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Original Contribution

Sedentary Behaviors and Cardiometabolic Risk: An Isotemporal Substitution Analysis

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Evidence suggests that time spent engaging in sedentary behaviors is associated with a greater risk of adverse cardiometabolic outcomes. We investigated the cross-sectional associations of 6 unique sedentary tasks (watching television, using the computer, completing paperwork, reading, talking on the telephone, and sitting in a car) with cardiometabolic risk factors, and also examined the effect of replacing one type of sedentary behavior with another on the level of cardiometabolic risk. Participants consisted of 3,211 individuals from the Coronary Artery Risk Development in Young Adults Study who visited the clinic between 2010 and 2011. Linear regression models examined the independent and joint associations of sedentary tasks with a composite cardiometabolic risk score, as well as with individual cardiometabolic risk factors (waist circumference, blood pressure, fasting glucose, insulin, triglycerides, and high density lipoprotein cholesterol) after adjusting for physical activity and other covariates. Replacing 2 hours of television viewing with 2 hours spent performing any other sedentary activity was associated with a lower cardiometabolic risk score of 0.06–0.09 standard deviations (all 95% confidence intervals: −0.13, −0.02). No other replacements of one type of sedentary task for another were significant. Study findings indicate that television viewing has a more adverse association with cardiometabolic risk factors than other sedentary behaviors.

cardiometabolic risk; Coronary Artery Risk Development in Young Adults; isotemporal substitution; sedentary behaviors

Abbreviations: CARDIA, Coronary Artery Risk Development in Young Adults; HDL-C, high-density lipoprotein cholesterol.

Sedentary behaviors have become highly prevalent in today's society and are associated with a variety of adverse health outcomes, including all-cause and cardiovascular disease mortality, diabetes, as well as some cancers (1). In addition, studies have identified associations between sedentary time and markers of cardiometabolic risk (e.g., higher waist circumference, blood pressure, glucose, insulin, and triglycerides, and lower high-density lipoprotein cholesterol (HDL-C)), which are largely independent of physical activity level (2–6). To date, the majority of research has focused on broad measures of sedentary time or television viewing, and less is known about the associations between other types of sedentary tasks (e.g., sitting in a car during transportation) and cardiometabolic risk. This knowledge is important for informing future preventive actions.

A small body of evidence suggests that television viewing may have a stronger association with obesity and risk of chronic disease than other sedentary behaviors (7–9). Possible reasons for this include: passive overconsumption of energy-dense foods and beverages while watching television (10); influence of obesogenic marketing messages on television (11); adverse associations between television viewing and mental health outcomes (12–14), known risk factors for obesity and other chronic diseases (15, 16); and more accurate reporting of television time compared with other sedentary behaviors (17).

To our knowledge, no studies have, in a single analysis, directly replaced time spent watching television with time spent performing other sedentary tasks, and then examined its associations with cardiometabolic risk. For example, we asked whether time spent watching television would yield the same health risks if it was replaced by an equal amount of time spent reading or driving a car. The isotemporal substitution paradigm is a methodologic approach that is well suited to address this research question because it examines the associations of alternating allocations of time engaging in different types of behaviors while holding total time constant (18). This approach was originally developed for nutritional epidemiology and has recently been used in the physical activity literature to investigate patterns when replacing sedentary time with different types and intensities of physical activities across a variety of outcomes, including cardiometabolic risk factors (19–21), depression (22), self-rated health (23), and all-cause mortality (24–26). Our use of the isotemporal analysis approach is novel, as we are examining the substitution of one sedentary behavior for a different sedentary behavior with respect to chronic disease risk factors. Typical models used to evaluate the associations between sedentary behaviors and cardiometabolic risk factors do not directly address these substitutions.

The Coronary Artery Risk in Young Adults (CARDIA) study provides an opportunity to examine the associations of 6 distinct self-reported sedentary tasks (watching television, using the computer, completing paperwork, reading, talking on the telephone, and sitting in a car) with cardiometabolic risk factors in a diverse sample of black and white adults. The objectives of this study were: 1) to examine the cross-sectional associations of sedentary behaviors with a composite cardiometabolic risk score (primary outcome) as well as individual cardiometabolic risk factors (secondary outcomes), and 2) to examine what occurs when one type of sedentary behavior is compared with another in relation to cardiometabolic risk. We hypothesized that: 1) time spent engaging in sedentary behaviors will be detrimentally associated with cardiometabolic risk, independent of physical activity; 2) time spent watching television will be the strongest predictor of cardiometabolic risk compared with other sedentary behaviors; and 3) replacing time spent watching television with time spent performing other sedentary behaviors will result in a less adverse cardiometabolic risk profile.

METHODS

CARDIA is an ongoing, community-based prospective cohort study of adults who were initially recruited in 1985–1986 from 4 communities: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. A total of 5,115 participants completed the initial baseline visit. Follow-up visits occurred in 1987–1988 (year 2), 1990–1991 (year 5), 1992–1993 (year 7), 1995–1996 (year 10), 2000–2001 (year 15), 2005–2006 (year 20), and 2010–2011 (year 25). At year 25, 3,458 participants completed the sedentary behavior questionnaire. Of these, 93 were missing data on the cardiometabolic outcomes of interest, and 154 were missing data on potential confounders, resulting in a final sample size of 3,211 participants for our analyses. Written informed consent was obtained from participants at each examination, and study protocols were approved by the institutional review board at each center.

Sedentary behaviors

Sedentary behavior was assessed using a self-reported questionnaire. Participants were asked to report how much time they spend sitting while engaging in 6 types of tasks: 1) watching television; 2) using the computer for nonwork activities or playing video games; 3) doing noncomputer office work or paperwork; 4) listening to music, reading, or doing arts and crafts; 5) talking on the telephone or texting; and 6) sitting in a car, bus, train, or other mode of transportation. Time spent engaging in these tasks was assessed for the average weekday and weekend day. Response options were: none, 15 minutes or less, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, and 6 hours or more. The number of sedentary hours per day was computed for each of the 6 tasks (television, computer, paperwork, reading, telephone, and car) by multiplying the hours spent performing each task on a weekday by 5, and the hours spent in each task on a weekend day by 2. Values were then summed to obtain the average hours spent performing each task per week, and divided by 7 to ascertain the average sedentary hours per day spent on each task type. An estimate of total sedentary time per day was calculated by summing the averages across the 6 types of sedentary tasks.

Cardiometabolic outcomes

Participants were asked to fast for at least 12 hours prior to the study visit, and to abstain from smoking or engaging in heavy physical activities for at least 2 hours prior. Waist circumference was measured to the nearest 0.5 cm in duplicate at the minimal abdominal girth, and then averaged. Blood pressure was measured 3 times on the right arm using an automated sphygmomanometer (HEM-907XL Professional Blood Pressure Monitor, Omron, Kyoto, Japan) with the participant seated at 1-minute intervals after 5 minutes of rest. The average of the second and third blood pressure readings were used for analyses. From obtained venous blood samples, fasting serum glucose was measured using hexokinase coupled to glucose-6-phospate dehydrogenase, insulin levels were measured using radioimmunoassay by Linco Research (St. Louis, Missouri), and triglycerides and HDL-C were measured using an enzymatic assay by Northwest Lipids Research Laboratory (Seattle, Washington).

The composite cardiometabolic risk score was estimated by standardizing and summing the cardiometabolic risk variables (waist circumference, average of systolic and diastolic blood pressures combined, fasting blood glucose, insulin, triglycerides, negative HDL-C), then dividing by 6 to obtain a z score, as previously reported in the literature (27–29). Because of skewed distributions, log transformations were first performed on glucose, insulin, triglycerides, and HDL-C before standardization. Standardization was achieved by subtracting the sample mean from the individual mean and dividing by the standard deviation of the sample mean. Sex-specific standardizations were performed for waist circumference and HDL-C.

Covariates

Study covariates of year 25 included self-reported age, sex (men vs. women), race (black vs. white), years of education completed, unemployment status (yes vs. no), health insurance over the past 2 years (yes vs. no), and field center. Smoking behaviors were self-reported via a tobacco use questionnaire (previously validated by a study using serum cotinine levels), and categorized as former, current, or nonsmoker (30). Alcohol intake (milliliters per day) was calculated using self-reported levels of wine, beer, and hard liquor consumption. The frequency of fast food consumption was assessed by asking participants to identify the number of times per week they ate a meal at places such as McDonald's (Oak Brooks, Illinois), Arby's (Atlanta, Georgia), Pizza Hut (Plano, Texas) or Kentucky Fried Chicken (Louisville, Kentucky). The frequency of consumption of sugar-sweetened beverages was measured by the amount of regular soda, sweetened fruit drinks, sports, or energy drinks consumed per week. Symptoms of depression were measured by the Center for Epidemiologic Studies Depression Scale (31). Intensity of moderate to vigorous physical activity was assessed by the validated CARDIA Physical Activity History (32–34), and body mass index was calculated using measured weight and height (kg/m^2).

Statistical analyses

Means and frequencies of participant characteristics were calculated across quintiles of total sedentary time. Spearman correlations were calculated to describe the bivariate associations between the sedentary tasks. Three types of regression models were fitted to assess the associations of task-specific sedentary time with cardiometabolic risk factors, as seen in Table 1. First, single-variable models estimated the "total association" of task-specific sedentary time with the outcome (models 1–6). These models represent the raw associations between the specified sedentary task and cardiometabolic risk factors, adjusted for confounding factors, but not for the other sedentary tasks. Second, partition models were used to estimate the "unique associations" of each sedentary task while holding time in other sedentary tasks constant (model 7). These models represent the unique associations of each sedentary task with cardiometabolic risk factors, adjusted for confounders as well as the other sedentary tasks. Third, isotemporal substitution models were used to estimate the "substitution associations" of replacing sedentary time from 1 task for an equal amount of sedentary time from another task (models 8–12). This was done by entering a total sedentary time variable (television + computer + paperwork + music + telephone + car) and the task-specific sedentary variables to the models simultaneously. The specific sedentary task of interest was then dropped from the model. These models represent the estimated associations when replacing the dropped sedentary variable with the other sedentary variables in the model. Inclusion of a total sedentary variable in the model constrains total time and allows for direct comparison between sedentary tasks and cardiometabolic risk factors to determine associations. In all models, associations were reported per 2 hours per day of sedentary time by dividing each sedentary behavior by 2 prior to running the regression models, as previously reported in the literature (20). For example, if television viewing is dropped from the model, then the interpretation of the β coefficient for computer use is the estimated change in cardiometabolic risk when substituting 2 hours per day of television viewing with 2 hours of computer use.

All models were adjusted for center, age, sex, race, educational level, unemployment, health insurance, smoking status, alcohol consumption, total physical activity level, consumption of fast food and sugar-sweetened beverage, depressive symptoms, and BMI, as these factors could be potential confounders of the sedentary behavior-cardiometabolic risk associations. Differences by sex and racial group were examined in exploratory analyses by including cross-product terms in the isotemporal substitution models. Because no interactions were significant, stratified analyses are not reported. In the sensitivity analyses, we excluded individuals with prior cardiovascular disease, including self-reported history of myocardial infarction, heart failure, angina, peripheral vascular disease, stroke or transient ischemic attack ($n = 146$). As study findings did not materially change, we present results with the full study sample. All statistical analyses were conducted using SAS, version 9.4 (SAS Institute, Inc., Cary, North Carolina). All tests were 2-sided, with statistical significance set at $P < 0.05$.

RESULTS

As shown in Table 2, there were significant differences across sedentary quintiles for all participant characteristics, with the exception of sex and alcohol consumption. For example, waist circumference, systolic and diastolic blood pressure, glucose, insulin, and triglyceride level increased over sedentary quintiles, whereas HDL-C decreased (indicating an adverse association). Bivariate associations between the sedentary tasks are presented in Web Table 1 (available at https://academic.oup.com/aje). The 6 distinct sedentary tasks were weakly associated ($r_s < 0.40$), whereas stronger correlations were observed between total sedentary time and specific individual tasks (r_s ranging from 0.46 to 0.63).

After adjustment for potential confounders, we found that time spent watching television, using the computer, doing paperwork, reading or listening to music, or talking on the telephone was positively associated with higher cardiometabolic risk score in single-variable models (see Table 3). When all sedentary tasks were entered simultaneously into the model (partition model), television viewing was the only variable that remained associated with the cardiometabolic risk score ($\beta = 0.08$, 95% confidence interval (CI): 0.06, 0.11; $P < 0.001$). Results from the isotemporal substitution models show that replacing time spent watching television with time spent engaging in any other sedentary activity (computer, paperwork, reading, telephone, car) was associated with a 0.06–0.09 standard deviation lower cardiometabolic risk score (all 95% CI: −0.13, −0.02; all $P \leq 0.007$). Alternately, replacing any other sedentary task with television viewing was associated with a 0.06–0.09 higher cardiometabolic risk score (all 95% CI: 0.02, 0.13; all $P \leq 0.007$). No other replacements between sedentary tasks were significant. Although we also examined the associations of total sedentary time with the cardiometabolic risk score, effect sizes were smaller than observed for television viewing and cardiometabolic risk.

Single-variable, partition, and isotemporal substitution models examining associations of the 6 sedentary tasks with the individual cardiometabolic risk factors are located in Web Tables 2–7. Associations observed between the sedentary tasks and waist circumference, glucose, insulin and triglycerides were similar to that observed for the overall cardiometabolic risk score, with replacement effects observed for television viewing only. For example, replacing television viewing with any of the other

Table 1. Linear Regression Models Used to Test Associations of Sedentary Tasks With Cardiometabolic Risk Factors[a], the Coronary Artery Risk Development in Young Adults Study, 2010–2011

Model	Sedentary Tasks Included[b], hours/day						
	Watching Television	Computer Work	Completing Paperwork	Reading	Talking on the Telephone	Sitting in a Car	Total
Single-variable models[c]							
1	X						
2		X					
3			X				
4				X			
5					X		
6						X	
Partition models[d]							
7	X	X	X	X	X	X	
Isotemporal substitution models[e]							
8	Omit	X	X	X	X	X	X
9	X	Omit	X	X	X	X	X
10	X	X	Omit	X	X	X	X
11	X	X	X	Omit	X	X	X
12	X	X	X	X	Omit	X	X
13	X	X	X	X	X	Omit	X

[a] There were 3 types of regression models used to test associations between sedentary tasks and cardiometabolic health markers.
[b] Blank cells indicate that the variable was not included in the model. "Omit" indicates that the variable was removed from the model.
[c] Single-variable models tested the total association of each sedentary task, unadjusted for other sedentary tasks.
[d] Partition models tested the unique associations of each sedentary task, adjusted for all other sedentary tasks.
[e] Isotemporal substitution models tested the substitution association of each sedentary task, holding time constant.

5 sedentary tasks resulted in a 0.03–0.06, 0.08–0.13, 0.05–0.10, and 0.12–0.20 standard deviation lower waist circumference, glucose, insulin, and triglyceride level, respectively. Similarly, replacing television viewing with other sedentary tasks resulted in 0.02–0.12 standard deviation decrease in blood pressure. However, we also found that replacing computer time with reading or telephone use resulted in a 0.10–0.11 standard deviation increase in blood pressure. Replacement effects for HDL-C were less consistent across the isotemporal models.

DISCUSSION

We examined the cross-sectional associations of 6 different sedentary tasks with cardiometabolic risk factors in a large cohort of middle-aged black and white adults. Consistent with our hypothesis, we found that time spent engaging in sedentary behaviors was detrimentally associated with cardiometabolic risk, independent of physical activity and other potential confounders. The primary driver of the associations between sedentary behaviors and cardiometabolic risk was time spent watching television. We found that replacing time spent watching television with time spent doing any other type of sedentary task (computer use, paperwork, reading, using the telephone, sitting in a car), resulted in a lower cardiometabolic risk score. Our findings make a novel contribution to the existing literature, as to our knowledge, this is the first study to use a methodologic approach to examine the context of sedentary time by directly comparing types of sedentary behavior in relation to cardiometabolic risk. Television viewing was shown to have the strongest association with cardiometabolic risk. This work may have important implications for interventions, as it provides evidence that different sedentary activities have distinct associations with health outcomes.

Although our observed effect size for replacing television viewing with other sedentary behaviors was small (0.06–0.09 standard deviations lower cardiometabolic risk score per 2 hours of sedentary time), it is important to emphasis that this reflects replacing one sedentary behavior with another sedentary behavior. The focus is on the context of sedentary time, rather than the replacement of sedentary behavior with physical activity, as previously reported in the literature. Therefore, we anticipated observing small effect estimates. The objective of the present study was not to report on the clinical significance of the observed effect estimates, but rather to inform future research by using a novel methodologic approach to identify unique sedentary behaviors that may differentially alter cardiometabolic risk.

In addition to examining associations between sedentary behaviors and the overall cardiometabolic risk score, we also

Table 2. Sample Characteristics by Sedentary Index Quintiles, the Coronary Artery Risk Development in Young Adults Study, 2010–2011

Characteristic	Quintiles of Sedentary Time, mean (SD)						
	Total (n = 3,211)	1 (n = 635)	2 (n = 649)	3 (n = 641)	4 (n = 638)	5 (n = 648)	P Value[a]
Age, years	50.1 (3.6)	50.4 (3.5)	50.2 (3.4)	50.4 (3.6)	50.1 (3.7)	49.6 (3.7)	<0.001
Female sex[b]	56.2	55.1	55.8	57.7	55.8	56.5	0.908
White race[b]	53.6	73.4	69.2	56.0	42.3	27.3	<0.001
Years of education	15.1 (2.7)	15.7 (2.6)	15.5 (2.7)	15.1 (2.7)	15.0 (2.6)	14.2 (2.6)	<0.001
Unemployed[b]	15.1	10.1	9.2	15.8	19.1	21.5	<0.001
Had health insurance[b]	87.2	91.3	90.5	88.8	85.0	80.4	<0.001
Ever smoker[b]	37.8	32.8	34.8	39.8	38.1	43.5	<0.001
Alcohol consumption, mg/day	11.6 (23.6)	12.7 (25.8)	11.5 (18.9)	12.2 (22.0)	12.4 (31.5)	9.4 (17.3)	0.056
Total physical activity, exercise units	340.9 (276.6)	400.1 (286.1)	369.1 (281.6)	311.2 (251.94)	332.3 (279.6)	292.7 (270.0)	<0.001
Fast food consumption per week	2.1 (3.1)	1.7 (3.1)	1.7 (2.5)	2.0 (2.5)	2.4 (3.2)	2.9 (3.6)	<0.001
Sugar-sweetened beverage consumption per week	3.9 (7.9)	2.6 (6.5)	2.7 (6.2)	3.6 (6.9)	4.4 (7.4)	6.5 (10.8)	<0.001
Depressive symptoms	9.3 (7.7)	8.3 (7.5)	8.2 (6.3)	9.6 (8.1)	9.6 (7.4)	10.9 (8.7)	<0.001
Body mass index[c]	30.2 (7.2)	27.6 (6.4)	29.0 (6.5)	30.5 (7.0)	31.5 (7.3)	32.2 (7.6)	<0.001
Time spent on sedentary tasks, hours/day							
Total	7.0 (4.0)	3.0 (0.8)	4.7 (0.4)	6.1 (0.5)	8.1 (0.7)	13.2 (4.0)	<0.001
Watching television	2.2 (1.5)	0.9 (0.7)	1.6 (0.9)	2.1 (1.1)	2.7 (1.4)	3.6 (1.5)	<0.001
Computer work	1.1 (1.3)	0.4 (0.4)	0.7 (0.5)	0.9 (0.8)	1.3 (1.2)	2.3 (1.8)	<0.001
Paperwork	0.7 (0.8)	0.3 (0.2)	0.4 (0.3)	0.6 (0.5)	0.8 (0.8)	1.4 (1.3)	<0.001
Reading	1.1 (1.1)	0.5 (0.4)	0.7 (0.6)	1.0 (0.8)	1.2 (1.0)	2.0 (1.5)	<0.001
Talking on the telephone	0.7 (1.0)	0.3 (0.3)	0.4 (0.3)	0.5 (0.5)	0.8 (0.7)	1.7 (1.5)	<0.001
Sitting in a car	1.2 (1.1)	0.6 (0.4)	0.9 (0.6)	1.0 (0.7)	1.3 (1.1)	2.2 (1.6)	<0.001
Cardiometabolic risk factors							
Waist circumference, cm	94.4 (15.8)	88.9 (14.8)	92.3 (15.0)	95.3 (15.9)	96.8 (15.6)	98.7 (15.9)	<0.001
Systolic blood pressure, mmHg	118.7 (15.4)	116.4 (15.1)	116.8 (15.0)	119.2 (15.7)	119.0 (15.0)	121.9 (15.8)	<0.001
Diastolic blood pressure, mmHg	73.9 (10.9)	71.2 (10.6)	72.4 (10.6)	74.6 (10.7)	74.8 (10.5)	76.7 (10.9)	<0.001
Glucose, mg/dL	99.5 (28.7)	96.2 (24.3)	97.1 (21.0)	99.7 (33.0)	100.5 (27.6)	103.7 (34.5)	<0.001
Insulin, uU/mL	11.2 (9.6)	8.4 (6.9)	10.0 (7.4)	11.6 (8.8)	12.3 (8.7)	13.9 (13.6)	<0.001
Triglycerides, mg/dL	113.7 (81.3)	104.0 (82.3)	113.4 (79.9)	119.5 (87.3)	114.3 (76.8)	117.0 (79.2)	0.009
HDL-C, mg/dL	58.0 (18.0)	61.7 (19.3)	58.8 (18.0)	57.5 (17.6)	56.4 (16.5)	55.6 (17.8)	<0.001
Cardiometabolic risk score[d]	−0.04 (0.7)	−0.3 (0.6)	−0.1 (0.6)	0.0 (0.7)	0.0 (0.6)	0.2 (0.6)	<0.001

Abbreviations: HDL-C, high-density lipoprotein cholesterol; SD, standard deviation.

[a] P value for linear trend over sedentary quintiles was tested using linear regression (continuous variables) or χ^2 test of independence (categorical variables).

[b] Values are expressed as column percentages.

[c] Weight (kg)/height (m)^2.

[d] Cardiometabolic risk score was calculated by standardizing and summing waist circumference, average blood pressure ([systolic + diastolic]/2), log glucose, log insulin, log triglycerides, and negative log HDL-C and then dividing by 6 to create a z score.

examined associations between each individual cardiometabolic risk factor. Associations of the sedentary tasks with waist circumference, glucose, insulin, and triglyceride levels were largely consistent with findings from the overall cardiometabolic risk score. However, it is worth noting that the effect estimates were larger for triglycerides compared with any other individual risk factor as well as the overall cardiometabolic risk score, indicating that replacing television viewing with other sedentary behaviors may have a particularly strong influence on triglyceride levels. Interestingly, we found that replacing computer time with reading or telephone use resulted in a higher average blood pressure. This finding should be interpreted with caution, as this was not consistently observed across risk factors and may have been a spurious association.

There are many potential explanations for why television viewing is more strongly associated than other sedentary tasks

Table 3. Single-Variable, Partition, and Isotemporal Substitution Models per Each 2-Hour/Day Increase in 6 Sedentary Tasks and Composite Cardiometabolic Risk Score[a] (n = 3,211), the Coronary Artery Risk Development in Young Adults Study, 2010–2011

Analysis Method	Sedentary Task[b]											
	Television Watching		Computer Work		Paperwork		Reading		Using the Telephone		Sitting in a Car	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Single[c]	0.09[d]	0.06, 0.11	0.03[d]	0.00, 0.05	0.03	−0.01, 0.07	0.04[d]	0.00, 0.07	0.04[d]	0.01, 0.08	0.01	−0.02, 0.04
Partition[e]	0.08[d]	0.06, 0.11	0.01	−0.02, 0.04	0.01	−0.03, 0.05	0.02	−0.02, 0.05	0.01	−0.03, 0.05	−0.01	−0.04, 0.02
Isotemporal[f]												
Replace television	Omit		−0.07[d]	−0.11, −0.03	−0.07[d]	−0.12, −0.02	−0.06[d]	−0.11, −0.02	−0.07[d]	−0.12, −0.02	−0.09[d]	−0.13, −0.05
Replace computer	0.07[d]	0.03, 0.11	Omit		−0.00	−0.06, 0.06	0.01	−0.04, 0.05	−0.00	−0.06, 0.05	−0.02	−0.06, 0.02
Replace paperwork	0.07[d]	0.02, 0.12	0.00	−0.06, 0.06	Omit		0.01	−0.05, 0.06	−0.00	−0.06, 0.06	−0.02	−0.07, 0.04
Replace reading	0.06[d]	0.02, 0.11	−0.01	−0.05, 0.04	−0.01	−0.06, 0.05	Omit		−0.01	−0.07, 0.05	−0.03	−0.07, 0.02
Replace telephone	0.07[d]	0.02, 0.12	0.00	−0.05, 0.06	0.00	−0.06, 0.06	0.01	−0.05, 0.07	Omit		−0.02	−0.07, 0.04
Replace car	0.09[d]	0.05, 0.13	0.02	−0.02, 0.06	0.02	−0.04, 0.07	0.03	−0.02, 0.07	0.02	−0.04, 0.07	Omit	

Abbreviations: CI, confidence interval; HDL-C, high density lipoprotein cholesterol; isotemporal, isotemporal substitution models; partition, partition models; single, single-variable models.

[a] Cardiometabolic risk score was calculated by standardizing and summing waist circumference, average blood pressure ([systolic + diastolic]/2), log glucose, log insulin, log triglycerides, and negative log HDL-C and then dividing by 6 to create a *z* score. All models were adjusted for center, age, sex, race, educational level, unemployment, health insurance, smoking, alcohol consumption, physical activity, consumption of fast food and sugar-sweetened beverage, depressive symptoms and body mass index.

[b] Blank cells indicate that the variable was not included in the model. “Omit” indicates that the variable was removed from the model.

[c] Single-variable models tested the total associations of each sedentary task, unadjusted for other sedentary tasks.

[d] Statistically significant ($P < 0.05$).

[e] Partition models tested the unique associations of each sedentary task, adjusted for all other sedentary tasks.

[f] Isotemporal substitution models tested the substitution associations of each sedentary task, holding time constant.

with cardiometabolic risk factors. First, it has been hypothesized that television viewing is related to a lower resting metabolic rate than other sedentary tasks (e.g., sitting quietly while reading), thus resulting in lower energy expenditure. Although there have been few studies in which investigators directly compared the energy cost of television viewing with other sedentary behaviors, evidence suggests no differences in energy expenditure across sedentary activities (35–37). For example, Newton et al. (35) reported no differences in energy cost between seated reading, typing, or watching television among adults in a metabolic chamber study (1.03–1.06 metabolic equivalents). Although there do not appear to be differences in energy expenditure, it is feasible that television viewing requires less muscle activation than activities such as driving. Muscle inactivity is associated with a reduction in lipoprotein lipase (38), a protein that plays a key role in controlling lipid metabolism and other metabolic properties (39). Therefore, although not necessarily influencing energy expenditure at a detectable threshold, the more passive behavior of television viewing may have a stronger association with cardiometabolic risk factors than other sedentary tasks as a result of reduced lipoprotein lipase activity.

A second, alternative explanation is that the observed associations between television viewing and cardiometabolic risk factors may be due to the attributes of television viewers other than the nature of the sedentary activity. For example, evidence suggests that television viewing is associated with unhealthy dietary habits, including reduced consumption of fruits and vegetables and increased consumption of energy-dense snack foods, fast food and sugar-sweetened beverages (10). This may be the result of increased snacking behaviors while watching television, or exposure to food and beverage advertising that prime individuals to make unhealthy dietary choices (40). Higher levels of television viewing are also associated with the development of depression and other mental health disorders (14, 41, 42), which are known risk factors for adverse cardiometabolic outcomes, possibly due to diminished social interactions as a result of excessive screen time (42).

Finally, a third potential explanation is that individuals may be better able to recall time spent watching television as compared with time spent in other sedentary behaviors. Higher test-retest reliability has been reported for television viewing compared with other sedentary behaviors, such as talking on the telephone (17). Time may be more easily quantified within the context of a 30–60 minute television program as compared with other sedentary behaviors, which occur in shorter bouts and may be more irregular.

Strengths of the present study include the large racially diverse study sample, the independent examination of 6 unique sedentary tasks with objective measures of cardiometabolic risk, and the use of the isotemporal substitution paradigm to examine the associations with cardiometabolic risk when replacing one sedentary behavior with another. However, several limitations must be noted. First, the isotemporal substitution analysis approach is a statistical model that does not reflect real time reallocation, and as with all cross-sectional studies, we cannot infer causality between sedentary behaviors and cardiometabolic risk factors. Second, sedentary behaviors were assessed via self-report, and are therefore subject to social desirability and recall bias. However, a benefit of examining self-reported sedentary time is the ability to assess distinct tasks while sitting. In contrast, other studies with accelerometer- or inclinometer-based measures of sedentary time are unable to parse out the specific task being performed while sedentary. Use of wrist mounted accelerometers coupled with inclinometers and integration of machine learning for activity classification may enable researchers to better estimate the context of sedentary behavior in the future (43). Third, we did not account for sleep duration or quality in our analyses, as done in a few prior studies (19, 24, 44), nor did the sedentary behavior questionnaire assess computer time or office work related to one's job, which may represent a large proportion of daily sedentary time. It is important to note that isotemporal analyses do not require representation from the full 24-hour day; therefore, the omission of sleep and sitting time at work is acceptable within this paradigm. However, the results presented are not free of potential confounding due to unequal sleep or sedentary time at work across individuals. Given that time spent both sleeping and sitting in the workplace varies widely between individuals, it is hard to know the potential impact of these factors on the study findings. It is possible that the association between television time and cardiometabolic risk factors may be overestimated in those who spend more time sitting in the workplace, as we were unable to control for this potential confounder; however, this is speculative. Fourth, the sedentary behavior questionnaire is relatively new and has not yet been tested for reliability or validity. Lastly, it is possible that unmeasured or poorly measured variables, such as snacking behaviors, may have confounded the observed relationship between sedentary behaviors (particularly television viewing) and cardiometabolic risk.

In conclusion, this study provides evidence that television viewing may be a primary driver of the association between sedentary behaviors and cardiometabolic risk factors, independent of physical activity level and other potential confounders. Findings indicate the potential importance of reducing time spent watching television for improving cardiometabolic risk. Future prospective studies on the subject, as well as studies evaluating potential mechanisms between various sedentary behaviors and cardiometabolic risk, will provide better context for the original findings of this study.

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