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Sedentary behavior, physical activity, and concentrations of insulin among US adults

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Abstract

Time spent watching television has been linked to obesity, metabolic syndrome, and diabetes, all conditions characterized to some degree by hyperinsulinemia and insulin resistance. However, limited evidence relates screen time (watching television or using a computer) directly to concentrations of insulin. We examined the cross-sectional associations between time spent watching television or using a computer, physical activity, and serum concentrations of insulin using data from 2800 participants aged at least 20 years of the 2003-2006 National Health and Nutrition Examination Survey. The amount of time spent watching television and using a computer as well as physical activity was self-reported. The unadjusted geometric mean concentration of insulin increased from 6.2 μU/mL among participants who did not watch television to 10.0 μU/mL among those who watched television for 5 or more hours per day (P = .001). After adjustment for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, physical activity, waist circumference, and body mass index using multiple linear regression analysis, the log-transformed concentrations of insulin were significantly and positively associated with time spent watching television (P = < .001). Reported time spent using a computer was significantly associated with log-transformed concentrations of insulin before but not after accounting for waist circumference and body mass index. Leisure-time physical activity but not transportation or household physical activity was significantly and inversely associated with log-transformed concentrations of insulin. Sedentary behavior, particularly the amount of time spent watching television, may be an important modifiable determinant of concentrations of insulin.
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1. Introduction

The ubiquitous presence of televisions and computers in many societies has contributed to the sedentary lifestyles of many. A sedentary lifestyle has been linked to the metabolic syndrome [1], obesity [2], and diabetes [3]. All of these conditions are to some degree characterized by insulin resistance. Although it makes sense that sedentary behaviors would therefore lead to insulin resistance and hyperinsulinemia [4,5], little is known about these relationships. Establishing these links would provide additional insights into the pathogenesis of conditions such as the metabolic syndrome and diabetes. Therefore, our primary objective was to examine the cross-sectional association between sedentary behavior in terms of time spent watching television or using a computer and concentrations of insulin. In addition, we examined the associations between household, transportation, and leisure-time physical activity and concentrations of insulin.

2. Methods

We used data from the National Health and Nutrition Examination Survey 2003-2006. Each 2-year cycle included a national sample—recruited using a multistage, stratified

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sampling design—that was designed to be representative of the civilian, noninstitutionalized population in the United States. Participants were interviewed at home and were invited to attend a mobile examination center, where they were asked to complete additional questionnaires, to undergo various examinations, and to provide a blood sample. The study received human subjects approval; and participants were asked to sign an informed consent form. Details about the survey may be found elsewhere [6].

Serum concentrations of insulin were measured for participants who attended the morning examination. For the 2003-2004 cycle, concentrations of insulin were measured by the Tosoh AIA-PACK IRI (South San Francisco, CA), an immunoenzymometric assay, at the University of Missouri–Columbia. For the 2005-2006 cycle, concentrations of insulin were measured by using the Mercodia Insulin ELISA assay (Winston Salem, NC) at the Fairview Medical Center Laboratory at the University of Minnesota. Fasting plasma concentrations of glucose were measured using a hexokinase method on a Roche/Hitachi 911 instrument (Indianapolis, IN) for the 2003-2004 specimens and on a Roche Cobas Mira instrument (Indianapolis, IN) for the 2005-2006 specimens. Based on the results of crossover studies, regression equations were developed to convert insulin and glucose values derived from one method to those of the other method [7].

Sedentary behavior was determined from 2 questions: “Over the past 30 days, on average how many hours per day did you sit and watch TV or videos outside of work?” and “Over the past 30 days, on average how many hours per day did you use a computer or play computer games outside of work?” Responses to these questions were none, less than 1 hour, 1 hour, 2 hours, 3 hours, 4 hours, and 5 or more hours. We examined the responses to each of the 2 questions separately and also summed the responses to reflect total screen time.

The physical activity questionnaire included questions about transportation physical activity (“Over the past 30 days, have you walked or bicycled as part of getting to and from work, or school, or to do errands?”), household physical activity (“Over the past 30 days, did you do any tasks in or around your home or yard for at least 10 minutes that required moderate or greater physical effort?”), and leisure-time physical activity (“Over the past 30 days, did you do any vigorous activities for at least 10 minutes that caused heavy sweating, or large increases in breathing or heart rate?” and “Over the past 30 days, did you do moderate activities for at least 10 minutes that cause only light sweating or a slight to moderate increase in breathing or heart rate?”). For the various activities, participants were queried about the frequency during the past 30 days and the duration on each day or occasion allowing the calculation of the time spent in these activities during that time frame. For transportation and household physical activity, we estimated the 30-day MET-hour totals by multiplying the total hours spent in each activity during the past 30 days by the corresponding MET levels (4.0 for transportation, 4.5 for household). For leisure-time physical activity, we calculated a 30-day MET-hour index by summing over all activities the product of the hours engaged in each reported activity during the past 30 days and its corresponding MET level. One MET is the energy expenditure of approximately 3.5 mL oxygen per kilogram body weight per minute or 1 kcal/kg body weight per hour.

We included the following covariates: age, sex, race or ethnicity (white, African American, Mexican American, other Hispanic, other including multiracial), educational status (<high school, high school graduate, >high school), concentration of cotinine, alcohol intake, waist circumference, and body mass index. Serum concentrations of cotinine were measured by isotope dilution high-performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. Grams of alcohol intake were the average of two 24-hour dietary recalls. The first recall was obtained during the examination, and the second was obtained by telephone 3 to 10 days later. The waist circumference was measured at the high point of the iliac crest at minimal respiration to the nearest 0.1 cm. We also examined several dietary variables including the intakes of energy, sugar, fiber, total fat, and saturated fat from the 24-hour dietary recalls.

The analyses were limited to men and nonpregnant women aged at least 20 years who had fasted at least 8 hours. Participants who reported having been diagnosed with diabetes were excluded. Linear regression was used to examine the relationships between log-transformed concentrations of insulin and measures of sedentary behavior and physical activity. Least-square means were calculated using linear regression analysis. Regression coefficients were used to judge the significance of the differences of these means. Prevalence ratios for hyperinsulinemia (>20 μU/mL) were calculated using log-binomial regression analysis. SUDAAN (Software for the Statistical Analysis of Correlated Data) (Research Triangle Institute, Research Triangle Park, NC) was used for the analyses to account for the complex sampling design.

3. Results

Of the 3959 adults attending the morning examination, 3869 had a value for insulin. Excluding pregnant women left 3635 participants, and excluding participants with diagnosed diabetes reduced this number to 3254. After excluding participants with missing data for the study variables, 2800 participants were included in the analyses.

The demographic composition of the analytic sample was as follows: 49.1% of the sample was male, 38.8% was aged 20 to 39 years, 40.2% was aged 40 to 59 years, 21.0% was aged at least 60 years, 74.0% was white, 10% was African American, 7.6% was Mexican American, and 8.4% was of another race or ethnicity.

The majority of participants reported watching television for at least 2 hours per day: 1.5% did not report watching television, 15.3% watched television for less than 1 hour per day, 17.7% watched television for 1 hour per day, 29.3%

watched for 2 hours per day, 16.7% watched for 3 hours per day, 9.3% watched for 4 hours per day, and 10.4% watched for 5 or more hours per day. Participants reported spending less time using a computer than watching television: 34.9% did not report using a computer, 34.1% used a computer for less than 1 hour per day, 15.5% used a computer for 1 hour per day, 8.1% used a computer for 2 hours per day, 3.4% used a computer for 3 hours per day, 1.5% used a computer for 4 hours per day, and 2.6% used a computer for 5 or more hours per day.

The concentration of insulin ranged from 0.06 to 205.57 μU/mL with a mean concentration of 10.01 μU/mL, a median concentration of 7.18 μU/mL, and a geometric mean concentration of 7.16 μU/mL.

3.1. Screen time

The unadjusted geometric mean concentration of insulin increased from 6.2 μU/mL among participants who reported not watching television to 10.0 μU/mL among those who reported watching television for 5 or more hours per day, representing a 61% increase ($P_{0 \text{ vs } \geq 5 \text{ hours}}$ = .001) (Fig. 1). After adjustment for the covariates including waist circumference, the change in concentrations of insulin between the extremes of the television categories was markedly attenuated. The adjusted geometric mean concentration was 7.1 μU/mL among participants who did not watch television and 8.2 μU/mL among those who watched television for 5 or more hours per day, representing a 14% increase ($P_{0 \text{ vs } \geq 5 \text{ hours}}$ = .194). The results from the multiple linear regression analysis show that time spent watching television was significantly and positively associated with concentrations of insulin (Table 1).

Time spent using a computer was less strongly associated with concentrations of insulin than time spent watching television. The unadjusted geometric mean concentration of insulin increased from 7.3 μU/mL among participants who reported not using a computer to 9.3 μU/mL among those who reported using one for 5 or more hours per day, representing a 27% increase ($P_{0 \text{ vs } \geq 5 \text{ hours}}$ = .032) (Fig. 1). After adjustment for covariates, this gradient became less steep. The adjusted geometric mean concentration was 7.2 μU/mL among participants who reported not using a computer and 8.0 μU/mL among those who reported using one for 5 or more hours per day, representing an 10%

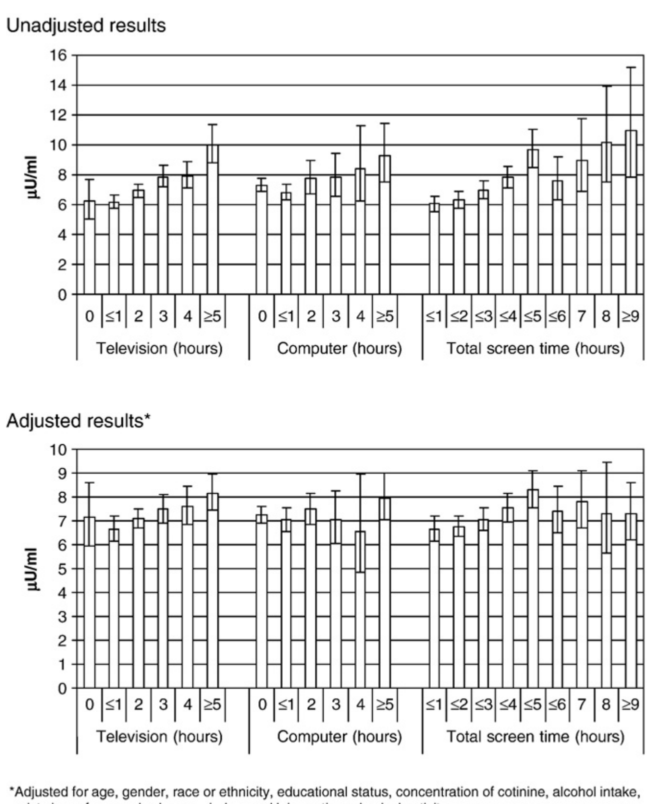

Fig. 1. Unadjusted and adjusted geometric mean concentrations of insulin by hours of time spent watching television, using computers, and total screen time among 2800 US adults aged at least 20 years, National Health and Nutrition Examination Survey 2003-2006.

Table 1
Results from linear regression analysis between log-transformed concentration of insulin (dependent variable in microunits per milliliter) and components of physical activity or sedentary behavior among 2800 US adults aged at least 20 years, National Health and Nutrition Examination Survey 2003-2006

	β	SE	P
Sedentary behavior (/h)			
Television			
Model 1A	0.10505	0.01086	<.001
Model 2A	0.09727	0.01259	<.001
Model 3A	0.04566	0.01102	<.001
Computer			
Model 1A	0.04384	0.01452	.005
Model 2A	0.04919	0.01400	.001
Model 3A	0.00874	0.00957	.368
Total screen time			
Model 1A	0.07897	0.00930	<.001
Model 2A	0.07301	0.00965	<.001
Model 3A	0.02945	0.00738	<.001
Physical activity (/MET-h)			
Transportation			
Model 1B	−0.00007	0.00018	.711
Model 2B	−0.00010	0.00021	.627
Model 3B	0.00018	0.00013	.172
Household			
Model 1B	−0.00019	0.00023	.407
Model 2B	0.00004	0.00023	.859
Model 3B	−0.00016	0.00016	.343
Leisure time			
Model 1B	−0.00066	0.00014	<.001
Model 2B	−0.00062	0.00015	<.001
Model 3B	−0.00031	0.00010	.006

Model 1A is unadjusted. Model 2A is adjusted for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, and leisure-time physical activity. Model 3A is adjusted for covariates in model 1 plus waist circumference and body mass index. Model 1B is unadjusted. Model 2B is adjusted for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, and screen time. Model 3B is adjusted for covariates in model 1 plus waist circumference and body mass index.

increase ($P_{0 \text{ vs } \geq 5 \text{ hours}}$ = .123). Without adjustment for waist circumference and body mass index in multiple linear regression analysis, time reported using a computer was positively and significantly related to concentrations of insulin. However, after adding waist circumference and body mass index to the model, the regression coefficient was no longer significant (*P* linear trend = .368) (Table 1).

For total screen time, the unadjusted geometric mean concentration increased from 6.0 μU/mL among participants reporting 0 or up to 1 hour of screen time to 10.9 μU/mL for those reporting 9 or more hours of screen time, representing a 40% increase ($P_{\leq 1 \text{ vs } \geq 9 \text{ hours}}$ = .001) (Fig. 1). After adjustment, the geometric mean concentration was 6.7 μU/mL among participants with 0 or up to 1 hour of screen time and 7.3 μU/mL for those with 9 or more hours of screen time, representing an 9% increase ($P_{\leq 1 \text{ vs } \geq 9 \text{ hours}}$ = .315). The results of the multiple linear regression analyses show a significant and positive association between screen time and concentrations of insulin (Table 1).

We also examined associations after dichotomizing concentrations of insulin (>20 vs ≤20 μU/mL) (Table 2). Without adjustment, participants who watched television for 5 or more hours per day were about 3 times as likely to have hyperinsulinemia as participants who did not watch television or watched it for less than 1 hour per day. Adjustment for demographic variables, concentration of cotinine, alcohol use, and leisure-time physical activity affected the prevalence ratios little. However, additional adjustment for anthropometric variables resulted in serious attenuation of the prevalence ratios. Similar scenarios played out for computer use and total screen time.

3.2. Physical activity

The unadjusted geometric mean concentration of insulin was 6.5 μU/mL among participants who reported doing more than 120 MET-hours of transportation physical activity during the past 30 days (equivalent to >1.5 hours of moderate walking on week days) and 7.4 μU/mL among participants who did not report doing transportation physical activity (*P* = .320) (Fig. 2). The unadjusted geometric mean concentration of insulin was 6.8 μU/mL among participants who reported doing more than 54 MET-hours of household physical activity during the past 30 days (equivalent to about 3 hours of household physical activity per week) and 7.4 μU/mL among participants who did not report doing household physical activity (*P* = .212). The unadjusted geometric mean concentration of insulin was 6.1 μU/mL among participants who reported doing more than 120 MET-hours of leisure-time physical activity during the past 30 days (equivalent to 7.5 hours of moderate activity rated at a MET level of 4.0 each week) and 7.9 μU/mL among participants who did not report doing leisure-time physical activity (*P* < .001). After adjustment for the covariates, none of the comparisons for the 3 modes of physical activity was statistically significant.

Table 2
Prevalence ratios (95% confidence interval) for concentrations of insulin greater than 20 μU/mL among 2800 US adults aged at least 20 years, National Health and Nutrition Examination Survey 2003-2006

Television							
Time (h)	<1	1-<2	2-<3	3-<4	4-<5	≥5	
n	408	465	793	506	275	353	
Unadjusted % (SE)	6.9 (1.4)	8.2 (1.2)	8.5 (1.0)	11.3 (1.5)	11.3 (2.0)	21.1 (3.2)	
PR (95% CI)							
Model 1A	1.00	1.19 (0.73, 1.94)	1.23 (0.89, 1.70)	1.64 (0.99, 2.70)	1.64 (0.88, 3.05)	3.05 (1.92, 4.85)	
Model 2A	1.00	1.11 (0.68, 1.82)	1.20 (0.87, 1.67)	1.56 (0.94, 2.60)	1.58 (0.83, 3.00)	2.90 (1.82, 4.61)	
Model 3A	1.00	1.01 (0.62, 1.63)	0.94 (0.62, 1.42)	1.08 (0.68, 1.73)	1.26 (0.66, 2.43)	1.34 (0.81, 2.23)	
Computer							
Time (h)	0	<1	2	3	≥4		
n	1229	1180	191	89	111		
Unadjusted % (SE)	9.6 (0.9)	9.5 (1.0)	11.4 (2.6)	13.1 (4.2)	19.9 (3.8)		
PR (95% CI)							
Model 1A	1.00	0.98 (0.71, 1.35)	1.18 (0.75, 1.88)	1.36 (0.72, 2.59)	2.07 (1.45, 2.95)		
Model 2A	1.00	1.04 (0.74, 1.46)	1.24 (0.77, 2.00)	1.31 (0.72, 2.39)	1.99 (1.31, 3.03)		
Model 3A	1.00	1.06 (0.79, 1.43)	1.00 (0.69, 1.47)	1.14 (0.64, 2.03)	1.34 (0.89, 2.00)		
Total screen time							
Time (h)	≤1	>1-≤2	>2-≤3	>3-≤4	>4-≤5	>5-≤6	>6
n	499	605	643	401	370	158	124
Unadjusted % (SE)	7.5 (1.7)	6.2 (0.9)	9.0 (1.2)	11.1 (2.2)	16.1 (2.7)	16.9 (3.9)	20.9 (4.2)
PR (95% CI)							
Model 1A	1.00	0.82 (0.45, 1.49)	1.19 (0.76, 1.86)	1.48 (0.79, 2.74)	2.14 (1.19, 3.83)	2.24 (1.17, 4.32)	2.77 (1.66, 4.60)
Model 2A	1.00	0.82 (0.45, 1.50)	1.16 (0.73, 1.83)	1.51 (0.80, 2.83)	2.09 (1.16, 3.75)	2.08 (1.07, 4.06)	2.50 (1.49, 4.18)
Model 3A	1.00	0.69 (0.37, 1.26)	0.82 (0.50, 1.33)	0.92 (0.51, 1.66)	0.98 (0.57, 1.67)	1.46 (0.76, 2.82)	1.23 (0.71, 2.12)

Model 1A is unadjusted. Model 2A is adjusted for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, and leisure-time physical activity. Model 3A is adjusted for covariates in model 1 plus waist circumference and body mass index. PR indicates prevalence ratio; CI, confidence interval.

In multiple linear regression analysis, transportation and household physical activities were not significantly associated with concentrations of insulin (Table 1). However, leisure-time physical activity was inversely associated with concentrations of insulin even after adjustment for waist circumference and body mass index.

3.3. Glucose

Fasting plasma concentrations of glucose were significantly associated with the time spent watching television and total screen time in models that were unadjusted or accounted for covariates other than anthropometric variables (Table 3). However, the regression coefficients were no longer statistically significant after the anthropometric variables were added to the models. Computer use was not significantly associated with concentrations of glucose.

3.4. Nutrients

We calculated mean intakes of several nutrients by reported time spent watching television and using a computer (Table 4). Sugar intake was significantly and positively related to time spent watching television, and fiber intake was significantly and inversely related to time spent watching television. No significant trends were observed for intakes of energy, total fat, and saturated fat. No significant trends were observed for any of the nutrients and the amount of time spent using a computer.

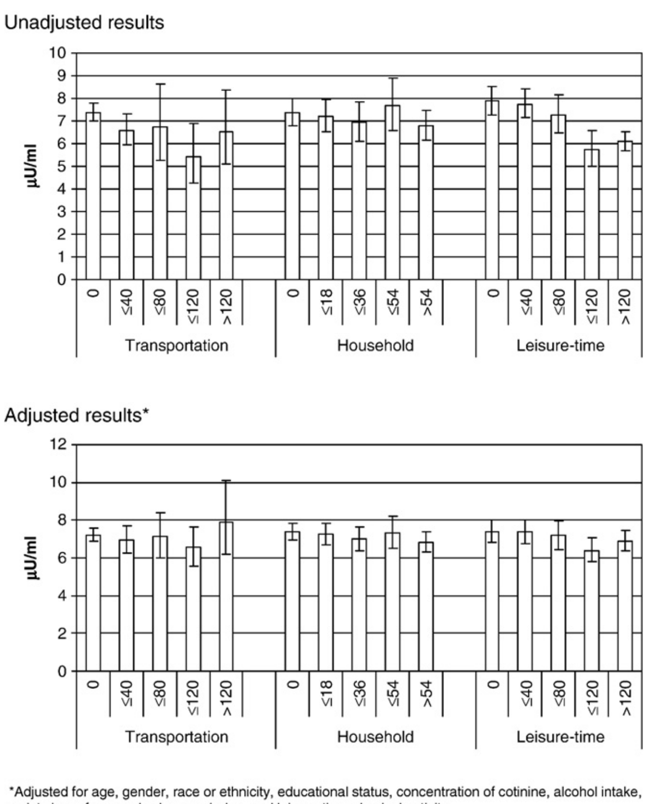

Fig. 2. Unadjusted and adjusted geometric mean concentrations of insulin by MET-hours of transportation, household, and leisure-time physical activity among 2800 US adults aged at least 20 years, National Health and Nutrition Examination Survey 2003-2006.

Table 3
Results from linear regression analysis between concentration of fasting glucose (dependent variable in milligrams per deciliter) and components of sedentary behavior or physical activity among 2800 US adults aged at least 20 years, National Health and Nutrition Examination Survey 2003-2006

	β	SE	*P*
Sedentary behavior (/h)			
Television			
Model 1A	1.21539	0.27447	<.001
Model 2A	0.64474	0.26307	.020
Model 3A	0.27420	0.24708	.276
Computer			
Model 1A	−0.14339	0.35618	.690
Model 2A	0.48809	0.30551	.121
Model 3A	0.19474	0.27737	.488
Total screen time			
Model 1A	0.68782	0.18199	.001
Model 2A	0.53964	0.16710	.003
Model 3A	0.22672	0.14344	.124
Physical activity (/MET-h)			
Transportation			
Model 1B	−0.00095	0.00272	.729
Model 2B	0.00284	0.00235	.237
Model 3B	0.00488	0.00180	.011
Household			
Model 1B	0.00063	0.00211	.767
Model 2B	−0.00292	0.00208	.171
Model 3B	−0.00437	0.00211	.048
Leisure time			
Model 1B	−0.00838	0.00178	<.001
Model 2B	−0.00380	0.00123	.004
Model 3B	−0.00156	0.00106	.152

Model 1A is unadjusted. Model 2A is adjusted for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, and leisure-time physical activity. Model 3A is adjusted for covariates in model 1 plus waist circumference and body mass index. Model 1B is unadjusted. Model 2B is adjusted for age, sex, race or ethnicity, educational status, concentration of cotinine, alcohol intake, and screen time. Model 3B is adjusted for covariates in model 1 plus waist circumference and body mass index.

4. Discussion

Watching television is a favorite pastime among US adults. According to Nielsen, Americans watched on average about 151 hours of television per month in the fourth quarter of 2008 [8]. In our sample, almost two thirds of adults watched 2 or more hours per day. The amount of time spent watching television proved to be strongly and positively associated with concentrations of insulin. This finding is consistent with previous research showing significant associations between the amount of time spent watching television and prevalent or incident obesity, metabolic syndrome, and diabetes [1-3]. Computer time was also significantly associated with concentrations of insulin in models that did not include the anthropometric variables. Of the types of physical activity examined in this study, reported

Table 4
Unadjusted mean intakes of selected nutrients among 2826 participants aged at least 20 years, by time spent watching television and using a computer, National Health and Nutrition Examination Survey 2003-2006

	n	Energy intake (kcal)		Sugar (g/d)		Fiber (g/d)		Total fat (g/d)		Saturated fat (g/d)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Television time (h/d)											
0	40	1998.9	121.5	97.9	6.8	18.7	1.8	73.2	4.5	23.2	2.0
≤1	833	2197.0	39.6	122.6	2.9	16.5	0.3	83.2	1.8	27.4	0.7
2	793	2177.0	34.7	115.0	2.9	16.1	0.4	83.1	2.0	27.9	0.7
3	506	2157.6	51.9	120.8	4.4	15.2	0.5	81.2	2.6	26.7	0.8
4	275	2258.2	57.8	128.7	3.9	15.8	0.6	87.7	3.2	29.3	1.1
≥5	353	2119.4	61.4	125.7	4.9	13.9	0.5	79.9	2.7	26.9	0.9
P for linear trend[a]		.313		.003		.015		.153		.089	
Computer time (h/d)											
0	1229	2098.5	31.0	119.0	2.7	15.2	0.4	77.6	1.6	25.8	0.5
≤1	1180	2210.7	26.3	119.2	2.6	16.3	0.3	85.5	1.7	28.4	0.6
2	191	2283.9	49.3	125.2	4.1	16.7	0.6	86.0	2.4	28.8	1.1
3	89	2325.3	131.4	134.5	12.2	14.9	0.8	90.9	5.6	30.3	2.3
4	41	2186.9	156.5	141.0	14.2	14.4	1.5	78.1	5.7	26.2	2.4
≥5	70	2138.3	142.9	123.3	12.0	14.8	1.1	81.4	6.2	26.7	2.0
P for linear trend[a]		.850		.232		.189		.958		.973	

[a] Trends were examined with orthogonal linear contrasts.

leisure-time physical activity was the only component that was significantly and inversely associated with concentrations of insulin.

Concentrations of insulin are moderately associated with criterion-standard measures of insulin resistance and, along with other measures such as the homeostasis model assessment of insulin resistance (HOMA), are often used as surrogate measures of insulin resistance [9]. To the extent that concentrations of insulin reflect insulin resistance, our results indicate that time spent watching television is positively associated and leisure-time physical activity is inversely associated with insulin resistance.

Despite a substantial and growing body of literature examining the associations between screen time and obesity, metabolic syndrome, and diabetes, few data concerning the relationships between screen time and concentrations of insulin or insulin resistance are available. Among 192 men and women in the ProActive UK trial, time spent watching television and videos was significantly and directly related to HOMA and concentrations of fasting insulin in cross-sectional but not prospective analyses [4]. Among 376 participants of the Medical Research Council Ely study, sedentary time measured with the flex heart rate method over a 4-day period was significantly and positively associated with concentrations of fasting insulin after 5.6 years of follow-up [5]. However, screen time per se was not assessed in that study.

Concentrations of insulin are positively associated with the risk of cardiovascular disease and diabetes in prospective studies [10,11]. Thus, the unadjusted difference of 3.8 μU/mL and the adjusted difference of 1.0 μU/mL between participants who did not report watching television and participants who watched for 5 or more hours per day suggest that the latter group may be at somewhat increased risk for these conditions. Thus, the differences in concentrations of insulin across levels of time spent watching television and levels of physical activity, besides being statistically significant, were likely clinically relevant.

The addition of anthropometric variables to our regression models seriously attenuated the magnitude of the regression coefficients, possibly indicating that the anthropometric variables mediate the association between sedentary behavior and concentrations of insulin. Obesity is a well-established risk factor of hyperinsulinemia [12].

The effect of watching television on concentrations of insulin may operate through at least 2 pathways. First, physical activity has been shown to be associated with concentrations of insulin [13]. Thus, a reduction in physical activity due to sedentary behavior would be expected to increase concentrations of insulin. Second, the influence of watching television on dietary behavior has received considerable attention. The cumulative evidence indicates that watching television is generally associated with a less healthy dietary behavior as characterized by increased snacking, increased intake of energy-dense foods, decreased consumption of fruits and vegetables, and increased energy intake. Because diet is one of the determinants of concentrations of insulin [14], alterations in dietary behavior could also impact concentrations of insulin.

The much weaker association between computer use and concentrations of insulin compared with the associations observed for television viewing in our study suggests that these 2 sources of screen time may impact health differently. Part of the deleterious effect of television viewing on obesity and perhaps concentrations of insulin has been attributed to television's potential influence on patterns of food and beverage consumption during [15-18] and subsequent to television viewing [19,20]. The impact of computer use on dietary behavior is less clear. Some research suggests that high use of computers is associated with unhealthy dietary habits in adolescents [21]. Our results regarding the intakes of selected nutrients show some significant relationships with time spent watching television but not with using a computer.

The inverse association between physical activity and concentrations of insulin is well known [13]. Our results pertaining to leisure-time physical activity are consistent with the existing evidence. Our finding that physical activity related to transportation and household activities was not significantly associated with concentrations of insulin is not easily explained. If energy expenditure explains the relationship between physical activity and concentrations of insulin, then all sources of physical activity would be expected to show inverse associations. It is conceivable that the reporting of physical activity was more accurate for some types of physical activity (ie, leisure-time physical activity) than others (ie, transportation and household physical activity).

Our results are subject to several limitations. The cross-sectional nature of our analyses precludes establishing cause and effect. Of note is a prospective study that found a significant association between sedentary behavior and concentrations of insulin and HOMA [5]. Physical activity and sedentary behavior were self-reported and therefore subject to some degree of misclassification. The associations were based on data collected at a single point in time, which may have underestimated the strength of the associations. The reliability and validity of the questions concerning television watching and computer use have not been established. However, they are similar to those used in other studies [22]. Furthermore, we were unable to distinguish computer use at home from that at work. The effects of computer use on concentrations of insulin may vary according to the context in which computers are used. In addition, we may not have adjusted for all relevant confounders; and residual confounding cannot be excluded.

Although research to reduce the amount of time spent watching television has been conducted among children and adolescents [23,24], similar research has not been conducted among adults [2]. No trials have apparently assessed the impact of reductions in screen time on concentrations of insulin, but evidence suggests that interventions that reduce screen time or that include a component to reduce screen time can have a beneficial effect on obesity in youth [25-29]. Reductions in adiposity are quite likely to be accompanied by reductions in concentrations of insulin.

The accumulated evidence suggests strongly that excessive television watching negatively impacts health. Consequently, health care providers should consider asking their patients about the amount of time that they watch television and perhaps use computers, especially in the context of routine physical examinations, and counsel their patients about the potential adverse health effects of sedentary behavior. Furthermore, if public health efforts to combat obesity, the metabolic syndrome, and diabetes are to be successful, reducing the amount of time spent watching television in the US population is likely to be an important strategy.

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