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Sleep timing is associated with overweight and snack consumption in children and adolescents in southern Brazil

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Abstract: Sleep timing is one of the dimensions of sleep that refers to the time of day when sleep occurs. It was included in sleep-related research because of the potential associations between overweight and consumption of meals and snacks. This cross-sectional study aimed to investigate associations between sleep timing, meal and snack consumption, and weight status in 1333 schoolchildren aged 7-14 years. The midpoint of sleep was used as a sleep timing measure obtained by the midpoint between bedtime and wake-up time and classify as Early, intermediate, and Late. Schoolchildren in the Early group were less likely to be overweight (OR: 0.83, 95% CI 0.69; 0.99), had higher odds of mid-morning snack consumption (OR: 1.95, 95%CI 1.56; 2.44) and lower probability to consume the evening snack (OR: 0.75, 95%CI 0.59; 0.94) compared with the Intermediate group. The Late group had lower odds of mid-morning snack consumption (OR: 0.67, 95%CI 0.55, 0.80) than the Intermediate group. The consumption of mid-morning and evening snacks was associated with the Early and the Late midpoint of sleep. These results suggest that bedtime and wake-up time are relevant to consuming meals and snacks and may also be related to a greater probability of being overweight in children and adolescents.

Keywords: midpoint of sleep; eating events; meals; obesity; schoolchildren; bedtime

1. Introduction

In the last decades, studies on chronotype and sleep have increased due to their important relationship with health [1]. Chronotype is a biological construct that allows to identifying individual preferences in timing of sleep and wake, also classified according to the tendency of individuals to be morningness/early or eveningness/late types [2–4]. This construct is directly related to sleep timing that refers to the time of day that sleep occurs [5], and is commonly measured by bedtime, wake-up time, and midpoint of sleep. The midpoint of sleep on free days (MSF) is defined as midpoint between bedtime and wake-uptimes on free days and identifies the chronotype [2].

The research on sleep, nutrition and obesity has predominantly focused on sleep duration [6,7]. However, other dimensions of sleep seem influence health, such as sleep timing may be a better predictor of obesity than sleep duration alone [8]. The evidence suggests that later sleep timing may be associated with poorer health outcomes in children and adolescents, such as sleep duration/quality, eating behaviours and physical activity and sedentary behaviours [9]. Delay and shift in sleep timing appears to cause weight gain due to behavioral and physiological changes [10]. These sleep delays can lead circadian misalignment contributing to weight gain, obesity and adverse metabolic health [11]. The circadian system is composed by a central clock (suprachiasmatic nucleus of hypothalamus) and by peripheral clocks in almost all tissues of body and imposes a rhythmic control over virtually all our bodily functions, for example from when we feel sleepy to when we feel hungry [12].

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Observational studies with children showed associations between later bedtimes, higher energy intake after dinner [13], and increased obesity risk [7,14]. Regarding the midpoint of sleep, a longitudinal study found a positive association between the midpoint of sleep and Fat Mass Index in adolescents aged 12-15 [15]. Studies have shown that morning habits are associated with healthy eating habits, such as breakfast daily [16] compared to children and adolescents with later habits. On the other hand, late habits are associated with higher unhealthy eating habits [16,17], skipping breakfast, eating higher energy dense foods [14,18], lower consumption frequency of fruit and vegetables [18,19] and with overweight and obesity, independent of sleep duration [10,18,20].

However, little is known about the association between sleep timing, frequency of meals and snacks, and weight status in children and adolescents. We hypothesized that children and adolescents with the later midpoint of sleep are more likely to be overweight or obese and consume evening snacks late at night. Moreover, they tend to skip earlier meals, such as breakfast and mid-morning snacks. On the other hand, those in the earlier midpoint of sleep are inversely associated with overweight or obesity and consume more frequently breakfast and mid-morning snacks, in addition to skipping evening snacks This study aimed to assess the association of the midpoint of sleep with children's weight status and meal and snack consumption in children and adolescents aged 7-14.

2. Materials and Methods

2.1. Study design and sample

This cross-sectional study was conducted as a part of a school-based surveillance named Study on the Prevalence of Obesity in Children and Adolescents in Florianópolis, southern Brazil (EPOCA survey), enrolled in public and private schools. The study was carried out between November 2018 and December 2019. The *EPOCA* survey aimed to investigate the prevalence of obesity and its associated factors in children and adolescents from 7 to 14-year-old enrolled between the second and ninth years of elementary school in public and private schools.

The sample size estimation was performed based on information from the School Census of 2017 (34,318 students and 82 schools); outcome overweight including obesity prevalence of 39% [21,22]; acceptable margin of error of 3.5 percentage points, 95% confidence interval and design effect of 1.8. The required sample size was doubled to allow comparisons with previous surveys and to enable subgroup analysis [23], with the addition of 10% for possible losses and refusals. The sample size was estimated at 2891 children and adolescents. The sampling procedure was performed by conglomerates, having primary sampling units the schools in the city divided into strata according to the administrative region and type of school. In each stratum, the sample units were randomly selected, totaling 30 schools (19 public and 11 private). The selection of classes was carried out by a systematic random sampling process based on the list of available classes (2nd to 9th). All students from the selected classes were invited to participate (n=6118) [24]. The schoolchildren who attended the collection day and whose parents/legal guardians signed the Free and Informed Consent Form were included. Anthropometric measurements (weight and height) and dietary intake data were collected from 1671 schoolchildren. Data were excluded for children who had no dietary data (n=188), children who reported implausible dietary data (n=87) (consumption of less than three food items per day or consumption of a number of items greater than the mean + 3 standard deviations assuming a Poisson distribution for food frequency reports) [25], and for children with missing sleep data (n=63). The final sample included 1333 schoolchildren aged 7–14 years (Figure S1).

The study was conducted in accordance with the guidelines of code of Ethics of the World Medical Association (Declaration of Helsinki) and approved by the human Research Ethics Committee of the Federal University of Santa Catarina (UFSC, protocol number 7539718.1.0000.0121).

2.2 Assessment of Sleep data

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Sleep data were assessed using a questionnaire with questions adapted from the School Sleep Habits Survey developed and validated by the Bradley Hospital/Brown University in 1994 [26]. The adapted questionnaire was administered to parents or guardians. Regarding sleep timing, the following questions were used: a) "What time does the child/adolescent usually go to bed on school days?" b) What time does the child/adolescent usually wake up on school days?"; c) "What time does the child usually go to bed on weekends (non-schooldays)? d) "What time does the child usually wake up on weekends (non-school days)?"Answers to these questions were requested within hours (local time) [27].

Daily sleep duration was calculated as the difference between bed and wake times plus the number of hours slept during the day (nap). Weekday and weekend sleep duration were also calculated. A total sleep duration was calculated as follows: [5 x weekday sleep (h) + 2 x weekend sleep (h)]/7. Bedtimes and wake-up times were described in local time according to the parent answers.

The midpoint of sleep on free days (MSF) was calculated as the halfway point between bedtime and wake-up time [bedtime (local time) + night sleep duration/2] on free days [28]. The hypothesis is that bedtime and waking time on free days (without school or work) is highly influenced by the circadian clock [29]. In this study we consider non-school days (Saturday and Sunday) as free days to calculate MSF. We also perform the correction of MSF, as proposed by Roenneberg et al (2004) [30] to compensate for sleep debt accumulated over the schooldays, obtaining the MSF sleep-corrected MSFsc = MSF - 0.5*(SDF - (5*SDW+ 2*SDF)/7) where SDF is sleep duration on non-schooldays and SDW is sleep duration on schooldays. For example, a child who go to bed 0:00 am and wake up 11:00 am on non-schooldays and go to bed 21:00 pm and wake up 7:00 am on schoolday: MSF= (0:00+ (11.00)/2) = 5.5h or in local time 5:30 and MSFsc= 5.5-0,5x*11.00-(5*10.00+2*11.00)/7= 5,14 or in local time 5:08. The dimension of MSFsc is not a score but a representation of local time and was transformed into tertiles. In the first tertile were those with more morning behaviors and this group was denominated "Early". The second tertile was named "Intermediate", and the third was named "Late" composed by schoolchildren with evening preference [31,32].

2.3 Socioeconomic data and anthropometric measurements

Type of school (public or private) and school shift (morning or afternoon) were obtained through a list provided by the school administration. Maternal education was classified into three categories (0-8, 9-11, and >12 years) and used as a proxy for socioeconomic status.

Weight and height measurements were performed at school by trained researchers following standard techniques [33] and taken in lightly dressed barefoot children. Researchers were trained according to the protocol proposed by the International Society for the Advancement of Kinanthropometry (ISAK) [34]. Weight was measured with a portable digital scale (Marte, model LS200P, 200kg maximum capacity, 50g precision). A portable stadiometer (AlturExata, 1mm precision) was used for height. The body mass index (BMI) was calculated as weight (kg) divided by height squared (m). Age-and sex-specific BMI z-scores were calculated according to World Health Organization criteria for children and adolescents aged 5-19 years [35]. The weight status was categorized into without overweight (underweight and normal weight, BMI z-score <+1) or overweight including obesity (BMI z-score for age >= +1).

2.4 Assessment of meal and snack consumption, physical activity, and screen use

Data on meal and snack consumption, frequency of physical activity and screen use were obtained using the Food Intake and Physical Activity of Schoolchildren (Web-CAAFE) questionnaire, a validated, web-based, self-report tool for use in the school setting. The Web-CAAFE was developed and validated for use with children [36,37] and adolescents [38], considering the cognitive development of 7-10 year-olds [37]. Usability tests showed child capacity to understand and respond to Web-CAAFE [37]. Concerning food consumption, a reproducibility test showed moderate-to-high values of intraclass correlation coefficients [39].

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Web-CAAFE consists of three sections: registration (name, sex, age, weight, height, date of birth and school shift), food intake and physical and sedentary activities. The food intake section is a previous-day recall divided into three meals and three snacks consumption ordered chronologically and presented sequentially on the screen: Breakfast, mid-morning snack, lunch, mid-afternoon snack, dinner, and evening snack. For the food intake section, a robot like avatar explains the concept of each meal or snack. Children who did not consume any food item available in the list of 31 food icons or consumed only water were classified as meal/snack skippers. More details about this section could be found elsewhere [40]. Physical activity and screen use were described in details by Costa et al. 2013 and assessed by three periods of the day (morning, afternoon and night). Daily frequency of physical activity was categorized into tertiles: 0 to 2 times (first tertile), 3 to 4 times (second tertile), and 5 times or more (third tertile). Daily frequency of screen use (watching television, using a computer, using a smartphone/tablet, and playing video games) was categorized into never, once a day, twice a day, and more than 3 times a day [27].

Each child and adolescent answered the instrument once. Web-CAAFE does not provide the time of eating event but the six daily eating occasions are ordered chronologically. Also screen time and physical activity duration are not assessed by the tool, although these activities were presented in three periods of the day. The questionnaire was applied in a school computer room in the presence of trained researchers who assisted the respondents when needed. Data were collected on morning and afternoon shift and in different days of the week to reflect meal and snack consumption on school days (Monday to Thursday) and a weekend day (Sunday).

2.5 Statistical analysis

Sample characteristics are described as absolute and relative frequencies and 95% confidence intervals (95% CI) for categorical variables. All continuous sleep variables presented non-normal distribution, opting for standard presentation of the results (median; 25th and 75th percentiles). To investigate the midpoint of sleep differences according to sleep continuous variables the Kruskal-Wallis test was applied. Mann-Whitney test was performed to verify median differences in sleep variables by weight status and the frequency of meals and snack consumption.

The association of midpoint of sleep (MSFsc) (principal exposure variable) with weight status, meal and snack consumption (outcome variables) was tested using multivariate logistic regression. The intermediate category of midpoint of sleep was considered as the reference. The model 1 considers the weight status as the outcome and was adjusted for the following exposure variables: gender, age group (7–10 or 11–14 years), daily frequency of screen use (never, once a day, twice a day, and more than 3 times a day), daily frequency of physical activity (0 to 2 times (first tertile), 3 to 4 times (second tertile), and 5 times or more (third tertile), type of school (public/ private), maternal education (0-8, 9-11 or ≥12 years of schooling) and total sleep duration (hours). In model 2 meal and snack consumption was the outcome adjusted for variables from Model 1, weight status (overweight including obesity or not overweight) and day of food intake report (weekday or weekend). The final models did not include the school shift due to multicollinearity with sleep duration as previously reported [27]. Due to the proximity of breakfast, mid-morning snack and evening snack with sleep time, the results will be focused on these meals. The analysis performed for lunch, afternoon snack and dinner were not associated with the midpoint of sleep and, therefore, will be shown as a supplementary material (see SM). Stata version 14.0 was used for analysis and $p < 0.05$ was considered statistically significant. All analyses were adjusted for the survey design effect (using svyset command in Stata).

3. Results

The total sample consisted of 1333 children aged 7-14 years. Overweight (including obesity) was observed in one-third of the sample and was more prevalent in boys than girls. Lunch and dinner were consumed by more than 90% of the children, mid-afternoon snack and breakfast were

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consumed by around 80% of the children, whereas mid-morning snack (58.7%) and evening snack (54.8%) were consumed by around 50% of the children. (Table 1).

Table 1. Description of the sample of 7–14-year-old schoolchildren according to gender. Floriano-polis, Brazil, 2018/2019.

Characteristics	Total (n=1333)		Female (n=756)		Male (n=577)	
	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)
Gender (n=1333)						
Female	756	53.1 (49.2-57.0)	-	-	-	-
Male	577	46.9 (42.9-50.8)	-	-	-	-
Age (n=1333)						
7-10 years	782	57.8 (49.7-65.6)	446	58.0 (48.3-67.2)	331	57.4 (50.2-64.2)
11-14 years	551	42.2 (34.4-50.3)	310	41.9 (32.8-51.8)	246	42.6 (35.8-49.8)
Weight status[a] (n=1316)						
Non-overweight	876	66.2 (63.0-69.4)	530	73.1 (63.8-80.7)	346	58.4 (53.3-63.4)
Overweight including obesity	440	33.8 (30.6-37.1)	218	26.9 (19.3-36.2)	222	41.6 (36.6-46.7)
Type of school (1333)						
Public	783	58.7 (56.1-61.4))	468	61.9 (58.4-65.3)	315	54.6 (50.5-58.6)
Private	550	41.3 (38.6-43.9)	288	38.1 (34.7-41.6)	262	45.4 (41.4-49.5)
School shift (1328)						
Morning	746	52.4 (44.9-59.8)	405	53.9 (50.3-57.4)	341	59.2 (55.1-63.2)
Afternoon	582	47.6 (40.2-55.1)	347	46.1 (42.6-49.7)	235	40.8 (36.8-44.9)
Daily frequency of physical activity (n=1333)						
0-2 times	804	58.6 (53.7-63.3)	434	58.6 (51.1-65.8)	370	58.5 (52.3-64.4)
3-4 times	366	27.2 (23.9-30.8)	222	27.8 (23.9-32.0)	144	26.6 (22.4-31.2)
≥ 5 times	163	14.2 (11.6-17.3)	100	13.6 (9.4-19.4)	63	14.9 (10.4-20.9)
Daily frequency of screen use (n=1333)						
never	319	21.1 (15.7-27.8)	165	18.1 (11.9-26.6)	154	24.5 (19.3-30.5)
once	332	26.5 (24.2-29.0)	205	29.3 (24.4-34.6)	127	23.4 (19.2-28.1)
twice	246	17.3 (15.1-19.7)	127	16.9 (15.8-18.2)	119	17.7 (12.8-23.9)
three times or more	436	35.1(31.1-39.2)	259	35.6 (32.4-39.0)	177	34.5 (27.6-42.0)
Maternal education, years of schooling (n=1288)						
0-8	244	9.1 (2.4-28.5)	138	9.8 (2.7-29.7)	106	8.2 (2.2-26.9)
9-11	386	22.2 (12.4-36.4)	226	25.2 (15.3-38.6)	160	18.9 (9.0-35.3)
≥12	658	68.7 (43.0-86.5)	365	65.0 (40.5-83.5)	293	72.9 (45.6-89.6)
Meals and snacks consumed						
Breakfast	1114	83.0 (80.4-85.4)	632	82.1 (76.8-86.4)	482	84.1 (80.4-87.2)
Mid-morning snack	753	58.7 (53.4-63.8)	452	62.4 (54.2-70.1)	301	54.5 (50.0-59.3)
Lunch	1293	97.8 (96.6-98.6)	730	97.7 (95.8-98.8)	563	97.9 (96.3-98.8)
Mid-afternoon snack	1115	88.0 (82.2-87.3)	656	88.3 (84.4-91.2)	459	81.2 (76.8-84.9)
Dinner	1218	92.2 (89.3-94.4)	694	91.4 (86.6-94.6)	524	93.2 (90.2-95.2)
Evening snack	738	54.8 (50.8-58.8)	449	59.7 (54.1-65.1)	289	49.3 (45.6-53.1)
Day of food intake report (n=1333)						
Weekday	1067	87.6 (70.0-95.6)	598	86.7 (67.9-95.2)	469	88.6 (69.6-96.3)
Weekend	266	12.4 (4.4-30.5)	158	13.3 (4.8-32.1)	108	11.4 (3.7-30.4)
	Median (p25; p75)		Median (p25; p75)		Median (p25; p75)	
Sleep duration (h) (n=1333)						
Total	9.79 (9.14;10.54)		9.86 (9.21; 10.64)		9.71 (9.08; 10.43)	
Weekday	9.50 (8.33;10.50)		9.67 (8.75; 10.50)		9.50 (9.92; 10.50)	
Weekend	10.5 (9.50;11.00)		10.50 (10.00;11.17)		10.00 (9.50; 11.00)	
Bedtime (local time) (n=1333)						

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Weekday	22:00 (21:30; 23:00)	22:00 (21:30; 23:00)	22:00 (21:30; 23:00)
Weekend	23:00 (22:30; 0:00)	23:00 (22:30; 0:00)	23:00 (22:30; 0:00)
Wake up time (local time) (n=1333)			
Weekday	7:00 (6:30; 8:30)	7:00 (6:30; 9.00)	7.00 (6:40; 8:30)
Weekend	9:30 (8:30; 10:30)	9:35 (9:00; 10:30)	9:00 (8:30; 10:00)
MSFsc (n=1333)	3:58 (3:15; 4:38	3:35 (3:14; 4:38)	3:56 (3:17; 4:38)

Note: CI, confidence interval. P25; P75, interquartile range MSFsc: midpoint of sleep on free days corrected to sleep debt.

[a] Classified according to WHO (2007).

Students with overweight and obesity had later bedtimes on weekdays (median: 22:00, p25; 75= 21:30; 23:00) and weekends (median: 23:00 p25; 75=22:30; 0:00) than non-overweight students (median: 22:00, p25; 75=21:30; 22:30 and median: 23:00, p25; 75=22:30; 0:00), respectively) (Table 2). The means were 22:17; 23:18 and 22:09; 23:11, respectively (data not shown).

Table 2. Median of sleep variables according to weight status. Florianopolis, Brazil, 2018/2019.
Note: MSFsc: midpoint of sleep on free days corrected to sleep debt debt *Mann-Whitney test

Sleep characteristics	**Non- overweight (n= 876)**	**Overweight including obesity (n= 440)**	**p***
	median (p25; p75)	**median (p25; p75)**	
Sleep duration (h)			
Total	9.79 (9.14; 10.60)	9.79 (9.14; 10.43)	0.291
Weekday	9.50 (8.75; 10.50)	9.50 (8.83; 10.50)	0.335
Weekend	10.50 (9.58; 11.00)	10.08 (9.5; 11.00)	0.290
Bedtime (local time)			
Weekday	22:00 (21:30; 22:30)	22:00 (21:30; 23:00)	0.021
Weekend	23:00 (22:30; 0:00)	23:00 (22:30; 0:00)	0.020
Wake up time (local time)			
Weekday	7:00 (6:30; 9:00)	7:00 (6:30; 8:30)	0.829
Weekend	9:30 (8:30; 10:20)	9:30 (8:30; 10:30)	0.455
MSFsc	3:56 (3:13; 4:37)	3:59 (3:18; 4:40)	0.223

The breakfast consumers had higher sleep duration in total and on weekdays, an earlier bedtime on weekdays and weekends, an earlier wake-up time on weekends, and consequently lower MSFsc than breakfast-skippers (Table 3).

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Table 3. Median of sleep variables according to breakfast, mid-morning snack, and evening snack, Florianopolis, Brazil, 2018/2019

Sleep characteristics	Breakfast			Mid-morning snack			Evening snack		
	No (n=219)	Yes (n=1114)	p*	No (n=580)	Yes (n=753)	p*	No (n=595)	Yes (n=738)	p*
	median (p25; p75)	median (p25; p75)		median (p25; p75)	median (p25; p75)		median (p25; p75)	median (p25; p75)	
Sleep duration (h)									
Total	9.60 (9.00;10.29)	9.86 (9.17;10.64)	0.005	9.95 (9.29;10.64)	9.69(9.04;10.45)	0.001	9.69(9.07;10.36)	9.92(9.21;10.68)	0.002
Weekday	9.33 (8.50;10.25)	9.67 (8.83;10.50)	0.002	10.00 (9.00;10.50)	9.50(8.65;10.50)	<0.001	9.50(8.65;10.33)	9.88(9.00;10.50)	0.001
Weekend	10.15 (9.50;11.00)	10.50 (9.50;11.00)	0.467	10.50 (10.00;11.00)	10.15(9.50;11.00)	0.364	10.00(9.50;11.00)	10.50(9.50;11.00)	0.189
Bedtime (local time)									
Weekday	22:15 (22:00; 23:00)	22:00 (21:30; 22:45)	<0.001	22:00 (21:55; 23:00)	22:00(21:30; 22:30)	<0.001	22:00(21:30; 22:30)	22:00(21:30; 23:00)	0.071
Weekend	23:30 (22:30; 0:00)	23:00 (22:30; 0:00)	<0.001	23:00(22:30; 0:00)	23:00(22:00; 23:40)	<0.001	23:00(22:30; 0:00)	23:00(22:30; 0:00)	0.464
Wake-up time (local time)									
Weekday	7:00 (6:30; 8:30)	7:00 (6:30; 8:50)	0.352	7:30 (6.45;9:00)	7:00(6:30;8.00)	<0.001	7:00(6:30; 8:00)	7.08(6:30;9:00)	<0.001
Weekend	10:00 (8.65;11:00)	9:30 (8:30; 10:00)	0.001	9:40 (9:00; 10:30)	9.00(8:30;10.00)	<0.001	9:30(8:30; 10:15)	9:30(8:30; 10:30)	0.079
MSFsc	4:03 (3:19; 5:00)	3:56 (3:23; 4:35)	0.010	4:09 (3:28; 4:51)	3:27(3:08; 4:30)	<0.001	3:92(3:21; 4:52)	4:00(3:29; 4:71)	0.033

Note: MSFsc: midpoint of sleep on free days corrected to sleep debt debt

*Mann Witney test

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The differences in bedtime, wake-up time, and sleep duration across the 3 categories of the midpoint of sleep were statistically significant except for sleep duration on weekdays (see Table S1). Table 4 shows the odds ratio of the associations between the midpoint of sleep categories and weight status. Belonging to the Early group of the midpoint of sleep was associated with lower odds of being overweight (including obesity) (OR: 0.83; 95% CI 0.69; 0.99) after covariates adjustments.

Table 4. Associations between weight status and the midpoint of sleep categories. Florianopolis, Brazil, 2018/2019.

	Weight status (overweight including obesity)			
	Crude OR (95% CI)	p	**Adjusted[a] OR (95% CI)**	**p**
Early	0.77 (0.58;1.04)	0.084	0.83 (0.69;0.99)	0.043
Intermediate	1	-	1	-
Late	0.75 (0.41;1.37)	0.309	0.87 (0.49;1.55)	0.595
Gender	0.52 (0.29;0.93)	0.032	0.51 (0.27;0.96)	0.040
Age	0.92 (0.80;1.05)	0.202	0.86 (0.75;0.97)	0.022
Screen use				
once	0.60 (0.43;0.84)	0.008	0.63 (0.43;0.91)	0.020
twice	0.73 (0.51;1.04)	0.076	0.77 (0.54;1.10)	0.127
three times or more	0.86 (0.59;1.25)	0.389	0.92 (0.65;1.29)	0.574
Physical activity				
3-4 times	0.96 (0.57;1.64)	0.876	0.96 (0.53;1.75)	0.884
≥5 times	0.84 (0.41;1.75)	0.606	0.81 (0.34;1.93)	0.597
Type of school	0.90 (0.72;1.12)	0.302	0.91 (0.70;1.18)	0.424
Maternal education, years of schooling				
9-11	1.58 (0.90;2.45)	0.106	1.59 (0.99;2.51)	0.051
≥12	1.12 (0.73;1.66)	0.624	1.13 (0.60;2.11)	0.691
Total sleep duration (h)	0.92 (0.83;1.02)	0.097	0.90 (0.79;1.03)	0.108

Note: OR, odds ratio. CI, confidence interval. Reference categories: gender (male); age (7-10 years); screen use (never); Physical activity (0-2 times); type of school (public school); maternal education (0-8 years). [a]Adjusted by gender, age, screen use, physical activity, type of school, maternal education, and total sleep duration

Regarding meal and snack consumption, the Early group had higher odds of mid-morning snack consumption (OR: 1.95; 95%CI 1.56; 2.44), and the Late group had lower odds of mid-morning snack consumption (OR: 0.67; 95%CI 0.55; 0.80) than Intermediate group (Table 5).

In evening snack, the students in the Early group had lower odds of consuming this snack (OR: 0.75; 95%CI 0.59; 0.94), and the Late group had higher odds of evening snack consumption (OR: 1.30; 95%CI 0.99; 1.71) compared to the Intermediate group. We also observed that overweight or obese children with overweight were less likely to consume breakfast (OR: 0.65; 95%CI 0.47 0.90) and mid-morning snacks (OR: 0.75; 95%CI 0.64; 0.87) than those without overweight children (Table 5). No differences were found in lunch, mid-afternoon snacks, and dinner (see Table S2).

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Table 5. Associations between breakfast, mid-morning snack, evening snack consumption, and the midpoint of sleep categories. Florianopolis, Brazil, 2018/2019.

	Breakfast				Mid-morning snack				Evening snack			
	Crude OR (95% CI)	p	Adjusted[a] OR (95% CI)	p	Crude OR (95% CI)	p	Adjusted[a] OR (95% CI)	p	Crude OR (95% CI)	p	Adjusted[a] OR (95% CI)	p
Early	0.98(0.44;2.20)	0.966	0.97(0.43;2.21)	0.936	1.82(1.34;2.49)	0.002	1.95(1.56;2.44)	<0.001	0.83(0.64;1.08)	0.138	0.75(0.59;0.94)	0.019
Intermediate	1	-	1	-	1	-	1	-	1	-	1	-
Late	0.63(0.31;1.27)	0.167	0.54(0.29;1.02)	0.057	0.66(0.52;0.82)	0.002	0.67(0.55;0.80)	0.001	1.34(0.96;1.87)	0.078	1.30(0.99;1.71)	0.057
Gender	0.87(0.54;1.39)	0.514	0.77(0.51;1.16)	0.190	1.38(0.99;1.94)	0.058	1.48(1.01;2.17)	0.045	1.52(1.21;1.91)	0.003	1.45(1.21;1.73)	0.001
Age	0.73(0.55;0.96)	0.029	0.78(0.44;1.39)	0.350	1.23(0.62;2.46)	0.513	1.14(0.60;2.18)	0.660	0.64(0.45;0;91)	0.018	0.63(0.46;0.85)	0.007
Screen use												
once	1.05(0.67;1.63)	0.821	1.23(0.67;2.26)	0.454	0.99(0.76;1.29)	0.964	0.95(0.66;1.37)	0.763	1.21(0.79;1.86)	0.346	1.29(0.86;1.95)	0.193
twice	0.72(0.36;1.45)	0.318	0.73(0.39;1.40)	0.308	0.62(0.40;0.97)	0.038	0.61(0.39;0.96)	0.037	0.89(0.52;1.54)	0.655	0.94(0.68;1.31)	0.704
three times or more	1.01(0.57;1.80)	0.973	1.08(0.51;2.29)	0.812	1.06(0.77;1.45)	0.693	0.92(0.63;1.36)	0.654	1.35(0.64;2.86)	0.386	1.54(0.69;3.47)	0.256
Physical activity												
3-4 times	1.53(0.72;3.23)	0.231	1.48(0.74;2.96)	0.238	1.51(1.05;2.17)	0.030	1.46 (0.96;2.22)	0.071	1.42(1.06;1.89)	0.023	1.55(1.12;2.15)	0.014
5 times	2.64(1.95;3.57)	<0.001	2.33(1.72;3.16)	<0.001	2.28(1.08;4.80)	0.033	2.00(0.80;5.03)	0.122	3.04(1.62;5.72)	0.003	2.95(1.55;5.65)	0.004
Type of school	1.18(0.80;1.73)	0.362	1.08(0.68;1.73)	0.710	1.45(0.95;2.21)	0.075	1.15(0.60;2.20)	0.638	0.83(0.61;1.12)	0.193	0.78(0.52;1.18)	0.211
Maternal education, years of schooling												
9-11	0.81(0.51;1.30)	0.343	0.85(0.58;1.25)	0.362	1.06(0.57;1.95)	0.847	1.01(0.50;2.02)	0.987	1.07(0.71;1.62)	0.713	1.22(0.80;1.86)	0.306
≥12	0.98(0.61;1.59)	0.943	0.90(0.53;1.50)	0.640	1.28(0.76;2.14)	0.310	0.94(0.48;1.84)	0.830	0.84(0.68;1.04)	0.096	1.06(0.73;1.52)	0.738
Day of the food intake report												
Weekday	0.90(0.56;1.45)	0.638	0.83(0.51;1.35)	0.415	2.07(1.19;3.61)	0.016	1.98(1.08;3.62)	0.031	0.86(0.53;1.41)	0.517	0.87(0.50;1.51)	0.587
Weight status												
overweight	0.66(0.42;1.04)	0.068	0.65(0.47;0.90)	0.015	0.72(0.63;0.83)	<0.001	0.75(0.64;0.87)	0.002	0.67(0.41;1.10)	0.101	0.71(0.38;1.33)	0.248
Total sleep duration (h)	1.16 (1.02;1.31)	0.026	1.19(1.03;1.38)	0.023	0.75 (0.59;0.97)	0.034	0.84(0.71;0.99)	0.039	1.21 (1.09;1.36)	0.004	1.08(1.00;1.16)	0.040

Note: OR, odds ratio. CI, confidence interval. Reference categories: gender (male); age (7-10 years); screen use (never); Physical activity (0-2 times); type of school (public school); maternal education (0-8 years); day of food intake report (weekend); weight status (non-overweight) [a]Adjusted by gender, age, screen use, physical activity, type of school, maternal education, day of food intake report, weight status, and total sleep duration.

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4. Discussion

In the present study, we observed an inverse association between overweight (including obesity) and the Early midpoint of sleep. These cross-sectional results do not allow cause and effect association; however, one possible explanation is that children in Early group tend to had healthier eating patterns and have more physical activities, which may impact weight status [19]. It is also possible that they have more adequate sleeping and waking behavior therefore there is no entrainment of circadian rhythms that affect metabolism and weight regulation [41]. For example, if a child stays up late at night, exposed to artificial lights, it causes the entrainment of circadian cycle, which can affect the weight control. Light (and darkness) is the predominant zeitgeber (entraining stimulus) for the circadian clocks [1].

However, we did not observe association between overweight and the Late group, similarly to the observed by other studies [19,42]. On the other hand, previous studies reported that later chronotypes were related to higher BMI scores [18,20]. A longitudinal study found association between the midpoint of sleep and Fat Mass Index, particularly in adolescents of 12-15 years [15].

Children and adolescents with overweight had later bedtimes on school nights and weekend nights than without overweight students, similar to other studies [10,20]. One possible explanation is that the students who go to bed later may be eating more energy-dense foods that are convenient for late night eating, reported by previous studies [17,43–45]. Furthermore, Golley et al. (2013) reported that late bed–late rise was predictive of a higher BMI and a lower diet quality in children and adolescents [14]. Another study investigated the impact of sleep improvement on food choices in adolescents with later bedtimes. After the intervention, they observed that earlier bedtimes were positively associated with healthy foods intake on breakfast [46]. In addition, one important factor that could explain delayed bedtime is screen use [47]. A study found children postpone their bedtime to prolong screen entertainment at night [48]. Furthermore, exposure to bright light before bedtime might lead to cognitive and emotional activation and reduce melatonin production [47] keeping children on alert mode and delaying sleepiness. On school days this behavior is not desirable, particularly in children who go to school in the morning shift. As a result, children tend to sleep less, accumulating a sleep debt during the week that could result in a short sleep, which is prospectively associated with overweight and obesity [49

Our study observes no differences in midpoint of sleep categories of breakfast consumers, but we found they tend to have earlier bedtimes than breakfast skippers. Similar to this finding, other studies reported that schoolchildren who had later bedtimes were more likely to skip breakfast [16,50]. In addition, we found that overweight children and adolescents were less likely to have breakfast and mid-morning snack than those without overweight (Data not shown). The result related to breakfast is in agreement with a systematic review that showed that children and adolescents who skipped breakfast had an obesity risk of 43% greater than breakfast consumers in cross-sectional studies (no significant link was found in cohort studies) [51].

To date no studies were found in relation to mid-morning and evening snacks and its association with overweight. We also observed girls were more likely to consume the evening snack, however, other study found no gender differences in meal skipping [52].

In this study, we identified an association between the Early and Late midpoint of sleep and mid-morning and evening snack consumption. The mid-morning associations could be related to the time interval between eating events. Child/adolescent in Early group wakes up earlier, he/she has an intermediate mid-morning or pre-lunch snack, while a child/adolescent in the Late group who wakes up later had breakfast and does not necessarily have an intermediate snack because there are not many hours for lunch.

Similarly, a negative association was observed between evening snack consumption and children who had the Early chronotype. One explanation is because they go to bed earlier and there is not enough time to have a snack after dinner, while children in the Late group supposedly go to bed later and may feel hungry after dinner and before bedtime. Although chronotype was not measured, a study found a positive association between later bedtime and more calories and fat intake after

dinner [13]. These hypotheses are support by differences also found in wake-up time, bedtime and between consumers and skippers of these snacks.

In the present study, foods eaten on mid-morning and evening snack were not assessed. Nevertheless, studies performed in public schools on the same city of this study identified an "unhealthy" evening snack pattern composed by pizza/hamburger/hot dog, chips, sodas, cake and fruit juice by children [40,53]. The use of midpoint of sleep, bedtime, wake time, not only sleep duration are a strength of this study. It has been shown that sleep habits, not only sleep duration, play an important role related to obesogenic behaviors in children [10]. In addition, our study included a sample composed of students from public and private schools, a proxy for socioeconomic position. However, we found no association with this variable, although there are important socioeconomic differences between these groups that may affect sleep timing [54]. The analyses were adjusted to account for physical activities [55], screen use [56], sleep duration [9,19], age and gender, which has recognized associations with sleep patterns and chronotype [2].

This study has some limitations, including cross-sectional nature that cannot fully demonstrate a clear cause-effect conclusion. Furthermore, sleep data were measured subjectively by parents or guardians, however, subjectively measures are used in most large epidemiological studies [57]. Meal and snack consumption, frequency of screen use and physical activities were self-reported by children and adolescents, and we cannot exclude the possibility of social desirability and difficulties in recalling past events [37]. The Web-CAAFE avatar explains the concept of each meal or snack to help children and adolescents to identify eating occasions. However, it is possible that some of them incorrectly allocated foods on eating occasions [40]. Children younger than 10 years are still developing cognitive abilities to accurately recall diet and physical activity [58,59]. The dietary and physical activity information are derived from the children themselves without help from parents or guardians as the questionnaire was designed considering the cognitive skills and literacy levels of children aged 7–10 years and has been validated in the study population [36,38]. Also, the use of one-day meal and snack consumption data, may not reflect the usual frequency of consumption of meals and snack [60]. However, this method is widely accepted to assess food intake and meal/snack frequency at the population level [61]. Dietary intake or meal timing were not evaluated or controlled for, limiting our ability to investigate the influence of these characteristics in midpoint of sleep. The findings of this study elucidated important aspects related to sleep timing associated with overweight and meal and snacks consumption in schoolchildren aged 7–14 years in southern Brazil. These finding suggest interventions promoting a consistent early bedtime that may reduce obesity risk by promoting earlier meal timing [13] and improve healthier foods intake [46]. Parental control of sleep timing, including a bedtime routines and earlier betimes could be important in a long run to children and adolescents health [62,63] and for weight management concurrently and in the transition to adulthood [64].

5. Conclusions

This study identified that children and adolescents with the early midpoint of sleep were less likely to be overweight, and the overweight students had later bedtimes. The consumption of mid-morning and evening snacks was associated with the midpoint of sleep. The earlier type of schoolchildren was more likely to consume the mid-morning snack, while the later type of schoolchildren was less likely to consume this snack. The earlier type was less likely to consume the evening snack.

These results suggest that sleep timing is relevant to snack consumption and may also be related to a greater risk for the development of overweight in children and adolescents. School interventions could be proposed to promote earlier bedtimes and reduce screen use. Further research is needed to examine the causal relationship between sleep timing and meal and snack intake and the association of meal patterns and sleep timing with a prospective and longitudinal study design.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: Flow chart of the study design; Table S1: Description of sleep variables

according to the midpoint of sleep. Florianopolis, Brazil, 2018/2019.; Table S2: Associations between the midpoint of sleep and mid-afternoon snack, lunch, and dinner. Florianopolis, Brazil, 2018/2019.

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