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Heavy Screen Use on Weekends in Childhood Predicts Increased Body Mass Index in Adolescence: A Three-Year Follow-Up Study

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A B S T R A C T

Purpose: We aimed to examine whether sedentary screen time changes when transitioning from childhood to adolescence and whether children's screen time, separately for school days and weekends, affects body mass index (BMI) in adolescents.
Methods: This prospective 3-year follow-up study included 5,084 children with a mean (standard deviation) age of 11 (1) years at baseline and 14 (1) years at follow-up. Children reported screen time, more specifically, time spent viewing TV programs and using a computer outside school while sitting. We categorized children into light, medium, and heavy TV viewers and computer users separately for school days and weekends. We also calculated the age- and gender-specific BMI z-score (BMIz).
Results: Time spent viewing TV changed from baseline to follow-up on school days and on weekends ($p < .001$ for both); the proportion of heavy TV viewers on school days (≥3 h/d) increased from 16% to 23% and on weekends (≥4 h/d) from 19% to 30%. Heavy TV viewers and computer users on both school days and on weekends had a higher BMIz 3 years later ($p < .001$ for all). After adjusting for age, gender, language, baseline BMIz, sleep duration, eating habits, exercise, and the other screen-time variables, heavy TV viewing on weekends remained significantly associated with an increased BMIz at follow-up ($B = .078$; $p = .013$).
Conclusions: The proportion of heavy screen users increases when transitioning from childhood to adolescence. Moreover, heavy screen use, especially on weekends in 11-year-old children, is associated with an increased BMI 3 years later.

IMPLICATIONS AND CONTRIBUTION

Children today live in a digital world, but little is known about its consequences. This study shows that children's heavy screen use, particularly on weekends, associates with an increased weight in adolescence. Replacing sedentary screen use with more active hobbies on weekends could prevent becoming overweight or obese.

Conflicts of interest: The authors declare that they have no conflicts of interest.
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The high prevalence of child and adolescent obesity represents one of the most serious global health challenges of the 21st century [1]. Children's leisure-time behaviors, such as exercise and sedentary screen time, may play important roles in the current obesity epidemic [2,3]. Studies indicate that children's screen time increases with age, particularly during preadolescence [4]. Although traditional TV viewing has declined in the last decade, the use of alternative screen-based devices to view TV programs and for other recreational purposes appears to be increasing, leading to higher total amounts of screen time in youth [4–6].

Results from cross-sectional studies suggest that more time spent in sedentary behaviors, that is, behaviors that do not increase energy expenditure substantially above what is needed when resting, correlates with an adverse cardiometabolic health status and a heavier weight in children and adolescents [7–9]. Recent systematic reviews and a meta-analysis of longitudinal studies, in turn, do not support the association between sedentary behavior and adiposity in youth [9,10]. However, existing research on the causal relationship remains insufficient, given the conflicting findings [4,9,10].

The key potential confounders in the relationship between sedentary behaviors and adiposity in children consist of physical activity, dietary intake, pubertal status, and, possibly sleep [9]. However, only a few previous prospective studies have included physical activity and sleep as confounding factors [9,10]. Moreover, those studies that considered physical activity reported conflicting results. Some prospective studies suggest that parent- or self-reported screen time [11] as well as accelerometer-measured sedentary time associated with increased adiposity even when taking physical activity into account [12–14]. Yet, other studies indicated that sedentary time did not affect cardiometabolic risk factors in youth when adjusting for confounding factors such as physical activity [15,16]. Or the relationship between screen time and adiposity was partly mediated by less physical activity [17]. Furthermore, although children spend more time on screen-based devices on weekends than on school days [18], few studies have examined the relationship of screen time separately for school days and weekends with adiposity [10].

Screen-based sedentary behaviors are highly prevalent in modern society. Simultaneously, obesity represents a major health concern among youth. Resolving the impact of sedentary screen time on excess weight would aid the development of effective strategies to tackle the obesity epidemic. This prospective 3-year follow-up study examines, first, whether children's sedentary screen time outside school hours changes when transitioning from childhood to adolescence and, second, whether children's screen time, on school days and on weekends, respectively, affects their body mass index (BMI) during adolescence.

Methods

Study design and participants

This analysis uses data from the Finnish Health in Teens study (Fin-HIT), a prospective cohort study, including children from 496 schools and 44 municipalities in Finland. Here, we include 5,084 children for whom information is available on the relevant baseline characteristics and BMI at follow-up. We collected the baseline data between 2011 and 2014 when the children were aged 9–12 years, whereas follow-up data were collected in 2015 and 2016. More detailed information on the Fin-HIT cohort appears elsewhere [19]. All study procedures adhered to the 1964 Helsinki Declaration and its later amendments or by applying comparable ethical standards. The Coordinating Ethics Committee of the Hospital District of Helsinki and Uusimaa approved the study protocol (169/13/03/00/10), and we obtained a written informed consent from all participants and their guardians.

Measurements

Body mass index. At baseline, trained fieldworkers measured children's weight and height at schools, as described elsewhere [19]. At follow-up, families received a measuring tape and written and graphical instructions on how to measure and report the weight and height of the adolescent. The self-reported anthropometric measurements were previously validated, whereby BMI did not significantly differ when calculated based on the home measurement or the standardized measurement at school [20]. We transformed BMI into an age- and gender-specific BMI z-score (BMIz) based on the International Obesity Task Force reference values, and further categorized the children as underweight, normal weight, overweight, or obese using the International Obesity Task Force cut-offs [21].

Sedentary screen time. Children completed a Web-based questionnaire, which included health- and lifestyle-related questions. We asked children about their screen time outside school hours and performed when sitting. More specifically, we assessed time spent viewing TV programs and using a computer through questions adapted from the World Health Organization (WHO) Health Behavior in School-aged Children (HBSC) study [22]. The screen time questions in the WHO HBSC study have fair to substantial test–retest reliability depending on the criteria used [23–25]. One study showed Intraclass Correlation Coefficients (ICCs) for test–retest reliability from .54 to .66 in different TV viewing and computer use questions [23]. Another study, in turn, reported ICCs of .72–.74 for TV viewing, but lower ICCs for computer use [24]. We assessed TV viewing at baseline and at follow-up through the following question: "How many hours a day during your free time do you normally watch TV, videos or DVDs? By TV, we mean programs that can be watched on TV as well as on a computer." In addition, we assessed computer use at baseline by asking the following: "How many hours a day during your free time do you normally use a computer, e.g., spend time on the Internet, chat or play computer or TV games sitting down (e.g., PlayStation, Xbox)?" At follow-up, we assessed computer use through two different questions to those used at baseline. One question focused on playing computer games: "How many hours a day during your free time do you normally play computer games or console games (PlayStation, Xbox, GameCube etc.)? Do not count any so-called moving games (e.g., Move, Wii)." The other question addressed screen use other than gaming: "How many hours a day during your free time do you normally use a computer, tablet (e.g., iPad) or smart mobile phone for other purposes than games? For example, homework, emailing, tweeting, Facebook, chatting, surfing the internet?"

Children answered questions on TV viewing and computer use by choosing between nine response options, ranging from (1) "I do not watch TV, videos or DVDs/I do not use a computer" to (9) "Around seven or more hours a day." We assessed screen time questions separately for school days and for weekends or days off, resulting in four sedentary screen time variables: TV viewing on school days, TV viewing on weekends, computer use on school days, and computer use on weekends. Based on their responses, we categorized children into heavy (roughly the highest 25% of children), medium (roughly the middle 50%), and light (roughly the lowest 25%) TV viewers and computer users on school days or on weekends. We could not categorize the children into exact 25%/50%/25% because the variables were not continuous. Therefore, we chose the cut-offs that were closest to these proportions based on the distribution of the responses.

Demographics. Parents reported their child's age, gender, and language spoken at home, that is, Finnish, Swedish (the two main official languages of Finland), or other. Language can be seen as a proxy for socioeconomic status because compared with Finnish-speaking Finns, Swedish-speaking Finns have, on average, higher income and education, whereas persons with foreign background (i.e., both parents born abroad) have on average lower income and education [26,27]. We confirmed the information supplied by linking data to the National Population Information System at the Population Register Center [19].

Sleep. We assessed children's baseline sleep time through the following questions: “When do you usually fall asleep in the evenings on a school night?” (with 12 response options) and “When do you usually wake up on school days?” (with seven response options). Questions were adapted from questions used in the LifeGene, WHO HBSC, and Finnish School Study [22,28,29]. We calculated sleep duration on school nights and categorized children into those who slept less than recommended, recommended, and more than recommended based on the age-specific childhood sleep guidelines developed by the American Academy of Pediatrics [30].

Eating habits. We assessed baseline eating habits using a 16-item food frequency questionnaire. Children reported how frequently they consumed each item during the past month using a 7-point scale ranging from 0 (not consumed) to 6 (consumed several times per day). We previously identified three types of eaters in the Fin-HIT cohort based on a cluster and factor analysis: unhealthy eaters, fruit and vegetable avoiders, and healthy eaters [31]. Unhealthy eaters emerged as the most frequent consumers of sweet pastries, biscuits or cookies, ice cream, sugary juice drinks, fast food (hamburgers or hot dogs), and salty snacks. In turn, fruit and vegetable avoiders consumed the fewest fresh vegetables, fruits, and berries, while healthy eaters consumed more dark bread, fresh vegetables, fruits, and berries compared with others.

Exercise. We assessed leisure-time exercise duration through a question adapted from the Finnish School Study [29]: “How many hours a week do you normally exercise or do sports during your free time? Include all the exercise you do in a club or team and any exercise by yourself, with family or friends. Do not count any exercise at school or on the way to school.” Children answered by selecting from 10 response options ranging from (1) “An hour or less each week” to (10) “About 10 hours a week.” Questions on exercise were previously validated against an accelerometer in 11-year-olds, for which a moderate capability was found of categorizing children according to their activity levels [32]. We, then, recategorized responses into groups with high (roughly the highest 25% of children), medium (roughly the middle 50%), and low (roughly the lowest 25%) weekly exercise duration. The final exercise groups consisted of high ($\geq$10 h/wk), medium (5–9 h/wk), and low ($\leq$4 h/wk) levels.

Statistical analyses

In the analysis, we excluded children with missing values for the screen time variables or for covariates at baseline or for BMI at follow-up. We describe screen-time behavior providing the number and percentage of participants in each category for TV viewing and computer use at baseline and at follow-up. In addition, we visually examined whether BMIz at follow-up was normally distributed. We analyzed the change in BMIz from baseline to follow-up using the paired sample *t*-test while analyzing changes in TV viewing (heavy, medium, and light) using the Wilcoxon test. We also tested the crude associations of the baseline variables with BMIz at follow-up using the independent samples *t*-test, or analysis of variance with the Tukey test for multiple comparisons when an analysis of variance result was significant. Furthermore, we examined the associations between TV viewing and computer use at baseline, respectively, and BMIz at follow-up using the linear regression models. We tested three models: model 1 was adjusted for baseline BMIz to examine the associations between baseline screen time variables and a change in BMIz; model 2 was adjusted for all other baseline variables except for BMIz to examine the associations between baseline screen time variables and follow-up BMIz when taking into account possible confounding factors (age, gender, language, sleep duration, eating habits, and exercise) [9]; and model 3 was adjusted for all baseline variables, including BMIz to examine the associations between baseline screen time variables and a change in BMIz when taking into account possible confounding factors. We also determined whether variation in the follow-up time affected the results by adding the follow-up time into model 3. In addition, we tested the interactions between gender and screen-time variables and between exercise and screen-time variables in model 3. All analyses were conducted using IBM's SPSS Statistics software program, version 25 (IBM Corp., Armonk, NY), considering $p < .05$ as significant.

Results

Participants' characteristics

In total, we had information on BMI and screen time at baseline and BMI at follow-up for 5,198 children. In our final analysis, we included a total of 5,084 children after removing children because of missing values in sleep duration (n = 19), eating habits (n = 93), and exercise (n = 9). The mean follow-up time was 2.5 years (standard deviation [SD] .8). The mean age of the children was 11.1 years (SD .8) at baseline and 13.7 years (SD 1.2) at follow-up, whereas the mean BMIz was .17 (SD .98) at baseline and .30 (SD .94) at follow-up ($p < .001$).

Table 1 summarizes the baseline characteristics of the children and the corresponding BMIz at follow-up. Among the baseline characteristics, BMI, sleep duration, TV viewing, and computer use associated with BMIz at follow-up. Specifically, the follow-up BMIz was highest among those who were overweight or obese, who slept less than recommended, and who were medium or heavy TV viewers or heavy computer users at baseline (Table 1).

At follow-up, 386 adolescents (7.6%) were underweight, 3,964 (78%) normal weight, 652 (12.3%) overweight, and 109 (2.1%) obese. We previously reported that the participation rate in the follow-up was 53.5% [19]. No clinically significant differences were found in age, gender, BMI categories, language spoken at home, and pubertal stage between adolescents who participated in the follow-up and who were lost to follow-up [19]. Parental educational level of those who participated in the follow-up was slightly higher, but that information was available only for a subset of the participants [19].

Change in sedentary screen time. Table 2 summarizes sedentary screen time use among adolescents at follow-up. Figure 1A, B reveals that the amount of time spent viewing TV programs changed from the baseline measurement to follow-up both on school days and on weekends ($p < .001$ for both). More specifically, from baseline to follow-up, the proportion of heavy TV viewers (≥3 h/d) on school days increased from 16% to 23%, whereas the proportion of heavy TV viewers (≥4 h/d) on weekends increased from 19% to 30%. In addition, Figure 1C summarizes the proportion of adolescents who increased, decreased, and did not change with regards to TV viewing. We could not examine the change in computer use because we asked one general question on computer use at baseline and two more specific questions at follow-up. At baseline, however, 30% of children were heavy computer users on school days (≥2 h/d), whereas 27% were heavy computer users on weekends (≥3 h/d; Table 1). When using the same cut-offs for groups at follow-up, 19% of adolescents were heavy computer gamers, and 20% were heavy screen users on school days, whereas 22% were heavy computer gamers, and 32% were heavy screen users on weekends (Table 2). Finally, when taking into account both computer questions at follow-up, 1,824 (36%) adolescents were either heavy computer gamers or heavy screen users or both on school days. Similarly, 2,439 (48%) adolescents were heavy computer gamers or heavy screen users or both on weekends.

The prospective relationship between screen time and body mass index. Figure 2 provides the crude associations between screen time at baseline and BMIz at follow-up. Here, we see that more time spent on TV viewing or computer use associated with a higher BMIz 3 years later ($p < .001$ for all). BMIz was highest among heavy TV viewers and heavy computer users both on school days and on weekends. In addition, Table 3 provides the relationships between baseline TV viewing and computer use, respectively, to follow-up BMIz after adjusting for confounding factors. Specifically, heavy TV viewing on weekends associated with a higher BMIz 3 years later in all three models. That is, this relationship held after adjusting for age, gender, language, sleep duration, eating habits, exercise, the other screen-time variables, and BMIz at baseline (B = .078; $p = .013$). Furthermore, this result held after adding the follow-up time to model 3 (B = .079; $p = .011$ for TV viewing on weekends). In addition, heavy computer use on weekends associated with a higher follow-up BMIz only when baseline BMIz was not taken into account (model 2), whereas TV viewing or computer use on school days did not associate with later BMIz after adjustments. We found no interactions between gender and the screen-time variables or between exercise and the screen-time variables in relation to BMIz at follow-up.

Discussion

This prospective study of 11-year-old children showed that the proportion of heavy TV viewers increased during a 3-year follow-up. Furthermore, heavy TV viewing on weekends (≥4 h/d) associated with an increased BMI 3 years later.

We detected an increase in TV viewing from 2011 through 2014 when the mean age of the children was 11 years to 2015 and 2016 when their mean age was 14 years. Similar to previous studies [4], our results indicate that children's screen time increases with age, in particular, during preadolescence. The development of screen-based devices over time may have also affected screen time among youth. Although a significant decrease occurred in TV viewing from 1999 to 2015 as well as from 2013 to 2015 among 10–24-year-olds in the U.S. [33], a simultaneous increase occurred in computer use and in overall

Table 1
Baseline characteristics of participants and corresponding BMIz at 3-year follow-up (n = 5,084)

Baseline characteristics	n (%)	BMIz at follow-up, mean (SD)	p[a]
Gender			.620
Girl	2,708 (53.3)	.30 (.93)	
Boy	2,376 (46.7)	.31 (.95)	
BMI categories			**<.001**
Underweight	595 (11.7)	−.94 (.64)[c]	
Normal weight[b]	3,784 (74.4)	.26 (.70)	
Overweight	602 (11.8)	1.46 (.59)[c]	
Obese	103 (2.0)	2.32 (.49)[c]	
Language			.195
Other	81 (1.6)	.46 (.97)	
Swedish	200 (3.9)	.24 (.94)	
Finnish	4,803 (94.5)	.30 (.93)	
Sleep duration			**<.001**
Less than recommended	336 (6.6)	.50 (.98)[c]	
More than recommended	76 (1.5)	.48 (.97)	
Recommended[b]	4,672 (91.9)	.29 (.93)	
Eating habits			.925
Unhealthy	548 (10.8)	.30 (.96)	
Fruit and vegetable avoider	2,164 (42.6)	.31 (.98)	
Healthy	2,372 (46.7)	.30 (.88)	
Leisure-time exercise			.253
Low (≤4 h/wk)	1,302 (25.6)	.33 (1.02)	
Medium (5–9 h/wk)	2,682 (52.8)	.30 (.92)	
High (≥10 h/wk)	1,100 (21.6)	.27 (.86)	
TV viewing on school days			**<.001**
Light (≤.5 h/d)[b]	1,260 (24.8)	.21 (.91)	
Medium (1–2 h/d)	3,003 (59.1)	.31 (.93)[c]	
Heavy (≥3 h/d)	821 (16.1)	.43 (.98)[c]	
TV viewing on weekends			**<.001**
Light (≤1 h/d)[b]	1,430 (28.1)	.21 (.90)	
Medium (2–3 h/d)	2,681 (52.7)	.30 (.93)[c]	
Heavy (≥4 h/d)	973 (19.1)	.46 (.97)[c]	
Computer use on school days			**<.001**
Light (0 h/d)[b]	805 (15.8)	.21 (.92)	
Medium (.5–1 h/d)	2,778 (54.6)	.29 (.91)	
Heavy (≥2 h/d)	1,501 (29.5)	.38 (.98)[c]	
Computer use on weekends			**<.001**
Light (≤.5 h/d)[b]	1,149 (22.6)	.22 (.89)	
Medium (1–2 h/d)	2,570 (50.6)	.27 (.93)	
Heavy (≥3 h/d)	1,365 (26.8)	.44 (.97)[c]	

Bold values are statistically significant ($p < .05$).
BMI = body mass index; BMIz = body mass index z-score; SD = standard deviation.
[a] Difference in BMIz at follow-up, results from a *t*-test or analysis of variance.
[b] Reference category in the Tukey post-hoc test.
[c] Differs compared with the reference category ($p < .05$ from the Tukey post-hoc test).

Table 2
Sedentary screen time outside school hours at 3-year follow-up (n = 5,084)

Recreational screen time	n (%)
TV viewing on school days	
Light (≤.5 h/d)	914 (18.0)
Medium (1–2 h/d)	3,012 (59.2)
Heavy (≥3 h/d)	1,146 (22.5)
Missing	12 (.2)
TV viewing on weekends	
Light (≤1 h/d)	986 (19.4)
Medium (2–3 h/d)	2,569 (50.5)
Heavy (≥4 h/d)	1,517 (29.8)
Missing	12 (.2)
Computer gaming on school days[a]	
Light (0 h/d)	2,816 (55.4)
Medium (.5–1 h/d)	1,300 (25.6)
Heavy (≥2 h/d)	956 (18.8)
Missing	12 (.2)
Computer gaming on weekends[a]	
Light (.5 h/d)	2,772 (54.5)
Medium (1–2 h/d)	1,204 (23.7)
Heavy (≥3 h/d)	1,096 (21.6)
Missing	12 (.2)
Screen time other than gaming on school days[a]	
Light (0 h/d)	1,659 (32.6)
Medium (.5–1 h/d)	2,387 (47.0)
Heavy (≥2 h/d)	1,026 (20.2)
Missing	12 (.2)
Screen time other than gaming on weekends[a]	
Light (.5 h/d)	1,365 (26.8)
Medium (1–2 h/d)	2,070 (40.7)
Heavy (≥3 h/d)	1,637 (32.2)
Missing	12 (.2)

[a] This question on computer use differed from the baseline question.

sedentary time among youth [33,34]. Although some previous studies reported a decrease, our study indicated an increase in TV viewing, likely explained by the assessment method for the type of TV viewing. For example, other studies assessed traditional TV viewing while we assessed viewing TV programs, DVDs, and videos also on other screen-based devices. Thus, in accordance with other studies, our results suggest that the amount of screen time among children increased when all screen-based devices are taken into account [4–6].

We assessed TV viewing using a similar question at baseline and at follow-up. Yet, the assessment of computer use differed at the two time points. Therefore, we could analyze the change in TV viewing, but not in computer use. Nevertheless, it is plausible that computer use also increased during the follow-up period in our study. Screen time at follow-up appeared substantially high because the proportion of adolescents who viewed TV programs at least 3 hours each day on school days increased from 16% to 23%, and the proportion of those who viewed TV programs at least 4 h/d on weekends increased from 19% to 30% during the follow-up. Moreover, 36% of adolescents played computer games or used screen-based devices for other purposes during their free time at least 2 hours each day on school days, and 48% at least 3 h/d on weekends at follow-up. A recent nationwide report showed that the proportion of Finnish 9- to 15-year-old children reporting more than 2 hours of any screen time (active and passive) use on at least 5 d/wk increased from 49% to 55% between 2016 and 2018 [35]. There is still a lack of sufficient evidence that can provide guidance on the dose–response relationship between sedentary behaviors and various health outcomes in children and adolescents [4,7]. Therefore, although some of the current guidelines recommend no more than 2 h/d of recreational screen time for school-aged and older children [36], others state that sedentary screen-based activities should be reduced, but further evidence is required to establish more detailed guidelines [4,7,37].

We found that a greater amount of time spent viewing TV on weekends impacted BMI 3 years later. Similar to our results, a recent prospective study of 600 6-year-old children reported that more accelerometer-measured time spent on sedentary behaviors associated with a higher BMI across 5 years even when physical activity was taken into account [14]. In addition, a Norwegian study of 393 preadolescents adjusted the analysis for physical activity and diet, finding that screen time of more than 3 h/d at 12–13 years old increased the risk of being overweight at 15–16 years old [38]. Yet, a systematic review of previous prospective studies found insufficient evidence for the relationship between TV viewing and BMI or BMIz as a continuous variable [10]. However, the results from our study and from the studies described previously indicate a linear positive association between TV viewing and BMI in youth. For computer use, we identified a crude positive relationship with later BMI, although the association disappeared after adjusting for confounding factors. These results agree with a systematic review that found no evidence for a relationship between computer use and later

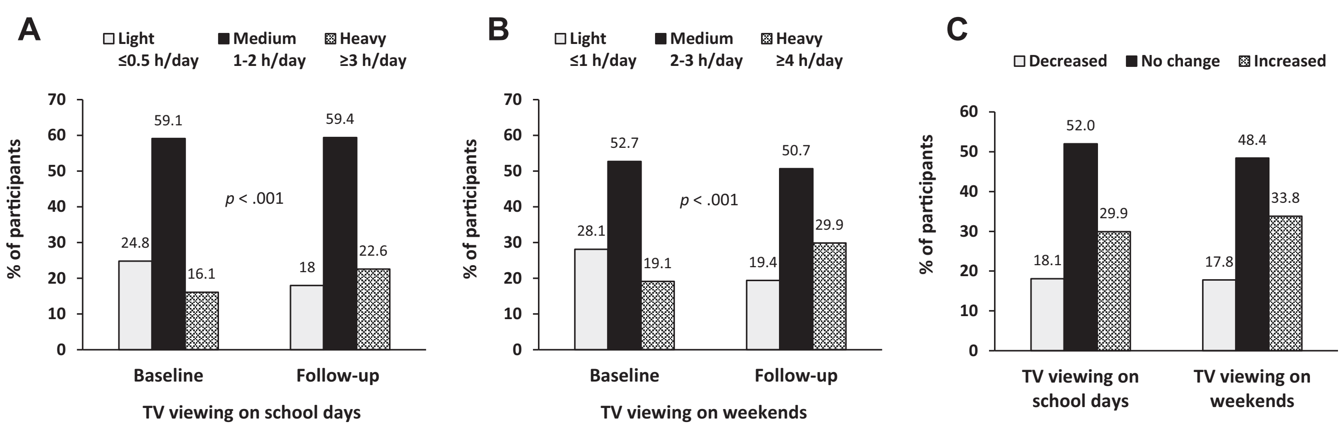

Figure 1. TV viewing at baseline (mean age 11 years) and at follow-up (mean age 14 years) on school days (A) and weekends or days off (B). (C) The proportion of adolescents who decreased (from heavy to medium or light or from medium to light), increased (from light to medium or heavy or from medium to heavy), and did not change TV viewing from baseline to follow-up. n = 5,084 at baseline and n = 5,072 at follow-up. Results from the Wilcoxon test. h = hours.

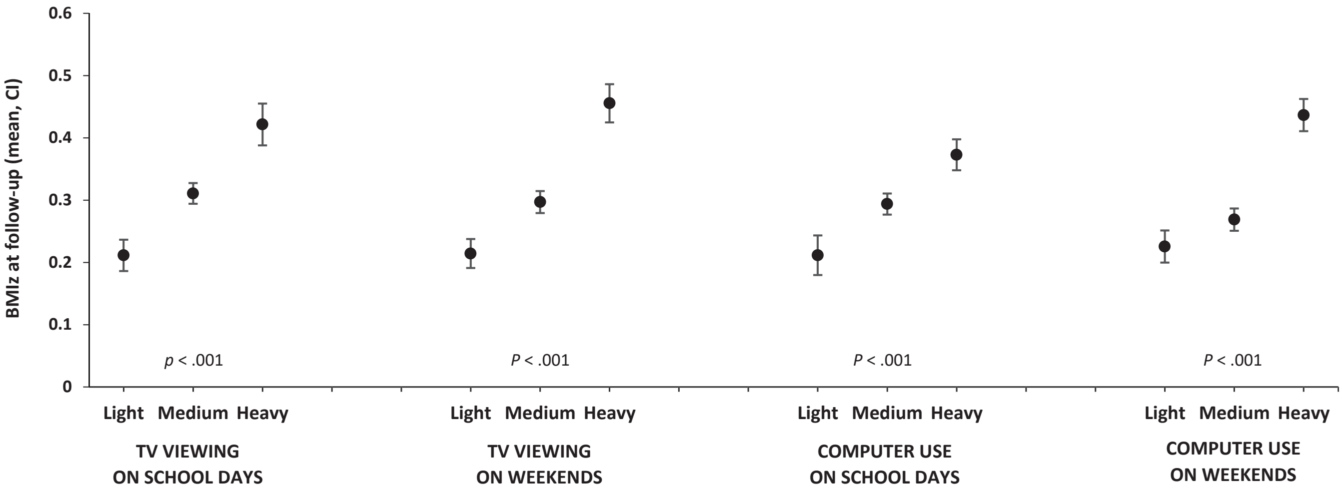

Figure 2. Children's sedentary TV viewing and computer use outside school hours at baseline (mean age 11 years) and BMIz (mean and CI) at follow-up (mean age 14 years). n = 5,084. Results from analysis of variance. BMIz = body mass index z-score; CI = 95% confidence interval.

BMI [10]. TV viewing may be easier to recall and report than computer use, which may account for stronger associations found between TV viewing and later BMI. In most previous studies, computer use included both active and passive computer use or gaming [10], whereas we assessed computer use while sitting—that is, sedentary computer use excluding exergames (i.e., video games that require physical exercise).

School-aged children spend more time on sedentary behaviors including screen time and less time on physical activities on weekends than on school days [18,35]. However, most previous studies examined the relationship between screen time on school days and adiposity, but not screen time on weekends [9,10]. We found that heavy screen time, particularly on weekends, associated with a higher BMI 3 years later. This suggests that sedentary screen time during weekends may play a more important role in excess weight in adolescents than sedentary screen time on school days. Possible explanations for this include children engaging in some physical activities at school and that being at school limits the time available for recreational screen time. Furthermore, children who do not play sports or have other physically active hobbies probably spend more time in front of screens on weekends. Somewhat contrary to our results, a recent cross-sectional study of more than 5,000 nine- to 11-year-old children from 12 countries revealed that higher levels of accelerometer-measured sedentary time, on either weekdays or weekends, associated with an increased risk of obesity [39]. However, unlike our study, that study was cross-sectional and did not include a follow-up.

The limitations of our study include our reliance on the self-reported measurement of sedentary screen time and exercise, not assessed using a device such as an accelerometer. Anyhow, similar screen time questions that we used have shown fair to substantial test–retest reliability [23–25], whereas the content validity of self-reported screen time measures is considered difficult to assess against more objective measures [40]. Self-report measurements of sedentary behavior may be somewhat biased because of either under- or over-reporting. Yet, such measurements are relatively inexpensive, easy to administer, and, thus, more feasible in large-scale studies. More importantly, self-reporting tools, unlike accelerometers, allow us to assess the type of sedentary behavior, such as screen time. In short, self-report measures provide solid estimates of context-specific sedentary behavior [40]. A further limitation lies in the possible overlap in responses regarding viewing TV programs and computer use. Moreover, our baseline questionnaire did not include specific questions on the use of mobile devices. Nevertheless, we asked about computer use and watching TV programs on screen-based devices and were able to examine the phenomenon of sedentary screen time.

A major strength of our study is that we examined screen time during free time separately on school days and on

Table 3
Associations between children's screen time at baseline and BMIz at 3-year follow-up (n = 5,084)

Sedentary screen time outside school hours at baseline	Model 1		Model 2		Model 3	
	B	*p*	B	*p*	B	*p*
TV viewing on school days						
Heavy	−.061	.064	.050	.387	−.057	.081
Medium	−.029	.189	.046	.224	−.024	.272
Light (reference category)						
TV viewing on weekends						
Heavy	**.089**	**.005**	**.132**	**.016**	**.078**	**.013**
Medium	.020	.344	.034	.359	.013	.550
Light (reference category)						
Computer use on school days						
Heavy	.014	.628	.015	.765	.017	.565
Medium	.038	.101	.068	.091	.036	.123
Light (reference category)						
Computer use on weekends						
Heavy	−.040	.174	**.150**	**.004**	−.036	.230
Medium	−.035	.096	.005	.893	−.027	.212
Light (reference category)						

Results from linear regression models using BMIz at follow-up as the dependent variable.
Variables included in the models:
Model 1: BMIz at baseline and all screen-time variables.
Model 2: age, gender, language, sleep duration, eating habits, exercise, and all screen-time variables.
Model 3: age, gender, language, sleep duration, eating habits, exercise, BMIz at baseline, and all screen-time variables.
Bold values are statistically significant ($p < .05$).
BMIz = body mass index z-score; SD = standard deviation.

weekends, unlike most previous studies [9]. In addition, we adjusted the models for several relevant factors, including dietary habits, exercise, and sleep, key factors found to modify the relationship between sedentary behavior and adiposity in youth [9]. However, residual confounding may still exist even after adjustments because of possible measurement errors in the self-reported confounders. An additional major strength to our study lies in its prospective study design, which provides a stronger indication for causality than cross-sectional studies. We had a large sample size, whereby our results can be generalized to Finnish youth [19] and, at least to some extent, to youth in other Western countries.

To conclude, this prospective study showed that the proportion of heavy screen users increases when transitioning from childhood to adolescence. Moreover, children's heavy screen use on weekends associates with an increased weight 3 years later. Because of the high prevalence, adverse health consequences, and costs associated with obesity, effective methods are needed to prevent excess weight gain in youth. Combining increased physically active hobbies, such as sport club activities and outdoor activities with family, and decreasing sedentary screen use among children especially on weekends may prove effective in preventing becoming overweight or obese.

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