social and environmental factors that place individuals at a greater risk of being overweight or obese by reducing opportunities for physical activity and/or increasing opportunities to consume more energy. In a nationally representative survey of Australian children and adolescents, a late bed time was associated with higher screen time and lower moderate-to-vigorous physical activity (MVPA), independent of sleep duration [25]. While similar findings do not appear to have been examined in relation to dietary habits for children, Baron and colleagues found that adults who went to bed later consumed more energy, fast foods and soda and had lower fruit and vegetable consumption compared with 'normal' sleepers [28]. Although this finding was not independent of sleep duration, the authors acknowledged that this may be since the sample's sleep timing was associated with sleep duration, making it difficult to determine the independent effects.

Given this evidence, it is plausible that sleep timing behaviour may be associated with food habits in children and adolescents. Therefore, the purpose of this study was to determine whether sleep timing behaviour is associated with diet quality, energy intake, weight-related food intake and adiposity in Australian 9-16 year olds.

Methods

The sample were participants of the 2007 Australian National Children's Nutrition and Physical Activity Survey aged 9-16 years with two days of food intake data, four days of use of time data and complete demographics and anthropometry (n=2200/2382, 92% of the eligible survey sample) [29]. The survey methodology has been described in detail elsewhere [29]. Briefly, the survey was based on non-proportional stratified sampling of Australian households. The primary sampling unit was randomly selected clusters of postcodes stratified for state/territory and locality [metropolitan and rest of state (i.e. rural)]. Households were sampled using random digit dialling with quota sampling to ensure representation of age and gender groups within the sample. Only one child was surveyed from each household. The response rate (ratio of households providing complete data to eligible households contacted) was 41%. Compared to 2006 census data, the survey sample had fewer parents and children born overseas, fewer households in the highest income bracket, fewer tertiary educated parents and more single parent families [29]. Data collection was conducted seven days a week between February and August 2007 and involved a home visit and a telephone interview. Ethics approval for the survey was provided by National Health and Medical Research Council registered ethics committees of the Commonwealth Scientific and Industrial Research Organisation and the University of South Australia.

Use of time data collection

Use of time data were collected using the Multimedia Activity Recall for Children and Adults (MARCA) [30]. The software allowed young people to recall everything they did on the previous day from wake-up to bedtime, in time-slices as fine as 5 minutes, using a segmented day format. Young people chose from a list of 250 activities grouped under seven rubrics (Inactivity, Transport, Sport and Play, School, Self-Care, Chores and Other). Spearman's rho between MARCA-estimated PAL and total accelerometry counts/min was 0.45 (in a separate

sample)[30] and between PAL and pedometer steps was 0.54 (in this sample) [31]. Self-reported estimates of bed time, wake time and sleep duration are reliable and valid. In the present sample, test-retest reliabilities for wake time are r=0.94, and for bed time were r=0.99. Previous studies have found good agreement between self-reported sleep timing and objective measure such as actigraphy.The MARCA was administered on two occasions. Each time, young people recalled their activities over the two previous days (i.e. a total of four days were sampled). Wherever possible, at least one school day and one non-school day (i.e. weekends, holidays or student-free days) were sampled.

Food intake

Food intake was assessed via two 24-hour food recalls conducted by 90 trained interviewers (36% with a tertiary degree in dietetics or nutrition) and checked by dietitians. The first recall was conducted with the young people face-to-face in the home, with the second recall conducted within 7-21 days later by telephone. A three-pass protocol was used to collect information on all foods and beverages consumed the previous day [32]. To assist with portion size estimation a food model booklet was provided, with picture guides of common household measures and life size images, plates, bowls, glasses and amorphous dishes. At the group level, all days of the week were represented (75% weekdays, 25% weekend days). A nutrient composition database developed specifically for the survey (AUSNUT2007 [33]) was used to derive energy intake and food groupings. Foods were categorised into 22 major food groups based on the primary food or ingredient of a food product or dish. Dietary data analysed reflected the mean food, beverage and energy intake of the two recalled days.

Socio-demographic variables and Anthropometry

During the home visit an interviewer-administered questionnaire was used to collect socio-demographic details. Information was reported by the primary caregiver, who for over 90%

of participants was the young person's female caregiver. Socio-demographic information included total household income (six categories, with those reporting 'don't know' or 'refused' assigned as missing) and maternal education (seven categories spanning no qualification to postgraduate diploma or higher). Child gender and birth date were also reported. The later was used to derive child age, categorised based on the age groupings used in the Australian Guideline to Healthy Eating (AGHE) [34]. Height and weight were measured according to the protocols of the International Society for the Advancement of Kinanthropometry [35], and BMI (kg/m^2) was calculated. BMI was converted to a z-score and adjusted for age and sex by using the least mean squares method[36]. Because of the lack of Australian data, calculations were based on British reference data provided as a computer program [37]. Children's weight status was classified using BMI z-score by the International Obesity Task Force definition [36].

Data treatment

Sleep duration was the amount of time reported sleeping in each 24 h period. Bedtime and wake up times were extracted from the MARCA recalls. Since Australian children spend about one day in two at school (taking into account weekends, holidays and student-free days), all use of time variables were calculated as the average of school day and non-school day values. Bed time was defined as the start of the last sleeping bout of the day (when the child "turned out the light and went to sleep"), and wake up time as the end of the first sleeping bout of the day. Values for bedtime, wake-up time were adjusted for age and sex by regressing them against decimal age and fitting a fourth-order polynomial. This was done separately for boys and girls. These values represented the degree to which an individual participant deviated from the expected value for children and adolescents of the same age and sex. Using median splits for age- and sex-adjusted bedtime and wake-up time, participants were classified into one of four categories based on their bedtime and wake-up time combination: EE = Early Bed Early Rise (9:20 PM, 7:03 AM, sleep duration 9.7h); EL = Early Bed Late Rise (9:28 PM, 8:09

AM, sleep duration 10.7h); LE = Late Bed Early Rise (10:40 PM, 7:09 AM; sleep duration 8.5h); LL = Late Bed Late Rise (10:46PM, 8:22 AM, sleep duration 9.6h) [25]. There were significant between-group differences in bedtime and wake up time (all $p<0.001$) [25]. There were statistically significant differences in sleep duration across all four groups, however, the difference between the Early Bed/Early Rise group (averaging 9.6h sleep over a 24 h period) and the Late Bed/Late Rise group (9.7h) was quantitatively small [25]. Physical activity level (PAL) was defined as the average rate of energy expenditure, calculated by the factorial method, that is, by multiplying the number of minutes spent in activities by the estimated energy expenditure for each activity, summing the products, and dividing by the total number of minutes.

Energy intake was used as a continuous variable. Food and beverage intakes were converted to food group servings per day based on the standard energy value assigned to each food group in the AGHE [34]. Food group servings were assessed against the Dietary Guideline Index for Children and Adolescents (DGI-CA) [38]. The DGI-CA comprises eleven components representing the five core food groups (fruit, vegetables, breads and cereals, lean meat and alternatives, and dairy foods) as well as dietary variety, healthy fats and oils, water as a drink and extra foods (nutrient poor foods that are high in energy, fat, sugar and/or salt). Total DGI-CA score is the sum of the eleven components, expressed as a score out of 100. A higher DGI-CA score reflects greater compliance with the dietary guidelines and better energy and nutrient profile (i.e. higher diet quality) [38]. The DGI-CA score provides a measure of total diet and encompasses all food groups. For context, data were presented for selected core food groups that are common obesity intervention targets and may be hypothesised to be influenced by bedtime or wake-up times. This included fruit (fruit products and dishes and 100% fruit juices [juice capped at 125mLmaximum]) and vegetables (vegetable and legume products and dishes, excluding those containing fried potato), dairy foods (all milk products

and dishes, excluding soft cheeses) and extra foods (items such as sweet biscuits, cakes, buns and muffins, desserts including ice cream, pies and pastries, high fat snack items such as chips (crisps), takeaway foods such as hamburgers or hot chips, confectionery (candy), chocolate, soft drinks (soda), cordial (squash), fruit juice drinks).

Statistical analysis

Analyses were undertaken using SPSS 19.0 (SPSS Inc an IBM company, Chicago, IL) and STATA IC 11.0 (StataCorp, Texas, USA). Analyses were undertaken accounting for complex survey design (stratified sampling with non-proportional samples) using sampling weight (child age, gender and region (state x metropolitan/rest of state), strata variable (region) and cluster variable (de-identified postcode)). BMI z-score, energy intake and DGI-CA total score were normally distributed, with mean(standard deviation) reported and parametric statistics employed. Food group servings were not normally distributed and therefore median (interquartile range) are reported. Differences by gender and age group (9-11 years and 12-16 years) were evaluated via Independent t-test or Chi Square. BMI z-score, energy intake and DGI-CA total score by sleep-wake behaviour categories (EE, EL, LE and LL) were evaluated via 1-way ANOVA test for linear trend with Bonferroni posthoc comparison between categories. Food group servings by sleep-wake behaviour categories (EE, EL, LE and LL) were assessed using non-parametric test for differences in the median between independent groups. The associations among the dependent variables BMI z-score, DGI-CA score (i.e. diet quality), and energy intake and the independent variable sleep-wake behaviour category (EE, EL, LE and LL) were examined using multivariable linear regression models. In the unadjusted model only a single dependent and independent variable were entered. In the adjusted model the following child and socio-demographic characteristics were included as covariables: gender, age, BMI z-score (when not the dependent variable), energy intake (when not the dependent variable), sleep duration, PAL, household income and maternal education. All variables were

entered into the model in a single step and were retained in the final model. Analyses were repeated 1) stratified by age groups (9-11 and 12-16 years) and 2) only for plausible reporters of energy intake using the Goldberg cut-off values to identify mis-reporters[39, 40]. The cut off values are the confidence limits of agreement comparing measured physical activity level (PAL) and the ratio of measure energy intake: estimated basal metabolic rate. For simplicity, where results between the whole and sub-group analyses were not different, results for the whole sample are presented. Un-standardised regression coefficients (β) and 95% confidence intervals are used to evaluate the strength and precision of the associations.

Results

Participant characteristics are shown in Table 1. Adiposity (BMI z-score), diet quality (DGI-CA score) and energy intake by sleep timing behaviour category are shown in Table 2. BMI z-score was highest in the categories that included 'late to bed' behaviour and was lowest in the Early Bed/Late Rise group. Despite similar total sleep duration (9.6-9.7 h/d), BMI z-score was lower in the Early Bed/Early Rise group compared to the Late Bed/Late Rise group (0.46±1.10 v 0.68±1.24, p=0.008). Energy intake was similar between all four sleep timing behaviour categories, ranging from 9.0MJ in the categories that included 'late to rise' behaviour and 9.2 MJ in the Late Bed/Early Rise category. DGI-CA scores decreased across sleep timing behaviour categories (Table 2). There was a 4 point difference between the Early Bed/Early Rise category and the Late Bed/Late Rise category, with diet quality being highest in the sleep timing behaviour categories that included 'early to bed' behaviour.

Selected weight-related food group servings by sleep timing behaviour category are shown in Table 2. These foods were selected *a priori* based on hypothesised associations with obesity that may also be associated with sleep timing. For example, late bedtime may be associated with snacking and increased intake of energy-dense, nutrient-poor foods. Similarly, a late wake up time may result in poorer food choices at breakfast and impact on fruit or dairy intake. Fruit and vegetable intake was highest in the sleep timing behaviour categories that included early to bed behaviour. In contrast, intake of extra foods (i.e. energy dense nutrient poor foods) was highest in the sleep timing behaviour categories that included late to bed behaviour.

The associations between sleep timing behaviour, adiposity (BMI z-score), diet quality (DGI-CA score) and energy intake are shown in Table 3. In the unadjusted analysis, sleep timing behaviour category was associated with BMI z-score and DGI-CA score. Furthermore, the

direction and strength of these associations remained after adjustment for covariables including sleep duration, PAL and energy intake. In the adjusted analysis, compared to the Early Bed/Early Rise category, both categories that included late to bed behaviour had higher BMI z-scores (although p=0.05 for the Late Bed/Early Rise category). Similarly, compared to the Early Bed/Early Rise category, both categories that included late to bed behaviour had diet quality scores that were around 3 points lower. There was no association between sleep timing behaviour and energy intake. In multi-variate regression models with sleep duration as the independent variable and with adjustment for covariates, there was an association between sleep duration and BMI z score (β=-0.12 95% CI -0.002 to – 0.004, p=0.004) and energy intake (β=-4.5kJ 95% CI -6.7 to -2.4, p<0.001), but not DGI-CA score β=0.007 points 95% CI -0.004 to 0.17, p=0.25). When analyses were repeated stratified by gender or age group (9-11 or 12-16 years of age) or excluding mis-reporters of energy intake, results did not change.

Discussion

This is the first study to explore the association between children's sleep timing behaviours and food intake, diet quality and energy intake. This study found sleep timing behaviours were associated with diet quality. Young people who went to bed late had poorer diet quality, independent of sleep duration, physical activity level and socio-demographic characteristics. They also had a higher intake of extra foods (i.e. energy-dense, nutrient-poor foods) while children who went to bed early consumed more fruit and vegetables. Children's sleep timing behaviour was also associated with BMI z-score. Total energy intakes were associated with total sleep duration, but not sleep timing behaviour.

Previous studies have found associations between sleep duration and dietary patterns. Specifically, short sleep duration has been associated with an increased consumption of fat and fast foods, in 16-19 year old US adolescents [14], in Japanese adult males [41, 42] and in Chinese adults [13]. While these findings suggest short sleep duration may facilitate weight gain via unhealthy food choices, our study suggests that sleep timing behaviour is an independent and important predictor of diet quality. For example, on the basis of previous research, one might expect the greatest dietary differences to be between the Early Bed/Late Rise and Late Bed/Early Rise groups, which had a sleep duration difference of 132 minutes. However, our results showed that diet quality differed the most between the Early Bed/Early Rise and Late Bed/Late Rise categories whose sleep duration differed by only 7 minutes.

While very little research has been done in this area, Fleig and Randler [19] examined the relationship between adolescent sleep chronotype (i.e their *preferred* sleep timing) and dietary intake. These researchers found that a late sleep preference was associated with increased consumption of fast foods, reduced consumption of milk, and was unrelated to consumption of fruit and vegetables. Also supporting the concept that sleep timing behaviour

may be an independent predictor of diet quality than sleep duration alone are studies that investigate the relationship between meal timing and weight status. A number of studies have shown that children who eat breakfast are less likely to be overweight [43-49], while adults who consume more energy late in the day are more likely to be overweight [47, 48]. Sleep timing and meal timing may be different aspects of the same obesogenic behavioural pattern. These findings may explain why the Late Bed/Late Rise group had the worst dietary profile, despite having almost the same sleep duration as the Early Bed/Early Rise category. Children in this group may wake up late and skip breakfast and/or stay up late engaging in sedentary activities and consuming most of their daily energy intake. While this is purely speculation, sleep could potentially be a mediator of meal timing and in turn, influence weight status.

Given the clear gradients in BMI z-score across bedtime and wake time groups, it was somewhat surprising that differences in total energy intake were not observed between sleep timing groups. One explanation is that sleep timing pattern is associated with differences in the types of foods consumed, without differences in total energy intake. Alternatively, it may be that sleep timing is associated with differences in total energy intake, but methodological issues prevented such differences from being detected. Certainly, we did observe an inverse association between energy intake and sleep duration. Previous studies show that children with short sleep duration tend to be less physically active [50], but sleep timing behaviour is an independent predictor of both physical and sedentary activity level [25]. Collectively, our current and previous findings indicate that both sleep duration and sleep timing behaviour influence weight status and weight-related behaviours. However, the mechanisms influencing weight status may be different for dietary and activity predictors of energy balance.

Before considering the significance and implications of these findings, it is important to acknowledge the study's strengths and limitations. This study used a large, randomly selected national sample of young Australians. Furthermore, quality tools where used to quantify use of time and food intake. The use of a 24 h use of time recall is likely to have minimised the risk of under- or over-reporting of behaviours compared with other self-report measures [51]. Similarly, the three-pass dietary intake recall is believed to be one of the strongest methods to measure dietary intake, and minimises the risk of participants altering their food intake, as can be the case with food records [52]. Nonetheless, self-report is subject to recall bias, particularly in younger adolescents, and social desirability bias, and this may have affected the results[53]. In addition, young people's behaviours are extremely variable, and the use of a four-day use of time sample and a two-day dietary intake sample may not precisely capture typical individual behaviours. While this will increase variability and introduce statistical noise, it is unlikely to bias parameter estimates. A further limitation is that, while analyses were adjusted to account for age, the study that it did not measure pubertal stage, which has recognized associations with sleep patterns[54].

Importantly, studies to date which have considered sleep timing in children and adolescents have done so on the basis of sleep chronotype (i.e. preference for the timing of sleep) as opposed to observed sleep timing behaviours. Given the many demands on adolescents in the present day, such as the need to rise for school, sporting commitments, and part-time work, or to fit with such commitments of other family members, to us it seems that actual timing of sleep is more relevant than sleep preference. Thus the fact that this study considers actual sleep timing is a strength.

While the current analyses highlight differences in the dietary intakes between children with

late and early bedtimes, and late and early wake times, the interactions between sleep timing and eating timing are currently unclear. Our previous study of sleep timing behaviour and screen time revealed that young people in the Late-bed/Late rise group accrued nearly 50 minutes more screen time per day than their Early-bed/Early rise counterparts. It appears plausible that they may be staying up later watching television and using computers. Television viewing has been associated with increased snacking behaviour[55] and exposure to advertisements for energy-dense foods[56-58] in young people, which is consistent with the current study's findings. Future research should investigate the association between timing of energy intake to see if children with late-to-bed behaviours are consuming excess energy late at night. Longitudinal research would also help confirm the direction of associations between bed and wake time habits and dietary intake and weight status.

In conclusion, this is the first study to explore the association between children's sleep timing behaviours energy intake and diet quality. It showed that young people who went to bed late reported poorer diet quality, and a higher intake of energy-dense, nutrient-poor foods, while children who went to bed early tended to consume more fruit and vegetable. These findings highlight that bed time is an important factor for health professionals, parents and young people to consider for health outcomes, as distinct from total sleep duration. Longitudinal and intervention studies would help confirm causal pathways underlying the relationships between sleep timing behaviour and dietary intake.

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Table 1. Sample characteristics by gender and age group[1].

	All	**Boys**	**Girls**	**P value[2]**	**9-11 years**	**12-16 years**	**P value[2]**
***n* (%males)**	2200 (49)	1086	1114		904 (48)	1516 (50)	
Age, *years*	12.9 (2.2)	13.0 (2.2)	12.9 (2.2)	0.81	10.1 (0.8)	14.2 (1.3)	<0.001
BMI z-score[3]	0.54 (1.17)	0.56 (1.19)	0.52 (1.15)	0.87	0.54 (1.22)	0.54 (1.15)	0.68
Percent overweight	19	18	20		21	18	
Percent obese	6	6	7		7	6	
Sleep duration, *hours/day*	9.8 (1.1)	9.8 (1.0)	9.9 (1.1)	0.007	10.2 (0.8)	9.7 (1.1)	<0.001
Sleep category (%)[4]				0.91			0.08
EE	33	33	32		33	32	
EL	21	20	21		20	21	
LE	17	17	18		20	16	
LL	29	30	29		27	31	
PAL[5]	1.66 (0.25)	1.72 (0.26)	1.61 (0.22)	<0.001	1.72 (0.25)	1.63 (0.24)	<0.001
DGI-CA[6], *points/100*	47.1 (14.4)	46.0 (13.87	48.2 (15.0)	<0.001	50.1 (14.0)	46.0 (14.3)	<0.001
Energy intake, *MJ*	9.1 (2.7)	10.3 (3.0)	8.1 (2.2)	<0.001	8.5 (2.2)	9.5 (3.0)	<0.001

[1] Percent or means (standard deviation). [2] Statistical tests compared characteristics by gender or age group using independent t-test for continuous variables and χ^2 for categorical variables. [3]Body mass index (BMI) z-score and BMI category based on International Obesity Task Force categories [36]. [4]Sleep time preference (bed time; wake up time; sleep hours/day); EE = Early Bed Early Rise (9:20 PM, 7:03 AM, 9.7); EL = Early Bed Late Rise (9:28 PM, 8:09 AM, 10.7); LE = Late Bed Early Rise (10:40 PM, 7:09 AM; 8.5); LL = Late Bed Late Rise (10:46PM, 8:22 AM, 9.6). Bedtime, wake up time and sleep hours/d all $p<0.0001$ by sleep group [25]. [5]PAL: Physical Activity Level representing average measured energy expenditure measured using the Multimedia Activity Recall for Children and Adults (MARCA) [6] DGI-CA: Dietary Guideline Index for Children and Adolescents as measure of diet quality [38].

Table 2. BMI z-score, diet quality and energy intake by sleep timing behaviour category[1]

	ALL	**EE**	**EL**	**LE**	**LL**	**P value[2]**
n	2200	719	453	378	650	
			Mean (SD)			
BMI z-score	0.54 (1.17)	0.46 (1.10)	0.37 (1.18)	0.68 (1.15)	0.68 (1.24)	0.002
Diet quality, *points/100*	47.6 (14.4)	49.5 (14.3)	48.4 (13.8)	47.1 (14.5)	45.1 (14.5)	<0.001
Energy intake, MJ	9.1 (2.8)	9.1 (3.0)	9.0 (2.6)	9.2 (2.6)	9.0 (2.47)	0.50
			Median (IQR)			
Serves fruit[3], *per day*	1.5 (0.6 to 2.5)	1.6 (0.7 to 2.7)	1.6 (0.8 to 2.6)	1.4 (0.6 to 2.4)	1.4 (0.5 to 2.3)	0.035
Serves vegetables[3], *per day*	1.9 (0.8 to 3.4)	2.1 (0.9 to 3.6)	2.0 (0.7 to 3.4)	1.7 (0.6 to 3.2)	1.8 (0.7 to 3.3)	0.018
Serves dairy, *per day*	1.4 (0.8 to 2.3)	1.4 (0.8 to2.3)	1.4 (0.8 to 2.2)	1.5 (0.8 to 2.5)	1.3 (0.7 to 2.2)	0.54
Serves extras[3], *per day*	4.5 (2.9 to 6.4)	4.1 (2.7 to 6.2)	4.3 (2.8 to 6.1)	4.9 (3.1 to 7.0)	4.6 (3.0 to 6.7)	0.008

[1] Sleep timing behaviour category (bed time; wake up time; sleep hours/day). EE = Early Bed Early Rise (9:20 PM, 7:03 AM, 9.7); EL = Early Bed Late Rise (9:28 PM, 8:09 AM, 10.7); LE = Late Bed Early Rise (10:40 PM, 7:09 AM; 8.5); LL = Late Bed Late Rise (10:46PM, 8:22 AM, 9.6). [2] Statistical tests compared values by sleep timing behaviour category using 1-way ANOVA test for linear trend or and differences in median for food group servings. [3] Fruit included 100% juice; vegetables included legumes & non-fried potato; Extra foods are defined as nutrient-poor foods that are high in energy, fat, sugar and/or salt [34].

Table 3. Association between sleep timing behaviour, BMI z-score, energy intake and diet quality[1]

	Unadjusted[2]				Adjusted[2]			
	β	95% CI		P value	β	95% CI		P value
	Reference category= EE							
BMI z-score								
EL	-0.09	-0.25	0.08	0.307	-0.07	-0.23	0.10	0.413
LE	0.22	0.06	0.38	0.006	0.17	0.00	0.35	0.05
LL	0.22	0.08	0.36	0.002	0.20	0.06	0.34	0.007
DGI-CA score / 100								
EL	-1.07	-2.88	0.73	0.24	-0.14	-2.03	1.75	0.88
LE	-2.38	-4.42	-0.35	0.020	-3.09	-5.32	-0.86	0.007
LL	-4.39	-6.07	-2.70	<0.001	-3.99	-5.66	-2.32	<0.001
Energy intake, kJ								
EL	-130	-476	217	0.46	120	-226	466	0.49
LE	67	-296	429	0.72	-222	-572	127	0.21
LL	-151	-500	198	0.40	-158	-474	158	0.33

[1] Sleep timing behaviour category (bed time; wake up time; sleep hours/day). EE = Early Bed Early Rise (9:20 PM, 7:03 AM, 9.7); EL = Early Bed Late Rise (9:28 PM, 8:09 AM, 10.7); LE = Late Bed Early Rise (10:40 PM, 7:09 AM; 8.5); LL = Late Bed Late Rise (10:46PM, 8:22 AM, 9.6). [2]Multivariable linear regression with BMI z-score or dietary variables as the dependent variables, sleep category as independent variable and in adjusted model the following covariables; gender, age (years), BMI z-score, sleep duration (minutes), measured Physical Activity Level (PAL), income bracket and maternal education (No higher qualification, Trade Certificate, Advanced diploma, Bachelor degree, Graduate/ Postgrad dip or higher), and (in diet quality model) energy intake. Regression analyses were undertaken using STATA IC 11.0 accounting for complex survey design were the primary sampling unit was de-identified postcode, the strata variable was region (state x metropolitan/rest of state) and the sampling weight considered child age, gender and region.