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Sedentary Behavior and Cardiometabolic Health Associations in Obese 11–13-Year Olds

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Abstract

Background: Improved understanding of sedentary time's impact on cardiometabolic health can help prioritize intervention targets.

Objective: We investigated cross-sectional and longitudinal relations of reported screen time and objectively measured total percent of time spent sedentary with cardiometabolic health in obese youth.

Methods: Participants were 106 obese adolescents age 11–13 ($N = 106$, 51% girls, and 82% Hispanic) recruited from primary care clinics in southern California. Main predictor measures were child-reported screen time and objectively assessed sedentary time. Outcome measures were body mass index (BMI), waist and hip circumference, body fat, blood pressure, glucose, triglycerides, insulin, cholesterol, aspartate aminotransferase (AST), and serum alanine aminotransferase (ALT).

Results: Total percent sedentary time was not associated with the cardiometabolic health markers after adjusting for moderate-to-vigorous physical activity (MVPA). However, screen time was positively associated with BMI and diastolic blood pressure at baseline, and positive longitudinal associations were found with BMI, triglycerides, low-density lipoprotein, AST, and ALT.

Conclusions: Reported screen time, but not total sedentary time, was related to multiple cardiometabolic health markers in obese adolescents, independent of MVPA. The findings suggest that limiting and replacing screen time, which was more than 3 hours per day on average in this sample, is likely an important behavior change strategy for interventions treating childhood obesity and comorbidities. The associations with screen time were strongest with AST and ALT, suggesting that this form of sedentary behavior may impact liver health.

Keywords: cardiometabolic markers; obesity; screen time; sedentary behavior

Introduction

The benefits of physical activity for adolescents include cardiovascular and metabolic health, obesity prevention, cognitive development, and bone health.[1] Recent evidence suggests sedentary time and particularly TV viewing time are linked to poorer health markers in youth.[2–4] Despite this evidence, only 8% of young adolescents in the United States meet the 60-minute per day guideline for moderate-to-vigorous physical activity (MVPA), and only half watch less than the recommended 2 hours per day of TV.[5–7] Furthermore, objectively measured activity levels suggest U.S. children are sedentary 6–8 hours per day.[8]

Although reported TV viewing time has been consistently associated with weight status among youth in a dose-response manner,[4] associations between objectively measured sedentary time and health markers in youth are less clear.[9–10] For example, a recent study of 20,000 children and youth found that objectively measured MVPA, but not sedentary time, was related to cardiometabolic health indicators such as waist circumference, systolic blood pressure, fasting triglycerides, high-density lipoprotein cholesterol, and insulin.[3,11] However, few studies included objectively measured sedentary time when determining correlates of cardiometabolic health in youth, and even fewer have included both accelerometry and reported TV viewing time.[2,4] There is scant longitudinal evidence on the association

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between sedentary behavior and cardiometabolic health in obese youth, and findings are mixed.[2,12] Sedentary time is especially important to study among obese youth because of their high risk for comorbidities.[13]

The purpose of the present study was to investigate reported TV time and objectively measured sedentary time in relation to cardiometabolic risk factors among obese 11–13-year olds. Both cross-sectional and 1-year longitudinal associations were investigated. The health markers investigated were selected based on their importance to cardiometabolic health and included body mass index (BMI), waist and hip circumference, body fat, blood pressure, glucose, triglycerides, insulin, cholesterol, aspartate aminotransferase (AST), and serum alanine aminotransferase (ALT). AST and ALT have been less studied in relation to sedentary time, and were included because of their association with nonalcoholic fatty liver disease (NAFLD) in obese patients.[14]

Methods

Study Sample

Data for this study come from a randomized controlled trial (RCT) of a weight-loss intervention based in pediatric primary care (#NCT00415974).[15] Both the intervention and control group received educational materials about healthy diet and physical activity, visited a health educator, engaged in goal setting, and used self-monitoring logs and pedometers to track progress. Participants in the control group received one visit with the health educator, whereas the intervention group had multiple visits using a stepped-down approach (i.e., visit frequency was reduced if goals for weight reduction were being met).[15] BMI was the primary outcome of the RCT and sedentary behaviors were not specifically targeted in either group. Intervention and control group participants were included in all analyses in the present study.

Adolescents were eligible to participate if they met the following criteria: (1) 11–13 years old, (2) had a BMI ≥95th percentile for age and sex), (3) were literate in English, (4) were available to attend study visits during the 1-year intervention period, and (5) had a parent or guardian willing to participate. Parents were eligible if they were literate in English or Spanish. Adolescents were excluded if they (1) were taking or had taken weight-altering medications within 6 months before study initiation, (2) were unable to perform MVPA, (3) weighed more than 300 pounds, (4) were in foster care, (5) were receiving special education, (6) had participated in one of our other weight-loss studies, (7) were currently enrolled in a weight-loss program, or (8) had been diagnosed with obesity-related disorders requiring immediate weight-loss management or diseases of the liver, pancreas, or small intestine affecting absorption or processing of nutrients.

Participant Recruitment

Pediatricians from three primary care clinics recruited adolescents during routine usual care visits (e.g., annual visits, flu shots, school physicals). Recruitment flyers were also placed in office waiting rooms and distributed through physician-generated letters mailed to the patients' homes. Eligible participants who provided assent/consent were enrolled into the study. At baseline, adolescents in both study groups received a $15 incentive, and at 12 months they received a $25 incentive for completing measurements. Parents received a $15 incentive for completing measures at each assessment and $20 at each measurement point to compensate for transportation costs. A total of 460 adolescents were assessed for eligibility, of which 231 were interested and eligible and began a 2-week study run-in program. Of those completing the run-in program ($n = 128$), 106 adolescents were randomized into the study. Ethical approval for the study was obtained from participating healthcare organizations and the University of California, San Diego, Human Subjects Review Board.

Measures

Trained measurement staff conducted all assessments at baseline and 1-year follow-up at the UCSD NIH-supported General Clinical Research Center.

Sedentary time. Actigraph model GT1M waist-worn accelerometers were used to derive minutes per day of total sedentary time. Accelerometers were worn for up to 7 days and counts were recorded at 60-second epochs. Participants were required to wear the device for at least three valid days. A valid day was defined as having at least 9 hours of wear time,[16] with 20 or more consecutive minutes of zero counts used to indicate nonwear time.[17] Minutes with <100 counts were classified as sedentary time, and MVPA was scored using the Freedson 4-MET age-based cut points,[18] which has shown excellent classification accuracy.[19] Daily minutes of sedentary time was divided by daily wear time minutes to derive total percent sedentary time.

Reported screen time was assessed using two items from the Sedentary Behavior Questionnaire, which was completed by the child.[20] The two items asked about time spent per day (1) watching television and (2) playing computer video games. The response options were none, ≤15, 30 minutes, 1–5 hours, and ≥6 hours. The response options were recoded to minutes. In addition, the ≤15-minute category was recoded as 15 minutes, and the ≥6-hour category was recoded as 360 minutes. Test–retest reliability intraclass correlations (ICCs) were 0.65 and 0.55 in a previous study in youth.[21] Because the questions asked about behavior on school days and nonschool days separately, the final variable was derived by combining the two screen time values and estimating average daily screen time computed as ([screen time during school day] × 5 + [screen time during nonschool day] × 2)/7.

Cardiometabolic health markers. Height (without shoes) was measured using a stadiometer. The participant was instructed to stand erect against a wall with heels close to the wall. Weight was measured using a calibrated digital scale

while the participant was wearing light clothing. BMI was calculated as weight in kilograms per meters squared of height. Centers for Disease Control and Prevention (CDC) Vital and Health Statistics was used to calculate BMI z-scores using age- and sex-specific median, standard deviation, and power of the Box-Cox transformation.

Percent body fat was determined from dual-energy X-ray absorptiometry (DXA). Scans were conducted using the minimal radiation dose considered safe and appropriate for a pediatric population (<1/100th of the equivalent radiation exposure of a chest X-ray). Iliac waist and hip circumferences were based on the average of two measurements measured by research staff using a cloth measuring tape and following standardized procedures.

Blood pressure measurements were taken using a portable Critikon Dinamap 8100 monitor. After a 5-minute rest, five consecutive measurements of systolic and diastolic blood pressure were taken at 1-minute increments, with the third through fifth readings averaged for data analysis. Measurements were taken using the participant's left arm while the participant was sitting with the left forearm supported on a table and using the appropriate cuff size for the individual (two cuff sizes were available).

Fasting blood samples were used to assess glucose, triglycerides, insulin, high- and low-density lipoprotein (HDL and LDL) cholesterol, aspartate aminotransferase (AST), and serum alanine aminotransferase (ALT). AST and ALT are markers of liver function and were included in this study because of their implications in NAFLD[14] and cardiometabolic health.[22] Serum assays were conducted using established clinical assay protocols.

Statistical Analysis

Mplus software (Version 6)[23] was used to fit latent growth parallel process models with baseline and 1-year follow-up values as manifest variables to estimate an intercept and slope parameter for each cardiometabolic health marker and sedentary time variable. To assess cross-sectional associations, the intercept for each cardiometabolic health marker was regressed on the intercept for the sedentary variable (i.e., initial status of health marker associated with initial status of behavior). To assess longitudinal associations, the slope for each cardiometabolic health marker was regressed on the slope for the sedentary variable (i.e., change in health marker associated with change in behavior). Full information maximum likelihood estimation was used to account for missing data. The AST and ALT values were natural log transformed to better approximate normal distributions. Models were adjusted for age, sex, race/ethnicity (Hispanic vs. other), and treatment group.

The latent growth models also accounted for baseline status of the sedentary time and cardiometabolic health marker variables when the longitudinal slope-to-slope regression path was estimated. Variances for the sedentary time and cardiometabolic health marker variables were set to zero for model identification in the growth models. A correlation between age and the sedentary intercept was specified in each model with percent sedentary time. A second set of models was tested using baseline MVPA as a covariate by specifying a correlation between baseline MVPA and the sedentary latent intercept. Criteria for adequate model fit were comparative fit index (CFI) >0.9 and root mean squared error of approximation (RMSEA) <0.08.[24] Standardized coefficients were reported to compare effects across outcomes.

Sample size for the original RCT was determined to detect a difference in BMI between the treatment and control groups at 12 months. For the present study, a sample size of $N = 106$ provided 80% power to detect a correlation coefficient $r = .27$, which is considered a medium standardized effect size.

Results

A total of 106 participants completed baseline assessments, and 85 completed the 1-year follow-up. At baseline, the average age of participants was 11.9 years (standard deviation = 0.9), 51.2% were girls, 80.2% were Hispanic, and 28.3% had a parent with a college degree. These characteristics did not differ between study completers and noncompleters or between treatment groups. Descriptive statistics for sedentary time, screen time, and cardiometabolic health markers are presented in Table 1. Children reported an average of 3 hours 10 minutes per day of screen time at baseline and had 7 hours 37 minutes per day of total sedentary time (61% of wear time) according to the accelerometer. Using the greater than 2 hours per day threshold to define exceeding recommended screen time limits, 43.8% of adolescents exceeded the threshold on school days and 70.8% exceeded the threshold on nonschool days at baseline.

Cross-sectional and longitudinal relations of total sedentary time to cardiometabolic markers are presented in Table 2. All models had adequate fit, with the exception of the two triglycerides models that had RMSEAs >0.08. Total percent sedentary was associated positively with BMI and BMIz at baseline, although this effect was not statistically significant when adjusting for MVPA. Three p-values <0.10 suggested total percent sedentary may be associated positively with hip circumference and LDL and associated negatively with glucose at baseline. However, these effects were attenuated after adjusting for MVPA. No longitudinal associations between total percent sedentary and cardiometabolic markers were found.

Table 3 presents cross-sectional and longitudinal relations of screen time to cardiometabolic markers. All models had adequate fit with the exception of the two glucose models, which had CFIs <0.9 and RMSEAs >0.08 and one triglyceride model that had an RMSEA >0.08. These models did not include statistically significant findings that likely contributed to poorer model fit. Screen time was associated positively with BMI and diastolic blood pressure at baseline, and these associations remained after adjusting for MVPA. Associations between parallel process slopes (i.e., associations between change in

Table 1. Descriptive Statistics for Study Variables ($N = 106$)

	Observed mean (SD) or %	
	Baseline	One-year follow-up
Accelerometer wear time minutes/day	748.2 (85.2)	745.2 (117.0)
Accelerometer MVPA minutes/day	26.3 (19.3)	35.4 (25.7)
Accelerometer sedentary minutes/day	456.8 (78.1)	485.0 (125.0)
Reported screen time minutes/day	189.5 (119.7)	196.8 (134.7)
>2 hours/day screen time (school day), %	43.8	45.9
>2 hours/day screen time (nonschool day), %	70.8	68.2
BMI kg/m^2	29.3 (3.8)	29.6 (4.3)
BMIz	2.1 (0.3)	2.0 (0.4)
Waist circumference (cm)	98.1 (10.5)	98.4 (11.6)
Hip circumference (cm)	101.6 (9.0)	105.2 (11.1)
DXA body fat (percent)	44.9 (5.5)	41.7 (7.3)
SBP mm Hg	119.1 (11.0)	119.7 (10.5)
DBP mm Hg	67.7 (9.2)	67.2 (8.0)
Glucose mg/dL	88.9 (6.4)	86.6 (6.5)
Triglycerides mg/dL	117.7 (68.3)	107.7 (64.4)
Insulin U/mL	34.4 (24.0)	21.8 (14.6)
HDL mg/dL	40.5 (9.3)	44.8 (9.2)
LDL mg/dL	101.3 (22.5)	86.5 (20.9)
AST IU/L[a]	24.1 (1.4)	19.5 (1.4)
ALT IU/L[a]	22.7 (1.5)	18.4 (1.6)

[a]Geometric mean and standard deviation (SD) are presented because variables had skewed distributions.

AST, aspartate aminotransferase; ALT, alanine aminotransferase; BMI, body mass index; DBP, diastolic blood pressure; DXA, dual-energy X-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MVPA, moderate-to-vigorous physical activity; SBP, systolic blood pressure.

sedentary time and change in cardiometabolic markers) were found for screen time and BMI, BMIz, triglycerides, LDL, AST, and ALT. These longitudinal associations were in the positive direction (i.e., more screen time was associated with higher scores on each cardiometabolic marker) and were not attenuated after adjusting for MVPA.

Discussion

Reported screen time but not accelerometer-measured sedentary time was related to multiple cardiometabolic health markers in this study of obese 11–13-year olds, even after adjusting for MVPA. For screen time, cross-sectional associations were observed for BMI and diastolic blood pressure, and longitudinal associations were observed for BMI, BMIz, triglycerides, LDL cholesterol, and AST and ALT liver enzymes. These findings suggest reducing screen time may be an important behavioral target to positively impact cardiometabolic health in obese adolescents. Screen time-related behaviors other than total sedentary time, such as nutrition and prolonged patterns of sitting, may be important drivers of these associations since they contribute to positive energy balance resulting in obesity over time.

Notably, we are aware of very few studies that investigate sedentary time in relation to commonly utilized clinical assessments of liver function in youth. The cross-sectional and longitudinal relations of screen time to AST and ALT were the strongest of the cardiometabolic health markers assessed. While a majority of the youth in this study had decreases in AST and ALT over the 1-year period, those who increased their screen time had smaller decreases and in some cases increases in AST and ALT. Elevations in ALT and AST are circulating markers of potential NAFLD in obese patients.[14] Obesity and physical inactivity are both linked to NAFLD,[14,25] the excessive storage of lipids in the liver. NAFLD is the leading cause of liver disease in the pediatric population,[25] and the presence of pediatric nonalcoholic fatty liver disease increases cardiovascular disease risk[14] and causes early mortality.[26,27]

In the present sample, 14.6% of youth at baseline and 13.3% of youth at follow-up had elevated ALT levels (>30 IU/L), indicating increased risk of liver dysfunction and NAFLD in obese youth. Similarly, other studies have shown upper levels of ALT/AST are associated with prevalence of fatty liver disease in obese youth.[28] Reducing screen time in obese adolescents may be an important intervention strategy for reducing risk for liver disease.

Currently, it is unknown if nutritional quality (i.e., type and quantity of nutrients) specifically worsens liver enzyme levels in adolescents, but it is clear that obesity increases risk for fatty liver and elevated liver enzymes.[28] Furthermore, elevated consumption of simple sugars and saturated fats plays an important role in the development of adolescent obesity and has been shown to drive further metabolic pathologies (e.g., insulin resistance, dyslipidemia, and inflammation) in adolescents with fatty liver.[29] Thus, there is associative evidence that poor nutrition likely increases risk for elevated liver enzymes and fatty liver. Because sedentary behavior can have a direct effect on obesity and an indirect effect on obesity through poor nutrition behaviors, it is likely a modifiable risk factor of elevated liver enzymes.

Our findings are in agreement with previous reviews that documented cross-sectional associations between screen (mainly TV) time and multiple cardiometabolic health markers in youth, particularly BMI.[2–4,10] However, findings from longitudinal studies have been inconsistent.[4,10,11]

Table 2. Cross-Sectional and Longitudinal Relation of Accelerometer Sedentary Time to Cardiometabolic Markers ($N = 106$ at Baseline and 85 at Follow-Up)

		Model fit indices			Standardized β (SE); *p*-value	
	Model	CFI	RMSEA	X^2; *p*-value	Cross-sectional association	Longitudinal association
BMI kg/m^2	1	0.981	0.054	13.1; 0.220	**0.24 (0.11); 0.028**	0.21 (0.13); 0.096
	2	0.969	0.065	18.8; 0.130	0.17 (0.13); 0.177	0.16 (0.13); 0.211
BMIz	1	0.975	0.058	13.5; 0.196	**0.22 (0.11); 0.041**	0.14 (0.14); 0.316
	2	0.964	0.066	19.0; 0.124	0.14 (0.12); 0.246	0.09 (0.14); 0.536
Waist circumference (cm)	1	0.952	0.072	15.6; 0.113	0.18 (0.11); 0.107	0.18 (0.14); 0.191
	2	0.943	0.076	21.0; 0.073	0.11 (0.13); 0.419	0.14 (0.14); 0.327
Hip circumference (cm)	1	0.943	0.068	14.9; 0.137	0.20 (0.11); 0.061	0.18 (0.13); 0.162
	2	0.936	0.071	20.0; 0.095	0.16 (0.12); 0.189	0.15 (0.13); 0.245
DXA body fat%	1	0.975	0.054	13.1; 0.219	0.10 (0.12); 0.379	0.17 (0.12); 0.166
	2	0.965	0.062	18.4; 0.144	–0.02 (0.14); 0.892	0.12 (0.13); 0.337
SBP mm Hg	1	0.959	0.047	12.4; 0.260	0.06 (0.11); 0.614	0.13 (0.11); 0.260
	2	0.943	0.059	71.7; 0.178	0.01 (0.13); 0.955	0.13 (0.11); 0.240
DBP mm Hg	1	0.902	0.060	13.8; 0.181	0 (0.11); 0.997	0.11 (0.10); 0.247
	2	0.900	0.068	19.5; 0.110	–0.04 (0.13); 0.745	0.09 (0.10); 0.384
Glucose mg/dL	1	0.944	0.053	13.0; 0.225	–0.20 (0.11); 0.060	–0.09 (0.10); 0.387
	2	0.930	0.063	18.4; 0.143	–0.18 (0.13); 0.153	–0.09 (0.10); 0.391
Triglycerides mg/dL	1	0.905	0.082	17.1; 0.072	0.01 (0.12); 0.943	–0.15 (0.12); 0.229
	2	0.903	0.087	23.4; 0.037	–0.15 (0.13); 0.243	–0.15 (0.12); 0.201
Insulin U/mL	1	0.938	0.045	12.2; 0.274	0.04 (0.11); 0.741	–0.02 (0.05); 0.749
	2	0.923	0.058	17.7; 0.170	–0.03 (0.13); 0.837	–0.02 (0.05); 0.676
HDL mg/dL	1	0.963	0.059	13.7; 0.187	–0.11 (0.11); 0.342	–0.13 (0.13); 0.310
	2	0.952	0.065	18.9; 0.127	–0.05 (0.13); 0.708	–0.12 (0.13); 0.353
LDL mg/dL	1	0.969	0.045	12.1; 0.276	0.20 (0.10); 0.054	–0.01 (0.11); 0.922
	2	0.943	0.074	14.2; 0.114	0.19 (0.12); 0.118	–0.06 (0.12); 0.641
AST IU/L	1	0.973	0.045	12.1; 0.277	0.09 (0.10); 0.345	0 (0.13); 0.984
	2	0.953	0.060	18.0; 0.157	0.04 (0.11); 0.740	–0.01 (0.13); 0.948
ALT IU/L	1	0.970	0.050	12.6; 0.245	0.08 (0.11); 0.465	–0.01 (0.13); 0.916
	2	0.953	0.063	18.4; 0.143	–0.02 (0.12); 0.887	–0.05 (0.13); 0.692

Model 1 was adjusted for age, gender, race/ethnicity, and treatment group, and the slopes model was adjusted for baseline status on sedentary time and the outcome of interest.

Model 2 was additionally adjusted for baseline physical activity.

Values in bold are coefficients statistically different from zero with *p*-values of less than .05.

CFI, comparative fit index; RMSEA, root mean squared error of approximation.

Participants in the current study were all at or above the 95th percentile on BMI for age and gender. Thus, it is possible that screen time has a pronounced association with severity of adiposity in youth whose BMI is above the threshold for obesity.[30] Screen time increasing as adiposity increases also suggests among this population segment the plausibility of ''reciprocal causality'' and ''reverse causality'' hypotheses.[10] That is, as activity gets more labored and uncomfortable with increasing adiposity, adolescents engage in more screen time for entertainment in place of other activities. Limiting and replacing screen time, which was more than 3 hours per day on average in this sample, is likely an important behavior change strategy for weight-loss interventions and should be considered in conjunction

Table 3. Cross-Sectional and Longitudinal Relation of Reported Screen Time to Cardiometabolic Markers ($N = 106$ Baseline, 85 Follow-Up)

		Model fit indices			Standardized β (SE); *p*-value	
	Model	CFI	RMSEA	X^2; *p*-value	Cross-sectional association	Longitudinal association
BMI kg/m^2	1	0.977	0.070	10.6; 0.155	**0.19 (0.09); 0.045**	**0.37 (0.11); 0.001**
	2	0.985	0.050	11.4; 0.250	**0.20 (0.09); 0.035**	**0.37 (0.11); 0.001**
BMIz	1	0.971	0.074	11.1; 0.135	0.15 (0.09); 0.107	**0.28 (0.13); 0.026**
	2	0.968	0.065	14.4; 0.156	0.15 (0.09); 0.103	**0.28 (0.13); 0.028**
Waist circumference (cm)	1	0.959	0.078	11.5; 0.117	0.15 (0.09); 0.123	0.22 (0.12); 0.072
	2	0.971	0.057	12.1; 0.207	0.16 (0.09); 0.098	0.22 (0.12); 0.075
Hip circumference (cm)	1	0.954	0.069	10.5; 0.162	0.14 (0.09); 0.115	0.06 (0.12); 0.608
	2	0.968	0.050	11.4; 0.251	0.15 (0.09); 0.096	0.06 (0.12); 0.606
DXA body fat%	1	0.973	0.065	10.1; 0.181	0.08 (0.12); 0.482	0.20 (0.11); 0.072
	2	0.977	0.053	11.6; 0.236	0.09 (0.12); 0.436	0.19 (0.11); 0.084
SBP mm Hg	1	0.941	0.064	10.0; 0.340	0.05 (0.10); 0.621	0.14 (0.10); 0.175
	2	0.955	0.049	11.2; 0.260	0.05 (0.10); 0.618	0.15 (0.10); 0.148
DBP mm Hg	1	0.901	0.072	10.8; 0.147	**0.23 (0.09); 0.012**	0.14 (0.09); 0.099
	2	0.900	0.062	12.7; 0.178	**0.24 (0.09); 0.012**	0.15 (0.09); 0.082
Glucose mg/dL	1	0.817	0.100	14.4; 0.044	0.04 (0.10); 0.707	−0.16 (0.12); 0.154
	2	0.827	0.085	15.8; 0.070	0.03 (0.10); 0.728	−0.16 (0.12); 0.162
Triglycerides mg/dL	1	0.913	0.093	13.4; 0.064	−0.06 (0.10); 0.520	**0.32 (0.11); 0.003**
	2	0.925	0.076	14.5; 0.105	−0.05 (0.10); 0.617	**0.31 (0.11); 0.004**
Insulin U/mL	1	0.884	0.065	10.1; 0.181	0.02 (0.10); 0.844	−0.02 (0.05); 0.645
	2	0.915	0.050	11.4; 0.252	0.02 (0.10); 0.811	−0.03 (0.05); 0.514
HDL mg/dL	1	0.954	0.076	11.3; 0.128	−0.11 (0.10); 0.258	−0.18 (0.12); 0.152
	2	0.964	0.058	12.2; 0.205	−0.12 (0.10); 0.223	−0.19 (0.13); 0.143
LDL mg/dL	1	0.931	0.074	11.1; 0.136	−0.07 (0.09); 0.485	**0.31 (0.11); 0.005**
	2	0.933	0.064	12.8; 0.170	−0.06 (0.09); 0.516	**0.31 (0.11); 0.007**
AST IU/L	1	0.961	0.065	10.2; 0.178	−0.01 (0.09); 0.933	**0.38 (0.11); <0.001**
	2	0.972	0.049	11.3; 0.256	0 (0.09); 0.974	**0.39 (0.11); <0.001**
ALT IU/L	1	0.961	0.071	10.8; 0.148	0.06 (0.09); 0.519	**0.48 (0.10); <0.001**
	2	0.972	0.053	11.7; 0.232	0.06 (0.09); 0.491	**0.48 (0.10); <0.001**

Model 1 was adjusted for age, gender, race/ethnicity, and treatment group, and the slopes model was adjusted for baseline status on sedentary time and the outcome of interest.

Model 2 was additionally adjusted for baseline physical activity.

with MVPA and diet/nutrition strategies.[31] Findings from the present study are also in agreement with evidence suggesting a link between screen time and blood pressure in youth.[30–32]

Similar to previous studies in youth, accelerometer-measured sedentary time was not robustly associated with cardiometabolic health markers.[3] Accelerometer-measured sedentary time was associated with BMI and BMIz in the cross section at baseline, but these findings were attenuated after adjusting for MVPA. Accelerometer-measured sedentary time may not be an accurate measure of specific sedentary behaviors (e.g., TV viewing time) but rather a more general indicator of minutes of nonactivity summed over the course of the day. There is some uncertainty among researchers as to the most valid approach to estimating sedentary time from accelerometers, which may

have also affected the associations between sedentary time and the cardiometabolic markers.[33] Thus, more work is needed to improve the objective assessment of sedentary time with accelerometers.

It is possible the mechanisms linking screen time to cardiometabolic health in youth do not generalize to sedentary activities in all contexts. Numerous studies in youth have found associations between TV viewing time and poor nutrition,[34,35] and poor eating habits during TV viewing time,[36] and this has, in part, been explained by unhealthy food advertising and mindless eating.[37] Taking into account this evidence and the observed longitudinal positive relation of screen time to triglycerides and LDL cholesterol in the present study suggests that nutrition and eating habits may be the key mechanisms linking TV time to poor cardiometabolic health in youth. Future studies should investigate eating habits as a mediator of the association between TV time and cardiometabolic health in youth.

Strengths/Limitations

Study strengths included the longitudinal design over a 1-year period, assessment of multiple cardiometabolic health markers, and assessment of both accelerometer-measured total sedentary time and self-reported screen time. The estimated screen time from the self-report may be a conservative measure of risk due to underreporting by participants reflecting an impression management bias. It is important to note that causation cannot be inferred from these analyses, and there is potential for reverse causation (i.e., poor cardiometabolic health leading to more sedentary time) or that other unmeasured factors were causal mechanisms. Multiple statistical tests were conducted without adjustment to the threshold for statistical significance, which increases the risk of Type I errors. However, given the exploratory nature of this study, we did not adjust for Type I errors at the expense of Type II errors in our analyses. The study sample was not representative of many regions of the United States outside of Southern California as the population was mainly of Hispanic origin, and thus, findings may not be generalizable to other adolescent population segments. Larger samples should be investigated to identify whether gender, age, and race/ethnic differences exist in associations between screen time and cardiometabolic health.

Implications for Practice

Intervention studies have identified some evidence-based strategies for reducing screen time in youth. However, few strategies have seen wide-scale implementation, particularly when compared to strategies to increase physical activity.[38] TV allowance devices can be used to shut off the TV after a specified amount of viewing time (e.g., 2 hours per day), and have been shown to reduce screen time.[39,40] Other strategies that could be tested to modify environments where screen time occurs include incorporating standing furniture into living rooms, implementing bouts of physical activity to break up sitting, and encouraging children to earn screen time by spending time playing outdoors (not on a portable screen device).[41,42]

Conclusions

This study suggests screen time may coincide with multiple cardiometabolic health markers in obese youth, after adjusting for MVPA, including BMI, blood pressure, triglycerides, and LDL cholesterol. The present findings also suggest screen time may have a negative impact on liver function, a serious and growing concern in obese youth and adults. Screen time is of particular concern for obese youth because they spend large amounts of time in front of a screen and are at higher risk for cardiometabolic diseases. In agreement with several previous studies, this study failed to find associations between accelerometer-measured sedentary time and cardiometabolic health markers after adjusting for MVPA.[3,10] This study provides some initial hypothesis generating evidence to warrant further investigation of the impact of screen time on cardiometabolic health in obese adolescents.

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