



Late bedtime combined with more screen time before bed increases the risk of obesity and lowers diet quality in Spanish children

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ABSTRACT

This cross-sectional study aimed to investigate whether the combination of bedtime and screen time (ST) before bed were associated with obesity and diet quality in toddlers and school-aged children. Parents reported children's bedtimes and ST before bed (0 min, 1–30 min, >30 min). We then defined bed + screen time behavior using bedtime median cut-offs (early [EB] or late [LB]) and ST responses, resulting in four groups: EB–0'ST, EB ≤ 30'ST/LB–0'ST, EB > 30'ST/LB ≤ 30'ST, and LB > 30'ST. For all participants (n = 1133; 5.4 ± 2.7 years, 49.7% girls, 51.9% school-aged) we evaluated body mass index (BMI), diet quality, sleep-related variables, physical activity, and health-related quality of life (HRQoL). Outcome variables were compared across bed + screen time behavior groups, stratified by age group (toddlers and school-aged children) using general linear models for continuous variables, as well as chi-squared tests or logistic regressions for categorical variables. Additionally, we calculated linear p-trends. Analyses were adjusted for sociodemographic variables, BMI, and physical activity (unless the variable was tested). The results showed that toddlers and school-aged children in the LB ≥ 30'ST group were more likely to have overweight/obesity (OR: 3.42 [95%CI:1.41,8.26] and OR: 2.53 [95%CI:1.10,5.03], respectively) than those in the EB–0'ST group. Additionally, toddlers and school-aged children in the EB > 30'ST/LB ≤ 30'ST and LB > 30'ST groups showed significantly lower adherence to the Mediterranean diet compared to the other groups (p < 0.001). Regarding sleep-related outcomes, we observed that the combination of LB and more ST was associated with poorer sleep quality and shorter sleep duration in toddlers and school-aged children (p < 0.001). These findings emphasize the importance of promoting earlier bedtimes and limiting ST before bed as part of obesity prevention strategies for children. Furthermore, such intervention could benefit the quality of children's diet and overall lifestyle.

1. Introduction

Obesity in children, in part, can be attributed to a combination of behaviors that impact weight and dietary habits (Jebeile, Kelly, O'Malley, & Baur, 2022). For example, late bedtimes are associated with obesity, possibly due to factors such as short sleep duration and increased social jet lag (Adamo, Wilson, Belanger, & Chaput, 2014; Chaput et al., 2023; Golley, Maher, Matricciani, & Olds, 2013; Olds, Maher, & Matricciani, 2011; Skjåkødegård et al., 2021). Moreover, late bedtime can contribute to obesity by extending eating time into the night (Adamo et al., 2014). In addition, evidence shows that late bedtimes in school-aged children are associated with poor diet quality,

reduced physical activity, and increased screen time (Adamo et al., 2014; Golley et al., 2013; Olds et al., 2011; Ramírez-Contreras, Santamaría-Orleans, Izquierdo-Pulido, & Zerón-Rugero, 2022; Skjåkødegård et al., 2021).

Interestingly, Adamo et al. (Adamo et al., 2014) pointed out that screen time could be a potential role in the relationship between late-bedtime and obesity. As such, it has been suggested that greater screen time could be associated with excessive energy intake (Adamo et al., 2014). Note that eating while watching screens reduces satiety and encourages mindless eating (Chaput, Klingenberg, Astrup, & Sjödin, 2011; Jebeile et al., 2022). Furthermore, increased screen time is significantly related to the consumption of energy-dense foods in

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children (Chaput et al., 2011; Pérez-Farinós et al., 2017). Likewise, toddlers with more screen exposure tend to consume more sugary foods and beverages (P. Li et al., 2022). Additionally, greater screen time negatively affects sleep outcomes (Hill et al., 2016; C. Li, Cheng, Sha, Cheng, & Yan, 2020), including sleep timing and duration, which as mentioned above, can also be associated with obesity and poor dietary habits. Unfortunately, prior studies have focused on bedtime and screen time separately, which may not reflect real-life situations accurately, as highlighted by Chaput and Dutil (Chaput & Dutil, 2016). Accordingly, a more inclusive and integrated approach is needed to effectively address current health challenges (Chaput & Dutil, 2016). Thus, our study investigates whether the combination of two behaviors (bedtime and screen time) associates with BMI and dietary intake in toddlers and school-aged children. Furthermore, we examine how these variables associate with sleep-related outcomes and physical activity in this population.

2. Methodology

2.1. Study design, settings, participants and protocol

This cross-sectional study included Spanish toddlers (2–4 years) and school-aged children (5–12 years) whose parents/caregivers were subscribed to Laboratorio's Ordesa Family Club, a web platform that is intended to promote healthy habits in children. Parents/caregivers of eligible children received an e-mail explaining the project and encouraging them to participate by completing an online questionnaire. Each group was provided with a specific link to a questionnaire designed to assess variables according to their respective age ranges. To improve the quality of the collected data, online questionnaires were programmed to alert parents if they skipped a question and explicitly ask them to respond before moving to the next section. Additionally, alert messages were integrated to prompt parents to report any unusual bed or wakeup schedules. Note that these links were shared during the academic year (between May–June 2021). The inclusion criteria were being a parent of a child aged 2–12 years and willingness to participate in the study. Based on these criteria, a total of 1456 children were recruited for this study. Among them, 93 declined to participate, 23 were excluded for providing incorrect data regarding weight and height, 174 were outside the age range, and 33 were excluded for other reasons. This resulted in a final analytical sample of 1133 participants (Fig. S1).

2.2. Outcome variables

2.2.1. Body mass index

Parents reported children's height and weight to calculate BMI (kg/m²). Self-reported weight and height show a high agreement with direct measurements (Kee et al., 2017). Children's BMI was then classified according to the International Obesity Taskforce into: "underweight", "normal weight", or "overweight/obesity" according to specific age and gender BMI cut-off criteria (Cole & Lobstein, 2012). Furthermore, we calculated age- and sex- BMI z-scores using the Center for Disease Control and Prevention growth standards for children aged 2–18 years old (Centers for Disease Control and Prevention, 2009).

2.2.2. Diet quality

This variable was assessed using the Mediterranean Diet Quality Index (KIDMED) (Serra-Majem et al., 2004). The KIDMED test is based on the principles that sustain Mediterranean dietary patterns and those that undermine it. As such, it includes 16 items, each answered as "Yes" or "No" questions. Example of questions include: 'Does your child consume fruit or fruit juice every day?', 'Does your child consume a second piece of fruit every day?', 'Does your child you eat fresh or cooked vegetables regularly once a day?', 'Does your child eat fresh or cooked vegetables more than once a day?', 'Does your child eat nuts regularly (at least 2–3 times per week)?', 'Does your child go more than

once a week to a fast-food (hamburger, pizza) restaurant?'. Items denoting less adherence to the Mediterranean diet were scored -1, while those indicating greater adherence received +1. The total score ranged from -4 to 12, where higher scores indicated higher adherence to the Mediterranean Diet.

2.2.3. Meal timing

Parents reported children's habitual breakfast, lunch, and dinner times on weekends and weekdays using the following questions: 'During weekdays/weekends: At what time does your child you usually eat breakfast?', 'During weekdays/weekends: At what time does your usually eat lunch?', and 'During weekdays/weekends: At what time does your child usually eats dinner?' From these data, we calculated the average breakfast/lunch/dinner times (hh:mm), as a weighted mean.

2.2.4. Sleep-related variables

Parents reported children's habitual bed and wakeup times using the following questions: 'During weekdays/weekends: At what time does your child usually goes to bed?' and 'During weekdays/weekends: At what time does your child usually wakes up?' From these data, we calculated.

- i. Average bedtime (hh:mm) as a weighted mean of bedtime in weekdays and weekends.
- ii. Sleep duration (h) as the difference between bedtime and wakeup time.
- iii. Social jet lag (min) as the absolute difference between each participant's midpoint of sleep on weekends and weekdays (Wittmann, Dinich, Merrow, & Roenneberg, 2006).

Sleep quality was assessed using either the Spanish version of the Brief Infant Sleep Questionnaire (BISQ-E) (Cassanello et al., 2018) for toddlers or the Sleep Disturbances Scale for Children (SDSC) (Bruni et al., 1996) for school-aged children. Then, sleep quality was defined in toddlers as "poor" if: the child woke up > 3 times per night, nocturnal wakefulness was >1h, or the total of sleep time was <9h (Cassanello et al., 2018; Sadeh, 2004). In school-aged children, a total SDSC score >39 points indicated "poor" sleep quality, with higher scores reflecting more frequent sleep disturbances (Bruni et al., 1996).

2.2.5. Physical activity

Physical activity was assessed as Moderate to Vigorous Physical Activity (MVPA min/day) using the Early Years Physical Activity Questionnaire (EY-PAQ) (Bingham et al., 2016) for toddlers and the Physical Activity Unit 7 Item Screener (PAU-7S) (Schroder et al., 2021) for school aged-children. In both cases, more MVPA (min/day) indicated greater physical activity.

2.2.6. Health-related quality of life (HRQoL)

This variable was assessed using the KIDSCREEN-10 (Ravens-Sieberer et al., 2010), a 10-item scale that evaluates children's HRQoL. All items are rated on a 5-point Likert scale ranging from 1 ("never") to 5 ("always"). The total score ranges from 10 to 50, where higher scores indicate greater HRQoL.

2.3. Exposure variable

2.3.1. Bed + screen time behavior

Following the methodology proposed by Li and colleagues (Y. Li et al., 2018), we designed a scoring system that encompassed bedtime and screen time before bed, aiming to explore their collective association with outcome variables. Thus, first, bedtime categories were established using the methodology proposed by Olds and colleagues (Golley et al., 2013; Olds et al., 2011). Accordingly, we categorized bedtime behavior as 'early' or 'late' based on a median cutoff from our population data (21:55 for toddlers and 22:08 for school-aged children).

An 'early' bedtime received a score of 0, indicating the participant went to bed before the cutoff, while a 'late' bedtime received a score of 1, indicating the participant went to bed at or after the cutoff. Second, we scored screen time before bed with the question: *Before bedtime, how long does your child spends in front of a screen (computer/tablet, smartphone, TV, DVD/videos, video games)?* The possible answers were 0 ("No screen time before bed"), 1 ("1–30 min of screen time before bed"), or 2 (">30 min of screen time before bed") (Rey-López et al., 2012). Finally, we calculated a total score by summing the bedtime and screen time scores, resulting in four bed + screen time behavior groups ranging from 0 ('Early-Bed and 0 min of Screen Time', EB–0'ST) to 3 ('Late-Bed and more than 30 min of Screen Time', LB > 30'ST), where higher scores indicated unhealthy bed + screen time behavior. All four groups are described in Table 1.

2.4. Sociodemographic variables

Children's age and gender were collected using standardized questions. Parents' educational level and work status were evaluated through the questions: *'what is the education level of each parent?'*, with options "primary studies" or "more than primary studies" and *'what is the current employment status of each parent?'*, with options 'employed' or 'unemployed'. We also asked about single-parent families with options 'yes' or 'no'.

2.5. Statistical analyses

All the statistical analyses were stratified according to two age groups: "toddlers" and "school-aged children". Normality was confirmed for all variables by histograms and Q-Q plots. Descriptive characteristics, including mean and standard deviation for continuous variables and proportions for categorical variables, were presented for all participants by age group. Logistic regression analyses were conducted to examine whether bed + screen time behavior was associated with more odds of having overweight/obesity. Then, we used general linear models (GLMs) to test differences in diet quality based on bed + screen time behavior. Logistic regression models were used to estimate the odds of not meeting each of the 16 dietary habits evaluated in the KIDMED questionnaire as a function of bed + screen time behavior. We also tested the differences in sleep, meal timing, physical activity, and HRQoL as a function of bed + screen time behavior using GLMs for continuous variables and chi-squared tests for categorical variables. Finally, we examined possible linear associations between delaying bedtime and/or increasing screen time behavior groups with outcome variables using Pearson's tests to calculate p-trend values. The latter considered that bed + screen time behavior groups ranged from 0 (EB–0'ST) to 1 (EB ≤ 30'ST/LB–0'ST), 2 (EB > 30'ST/LB ≤ 30'ST), and 3 (LB > 30'ST). All analyses were adjusted for sociodemographic variables, BMI, and physical activity (unless the variable was tested). Tukey's post hoc comparisons between categories were done following GLMs. Statistical analyses were performed using SPSS statistical

Table 1
Description of bed + screen time before bed behavior groups.

Score	Groups	Description
0	EB–0'ST	Early Bedtime and 0 min of Screen Time before bed
1	EB ≤ 30'ST/ LB–0'ST	Early Bedtime and 1–30 min of Screen Time before bed or Late Bed and 0 min of Screen Time before bed
2	EB > 30'ST/LB ≤ 30'ST	Early Bedtime and 1–30 min of Screen Time before bed or Late Bedtime and 1–30 min of Screen Time before bed
3	LB > 30'ST	Late Bedtime and more than 30 min of Screen Time before bed

Participants were classified as 'early' or 'late' bedtime according to a median cut-off point of 21:55 for toddlers and 22:08 for school-aged children. The screen time before bedtime was between "0 min", "1–30 min", or ">30min".

software, version 25.0 (IBM SPSS Statistics, Armonk, NY, USA). Significance was considered at $p < 0.05$.

3. Results

In this cross-sectional study, 1133 children (51.9% school-aged) were included (Table 2). Toddlers had an average age of 3.2 ± 0.7 years, while school-aged children showed an average age of 7.5 ± 2.1 years, with a balanced gender distribution (Table 2). Regarding sociodemographic variables, we observed that the educational level and employment status of both parents were similar between toddlers and school-aged children. Likewise, we did not observe a significant difference regarding the number of single parent families. Note that, compared to toddlers, BMI was higher among school-aged children (16.1 ± 2.2 vs. 17.2 ± 3.5 , respectively), and so was the percentage of overweight/obesity (21.1% vs. 28.8%, respectively). Additionally, we observed that the average bedtime for toddlers was earlier than for

Table 2
General characteristics of the population studied.

	Toddlers <i>n</i> = 545	School-aged children <i>n</i> = 588	p- value [§]
Age, years	3.2 (0.7)	7.5 (2.1)	<0.001
Gender, % girls	48.3 (263)	51.0 (300)	0.192
Sociodemographic variables			
Educational level parent 1, ^a % (n)	75.0 (409)	70.2 (413)	0.075
Educational level parent 2, ^a % (n)	68.3 (372)	66.3 (390)	0.865
Employment parent 1, ^b % (n)	76.5 (450)	72.3 (394)	0.082
Employment parent 2, ^b % (n)	77.2 (421)	74.7 (439)	0.090
Single parent families, % (n)	7.2 (39)	9.2 (54)	0.128
Body mass index (BMI)			
BMI, kg/m ²	16.1 (2.2)	17.2 (3.5)	<0.001
BMI, z-score	0.3 (2.2)	0.8 (2.1)	0.002
Overweight/obesity ^c , % (n)	21.1 (115)	28.8 (169)	<0.001
Sleep-related variables			
<i>Bedtime</i>			
Weekdays, hh:mm	21:46 (00:49)	21:57 (00:40)	<0.001
Weekends, hh:mm	22:15 (00:49)	22:44 (00:51)	<0.001
Average, hh:mm	21:54 (00:46)	22:10 (00:39)	<0.001
<i>Wakeup time</i>			
Weekdays, hh:mm	07:55 (00:39)	07:49 (00:25)	<0.001
Weekends, hh:mm	08:40 (00:54)	08:58 (00:59)	<0.001
Average, hh:mm	8:08 (00:38)	08:08 (00:29)	0.735
Screen time before bed			
0 min, % (n)	22.0 (120)	19.7 (116)	0.021
1–30 min, % (n)	50.5 (275)	45.1 (265)	
More than 30 min, % (n)	27.5 (150)	35.2 (207)	
Bedtime + screen time behavior			
EB – 0'ST	14.2 (77)	11.7 (69)	<0.001
EB ≤ 30'ST/LB – 0'ST	23.2 (126)	29.6 (174)	
EB > 30'ST/LB ≤ 30'ST	46.3 (252)	36.1 (212)	
LB > 30'ST	16.4 (89)	22.6 (133)	

Continuous variables are expressed as mean (SD) and categorical variables are expressed as % (n). ^a More than primary school. ^b Currently employed. ^c BMI was categorized according to the International Obesity Task Force cut-offs. EB – 0'ST, early bedtime with 0 min of screen time before bed; EB ≤ 30'ST/LB – 0'ST, early bedtime with 1–30 min of screen time before bed or late bedtime with 0 min of screen time before bed; EB > 30'ST/LB ≤ 30'ST, early bedtime with <30 min of screen time before bed or late bedtime with 1–30 min of screen time before bed; LB > 30'ST, late bedtime with ≥30 min of screen time before bed. [§] Student's *t*-tests were used to examine the differences between continuous variables, while differences between categorical variables were tested by means of chi-squared tests. Significant differences are shown in bold.

school-aged children (21:54 ± 00:46 vs. 22:10 ± 00:39, respectively) (Table 2), with both groups waking up around the same time ($p = 0.735$). In terms of screen time habits before bed, half of the toddlers and school-aged children spent 1–30 min in front of a screen (50.5% and 45.1%, respectively), while 27.5% of toddlers and a 35.2% of school-aged children spent ≥ 30 min (27.5% vs. 35.2% $p = 0.021$). Regarding bed + screen time behavior, we observed that the percentage of participants classified as LB ≥ 30 'ST was significantly higher as children were older (16.3% vs. 22.6%, $p < 0.001$).

3.1. Bed + screen time behavior associates with obesity and lower diet quality

As summarized in Table 3, we observed a significant trend toward higher BMI as bed + screen time behavior was unhealthy in both toddlers and school-aged children (Table 3). Note that toddlers in the LB > 30 'ST group had 3.42 times higher odds of having overweight/obesity ($p = 0.006$), while school-aged children in the LB > 30 'ST group were 2.53 times more likely ($p = 0.027$) to have overweight/obesity compared to the EB-0'ST group (Table 3).

Likewise, in both age groups, unhealthy bed + screen time behavior was significantly related to a trend toward lower diet quality (Fig. 1a). In particular, toddlers and school-aged children in the EB > 30 'ST/LB ≤ 30 'ST and LB > 30 'ST groups showed significantly lower adherence to the Mediterranean diet compared to the other two groups ($p < 0.001$) (Fig. 1a).

Regarding the association between the 16 eating habits assessed in the KIDMED questionnaire, we observed that unhealthy bed + screen time behavior in toddlers and school-aged children was significantly associated with a trend toward greater odds of not consuming a first serving of fruit daily (Table S1). As such, compared to the EB-0'ST group, toddlers and school-aged children in the EB > 30 'ST/LB ≤ 30 'ST and the LB > 30 'ST groups were more likely to skip a first serving of fruit per day (OR: 4.32 [1.25; 14.89], OR: 6.38 [95% CI: 1.74; 23.39], OR: 3.18 [1.07; 9.45], and OR: 4.96 [95% CI: 1.63; 15.09], respectively). Additionally, we found that toddlers in the LB > 30 'ST group and school-aged children in the EB > 30 'ST/LB ≤ 30 'ST and the LB > 30 'ST groups were less likely to consume a second serving of fruit daily (OR: 2.28 [95% CI: 1.17; 4.47], OR: 2.63 [95% CI: 1.37; 5.05], and OR: 2.80 [95% CI: 1.39; 5.64] respectively).

We also observed a significant trend toward lower daily vegetable consumption as children showed an unhealthy bed + screen time behavior. Although, compared to the EB-0'ST group, only toddlers in the LB > 30 'ST group showed higher odds of not consuming a daily serving of vegetables (OR: 3.39 [95% CI: 1.55; 7.42]). In addition, toddlers in the LB > 30 'ST group were also not likely to consume a second serving of

vegetables each day (OR: 2.16 [1.11, 4.23]) (Table S1).

Our findings also indicated that toddlers with unhealthy bed + screen time behavior (Table S1) showed a trend toward a higher likelihood of not consuming a dairy product for breakfast, while they had higher odds of consuming sweets and candy daily. Notably, relative to toddlers in the EB-0'ST group, children in the EB > 30 'ST/LB ≤ 30 'ST and the LB > 30 'ST groups had significantly higher odds of consuming sweets and candy daily (OR: 0.22 [95% CI: 0.05, 0.96] and OR: 0.17 [95% CI: 0.04, 0.81], respectively).

In school-aged children, we observed that unhealthy bed + screen time behavior was associated with a lower probability of consuming a second daily serving of fruit (p -trend = 0.004) or consuming fish regularly (p -trend = 0.020) (Table S1). Although, relative to children in the EB-0'ST group, only school-aged children in the LB > 30 'ST group had significantly lower odds of not consuming fish regularly (OR: 3.42 [95% CI: 1.31; 8.94]). Additionally, we found that unhealthy bed + screen time behavior was significantly associated with a trend toward a lower probability of eating cereals/grains for breakfast and a higher likelihood of consuming commercially baked goods for breakfast.

3.2. Bed + screen time behavior associates with poor sleep quality and late dinner

In toddlers (Table 4), unhealthy bed + screen time behavior was associated with a significant trend toward shorter nighttime sleep duration and longer daytime sleep duration. Specifically, children in the EB > 30 'ST/LB ≤ 30 'ST and in the LB > 30 'ST groups showed significantly shorter nighttime sleep duration ($p < 0.001$), but longer daytime sleep duration compared to children with a healthier bed + screen time behavior (EB-0'ST and EB ≤ 30 'ST/LB-0'ST groups, $p = 0.025$). However, total sleep duration was not significantly different between the bed + screen time behavior groups ($p = 0.092$).

Regarding sleep quality, we observed that unhealthy bed + screen time behavior was related to poorer sleep quality ($p < 0.001$) (Table 4). Furthermore, bed + screen time behavior was associated with a significant trend toward delayed in breakfast and dinner timing. Specifically, toddlers in the EB > 30 'ST/LB ≤ 30 'ST and in the LB > 30 'ST groups ate breakfast and dinner later, compared to children in the EB-0'ST and EB ≤ 30 'ST/LB-0'ST groups ($p < 0.001$).

Similarly, in school-aged children, unhealthy bed + screen time behavior was associated with a significant trend toward a shorter nighttime sleep duration (Table 4). In this case, school-aged children in the EB > 30 'ST/LB ≤ 30 'ST and in the LB > 30 'ST groups exhibited the shortest sleep durations compared to children in the EB-0'ST and EB ≤ 30 'ST/LB-0'ST groups. Furthermore, our results showed that unhealthy bed + screen time behavior was associated with a trend toward poorer sleep quality and greater social jet lag. Specifically, school-aged children in the LB > 30 'ST group showed the highest levels of social jet lag compared to the other three bed + screen time behavior groups ($p = 0.003$).

Regarding meal timing, we observed a significant association between less healthy bed + screen time behavior and later breakfast and dinner timings (Table 4). Specifically, compared to school-aged children in the EB-0'ST and EB ≤ 30 'ST/LB-0'ST groups, children in the EB > 30 'ST/LB ≤ 30 'ST and in the LB > 30 'ST were found to have significantly later breakfast and dinner timing ($p < 0.001$).

3.3. Bed + screen time behavior is associated with lower physical activity and HRQoL

Finally, we found that school-aged children (Fig. 1b), but not toddlers, with unhealthy bed + screen time behavior showed a significant trend toward a lower physical activity. Particularly notable was the finding among children in the LB > 30 'ST group who showed the lowest levels of physical activity relative to the other three groups ($p = 0.027$).

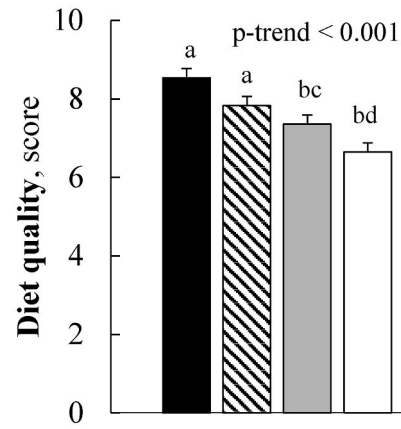
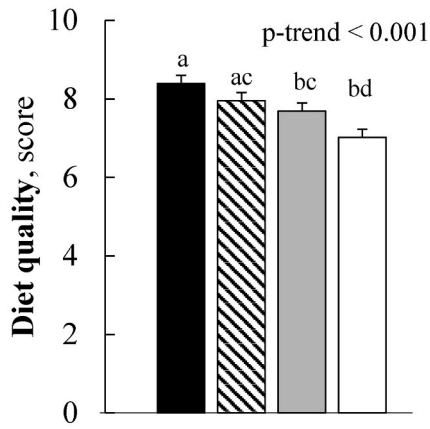
In contrast, among toddlers, unhealthy bed + screen time behavior

Table 3
Odd ratios (OR) for obesity as a function of bed + screen time behavior.

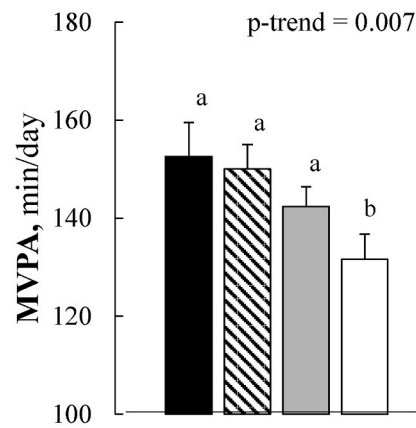
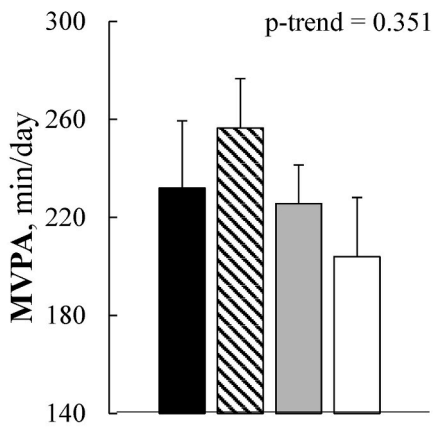
Bed + screen time behavior groups	Toddlers		School-aged children	
	n	OR [95% CI]	n	OR [95% CI]
EB - 0'ST	77	1 (reference)	69	1 (reference)
EB ≤ 30 'ST/LB - 0'ST	169	1.47 [0.62, 3.48]	174	1.30 [0.62, 2.71]
EB > 30 'ST/LB ≤ 30 'ST	210	1.88 [0.82, 4.30]	212	1.84 [0.90, 3.78]
LB > 30 'ST	89	3.42 [1.41, 8.26] **	133	2.53 [1.10, 5.03]*
<i>p</i> -trend		0.002**		0.007**

EB - 0'ST, early bedtime with 0 min of screen time before bed; EB ≤ 30 'ST/LB - 0'ST, early bedtime with 1–30 min of screen time before bed or late bedtime with 0 min of screen time before bed; EB > 30 'ST/LB ≤ 30 'ST, early bedtime with < 30 min of screen time before bed or late bedtime with 1–30 min of screen time before bed; LB > 30 'ST, late bedtime with ≥ 30 min of screen time before bed. The table shows OR [95% Confidence intervals]. Analyses were adjusted for sociodemographic variables and physical activity. * $p < 0.05$, ** $p < 0.01$.

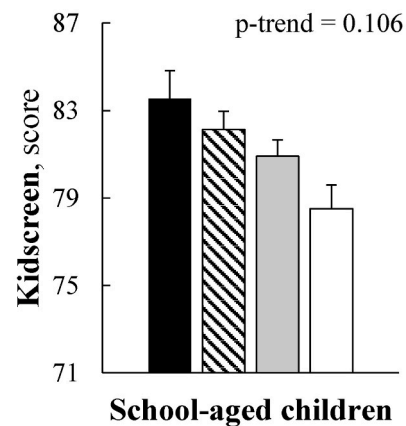
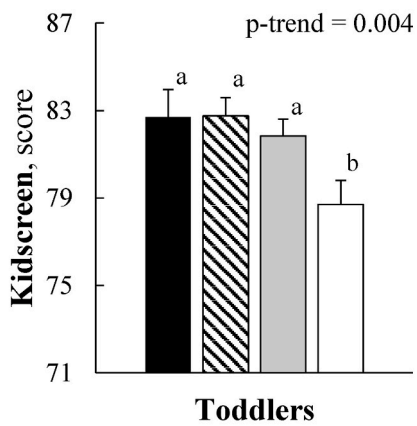
a. Diet quality



b. Physical activity



c. Health related quality of life



EB - 0°ST
 EB ≤ 30°ST / LB - 0°ST
 EB > 30°ST / LB ≤ 30°ST
 LB > 30°ST

(caption on next page)

Fig. 1. Comparison of diet quality (a), physical activity (b), and health related quality of life (b) as a function of bed + screen time behavior. MVPA, Moderate to vigorous physical activity; EB – 0'ST, early bedtime with 0 min of screen time before bed; EB ≤ 30'ST/LB – 0'ST, early bedtime with 1–30 min of screen time before bed or late bedtime with 0 min of screen time before bed; EB > 30'ST/LB ≤ 30'ST, early bedtime with <30 min of screen time before bed or late bedtime with 1–30 min of screen time before bed; LB > 30'ST, late bedtime with ≥30 min of screen time before bed. Values are expressed as mean (SD). General linear models (GLMs) were used to test differences between bed + screen time behavior groups, followed by Tukey post-hoc test to evaluate differences between groups. Values with different superscripts indicate significant differences. Pearson's tests were used to calculate P-trend values. All the analyses were adjusted for sociodemographic variables and physical activity (unless the variable was tested).

Table 4

Differences in sleep and meal timing as a function of bed + screen time behavior in toddlers and school-aged children.

	All	EB – 0'ST	EB ≤ 30'ST/LB – 0'ST	EB > 30'ST/LB ≤ 30'ST	LB > 30'ST	p-value [§]	p-trend [¶]
Toddlers, n	545	77	169	210	89		
<i>Sleep-related variables</i>							
Night sleep duration, h	9.9 (1.8)	10.2 (1.3) ^a	10.2 (1.9) ^a	9.8 (1.7) ^{bc}	9.1 (1.5) ^{bd}	<0.001	<0.001
Day sleep duration, h	1.4 (2.1)	0.7 (1.5) ^a	1.4 (2.3) ^{ac}	1.6 (2.2) ^{bc}	1.6 (1.8) ^{bc}	0.025	0.008
Total sleep duration, h	11.3 (2.8)	10.9 (1.9)	11.6 (3.3)	11.4 (2.7)	10.7 (2.1)	0.092	0.566
<i>Sleep quality</i>							
Good, % (n)	73.9 (402)	90.9 (70)	83.4 (141)	71.4 (150)	47.2 (42)	<0.001	<0.001
Poor, % (n)	26.1 (142)	9.1 (7)	16.6 (28)	28.6 (60)	52.8 (47)		
Social jet lag, min	36.0 (36.0)	34.6 (36.2)	37.4 (32.8)	39.4 (34.5)	39.4 (31.9)	0.811	0.420
<i>Meal timing</i>							
Breakfast, hh:mm	08:30 (00:39)	08:21 (00:30) ^a	08:20 (00:42) ^a	08:35 (00:36) ^b	08:45 (00:36) ^b	<0.001	<0.001
Lunch, hh:mm	13:36 (00:43)	13:32 (00:44)	13:37 (00:42)	13:35 (00:43)	13:40 (00:41)	0.310	0.072
Dinner, hh:mm	20:34 (00:37)	20:06 (00:32) ^a	20:25 (00:33) ^b	20:42 (00:35) ^c	20:54 (00:34) ^d	<0.001	<0.001
School-aged children, n	588	69	174	212	133		
<i>Sleep-related variables</i>							
Night sleep duration, h	10.0 (0.6)	10.4 (0.6) ^a	10.2 (0.6) ^b	9.9 (0.6) ^c	9.6 (0.5) ^d	<0.001	<0.001
<i>Sleep quality</i>							
Good, % (n)	50.7 (298)	65.2 (45)	56.9 (99)	49.5 (105)	38.6 (49)	<0.001	<0.001
Poor, % (n)	49.3 (290)	34.8 (24)	43.1 (75)	50.1 (107)	63.2 (84)		
Social jet lag, min	60.0 (42.0)	49.1 (36.8) ^a	57.0 (37.2) ^a	58.3 (40.6) ^a	71.4 (42.0) ^b	0.003	0.002
<i>Meal timing</i>							
Breakfast, hh:mm	08:31 (00:29)	08:19 (00:25) ^a	08:26 (00:26) ^{ab}	08:32 (00:29) ^b	08:41 (00:30) ^c	<0.001	<0.001
Lunch, hh:mm	13:57 (00:35)	13:55 (00:36)	13:55 (00:36)	13:58 (00:35)	14:01 (00:33)	0.771	0.466
Dinner, hh:mm	20:46 (00:34)	20:24 (00:25) ^a	20:41 (00:32) ^b	20:49 (00:36) ^b	21:02 (00:31) ^c	<0.001	<0.001

EB – 0'ST, early bedtime with 0 min of screen time before bed; EB ≤ 30'ST/LB – 0'ST, early bedtime with 1–30 min of screen time before bed or late bedtime with 0 min of screen time before bed; EB > 30'ST/LB ≤ 30'ST, early bedtime with <30 min of screen time before bed or late bedtime with 1–30 min of screen time before bed; LB > 30'ST, late bedtime with ≥30 min of screen time before bed. Values are expressed as mean (SD) for continuous variables and proportions (n) for categorical variables. [§]General linear models (GLMs) were used to compare differences between continuous variables, followed by Tukey post-hoc test to evaluate differences between groups. Values with different superscripts indicate significant differences. Differences between categorical variables were tested by means of chi-squared tests. Analyses were adjusted for sociodemographic variables, BMI, and physical activity. [¶]Pearson's tests were used to calculate P-trend values. Significant differences are shown in bold.

was related to a lower parent-reported HRQoL (p-trend = 0.004, Fig. 1c). Specifically, children in the LB > 30'ST group had the lowest HRQoL values compared to the other three groups (p < 0.05). Particularly, children with unhealthy bed + screen time behavior had lower school performance and perception of having fun with their friends. In school-aged children, the statistical significance of the relationship between bedtime + screen time behavior and HRQoL was lost after adjusting for physical activity.

4. Discussion

This research highlights, for the first time, that the combination of late bedtime and more screen time before bed (evaluated through the combined variable “bed + screen time behavior”) was significantly associated with a higher risk of obesity. Accordingly, toddlers and school-aged children in the LB > 30'ST group were more likely to have overweight/obesity (OR: 3.42 and 2.53, respectively) than those in the EB–0'ST group. Furthermore, we observed that children with unhealthy bed + screen time behavior consumed fewer fruits and vegetables and had a lower diet quality. Also, inadequate sleep, characterized by short nighttime sleep duration and poor sleep quality, was linked to unhealthy bed + screen time behavior.

As a first approach, we hypothesize that inadequate sleep may explain the association between unhealthy bed + screen time behavior with obesity and poor diet quality. Note that inadequate sleep has been

related to increased neuronal activity in response to highly palatable foods and a higher tendency to overeat when prompted by external cues (e.g. sight or smell) and/or palatable foods (Blumfield, Bei, Zimberg, & Cain, 2018; Burt, Dube, Thibault, & Gruber, 2014; McDonald, Wardle, Llewellyn, & Fisher, 2015; A. L. Miller et al., 2019; Ramírez-Contreras et al., 2022; St-Onge et al., 2012; Zerón-Ruggerio, Doblaz-Faxeda, Diez-Hernández, & Izquierdo-Pulido, 2023). This could be consistent with our findings, as children in the LB > 30'ST group had a lower diet quality, with toddlers consuming more sweets and candies, and school-aged children consuming more commercially baked goods and pastries for breakfast.

It is also plausible that the combination of two behaviors that enable food intake, such as late bedtime and more screen time before bed, may help explain the results of this research (Adamo et al., 2014; P. Li et al., 2022; Pérez-Farinós et al., 2017; Teekavanich, Rukprayoon, Sut-chritpongsa, & Rojmahomngkol, 2022). In agreement, Adamo et al. (Adamo et al., 2014) have demonstrated that daily caloric intake was ~425 kcal higher in adolescents with obesity showing late bedtimes, and this association was mediated by screen time. Note that greater screen time can reduce satiety, leading to mindless eating and a preference for sugary foods and beverages (Chaput et al., 2011; Hill et al., 2016; Jebeile et al., 2022; P. Li et al., 2022; Pérez-Farinós et al., 2017). Furthermore, late bedtimes provide additional opportunities for eating (Adamo et al., 2014; Dashti, Scheer, Jacques, Lamon-Fava, & Ordovas, 2015), particularly carbohydrate-rich and energy-dense snacks (Dashti

et al., 2015). These findings align with ours, as children with unhealthy bedtime/screen time behavior consumed more commercially baked goods, sweets, and candies.

Our findings also revealed that unhealthy bed + screen time behavior was associated with shorter nighttime sleep duration and poorer sleep quality in both toddlers and school-aged children. In agreement, other epidemiological studies and systematic reviews have pointed out the detrimental effects of greater screen time and later sleep timing, duration, and quality (Hale & Guan, 2015; C. Li et al., 2020; Lin et al., 2022; E. B. Miller et al., 2022; Staples, Hoyniak, McQuillan, Molfese, & Bates, 2021). While the cross-sectional design of our research limits us from establishing causation, this suggests that increased screen time before bed could be influencing these sleep-related outcomes (Chaput et al., 2023). Keep in mind that the exposure to bright light at night, especially blue-green light, reduces melatonin levels (Chaput et al., 2023; Hill et al., 2016), a hormone associated with sleepiness and relaxation (Pevet, 2014). Additionally, engaging screen-based activities might stimulate the brain, leading to delayed bedtimes and compromised sleep quality (Chaput et al., 2023; Hill et al., 2016).

Notably, our results showed that in school-aged children, the combination of staying up late and increasing screen time before bed was significantly related to greater social jet lag. This is common among individuals with late bedtimes, as they must adjust their wakeup timing to fit school schedules rather than their actual sleep needs (Arora & Taheri, 2015; Malone et al., 2016; Roenneberg, Pilz, Zerbini, & Winnebeck, 2019; Wittmann et al., 2006; Zerón-Ruggerio, Cambras, & Izquierdo-Pulido, 2019). Consequently, they end up sleeping less and accumulating a sleep debt throughout the week (Malone et al., 2016; Zerón-Ruggerio et al., 2019). In school-aged children, greater social jet lag has been identified as a potential risk factor for obesity and poor diet quality (Cetiner, Yildirim, & Kalyoncu, 2021; Feliciano et al., 2019), which is consistent with our results. Furthermore, social jet lag has been associated with irritable mood, poor academic performance, and daytime sleepiness in this population (Komada et al., 2016; Tamura, Komada, Inoue, & Tanaka, 2022).

We also found that unhealthy bed + screen time behavior was significantly associated with delayed breakfast and dinner timing. This is partially consistent with another study in Spanish school-aged children, where late-dinner timing was associated with delayed sleep and breakfast schedules (Martínez-Lozano et al., 2020). Furthermore, the authors of this study noted that children who delayed dinner timing were more likely to have overweight or obesity (Martínez-Lozano et al., 2020). Accordingly, having a late dinner is associated with obesity due to impaired glucose tolerance resulting from the overlap between the postprandial period and melatonin onset (Lopez-Minguez, Saxena, Bandín, Scheer, & Garaulet, 2018; Martínez-Lozano et al., 2020; Mchill et al., 2017; Zerón-Ruggerio et al., 2020).

Apart from inadequate sleep and unhealthy eating habits, our results showed a significant trend towards lower physical activity in school-aged children as bed + screen time behavior was healthier. In agreement, Olds et al. (Olds et al., 2011) showed that late bedtimes resulted in around 30 min less of MVPA, being replaced by sedentary behaviors, mainly screen-based activities like TV viewing and playing video games. Noteworthy, the benefits of exercise itself extend far beyond physical fitness and obesity prevention, as it also helps to improve children's quality of life (Jebeile et al., 2022). However, it seems that the relationship between physical activity and HRQoL has a threshold of 60 min of MVPA/day, beyond which physical activity no longer had a positive relationship with HRQoL. The authors of the study suggested that this could be due to a balance between daily time use and the stress/pressure of intense involvement in physical activity, such as competitive sports (Dumuid et al., 2017).

Finally, our results showed for the first time that the combination of late bedtimes and greater screen time before bed was significantly related to lower HRQoL in toddlers. Furthermore, our findings indicate that unhealthy bed + screen time behavior negatively affected toddlers'

school performance and socialization skills. These results highlight the importance of parents/caregivers adhering to the recommendations of the American Academy of Pediatrics to avoid screen time 1 h before bed (Hill et al., 2016). A practice that combined with early bedtimes is significantly related with HRQoL (Dumuid et al., 2017), as it was shown in toddlers who belonged to the EB-0'ST.

While our study provides valuable insights, it has some limitations worth noting. First, its cross-sectional design limits to establish causality. Second, we acknowledge the lack of generalizability of our findings since study participants that were recruited were part of the Laboratorio's Ordesa Family Club. Third, we acknowledge the stratification of the analyses based on broad age range as a limitation of the sample size and, thus, of the study. Fourth, we are aware that the use of parent-reported questionnaires to assess BMI, sleep-related variables, screen time before bed, and diet quality is a limitation of the study. Furthermore, we recognize as a limitation of the study the fact that we did not differentiate screen time behavior on weekends versus weekdays. Future studies should consider more objective measurement methods, such as body composition assessment and actigraphy. However, our study's strengths include a substantial sample size that provided sufficient statistical power to identify associations between bedtime, screen time before bed, BMI, and other outcome variables. Additionally, we considered socioeconomic variables as covariates, and the gender distribution was balanced with 50% girls.

5. Conclusion

In summary, our results highlight the detrimental effects of the combination of late bedtimes and increased screen time before bed in toddlers and school-aged children. Noteworthy, children in the LB > 30'ST group were more likely to have overweight/obesity and less adherent to the Mediterranean diet. Additionally, unhealthy bed + screen time behavior negatively affected sleep outcomes and meal timings, particularly as children get older. Moreover, school-aged children with unhealthy bed + screen time behavior experienced greater social jet lag and reduced physical activity, while toddlers had lower HRQoL. These findings emphasize the importance of promoting earlier bedtimes and limiting screen time before bed as part of obesity prevention strategies for children.

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Ethical statement

Participation was entirely voluntary and anonymous, following the general recommendations of the Declaration of Helsinki and were approved by Ethics Committee of the University of Barcelona (IRB00003099). Written informed consent was obtained from participants' legal guardians.

CRedit authorship contribution statement

María Fernanda Zerón-Ruggerio: Writing – original draft, Formal analysis, Conceptualization. **Alicia Santamaría-Orleans:** Writing – review & editing, Investigation. **Maria Izquierdo-Pulido:** Writing – original draft, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article to disclose.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.appet.2024.107293>.

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