Nutrition, Metabolism & Cardiovascular Diseases (2023) 33, 2508–2516

Available online at www.sciencedirect.com

Nutrition, Metabolism & Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd

Changes in screen time from 4 to 7 years of age, dietary patterns and obesity: Findings from the Generation XXI birth cohort

Marta Figueira [a], Ana Cristina Santos [b], Maria João Gregório [c,d], Joana Araújo [a,b,e,*]

[a] EPIUnit – Instituto de Saúde Pública da Universidade do Porto, Porto, Portugal
[b] Departamento de Ciências da Saúde Pública e Forenses, e Educação Médica –Faculdade de Medicina da Universidade do Porto, Porto, Portugal
[c] Faculdade de Ciências da Nutrição e Alimentação da Universidade do Porto, Porto, Portugal
[d] Direção-Geral da Saúde, Lisboa, Portugal
[e] Laboratório para a Investigação Integrativa e Translacional em Saúde Populacional (ITR), Porto, Portugal

Received 12 December 2022; received in revised form 14 July 2023; accepted 24 July 2023
Handling Editor: A Campanozzi
Available online 28 July 2023

KEYWORDS
Screen time;
Dietary intake;
Childhood obesity;
Pre-school;
School age

Abstract *Background and aims:* Increased screen exposure is associated with unhealthy eating behaviours and obesity. Screen time (ST) changes from pre-school to school age, and associations with dietary patterns (DP) and obesity remain unknown. We, therefore, analysed ST changes from 4 to 7 years of age, associated factors, and the relation with DP and obesity.
Methods and results: We included 4531 children evaluated at 4 and 7 years, as part of the Generation XXI birth cohort (Porto, Portugal). ST was assessed for weekdays and weekend, and average daily time was estimated. Associations between covariates and ST changes, and between ST changes and 3 DP previously identified (Energy-dense foods, Snacking, and Healthier) were estimated by odds ratios (OR) and 95% confidence interval (95%CI), using adjusted multinomial regression models. From 4 to 7 years, 31.5% of the children decreased their ST, 21.8% increased, 16.5% maintained low (≤60 min), and 30.2% maintained high (61–120 min or >120 min) ST. After adjustment, lower maternal education (OR = 2.33, 95%CI:1.82–2.99) and lower family income (OR = 1.72, 95%CI:1.35–2.21) were associated with higher odds of increasing ST, while being a girl was associated with 35% decreased odds of increasing ST. Children that increased and those that maintained high ST showed greater odds of presenting a Snacking DP at 7 years (OR = 2.34, 95%CI:1.64–3.35) and (OR = 2.65, 95%CI:1.89–3.72), respectively. No statistically significant differences were found regarding changes in ST and the child's BMI.
Conclusion: Children increasing screen exposure during this period were more frequently from lower socioeconomic strata and presented unhealthier DP.

1. Introduction

Early childhood high-screen exposure can negatively impact children's and adolescents' health [1,2], having been linked to a higher prevalence of violence and aggression [3], learning problems and poor school performance [4,5], and obesity [6,7]. The relationship between screen exposure and weight gain has been well documented in children and adolescents [8]. Three mechanisms are thought to explain the effects of screen time (ST) on obesity. Firstly, this sedentary behaviour reduces the time that children are enrolled in more active physical activities that promote energy expenditure [9]; secondly, as a result of food marketing and advertising [14], it promotes food consumption, namely larger portions of food, increased

* Corresponding author. Instituto de Saúde Pública da Universidade do Porto, Rua das Taipas 135, 4050-600, Porto, Portugal.
E-mail address: joana.araujo@ispup.up.pt (J. Araújo).

https://doi.org/10.1016/j.numecd.2023.07.032
0939-4753/

consumption of high-density foods, rich in fat, free sugars or salt [10–12] and decreased consumption of fruits and vegetables [13]. Finally, shorter sleep duration has also been linked to screen media exposure, excessive energy consumption and obesity [8]. Sleep deprivation can cause changes in the appetite-regulating hormones and increase hunger [15], and behavioural hypotheses such as "less sleep – more time to eat" have been discussed [16].

The American Academy of Paediatrics (AAP) recommends that the total media time should be limited to no more than 2 h of quality programming per day [2], and the Canadian Paediatric Society (CPS) and World Health Organization (WHO) both recommend that screen-related sedentary behaviours should not exceed the maximum of 1 h per day for children aged 2–4 years [17,18]. However, evidence shows that many children do not meet these recommendations [19–23]. According to the Portuguese National Food, Nutrition and Physical Activity Survey in 2015–2016, 37% of children and adolescents aged 3–14 years spend more than 2 h per day on weekdays watching television (TV), and this prevalence increases to 71% on weekends [24]. Moreover, data from 3–4-year-old Portuguese children showed that children spend an average of 92 min/day on weekdays and 167 min/day on weekends using screen digital media devices [25].

Although several studies have estimated the prevalence of high ST at different ages and the association with obesity, to our knowledge, few examined children's ST changes, specifically from preschool to school age [26,27]. Previous cross-sectional studies have reported a positive association between ST and unhealthier dietary patterns (DP), mainly in adolescents and adults [28–30] but also in children [31]. However, there is no information on the association between changes in ST during childhood and DP. As habits and routines are easily created and established at early ages, overexposure to screens increases the likelihood of overuse later in life [32], and the establishment of eating habits and food choices in childhood may also persist into adulthood [33,34]. Understanding how ST patterns evolve and their impact on children's DP can provide essential data on the early behavioural antecedents of obesity [26]. Therefore, this study aimed to analyse changes in ST (TV and electronic games) from 4 to 7 years of age and associated factors, and its association with DP and obesity at 7 years.

2. Methods

2.1. Participants

The present study was conducted within Generation XXI, a population-based birth cohort of new-borns and their mothers, recruited between April 2005 and August 2006, at each of the five maternity units of level III in the Porto Metropolitan Area [35,36]. Of the invited mothers, 91% agreed to participate, resulting in a total sample of 8647 children and 8495 mothers evaluated at baseline. The whole cohort was invited to attend follow-up re-evaluations, namely at ages 4, 7, 10 and 13 years.

The project Generation XXI was conducted according to the principles of the Declaration of Helsinki, and all procedures were approved by the Portuguese Authority of Data Protection and the Ethical Committee of the São João Hospital. At baseline and follow-up evaluations, parents or legal tutors of each participant signed an informed consent form.

Of the 8647 children evaluated at baseline, 7459 were re-evaluated at the age of 4 and 6889 at the age of 7. After the exclusion of children with incomplete information on ST, at either 4 or 7 years, a subsample of 4966 subjects was considered eligible for the present study. From these, we excluded subjects with incomplete information on variables of interest: DP at 7 years ($n = 119$), children's body mass index (BMI) ($n = 46$ and $n = 13$ at 4 and 7 years, respectively), maternal educational level ($n = 22$), children's sedentary activities at 7 years ($n = 19$), income at 4 years ($n = 74$), children's participation in sports ($n = 17$ and $n = 16$ at 4 and 7 years, respectively), children's active playtime at 7 years ($n = 26$), mother's parity ($n = 81$), and children's sleep duration at 4 years ($n = 2$). A total of 4531 children were used in the final analysis.

2.2. Data collection

Data at 4 and 7 years of age were collected using structured and standardized questionnaires answered by the primary caregivers (usually mothers), which trained interviewers applied in face-to-face interviews.

The amount of time, in hours: minutes (min), spent watching television (or playing video games) was evaluated using an open question, separately for weekdays and weekend days. The average daily time was computed and recoded into min per day, and participants were classified into three categories: ≤60 min, 61–120 min, and >120 min. ST changes from 4 to 7 years of age were assessed through a computed variable with four categories: maintaining a low ST (≤60 min), maintaining a high ST (maintaining in the category 61–120 min or the category >120 min), decreasing ST (changing to a category of lower duration) or increasing ST (changing to a category of higher duration).

Dietary intake of the child's diet over the previous 6 months was evaluated through a 35 and 38-item qualitative food frequency questionnaire (FFQ) at 4 and 7 years of age, respectively [37]. Caregivers were asked how many times, on average, children had consumed each food item, using nine frequency options. Items were then combined into eleven food groups: dairy; meat and meat products; fish; eggs; vegetables; fruits; cereals; salty snacks; sweets and pastry; sugar-sweetened beverages (SSB); and fat spread.

Three DP were previously identified in 4-year-old children through latent class analysis, described elsewhere [38]. Briefly, the DP definition included four conceptual levels: maternal socio-economic position at 12 years, maternal socioeconomic and demographic characteristics at the child's delivery, family characteristics at the child's 4 years, and maternal characteristics and behaviours at the child's 4 years, as well as children's dietary intake evaluated by the FFQ. The three DP identified were: "Energy-dense foods" (EDF) characterized by higher consumption of EDF (including sweets, SSB, pizza, burgers and processed meat); “Snacking” characterized by low consumption of foods consumed at main meals (vegetables, fish, meat, eggs, rice, pasta, potatoes and fruit) and intermediate in snacks (bread, milk, yoghurt, crips, pizza, burger, salty pastry and SSB); and “Healthier” characterized by higher consumption of healthy foods (vegetable soup, vegetables on the plate and fish), and lower in unhealthy ones (processed meat, crisps, pizza, burger, salty pastry, sweets and SSB) [38].

In both evaluations, children's anthropometric measurements were performed according to standard procedures by experienced examiners. Weight was measured using a digital scale to the nearest 0.1 kg, in underwear, without shoes, and body height was measured using a fixed stadiometer to the nearest 0.1 cm, without shoes, from the top of the head to the bottom of the feet. Children's BMI was calculated and then converted into age- and sex-specific standard deviation (SD) scores (BMI Z-scores), according to the WHO growth charts [39]. As the prevalence of underweight was very low at both 4 and 7 years (0.5% corresponding to 24 and 23 individuals, respectively), the “underweight” BMI Z-score category was merged with the “normal weight” category. Thus, BMI Z-score categories at 4 years were defined as: normal weight/underweight, $\leq +1$ SD; at risk of overweight, $+1 < \text{SD} \leq +2$; overweight, $+2 < \text{SD} \leq 3$; and obesity, $> +3$ SD. At 7 years, cut points were: normal weight/underweight, $\leq +1$ SD; overweight, $+1 < \text{SD} \leq +2$; and obesity, $> +2$ SD.

Children's sex and maternal characteristics were retrieved from the baseline. Mother's characteristics analysed included mother's parity (categorized as 1st pregnancy, 2nd pregnancy, and 3rd or further pregnancy), age, and education level (≤9, 10–12 or >12 completed years of formal schooling). Maternal pre-conception BMI was computed using self-reported weight before pregnancy (reported at study baseline) and height (measured, derived from clinical records or self-reported) and classified according to the WHO BMI cut-offs: underweight and normal weight (BMI<25 kg/m^2), overweight (BMI 25–30 kg/m^2) and obesity (BMI>30 kg/m^2) [40].

Family structure, number of siblings living with the child, and monthly available income in euros (≤1000, 1001–1500, and >1500) were assessed at the 4-year-follow-up evaluation. Children's participation in sports (yes or no), and children's sleep duration (the difference between the hour that the child goes to sleep and the hour the child wakes up), categorized as less than or ≥10 h per night, were also obtained at the 4-year follow-up evaluation. Other covariates were obtained in 7-year-follow-up evaluation: children's active playtime (average daily time spent playing, running, riding a bicycle), classified as ≤60 min/day or >60 min/day.

2.3. Statistical analyses

The characteristics of participants were presented as mean and standard deviation (SD) for continuous variables and as absolute (n) and relative frequencies (%) for categorical variables. Proportions were compared using the chi-square test and means through analysis of variance (ANOVA).

Using multinomial logistic regression models, associations between family and child characteristics and changes in ST between 4 and 7 years were estimated by crude and adjusted odds ratio and 95% confidence intervals. The models were adjusted for different variables according to the outcome. When the outcome was changes in ST, the reference category was ‘Maintained low’ and the model included the child's sex, mother's parity, child's participation in sports, maternal age, and household income. Due to the high correlation between the mother's education and household income, the model including the mother's education was not adjusted for income, and vice versa. For models with DP as the outcome (Healthier DP as reference), adjustments were made for maternal education and children's active playtime. For outcome nutritional status, the reference category was normal weight/underweight, and adjustments were maternal education, children's sex, and children's active playtime.

Statistical analyses were performed using the IBM®SPSS® Statistics software (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp), and the significance level was fixed at 0.05.

3. Results

Family and child characteristics are described in Table 1. About half the children were male (51.2%), and the majority corresponded to the mother's first pregnancy (58.6%). Mothers' mean age (SD) was 29.79 years (5.20) at baseline, and 41.3% had up to 9 years of education. At 4 years of age, most children did not have siblings (45.8%) and lived with both parents (88.9%). Regarding the household income at 4 years, 46.4% earned >1500 euros per month, while a quarter of the sample (25.2%) earned less than 1000 euros per month.

At 4 years of age, 68.2% of the children included in the analysis were exposed to screens for more than 1 h per day, and 27.9% of those were exposed to more than 120 min/day (Table 2). Associations between family and child characteristics and ST at 4 years showed that ST over 120 min/day was more frequent among boys, children with obesity, those not practicing sports, and sleeping less than 10 h/night. Children with ST over 120 min/day had younger mothers. Excessive ST was also more frequent among those with lower maternal education, lower household income, and no siblings living with the child. No differences were found for maternal pre-conception BMI and family structure.

Between 4 and 7 years, 16.5% of children maintained a low ST (≤60 min), 30.2% maintained a high ST (maintaining in the category 61–120 min or in the category >120 min), 21.8% increased their ST, and 31.5% decreased it (Table 2). The proportion of children maintaining low ST (≤60 min) was higher among girls ($p < 0.001$), normal-weight children ($p < 0.002$), those doing sports ($p < 0.001$) and sleeping ≥10 h/night at 4 years ($p = 0.011$), and among children whose mothers had

Table 1 Family and child characteristics of the sample.

	n (%)
Child characteristics at birth	
Child's sex	
Female	2210 (48.8)
Male	2321 (51.2)
Mother's parity	
First pregnancy	2654 (58.6)
Second pregnancy	1513 (33.4)
Third or further pregnancy	364 (8.0)
Maternal characteristics	
Age, mean (SD)	29.79 (5.20)
Pre-conception BMI	
Normal weight or underweight	1697 (67.7)
Overweight	579 (23.1)
Obesity	232 (9.3)
Missings	*2023*
Education	
≤9 years	1871 (41.3)
10–12 years	1295 (28.6)
>12 years	1365 (30.1)
Family and house characteristics (at 4 years)	
Household income (euros/month)	
≤1000	1143 (25.2)
1001–1500	1284 (28.3)
>1500	2104 (46.4)
Family structure	
Both parents	4030 (88.9)
Single parent	465 (10.3)
Other family structure	36 (0.8)
Number of siblings	
None	2075 (45.8)
1	1948 (43.0)
2 or more	508 (11.2)

SD, standard deviation.

higher education and higher household income at 4 years ($p < 0.001$).

Table 3 summarizes the crude and adjusted associations between family and child characteristics and changes in ST between 4 and 7 years. After adjustment for all variables in the table and using the category 'Maintained low' as the reference in the outcome variable, we found that boys were more likely to change their ST, either increasing (OR = 1.53; 95%CI 1.26–1.86) or decreasing (OR = 1.39; 95% CI 1.16–1.67) and were also more likely to maintain high ST (OR = 1.60; 95%CI 1.33–1.92). Children who did not practice sports showed 73% greater odds of decreasing their ST (OR = 1.73; 95% CI 1.41–2.12) and 33% greater odds of maintaining high ST (OR = 1.33; 95% CI 1.08–1.64). Regarding the maternal age, for each additional 5 years of mothers' age, children were 13% less likely to maintain a high ST (OR = 0.87; 95% CI 0.79–0.97). The lower the mother's education (≤9 years: OR = 2.33; 95% CI 1.82–2.99) and the family income (≤1000€/month: OR = 1.72; 95% CI 1.35–2.21), the greater the odds for children to increase their ST.

Considering the association between changes in ST and DP at 7 years (Table 4), children that increased or maintained a high ST between 4 and 7 years of age were more likely to present an Energy Dense-foods or a Snacking DP. After adjustment for maternal education and children's active playtime, and when compared to maintaining low ST, all the other three categories (maintained high, increased, and decreased) were associated with increased odds of following an Energy Dense-foods or a Snacking DP. Still, associations were stronger for those maintaining high or increasing ST between 4 and 7 years. Children who maintained a high ST showed 142% greater odds of following an Energy Dense-foods DP (OR = 2.42; 95% CI 1.98–2.95) and 165% great odds of having a Snacking DP (OR = 2.65; 95% CI 1.89–3.72). Associations for the category of increased ST were 2.13 (95% CI 1.73–2.64) and 2.34 (95% CI 1.64–3.35), respectively. Regarding the associations between changes in ST between 4 and 7 years and child's BMI at 7 years (Table 4), although no statistically significant differences were found ($p = 0.192$), we found a lower prevalence of overweight and obesity among those who maintained a low ST.

4. Discussion

In our sample, about 28% of 4-year-old children spent more than 2 h per day watching television or playing video games, thus exceeding the AAP guidelines. However, considering the CPS and WHO guidelines of less than 60 min per day, over two-thirds did not adhere to ST recommendations. Additionally, children increasing or maintaining a high ST from 4 to 7 years of age were more frequently from a lower socioeconomic strata and were more likely to follow unhealthier DPs at 7 years.

This study focused on ST changes between preschool and school age, representing a critical time in children's lives and future health [41]. In Portugal, although it is not mandatory, children aged of 3 and older can be enrolled in the public pre-school network and, once they turn 6 years old, they can enroll in the first cycle of schooling. From 4 to 7 years of age, just about one-third of the children decreased their ST, a smaller proportion maintained low, and half of the sample maintained high (30%) or increased (22%) ST exposure. Roberts and Foehr [27] examined how media exposure varies with age and found that media exposure begins early, increases until children start school (around 6–7 years), drops off briefly, and increases again around the age of 11–12. The decrease of ST from preschool to school age in some children is more likely due to the needs of the school and school-related activities, as well as the school television-free environment, which translates into less time available for the media [27]. However, in Certain and Kahn's longitudinal study [26], television viewing levelled off instead of declining from 3 to 7 years of age, attributed to the continuing environmental influences and the development of child preferences or habits. ST appears to maintain a role in children's daily lives, suggesting that higher ST in early childhood is associated with higher ST at school age [41].

Consistent with previous work [42,43], our results show that lower maternal educational level and lower household income were associated with greater odds of increasing ST. Also, a systematic review by Gebremariam et al. [44] reported an inverse relationship between

Table 2 Associations between family and child characteristics and screen time at 4 years and changes in screen time from 4 to 7 years of age.

	Screen Time at 4 years				Changes in Screen Time from 4 to 7 years				
	≤60 min	61–120 min	>120 min		Maintained low	Maintained high	Decreased	Increased	
	n (%)			p-value	n (%)				p-value
Total	1442 (31.8)	1826 (40.3)	1263 (27.9)		749 (16.5)	1367 (30.2)	1426 (31.5)	989 (21.8)	
Child characteristics									
Child's sex									
Female	772 (34.9)	865 (39.1)	573 (25.9)	<0.001	428 (19.4)	623 (28.2)	695 (31.4)	464 (21.0)	<0.001
Male	670 (28.9)	961 (41.4)	690 (29.7)		321 (13.8)	744 (32.1)	731 (31.5)	525 (22.6)	
Child's BMI									
Normalweight/underweight	1006 (32.3)	1271 (40.8)	841 (27.0)	<0.001	540 (17.3)	938 (30.1)	969 (31.1)	671 (21.5)	0.002
Risk of overweight	317 (32.7)	383 (39.5)	269 (27.8)		156 (16.1)	272 (28.1)	309 (31.9)	232 (23.9)	
Overweight	89 (28.2)	136 (43.0)	91 (28.8)		36 (11.4)	119 (37.7)	93 (29.4)	68 (21.5)	
Obesity	30 (23.4)	36 (28.1)	62 (48.4)		17 (13.3)	38 (29.7)	55 (43.0)	18 (14.1)	
Participation in sports									
Yes	1082 (34.6)	1275 (40.7)	774 (24.7)	<0.001	575 (18.4)	944 (30.2)	907 (29.0)	705 (22.5)	<0.001
No	360 (25.7)	551 (39.4)	489 (34.9)		174 (12.4)	423 (30.2)	519 (37.1)	284 (20.3)	
Sleep duration									
<10 h/night	439 (29.4)	604 (40.4)	451 (30.2)	0.015	217 (14.5)	491 (32.9)	468 (31.3)	318 (21.3)	0.011
≥10 h/night	1003 (33.0)	1222 (40.2)	812 (26.7)		532 (17.5)	876 (28.8)	958 (31.5)	671 (22.1)	
Family and parents' characteristics									
Maternal age (years), mean (SD)	30.27 (5.01)	29.85 (5.08)	29.15 (5.50)	<0.001	30.40 (4.72)	29.46 (5.11)	29.65 (5.39)	29.99 (5.33)	<0.001
Mother's pre-conception BMI									
Normalweight/underweight	541 (31.8)	680 (40.1)	476 (28.0)	0.552	280 (16.5)	498 (29.3)	539 (31.8)	380 (22.4)	0.767
Overweight	175 (30.2)	223 (38.5)	181 (31.3)		84 (14.5)	177 (30.6)	182 (31.4)	136 (23.5)	
Obesity	78 (33.6)	85 (36.6)	69 (29.7)		34 (14.7)	74 (31.9)	66 (28.4)	58 (25.0)	
Missings: 2023									
Mother's education									
≤9 years	551 (29.4)	708 (37.8)	612 (32.7)	<0.001	240 (12.8)	587 (31.4)	586 (31.3)	458 (24.5)	<0.001
10–12 years	389 (30.0)	523 (40.4)	383 (29.6)		204 (15.8)	382 (29.5)	427 (33.0)	282 (21.8)	
>12 years	502 (36.8)	595 (43.6)	268 (19.6)		305 (22.3)	398 (29.2)	413 (30.3)	249 (18.2)	
Household income (euros/month)									
≤1000	359 (31.4)	402 (35.2)	382 (33.4)	<0.001	158 (13.8)	336 (29.4)	364 (31.8)	285 (24.9)	<0.001
1001–1500	356 (27.7)	535 (41.7)	393 (30.6)		172 (13.4)	413 (32.2)	414 (32.2)	285 (22.2)	
>1500	727 (34.6)	889 (42.3)	488 (23.2)		419 (19.9)	618 (29.4)	648 (30.8)	419 (19.9)	
Family structure									
Both parents	1267 (31.4)	1652 (41.0)	1111 (27.6)	0.114	663 (16.5)	1225 (30.4)	1279 (31.7)	863 (21.4)	0.438
Single parent	163 (35.1)	162 (34.8)	140 (30.1)		81 (17.4)	134 (28.8)	135 (29.0)	115 (24.7)	
Other family structure	12 (33.3)	12 (33.3)	12 (33.3)		5 (13.9)	8 (22.2)	12 (33.3)	11 (30.6)	
Number of siblings									
None	618 (29.8)	844 (40.7)	613 (29.5)	0.046	312 (15.0)	649 (31.3)	660 (31.8)	454 (21.9)	0.185
1	660 (33.9)	779 (40.0)	509 (26.1)		353 (18.1)	573 (29.4)	608 (31.2)	414 (21.3)	
2 or more	164 (32.3)	203 (40.0)	141 (27.8)		84 (16.5)	145 (28.5)	158 (31.1)	121 (23.8)	

Proportions were compared using the Chi-square test and means through analysis of variance (ANOVA).

Table 3 Multinomial regression model for the associations between family and child characteristics at 4 years and changes in screen time between 4 and 7 years.

	Maintained high	Decreased	Increased	Maintained high	Decreased	Increased
	Crude OR (95% CI)[a]			Adjusted OR (95% CI)[a]		
Child's Sex						
Female	1	1	1	1	1	1
Male	1.59 (1.33–1.91)	1.40 (1.17–1.68)	1.51 (1.25–1.83)	1.60 (1.33–1.92)	1.39 (1.16–1.67)	1.53 (1.26–1.86)
Mother's parity						
First pregnancy	1	1	1	1	1	1
Second pregnancy	1.01 (0.83–1.22)	0.95 (0.79–1.15)	0.96 (0.78–1.18)	1.02 (0.69–1.50)	1.21 (0.83–1.76)	1.13 (0.76–1.67)
Third or further pregnancy	0.98 (0.69–1.40)	1.21 (0.86–1.70)	1.36 (0.95–1.95)	1.04 (0.84–1.29)	0.96 (0.78–1.18)	0.87 (0.69–1.09)
Child's participation in sports						
No	1.48 (1.21–1.82)	1.89 (1.55–2.31)	1.33 (1.07–1.66)	1.33 (1.08–1.64)	1.73 (1.41–2.12)	1.15 (0.92–1.44)
Yes	1	1	1	1	1	1
Maternal age (per 5 years)	0.84 (0.78–0.91)	0.87 (0.80–0.95)	0.93 (0.84–1.02)	0.87 (0.79–0.97)	0.90 (0.82–1.00)	1.00 (0.90–1.12)
Mother's education (years)						
≤9	1.87 (1.52–2.32)	1.80 (1.46–2.23)	2.34 (1.86–2.94)	1.67 (1.33–2.11)[b]	1.55 (1.23–1.95)[b]	2.33 (1.82–2.99)[b]
10-12	1.43 (1.14–1.80)	1.55 (1.24–1.93)	1.69 (1.32–2.16)	1.28 (1.02–1.62)[b]	1.38 (1.09–1.74)[b]	1.67 (1.29–2.15)[b]
>12	1	1	1	1	1	1
Household income (euros/month)						
≤1000	1.44 (1.15–1.81)	1.49 (1.19–1.86)	1.80 (1.42–2.29)	1.28 (1.01–1.62)[c]	1.28 (1.01–1.62)[c]	1.72 (1.35–2.21)[c]
1001–1500	1.63 (1.31–2.02)	1.56 (1.25–1.93)	1.66 (1.31–2.09)	1.50 (1.20–1.87)[c]	1.41 (1.13–1.76)[c]	1.62 (1.27–2.05)[c]
>1500	1	1	1	1	1	1

[a] The reference category of the outcome is "Maintained low". Adjusted models included all variables in the table.
[b] Adjusted for all variables in the table, except household income.
[c] Adjusted for all variables in the table, except the mother's education.

socioeconomic position and the presence of a TV in the children's bedroom, parental modelling for TV viewing, parental co-viewing and having meals in front of the TV, highlighting the impact of parental behaviours, attitudes, and beliefs on children's ST habits. For example, Rek et al. [45] showed that role modelling is crucial in developing children's media habits. Both parents' own media habits and their opinion and beliefs on children's appropriate daily ST, as well as their formal education, seems to impact parents' behaviour in terms of education significantly and therefore affect children's media exposure.

Socioeconomic status, characterized in our study by the household income and parental education, is an important confounding factor of the association between ST and DP. Higher-income families usually own more televisions, video players and computers [48], and research shows that higher-educated adults spend less time watching TV than lower-educated adults [49]. Higher socioeconomic status is also associated with healthier eating choices [50]. Thus, children from lower socioeconomic position families are at higher risk for the potential negative health outcomes of excessive ST and improving parents' screen behaviours might also improve their children's SB.

Of the child factors assessed, the male sex was associated with higher odds of increasing ST or maintaining a high ST exposure. This sex difference, with boys being more likely to have higher ST, is consistent with previous studies [43,46–48]. Two factors can partly explain this: on the one hand, parent-child interactions might differ according to the child's sex [43]; on the other hand, girls may take part in more activities, such as homework and extracurricular cultural activities, besides screen behaviours [48].

Surprisingly, children who did not practice sports showed greater odds of reducing their ST. Several studies in children have demonstrated a small but a significant inverse association between ST and physical activity [6,51]. Likewise, another study has shown that ST during childhood is not a significant predictor of physical activity [52]. One explanation for our findings may be that children who had a higher ST at 4 years decreased it when they entered school age because they were enrolled in other activities that not included practicing sports.

Furthermore, we aimed to study the associations between ST and DPs. Our results suggest that children that increased their ST or maintained a high ST from preschool to school age were more likely to present unhealthier DPs – either Snacking or EDF. Similar results among children and adolescents suggest that TV viewing is associated with unhealthier DPs, frequently characterized by high consumption of sweets, salted snacks, and soft drinks, after adjusting for covariates of interest [29–31,53]. Also, some studies show that a Mediterranean DP was inversely associated with ST, both among 4-year-old children [54] and adolescents aged 12–17 years [29]. Potentially, screens exposure interferes with satiety and hunger signs, leading to an overconsumption of low-nutrient high-energy foods due to the less pronounced regulation of food consumption when eating while doing other things, such as watching television or playing videogames [55,56].

In our study, there was no significant association between ST and obesity, although higher ST was more

Table 4 Associations of changes in screen time from 4 to 7 years with dietary patterns at 7 years and children's BMI at 7 years.

	Dietary patterns at 7 years				Dietary patterns at 7 years			
	Energy-dense foods	Snacking	Healthier		Energy-dense foods	Snacking	Energy-dense foods	Snacking
	n (%)			p-value	Crude OR (95% CI)		Adjusted OR (95% CI)[a]	
Changes in screen time								
Maintained low	260 (34.7)	54 (7.2)	435 (58.1)	<0.001	1	1	1	1
Maintained high	734 (53.7)	165 (12.1)	468 (34.2)		2.62 (2.16–3.18)	2.84 (2.03–3.97)	2.42 (1.98–2.95)	2.65 (1.89–3.72)
Decreased	716 (50.2)	135 (9.5)	575 (40.3)		2.08 (1.72–2.52)	1.89 (1.35–2.65)	1.90 (1.56–2.31)	1.74 (1.23–2.44)
Increased	520 (52.6)	115 (11.6)	354 (35.8)		2.46 (2.00–3.01)	2.62 (1.84–3.72)	2.13 (1.73–2.64)	2.34 (1.64–3.35)

	Children's BMI at 7 years				Children's BMI at 7 years			
	Normal-weight/Underweight	Overweight	Obesity		Overweight	Obesity	Overweight	Obesity
	n (%)			p-value	Crude OR (95% CI)		Adjusted OR (95% CI)[b]	
Changes in screen time								
Maintained low	503 (67.2)	155 (20.7)	91 (12.1)	0.192	1	1	1	1
Maintained high	856 (62.6)	309 (22.6)	202 (14.8)		1.17 (0.94–1.46)	1.13 (0.99–1.71)	1.18 (0.94–1.48)	1.22 (0.93–1.60)
Decreased	938 (65.8)	279 (19.6)	209 (14.7)		0.96 (0.77–1.21)	1.23 (0.94–1.61)	0.97 (0.77–1.21)	1.14 (0.87–1.50)
Increased	630 (63.7)	222 (22.4)	137 (13.9)		1.14 (0.90–1.45)	1.20 (0.90–1.61)	1.14 (0.90–1.45)	1.11 (0.82–1.48)

P-value is calculated using the Chi-square test.
[a] The reference category is Healthier; adjusted for maternal education and children's active playtime.
[b] The reference category is Normal-weight/underweight; adjusted for maternal education, children's sex, and children's active playtime.

frequent among children with obesity. For example, Sorrie et al. [19] reported that preschool children engaged in screen activities (watching television or playing games) for more than 2 h per day were more likely to be overweight or obese compared to those who spent less than 2 h. However, in our study, when analysing changes in ST, although not statistically significant, a greater prevalence of obesity among those who reduced ST was found. This tendency may be explained by reducing ST as an intervention strategy for weight control. A randomized controlled trial showed that reducing children's ST has resulted in less BMI gain, indicating a potential causal relationship between screen media viewing and weight gain and suggesting that reducing children's ST may be a promising intervention approach to prevent childhood obesity [57].

The current study is not without limitations. Firstly, no information about the context of screen use (parenting style and media use, media in the child's bedroom, number of screens) or a direct measure of advertisement were available, which would have been essential covariates to include in the analysis. Another limitation is that we did not address the content of children's viewing, only the average daily time. Therefore, it is not possible to distinguish between educational versus entertainment television. Also, both children's dietary intake and ST were reported by their caregivers. Thus, the possibility of misreporting cannot be discarded. Diet was assessed through an FFQ, and therefore, estimation of dietary intake using frequency and not quantity could be argued as a limitation [58]. However, a reasonable validity and reliability of the FFQ data was supported with comparison with 3-day food diaries [38]: participants from the EDF pattern identified based on FFQ data presented significantly higher energy according to the food diaries, than the snacking and Healthier DP; and participants from the Snacking DP presented significantly lower fibre levels. The data we analysed in the present paper was collected about ten years ago, and therefore, ST patterns might have changed, namely, there may have been an increase in the use of tablets and mobile devices among children aged 5 and younger, since 2014 [59]. Consistent with population-based studies, our study is affected by losses of follow-up and exclusions due to missing data. Nevertheless, we compared the characteristics of the included and excluded participants. For mother's age, mother's parity, mother's educational level and household income, the magnitude of the differences was small, according to Cohens' D and Cramer's V effect size (supplementary material).

Strengths of our study include being the first one, to our knowledge, to evaluate changes in ST from preschool to school age and its predictors using a longitudinal design in Portuguese children. Because ST patterns are modifiable behaviours and preschool is critical in children's lives, interventions to prevent the poor outcomes associated with screen overexposure should be considered at an early age. Another vital aspect of our study is the use of DP to assess the associations between ST and food consumption, instead of looking at isolated food groups, which allows us to examine children's overall diet. DPs used in this study were identified using latent class analysis, which is an appropriate methodology for categorical variables common in data from FFQ [60,61]. Moreover, using *a posteriori* DPs is an essential strength as they consider the different effects and interactions among food components [58]. This study is part of Generation XXI, a population-based cohort with a large sample size, conducted by experienced researchers with procedures in place to warrant the quality of the data assessment, thus reducing the risk of bias and supporting the validity of the results.

In conclusion, the results of our study suggest that preschool children are highly exposed to screens, and there is a positive association between ST and unhealthier food consumption. Also, screen exposure seems to persist into childhood, and lower parental education level, lower household income, and male child sex increased the likelihood of maintaining high or increasing ST from preschool to school age.

Our findings may be of interest to policymakers, researchers, and public health professionals and may provide valuable insights for the design of intervention programmes addressing childhood ST patterns. Given that children overexposed to screens tend to remain so in the future and that this behaviour is associated with several poor health outcomes, future interventions should promote awareness among parents and caregivers. Future research should examine the effect of TV content and food advertising to which children are exposed, as well as parental influences and the family TV environment.

Declaration of competing interest

None of the authors has any conflict of interest to declare.

Acknowledgments

The authors gratefully acknowledge the families enrolled in Generation XXI for their kindness, all members of the research team for their enthusiasm and perseverance, and the participating hospitals and their staff for their help and support.

This study was supported by national funding through Programa Operacional de Saúde – Saúde XXI, Quadro Comunitário de Apoio III and Administração Regional de Saúde Norte (Regional Department of Ministry of Health) and by FCT (Foundation for Science and Technology, I.P.), under the Epidemiology Research Unit (EPIUnit), from the Institute of Public Health of the University of Porto (UIDB/04750/2020), and by the Stimulus of Scientific Employment – Individual Support (CEECIND/01271/2018) and the FCT Investigator contract IF/01060/2015.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2023.07.032.

References

[1] Strasburger V, Jordan A, Donnerstein E. Health effects of media on children and adolescents. Pediatrics 2010;125:756–67.
[2] American Academy of Pediatrics. Children, adolescents, and television. Pediatrics 2001;107(2):423–6.
[3] Robinson TN, Wilde ML, Navracruz LC, Haydel KF, Varady A. Effects of reducing children's television and video game use on aggressive behavior: a randomized controlled trial. Arch Pediatr Adolesc Med 2001;155(1):17–23.
[4] Strasburger VC. Does television affect learning and school performance? Pediatrician 1986;13(2–3):141–7.
[5] Christakis DA, Zimmerman F, Giuseppe DL, McCarty C. Early television exposure and subsequent attention problems in children. Pediatrics 2004;113(4):708–13.
[6] Marshall SJ, Biddle SJH, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. Int J Obes 2004;28(10):1238–46.
[7] Mendoza JA, Zimmerman FJ, Christakis DA. Television viewing, computer use, obesity, and adiposity in US preschool children. Int J Behav Nutr Phys Activ 2007;4:44.
[8] Robinson TN, Banda JA, Hale L, Lu AS, Fleming-Milici F, Calvert SL, et al. Screen media exposure and obesity in children and adolescents. Pediatrics 2017;140(Suppl 2):S97–101.
[9] Epstein LH, Paluch RA, Gordy CC, Dorn J. Decreasing sedentary behaviors in treating pediatric obesity. Arch Pediatr Adolesc Med 2000;154(3):220–6.
[10] Taveras EM, Sandora TJ, Shih MC, Ross-Degnan D, Goldmann DA, Gillman MW. The association of television and video viewing with fast food intake by preschool-age children. Obesity 2006;14(11):2034–41.
[11] Börnhorst C, Wijnhoven T, Kunesova M, Yngve A, Rito A, Duleva V, et al. WHO European Childhood Obesity Surveillance Initiative: associations between sleep duration, screen time and food consumption frequencies. BMC Publ Health 2015;15:442.
[12] Matheson DM, Killen JD, Wang Y, Varady A, Robinson TN. Children's food consumption during television viewing. Am J Clin Nutr 2004;79(6):1088–94.
[13] Boynton-Jarrett R, Thomas TN, Peterson KE, Wiecha J, Sobol AM, Gortmaker SL. Impact of television viewing patterns on fruit and vegetable consumption among adolescents. Pediatrics 2003;112(6 Pt 1):1321–6.
[14] Robinson T, Borzekowski D, Matheson D, Kraemer H. Effects of fast food branding on young children's taste preferences. Arch Pediatr Adolesc Med 2007;161:792–7.
[15] Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med 2004;1(3):e62.
[16] Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. Obesity 2008;16(3):643–53.
[17] World Health Organization. Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. Geneva, Switzerland: World Health Organization; 2019.
[18] Canadian Paediatric Society. Healthy active living: physical activity guidelines for children and adolescents. 2012. Available from: https://www.cps.ca/en/documents/position/physical-activity-guidelines.
[19] Sorrie MB, Yesuf ME, GebreMichael TG. Overweight/Obesity and associated factors among preschool children in Gondar City, Northwest Ethiopia: a cross-sectional study. PLoS One 2017;12(8).
[20] Jeffery RW, French SA. Epidemic obesity in the United States: are fast foods and television viewing contributing? Am J Publ Health 1998;88(2):277–80.
[21] Jackson DM, Djafarian K, Stewart J, Speakman JR. Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children. Am J Clin Nutr 2009;89(4):1031–6.
[22] Garriguet D, Carson V, Colley RC, Janssen I, Timmons BW, Tremblay MS. Physical activity and sedentary behaviour of Canadian children aged 3 to 5. Health Rep 2016;27(9):14–23.
[23] Cox R, Skouteris H, Rutherford L, Fuller-Tyszkiewicz M, Dell' Aquila D, Hardy LL. Television viewing, television content, food intake, physical activity and body mass index: a cross-sectional

study of preschool children aged 2-6 years. Health Promot J Aust 2012;23(1):58–62.
[24] Lopes C, Torres D, Oliveira A, Severo M, Alarcão V, Guiomar S, et al. National food, nutrition and physical activity Survey, IAN-AF 2015-2016: results report. University of Porto; 2017.
[25] Rodrigues D, Gama A, Machado-Rodrigues AM, Nogueira H, Silva M-RG, Rosado-Marques V, et al. Screen media use by Portuguese children in 2009 and 2016: a repeated cross-sectional study. Ann Hum Biol 2021;48(1):1–7.
[26] Certain LK, Kahn RS. Prevalence, correlates, and trajectory of television viewing among infants and toddlers. Pediatrics 2002; 109(4):634–42.
[27] Roberts DF, Foehr UG. Trends in media use. Future Child 2008; 18(1):11–37.
[28] Charreire H, Kesse-Guyot E, Bertrais S, Simon C, Chaix B, Weber C, et al. Associations between dietary patterns, physical activity (leisure-time and occupational) and television viewing in middle-aged French adults. Br J Nutr 2011;105(6):902–10.
[29] Bibiloni Mdel M, Martínez E, Llull R, Pons A, Tur JA. Western and Mediterranean dietary patterns among Balearic Islands' adolescents: socio-economic and lifestyle determinants. Publ Health Nutr 2012;15(4):683–92.
[30] Lee JY, Jun N, Baik I. Associations between dietary patterns and screen time among Korean adolescents. Nutr Res Prac 2013;7(4): 330–5.
[31] Aranceta J, Pérez-Rodrigo C, Ribas L, Serra-Majem L. Sociodemographic and lifestyle determinants of food patterns in Spanish children and adolescents: the enKid study. Eur J Clin Nutr 2003; 57(Suppl 1):S40–4.
[32] Society CP. Screen time and young children: promoting health and development in a digital world. Paediatr Child Health 2017;22(8): 461–77.
[33] Northstone K, Emmett PM. Are dietary patterns stable throughout early and mid-childhood? A birth cohort study. Br J Nutr 2008; 100(5):1069–76.
[34] Ventura AK, Worobey J. Early influences on the development of food preferences. Curr Biol 2013;23(9):R401–8.
[35] Alves E, Correia S, Barros H, Azevedo A. Prevalence of self-reported cardiovascular risk factors in Portuguese women: a survey after delivery. Int J Publ Health 2012;57(5):837–47.
[36] Larsen PS, Kamper-Jørgensen M, Adamson A, Barros H, Bonde JP, Brescianini S, et al. Pregnancy and birth cohort resources in Europe: a large opportunity for aetiological child health research. Paediatr Perinat Epidemiol 2013;27(4):393–414.
[37] Vilela S, Severo M, Moreira T, Ramos E, Lopes C. Evaluation of a short food frequency questionnaire for dietary intake assessment among children. Eur J Clin Nutr 2019;73(5):679–91.
[38] Durão C, Severo M, Oliveira A, Moreira P, Guerra A, Barros H, et al. Association of maternal characteristics and behaviours with 4-year-old children's dietary patterns. Matern Child Nutr 2017; 13(2).
[39] Onis M, Onyango A, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school aged children and adolescents. Bull World Health Organ 2007;85:660–7.
[40] Expert Panel on the Identification, Evaluation and Treatment of Overweight in Adults. Clinical guidelines on the identification, evaluation and treatment of overweight and obesity in adults: executive summary. Am J Clin Nutr 1998;68:899–917.
[41] Hamilton K, Spinks T, White K, Kavanagh D, Walsh A. A psychosocial analysis of parents' decisions for limiting their young child's screen time: an examination of attitudes, social norms and roles, and control perceptions. Br J Health Psychol 2015;21.
[42] Trinh MH, Sundaram R, Robinson SL, Lin TC, Bell EM, Ghassabian A, et al. Association of trajectory and covariates of children's screen media time. JAMA Pediatr 2020;174(1):71–8.
[43] Chiu YC, Li YF, Wu WC, Chiang TL. The amount of television that infants and their parents watched influenced children's viewing habits when they got older. Acta Paediatr 2017;106(6):984–90.
[44] Gebremariam MK, Altenburg TM, Lakerveld J, Andersen LF, Stronks K, Chinapaw MJ, et al. Associations between socioeconomic position and correlates of sedentary behaviour among youth: a systematic review. Obes Rev 2015;16(11):988–1000.
[45] Rek M, Kovacic A. Media and Preschool children: the role of parents a role models and educators. Medijske Studije-Media Studies 2018;9(18):27–43.
[46] Atkin AJ, Sharp SJ, Corder K, van Sluijs EM. Prevalence and correlates of screen time in youth: an international perspective. Am J Prev Med 2014;47(6):803–7.
[47] Huang WY, Wong SH, Salmon J. Correlates of physical activity and screen-based behaviors in Chinese children. J Sci Med Sport 2013; 16(6):509–14.
[48] Cui Z, Hardy LL, Dibley MJ, Bauman A. Temporal trends and recent correlates in sedentary behaviours in Chinese children. Int J Behav Nutr Phys Activ 2011;8:93.
[49] Rhodes RE, Mark RS, Temmel CP. Adult sedentary behaviour: a systematic review. Am J Prev Med 2012;42:e3–28.
[50] Mayén AL, Marques-Vidal P, Paccaud F, Bovet P, Stringhini S. Socioeconomic determinants of dietary patterns in low- and middle-income countries: a systematic review. Am J Clin Nutr 2014;100: 1520–31.
[51] Pearson N, Braithwaite RE, Biddle SJ, van Sluijs EM, Atkin AJ. Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis. Obes Rev 2014;15(8): 666–75.
[52] Hearst MO, Patnode CD, Sirard JR, Farbakhsh K, Lytle LA. Multilevel predictors of adolescent physical activity: a longitudinal analysis. Int J Behav Nutr Phys Activ 2012;9(1):8.
[53] Tambalis KD, Panagiotakos DB, Psarra G, Sidossis LS. Screen time and its effect on dietary habits and lifestyle among schoolchildren. Cent Eur J Publ Health 2020;28(4):260–6.
[54] Leventakou V, Sarri K, Georgiou V, Chatzea V, Frouzi E, Kastelianou A, et al. Early life determinants of dietary patterns in preschool children: rhea mother-child cohort, Crete, Greece. Eur J Clin Nutr 2016;70(1):60–5.
[55] Lissner L, Lanfer A, Gwozdz W, Olafsdottir S, Eiben G, Moreno LA, et al. Television habits in relation to overweight, diet and taste preferences in European children: the IDEFICS study. Eur J Epidemiol 2012;27(9):705–15.
[56] Hastings G, McDermott L, Angus K, Stead M, Thomson S. The extent, nature and effect of food promotion to children: a review of the evidence. 2006. Technical paper prepared for the World Health Organization.
[57] Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. JAMA 1999;282(16):1561–7.
[58] Willet W. Nutritional Epidemiology. second ed. New York: Oxford University Press Am J Clin Nutr 1998;69(5):1020.
[59] Chen W, Adler JL. Assessment of screen exposure in young children, 1997 to 2014. JAMA Pediatr 2019;173(4):391–3.
[60] Muthén B, Muthén LK. Integrating person-centered and variable-centered analyses: growth mixture modeling with latent trajectory classes. Alcohol Clin Exp Res 2000;24(6):882–91.
[61] Fonseca MJ, Durão C, Lopes C, Santos AC. Weight following birth and childhood dietary intake: a prospective cohort study. Nutrition 2017;33:58–64.