



Association of sedentary patterns with body fat distribution among US children and adolescents: a population-based study

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Abstract

Background/Objectives Children and adolescents spend a substantial amount of time being sedentary. The impact of prolonged sedentary patterns on fat distribution has not been elucidated especially in the context of physical activity level. Our objective is to examine the independent and joint associations of prolonged sedentary patterns and physical activity level with fat distribution among children and adolescents.

Subjects/Methods This included US children (8–11 years) and adolescents (12–19 years) from the National Health and Nutrition Examination Survey 2003–2006. Sedentary patterns comprise accelerometer-measured average sedentary bout duration and self-reported time of sitting watching TV/videos. Fat distribution (trunk and total fat percentage) was determined via dual X-ray absorptiometry.

Results Among 810 children and 2062 adolescents, average sedentary bout duration was associated with greater total and trunk fat percentages only among male children, after adjusting for moderate-to-vigorous physical activity (MVPA) level by accelerometer. Prolonged sitting watching TV/videos was associated with higher total and trunk fat percentages in male children and all adolescents, independent of levels of MVPA (all *P* for trend <0.05). Compared with ≤1 h/day, male children who spent ≥4 h/day sitting watching TV/videos had 4.43% higher trunk fat (95% CI, 1.69–7.17%), with similar associations for female (3.53%; 95% CI, 1.03–6.03%) and male adolescents (4.78%; 95% CI, 2.97–6.60%). About 13–17% children and adolescents spent <1 h on MVPA and ≥4 h sitting watching TV/videos per day. Compared with the most active group (MVPA ≥1 h/day and sitting watching TV/videos ≤1 h/day), trunk fat in this least active group was 6.21% higher in female children, 9.90% higher in male children, 6.84% higher in female adolescents, and 5.36% higher in male adolescents.

Conclusions Prolonged time spent on sitting watching TV/videos was associated with fat accumulation among children and adolescents, independent of physical activity level.

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Introduction

The new 2020 World Health Organization guidelines update the previous version of 2010 and first time included

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a recommendation that children and adolescents should limit the amount of time spent being sedentary, particularly the recreational screen time [1]. Health risks associated with sedentary behaviors, in addition to the known benefits of physical activity, were also highlighted by the 2018 US Physical Activity Guidelines Advisory Committee [2]. However, quantitative guidelines for the adequate amount of sitting time that take into consideration of physical activity levels are lacking, in part due to limited evidence on the joint impact of the two [3, 4]. Evidence is much more limited for children and adolescents than adults, despite the increasingly prevalent sedentary lifestyle in this age period [5, 6]. In the US, children and adolescents spend half of their waking time being sedentary (6–8 h/day) [7]. In addition, the majority of children and adolescents have not met the recommended 1 h of moderate-to-vigorous physical activity (MVPA) per day, along with decreasing levels of physical activity as they grow up [8]. These alarming trends collectively highlight the urgent need to study the joint influence of sedentary behavior and physical activity level on health risks in early life stages [9].

Body fatness significantly predicts cardiometabolic health in children and adolescents [10, 11]. Prior studies showed that accelerometer-measured total sedentary time was positively associated with markers of obesity (e.g., body mass index) [12], but inconsistently associated with body fatness in children and adolescents [13–16]. Nevertheless, these findings were limited to indirect measurements of body fatness and/or small sample sizes, which suggest the need for large-scale epidemiologic studies that use a validated and accurate measure of body fat distribution, dual X-ray absorptiometry (DXA), in investigating these associations. Prolonged sedentary patterns, indicated by longer average sedentary bout, more likely impact metabolic risk compared with the same duration of sitting with more breaks [17, 18], and were also less explored in young people. In particular, sitting watching TV/videos, a major domain-specific sedentary behavior [4, 5, 19], is a prevalent recreational activity for the young generations especially in low socioeconomic families and racial minority populations [4], yet its association with body fat remains poorly understood. Moreover, few studies examined the joint associations of physical activity and sedentary behaviors with fat distribution in a sex-specific manner, although females tend to have more trunk fat than males in childhood, which is further amplified by pubertal maturation [20].

To address these knowledge gaps that are critical for prevention guideline development, we examined the independent and joint associations of sedentary patterns and accelerometer-measured physical activity level with fat distribution assessed by DXA in a nationally representative sample of US children and adolescents.

Methods

Study population

The National Health and Nutrition Examination Survey (NHANES) was designed to continuously monitor the health and nutritional status of a nationally representative sample of the civilian noninstitutionalized population and has been implemented in the US every 2 years since 1999 [21]. The NHANES participants completed a detailed in-person interview and underwent physical examinations in the mobile examination center. All NHANES protocols were approved by the ethics review board of the US National Center for Health Statistics and written informed consent was provided by each participant. In the present study, participants aged 8–19 years in the two NHANES cycles (2003–2004 and 2005–2006) who had available information on physical activity monitor and whole-body DXA scans were included.

Accelerometer-measured activity pattern

During the physical examination, participants were asked to wear an accelerometer (ActiGraph AM-7164) on the right hip for 7 consecutive days to assess free-living physical activity level. The ActiGraph AM-7164 is a validated, small lightweight device that records the raw acceleration magnitude of human movement in 3-axis and store the data in memory according to a specified time interval. The raw data are summed in an epoch (1-min time interval) and converted to activity count (AC) in the NHANES. The AC that ranged from 0 to 32,767 counts/min is considered valid; extreme high-count values (>32,767), which indicated voltage signal saturation (repeated values equal to $2^{15} - 1 = 32,767$), were excluded through filtering systems within the monitor. Device data were processed using R package “nhanesacel” [22] to generate intensity, frequency, and duration of movement during non-sleep time according to the algorithm from the US National Cancer Institute with proven accuracy among the young [23]. A valid day was defined as wear periods of ≥ 10 h/day, and participants with 3 or more valid days of data were considered to be eligible for inclusion [8]. The cutoff for sedentary behavior was set at $AC < 100$; the cutoffs for MVPA were age-specific: $AC \geq 1638$, ≥ 1770 , ≥ 1910 , ≥ 2059 , ≥ 2220 , ≥ 2393 , ≥ 2580 , ≥ 2781 , ≥ 3000 , ≥ 3239 , and ≥ 2020 for age 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and ≥ 18 years, respectively [23]. A sedentary bout was defined as a consecutive duration of at least one minute with $AC < 100$. Average sedentary bout duration (minute) was calculated using the total sedentary time divided by sedentary bout frequency within valid wear time. Levels of average sedentary bout duration were classified into age-specific quartiles (Qs).

Self-reported sitting watching TV

Self-reported data on time spent sitting watching TV/videos were collected during the in-person interview. The validity and reliability of this measurement have been convincing for use in children and adolescents [24]. Parents or guardians of children (aged 8–11) as their proxies and adolescents (aged 12–19) were asked to recall the frequency and duration of their daily sedentary activities: “Over the past 30 days, on average, about how many hours per day did [you/children’s name] sit and watch television or videos?”; available options for the answers were: none, less than 1, 1, 2, 3, 4, or 5 h or more. Duration of sitting watching TV/videos was further categorized into: ≤ 1 , 2, 3, and ≥ 4 h/day.

Measurement of fat distribution

Whole-body DXA scans were administered to eligible participants aged 8 years and older and performed in the NHANES mobile examination center using a Hologic QDR-4500A fan-beam densitometer. Each DXA scan was reviewed and analyzed by the Department of Radiology, University of California, San Francisco, using standard radiologic techniques and study-specific protocols developed for the NHANES. Hologic Discovery software 12.1 was used to analyze the DXA exams and provided the body composition data. Fat percentages of total body (including the head, limbs, and trunk area) and trunk (only the trunk area) were derived to measure the magnitude and distribution of body fat.

Assessment of covariates

Self-reported sociodemographic characteristics and lifestyle factors included age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), family poverty ratio, total energy intake, and Healthy Eating Index (HEI)-2010. Family poverty ratio was defined as the ratio of family income to the Federal Poverty Level and categorized as <1.30 , 1.30 – 3.49 , and ≥ 3.50 . A higher family poverty ratio indicated a higher family income status. Total energy intake and HEI-2010 were derived from a 24-h dietary recall interview. HEI-2010 is an energy-adjusted measure of diet quality according to the 2010 Dietary Guidelines for Americans (scores ranged from 0 to 100, with 0 indicating the worst-quality diet and 100 indicating the best-quality diet) [25].

Statistical analysis

Following the NHANES analytic guidelines, all analyses used sample weights that account for the complex survey design

and computed nationally representative estimates [26]. Due to biological differences in body composition, all analyses were conducted in a sex-specific manner [27]. First, the descriptive statistics were presented as numbers of participants (percentages) or mean (standard deviation) by sex. Weighted linear regression was used to examine the association of sedentary behavior patterns, using accelerometer-based average sedentary bout duration (age-specific quartile) or self-reported sitting watching TV/videos (≤ 1 , 2, 3, and ≥ 4 h/day), with percentages of total body and trunk fat. The first multivariable model was adjusted for age (years), sex, race/ethnicity, family poverty ratio, total accelerometer wear time (h/day), total energy intake (kcal), and HEI-2010 score. Time engaged in MVPA (per 30 min) was further adjusted in the second multivariable model. Individuals with missing data on covariates were excluded from the analysis. Regression coefficients (β s) with 95% confidence intervals (CIs) and P for trend were estimated. Joint analyses by sedentary behavior variables (average sedentary bout duration: age-specific quartile; sitting watching TV/videos: ≤ 1 , 2, 3, and ≥ 4 h/day) and MVPA level (≥ 1 and <1 h/day) were conducted. Interaction terms (i.e., sedentary behaviors \times MVPA) were created to examine the P for interaction between sedentary behaviors and MVPA levels on fat distribution. When calculating P for trend and P for interaction for average sedentary bout duration, the age-specific quartile was used as a continuous variable. For sitting watching TV/videos, the mid-point of each category was considered as a continuous variable. Multiple datasets were aggregated using SAS 9.4 (SAS Institute, North Carolina, USA), and analyzed using Stata 15.1 (StataCorp, College Station, Texas, USA). Two-sided $P < 0.05$ was considered statistically significant.

Results

A total of 810 children (8–11 years) and 2062 adolescents (12–19 years) were included in the present study. Participant characteristics are presented by age group and sex in Table 1. In this nationally representative sample, more than half of children (female: 68.2%; male: 72.5%) and adolescents (female: 57.9%; male: 64.7%) spent ≥ 2 h/day on sitting watching TV/videos, with a slightly higher proportion in males. Adolescents had a higher average sedentary bout duration (5.35 min in both sexes), compared with children (female: 3.97 min; male: 4.05 min). For both children and adolescents, females tended to spend less daily time on MVPA than their male peers (0.87 versus 1.18 h/day in children, $P < 0.001$; 0.54 versus 0.89 h/day in adolescents, $P < 0.001$). Also, majority of participants with average sedentary bout at Q1 and Q2 spent <2 h/day sitting watching TV/videos, while the majority of participants with average sedentary bout at Q3

Table 1 Characteristics of participants among US children and adolescents, NHANES 2003–2006.

Characteristics	Children (8–11 years)		Adolescents (12–19 years)	
	Female	Male	Female	Male
<i>No. of participants</i>	426	384	980	1082
<i>Race/ethnicity, No. (%)</i>				
Non-Hispanic white	248 (58.3)	225 (58.7)	631 (64.4)	686 (63.4)
Non-Hispanic black	66 (15.4)	43 (13.7)	144 (14.7)	155 (14.3)
Hispanic	82 (19.3)	68 (17.7)	148 (15.1)	181 (16.7)
Other ^a	30 (7.0)	38 (9.9)	57 (5.8)	60 (5.5)
<i>Family income poverty ratio, No. (%)</i>				
<1.30	128 (30.1)	105 (27.4)	265 (27.0)	262 (24.2)
1.31–3.49	169 (39.7)	161 (41.8)	370 (37.8)	446 (41.2)
≥3.50	129 (30.2)	118 (30.8)	345 (35.2)	375 (34.7)
<i>Energy intake (kcal), mean (SD)</i>	1943 (46)	2201 (40)	1948 (37)	2707 (50)
<i>HEI-2010 score, mean (SD)</i>	45.3 (0.7)	45.3 (1.0)	45.0 (0.7)	43.3 (0.5)
<i>Accelerometer derived variables, mean (SD)</i>				
Average sedentary bout duration (min) ^b	3.97 (0.04)	4.05 (0.06)	5.35 (0.08)	5.35 (0.34)
MVPA (h/day) ^c	0.87 (0.03)	1.18 (0.05)	0.54 (0.02)	0.89 (0.03)
<i>Sitting watching TV/videos (≥2 h/day), No. (%)</i>	290 (68.2)	278 (72.5)	558 (57.9)	685 (64.7)
<i>Body composition by DXA, mean (SD)</i>				
Total fat percentage	32.2 (0.5)	28.1 (0.5)	33.5 (0.3)	24.3 (0.3)
Trunk fat percentage	27.8 (0.6)	23.4 (0.6)	29.7 (0.4)	21.3 (0.3)

AC activity count, DXA dual energy X-ray absorptiometry, HEI Healthy Eating Index, MVPA moderate-to-vigorous physical activity, NHANES National Health and Nutrition Examination Survey, SD standard deviation.

^aOther race/ethnicity included multiple races other than non-Hispanic white, non-Hispanic black, or Hispanic.

^bAverage sedentary bout was calculated as total sedentary time divided by sedentary bout frequencies within valid wear time using accelerometer data; sedentary bout was a period of consecutive duration at least 1 min that AC <100.

^cAge-specific cutoffs for MVPA were used (AC ≥1638, ≥1770, ≥1910, ≥2059, ≥2220, ≥2393, ≥2580, ≥2781, ≥3000, ≥3239, and ≥2020 for age 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and ≥18 years, respectively) according to the thresholds used by the National Cancer Institute.

and Q4 spent ≥2 h/day sitting watching TV/videos (Supplementary Fig. 1).

Accelerometer-measured average sedentary bout duration

In both female and male children, average sedentary bout duration was associated with a higher percentage of total and trunk fat (all *P* for trend <0.05) after adjusting for age, total accelerometer wear time, race/ethnicity, family income poverty ratio, total energy intake, and HEI-2010 (Table 2). After time spent on MVPA was further taken into account, these associations were attenuated among female but not among male children. Compared with male children in the lowest quartile of average sedentary bout duration, those in the highest quartile had 3.13% higher total fat (95% CI, 0.77–5.48%; *P* for trend =0.004) and 3.49% higher trunk fat (95% CI, 0.84–6.15%; *P* for trend =0.006), independent

of the time spent on MVPA. In adolescents, average sedentary bout duration was only associated with total and trunk fat in female before adjusting for MVPA level; no association was observed in male adolescents.

Self-reported sitting watching TV/videos

In children, we observed a statistically significant positive association between sitting watching TV/videos and total and trunk fat only among males. Compared with male children who spent ≤1 h/day on sitting watching TV/videos, those who spent ≥4 h/day had 3.82% higher total fat (95% CI, 1.36–6.27%; *P* for trend =0.007) and 4.43% higher trunk fat (95% CI, 1.69–7.17%; *P* for trend =0.005), after adjusting for MVPA levels (Table 3).

In adolescents, time spent on sitting watching TV/videos was also positively associated with total and trunk fat percentage in a dose-response manner among both males and

Table 2 Association between average sedentary bout duration and body fat distribution among US children and adolescents, NHANES 2003–2006.

	<i>n</i>	<i>β</i> coefficient (95% CI)			
		Total fat percentage		Trunk fat percentage	
		Model 1 ^a	Model 2 ^b	Model 1 ^a	Model 2 ^b
<i>Children</i>					
Female 8–11 years					
Average sedentary bout duration ^c					
Q1	103	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
Q2	115	-0.35 (-2.80 to 2.10)	-0.37 (-2.64 to 1.90)	0.17 (-2.76 to 3.09)	0.14 (-2.62 to 2.91)
Q3	106	2.90 (0.50 to 5.31)	1.66 (-0.86 to 4.19)	4.08 (1.11 to 7.04)	2.64 (-0.51 to 5.79)
Q4	102	2.68 (-0.14 to 5.50)	0.90 (-1.83 to 3.63)	3.39 (0.01 to 6.77)	1.33 (-2.02 to 4.69)
<i>P</i> for trend ^d		0.010	0.253	0.009	0.218
MVPA (per 30 min) ^e			-3.05 (-4.13 to -1.97)		-3.54 (-4.91 to -2.16)
Male 8–11 years					
Average sedentary bout duration ^c					
Q1	104	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
Q2	93	1.91 (-1.34 to 5.17)	0.99 (-1.99 to 3.96)	2.27 (-1.19 to 5.74)	1.28 (-1.98 to 4.54)
Q3	98	4.03 (1.51 to 6.54)	2.53 (0.08 to 4.98)	4.36 (1.53 to 7.19)	2.75 (-0.14 to 5.64)
Q4	89	4.88 (2.11 to 7.64)	3.13 (0.77 to 5.48)	5.37 (2.41 to 8.34)	3.49 (0.84 to 6.15)
<i>P</i> for trend ^d		<0001	0.004	<0001	0.006
MVPA (per 30 min) ^e			-2.07 (-2.82 to -1.32)		-2.22 (-3.05 to -1.39)
<i>Adolescents</i>					
Female 12–19 years					
Average sedentary bout duration ^c					
Q1	191	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
Q2	255	0.42 (-1.38 to 2.22)	0.26 (-1.46 to 1.98)	0.88 (-1.45 to 3.21)	0.72 (-1.57 to 3.01)
Q3	262	2.26 (0.56 to 3.96)	1.65 (-0.06 to 3.36)	2.57 (0.51 to 4.63)	1.96 (-0.17 to 4.10)
Q4	272	2.08 (0.34 to 3.81)	1.63 (-0.02 to 3.29)	2.41 (0.41 to 4.42)	1.97 (-0.01 to 3.95)
<i>P</i> for trend ^d		0.006	0.020	0.009	0.029
MVPA (per 30 min) ^e			-1.58 (-2.39 to -0.76)		-1.58 (-2.62 to -0.55)
Male 12–19 years					
Average sedentary bout duration ^c					
Q1	322	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
Q2	270	-0.18 (-1.66 to 1.29)	-0.35 (-1.92 to 1.21)	-0.35 (-1.98 to 1.28)	-0.54 (-2.28 to 1.20)
Q3	268	0.78 (-0.83 to 2.39)	0.36 (-1.29 to 2.02)	0.73 (-0.97 to 2.42)	0.27 (-1.51 to 2.06)
Q4	222	1.10 (-0.51 to 2.71)	0.30 (-1.35 to 1.95)	1.10 (-0.70 to 2.90)	0.22 (-1.68 to 2.12)
<i>P</i> for trend ^d		0.135	0.578	0.166	0.671
MVPA (per 30 min) ^e			-1.07 (-1.61 to -0.53)		-1.17 (-1.79 to -0.56)

AC activity count, DXA dual energy X-ray absorptiometry, HEI Healthy Eating Index, MVPA moderate-to-vigorous physical activity, NHANES National Health and Nutrition Examination Survey.

^aModel 1 was adjusted for age, total accelerometer wear time (continuous), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or others), family income poverty ratio (<1.30, 1.30–3.49, ≥3.50), total energy intake (continuous), and HEI-2010 (continuous).

^bModel 2 was additionally adjusted for MVPA (continuous).

^cAverage sedentary bout duration was calculated as total sedentary time divided by sedentary bout frequency within valid wear time using accelerometer data; a sedentary bout was a period of consecutive duration in which AC < 100. Average sedentary bout duration was further categorized according to quartiles (Qs) within each year age: Q1 indicates the lowest quartile of bout duration, and Q4 indicates the highest quartile of bout duration.

^d*P* for trend was calculated using the quartile of average sedentary bout duration within each age group as a continuous variable.

^eAge-specific cutoffs for MVPA were used (AC ≥1638, ≥1770, ≥1910, ≥2059, ≥2220, ≥2393, ≥2580, ≥2781, ≥3000, ≥3239, and ≥2020 for age 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and ≥18 years, respectively) according to the thresholds used by the National Cancer Institute.

females. Compared with those with ≤ 1 h/day of sitting watching TV/videos, adolescents who spent ≥ 4 h/day had increased total fat (female: 2.52%; 95% CI, 0.52–4.52%; P for trend = 0.002; male: 4.06%, 95% CI, 2.43–5.68%, P for trend < 0.001) and trunk fat (female: 3.53%; 95% CI, 1.03–6.03%; P for trend = 0.001; male: 4.78%, 95% CI, 2.97–6.60%; P for trend < 0.001), after MVPA levels were taken into account.

Joint association of sedentary behaviors and MVPA

We examined the joint association of sitting watching TV/videos and MVPA level with fat distribution (Fig. 1 and Supplementary Table 2). In both female and male children, 13% of them were categorized as the least active, as indicated by < 1 h/day of MVPA and ≥ 4 h/day of TV/videos watching, and the higher prevalence was observed in adolescents (female: 17%; male: 14%) (Supplementary Table 1). No significant interactions between sitting watching TV/videos and MVPA level on trunk fat percentage were observed (all P for interaction > 0.05). Compared with the most active individuals (MVPA ≥ 1 h/day and ≤ 1 h/day of sitting watching TV/videos), those who were least active had the highest level of trunk fat across all age and sex groups (female children: 6.21%; 95% CI, 2.07–10.35%; male children: 9.90%; 95% CI, 5.75–14.04%; female adolescents: 6.84%; 95% CI, 3.63–10.05%; male adolescents: 5.36%; 95% CI, 3.25–7.47%) (Supplementary Table 2). We observed largely comparable results across age and sex groups, when sedentary bout duration was modeled instead of sitting watching TV/videos (Supplementary Fig. 2).

Discussion

In this large, nationally representative sample of US children and adolescents, prolonged sedentary patterns, particularly self-reported sitting watching TV/videos, were associated with higher levels of total and trunk fat. We observed a significant positive association between sitting watching TV/videos and total and trunk fat, independent of the MVPA levels. Of note, children and adolescents with the longest sitting watching TV/video time and the lowest levels of physical activity had the highest level of trunk fat across all sex and age groups.

Studies on the association between sedentary behavior patterns and fat distribution among children and adolescents are limited with mixed findings while MVPA levels were taken into account, in part due to the poor measurements of adiposity (e.g., bioimpedance and waist circumference) [14, 28]. Utilizing DXA-measured fat distribution, we

found that longer sedentary bout was associated with increased total and trunk fat percentages, only before accounting for MVPA levels. Interestingly, our subsequent analyses revealed significant associations of sedentary TV/videos watching time with increased total and trunk fat accumulation among male children and all adolescents, even after adjusting for MVPA level. Notably, these associations were also independent of poor diet quality, as indicated by HEI-2010 [25], a validated and widely accepted dietary index in children and adolescents [29]. Our observations highlighted the importance of evaluating the distinct health consequences of domain-specific sedentary behaviors among younger population.

Furthermore, we found a dose-response relationship between sitting watching TV/videos and fat accumulation generally starting at 2 h/day, in respective of MVPA levels. This lends support to the recommendation by the American Academy of Pediatrics that young population (≥ 6 years) should limit their TV viewing time to ≤ 2 h/day [30], and also agrees with a review of largely cross-sectional studies reported that ≥ 2 h/day of screen time was positively associated with childhood overweight/obesity compared with < 2 h/day [31]. It is also worth noting that 58–73% children/adolescents spent 2 h or more daily sitting watching TV/videos, and of these, the majority did not meet the physical activity guideline. Specifically, about 13–24% spent 2 h, 5–14% spent 3 h, and 13–17% spent 4 h or more sitting watching TV/videos daily, while engaging in less than 1 h of MVPA. Our joint analyses further revealed that fat percentages increased substantially as time spent sitting watching TV increased and time on MVPA decreased. Collectively, it is critical to develop effective interventions to reduce health risk associated with uninterrupted sitting time and sitting watching TV/videos among children/adolescents in the clinical setting.

Several biological and behavioral mechanisms could potentially explain the observed association. In general, accumulation of adiposity is induced by less energy expenditure during substantial time being sedentary with less skeletal muscle contraction [32], whereas breaks in sedentary time contribute to improved glucose and lipid metabolism [33] and promote additional energy expenditure [34]. Pooled data from 14 studies comprising 20,871 children and adolescents aged 4–18 years indicated that cardiometabolic markers, including waist circumference, systolic blood pressure, fasting insulin, and triglycerides, were worse among individuals with higher levels of sedentary time compared with the lower level, which provides a potential biological pathway between prolonged sedentary patterns and body fatness and central adiposity level. In addition, behavioral mechanisms can also provide a potential explanation for the strong link between sitting watching TV/videos and fat distribution. As a predominant

Table 3 Association between sitting watching TV/videos and body fat distribution among US children and adolescents, NHANES 2003–2006.

	<i>n</i>	β coefficient (95% CI)			
		Total fat percentage		Trunk fat percentage	
		Model 1 ^a	Model 2 ^b	Model 1 ^a	Model 2 ^b
<i>Children</i>					
Female 8–11 years					
Sitting watching TV/videos (h/day) ^c					
≤1	128	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
2	144	0.12 (–2.11 to 2.35)	0.53 (–1.53 to 2.60)	0.12 (–2.51 to 2.76)	0.61 (–1.93 to 3.14)
3	68	–0.03 (–3.01 to 2.95)	0.65 (–1.89 to 3.19)	0.17 (–3.56 to 3.91)	0.96 (–2.30 to 4.22)
≥4	85	2.04 (–1.01 to 5.10)	2.00 (–1.05 to 5.05)	2.18 (–1.55 to 5.91)	2.13 (–1.66 to 5.92)
<i>P</i> for trend ^d		0.219	0.207	0.268	0.264
MVPA (per 30 min) ^e			–3.32 (–4.37 to –2.27)		–3.88 (–5.21 to –2.55)
Male 8–11 years					
Sitting watching TV/videos (h/day) ^c					
≤1	98	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
2	133	2.51 (0.33 to 4.69)	2.33 (0.32 to 4.35)	2.65 (0.12 to 5.18)	2.46 (0.11 to 4.82)
3	61	2.01 (–1.05 to 5.06)	1.95 (–1.07 to 4.98)	2.39 (–1.19 to 5.97)	2.34 (–1.22 to 5.89)
≥4	92	4.77 (1.88 to 7.65)	3.82 (1.36 to 6.27)	5.45 (2.28 to 8.61)	4.43 (1.69 to 7.17)
<i>P</i> for trend ^d		0.004	0.007	0.003	0.005
MVPA (per 30 min) ^e			–2.26 (–3.00 to –1.51)		–2.41 (–3.20 to –1.63)
<i>Adolescents</i>					
Female 12–19 years					
Sitting watching TV/videos (h/day) ^c					
≤1	347	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
2	237	0.83 (–0.24 to 1.89)	0.80 (–0.20 to 1.80)	1.07 (–0.27 to 2.40)	1.04 (–0.25 to 2.33)
3	162	2.16 (0.73 to 3.58)	1.76 (0.32 to 3.21)	2.98 (1.12 to 4.85)	2.61 (0.73 to 4.49)
≥4	217	2.86 (0.69 to 5.04)	2.52 (0.52 to 4.52)	3.85 (1.20 to 6.50)	3.53 (1.03 to 6.03)
<i>P</i> for trend ^d		0.001	0.002	0.001	0.001
MVPA (per 30 min) ^e			–1.55 (–2.31 to –0.78)		–1.47 (–2.40 to –0.53)
Male 12–19 years					
Sitting watching TV/videos (h/day) ^c					
≤1	329	0 [Reference]	0 [Reference]	0 [Reference]	0 [Reference]
2	262	3.09 (1.54 to 4.64)	2.94 (1.46 to 4.43)	3.39 (1.78 to 5.00)	3.23 (1.68 to 4.78)
3	205	2.83 (1.35 to 4.31)	2.54 (1.06 to 4.01)	3.24 (1.63 to 4.85)	2.93 (1.29 to 4.56)
≥4	262	4.30 (2.65 to 5.95)	4.06 (2.43 to 5.68)	5.05 (3.21 to 6.88)	4.78 (2.97 to 6.60)
<i>P</i> for trend ^d		<0.001	<0.001	<0.001	<0.001
MVPA (per 30 min) ^e			–0.90 (–1.40 to –0.40)		–0.97 (–1.50 to –0.44)

AC activity count, DXA dual energy X-ray absorptiometry, HEI Healthy Eating Index, MVPA moderate-to-vigorous physical activity, NHANES National Health and Nutrition Examination Survey.

^aModel 1 was adjusted for age, total accelerometer wear time (continuous), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or others), family income poverty ratio (<1.30, 1.30–3.49, ≥3.50), total energy intake (continuous), and HEI-2010 (continuous).

^bModel 2 was additionally adjusted for MVPA (continuous).

^cSitting watching TV/videos was derived from questionnaire by asking “Over the past 30 days, on average, about how many hours per day did [you/children’s name] sit and watch television or videos?” with options for the answer: none, less than 1, 1, 2, 3, 4, or 5 h or more.

^d*P* for trend was calculated using the time spend on sitting watching TV/videos using the mid-point of each category as a continuous variable.

^eAge-specific cutoffs for MVPA were used (AC ≥1638, ≥1770, ≥1910, ≥2059, ≥2220, ≥2393, ≥2580, ≥2781, ≥3000, ≥3239, and ≥2020 for age 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and ≥18 years, respectively) according to the thresholds used by the National Cancer Institute.

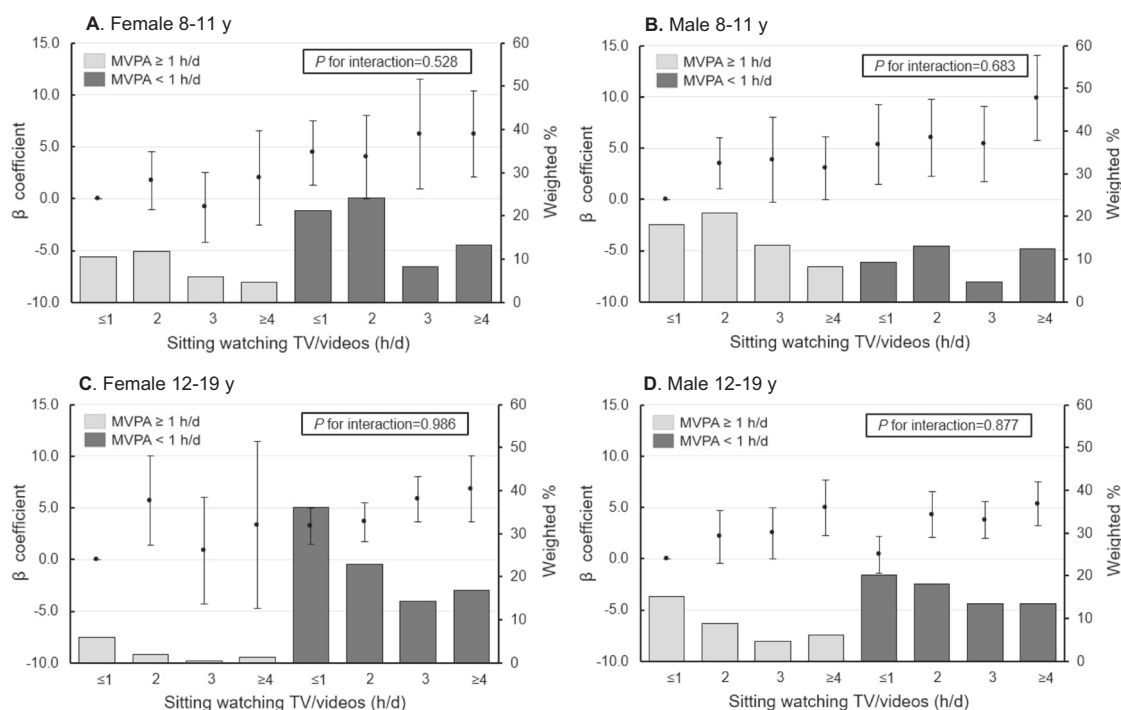


Fig. 1 Joint association of sitting watching TV/videos and MVPA level with trunk fat percentage among US children and adolescents, NHANES 2003–2006. Joint association of sitting watching TV/videos and MVPA level with trunk fat percentage (dot plot; error bars indicate 95% CIs) and weighted percentage within each joint subgroup (bar graph): female children (A), male children (B), female adolescents (C), and male adolescents (D). Sitting watching TV/videos was derived from questionnaire by asking “Over the past 30 days, on average, about how many hours per day did [you/children’s name] sit

and watch television or videos?” with options for the answer: none, less than 1, 1, 2, 3, 4, or 5 h or more. Age-specific cutoffs for MVPA were used (AC ≥ 1638 , ≥ 1770 , ≥ 1910 , ≥ 2059 , ≥ 2220 , ≥ 2393 , ≥ 2580 , ≥ 2781 , ≥ 3000 , ≥ 3239 , and ≥ 2020 for age 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and ≥ 18 years, respectively) according to the thresholds used by the National Cancer Institute. MVPA moderate-to-vigorous physical activity, NHANES National Health and Nutrition Examination Survey.

sedentary domain among children and adolescents [5], sitting watching TV/videos is usually characterized by a prolonged duration and combined with a cluster of other behaviors including displaced physical activity, excess energy intake, and sleep problems [35], which can all promote body fat accumulation. Our findings provide preliminary evidence that reducing time spent on sitting watching TV/videos may be an effective strategy to reduce the burden of overweight and obesity in early life stages and the rising burden of metabolic diseases in adult life.

This study has several strengths. First, we investigated both accelerometer-measured and validated self-reported sedentary behaviors with DXA, a gold standard measurement of body fat distribution, aiming to provide a comprehensive understanding of the link between sedentary patterns and adiposity [36]. Second, our multivariable adjustment for MVPA level and joint analyses of sedentary behaviors and MVPA level allowed us to delineate the independent association of sedentary behaviors with fat distribution among children and adolescents. Third, we have adjusted for a list of potential confounders including dietary intake and sociodemographic factors. Finally, our use of nationally representative data ensured generalizability.

Our study has limitations. The cross-sectional design does not infer a causal relationship between prolonged sedentary behaviors and body fat accumulation. In addition, accelerometer data cannot distinguish sedentary behaviors by domains, while information on bout duration of self-reported TV/video watching was lacking. Future studies focusing on device-measured domain-specific sedentary behaviors are warranted.

Conclusion

In conclusion, our findings demonstrated that sitting watching TV/videos may be an important component in prolonged sedentary pattern and was positively associated with body fat distribution in both children and adolescents, in a dose-response manner and independent of physical activity level.

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Author contributions JL, CC, and YC had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: JL, CC, YC. Acquisition, analysis, or interpretation of data: all coauthors. Drafting of the manuscript: JL, CC, YC. Critical revision of the manuscript for important intellectual content: all authors. Statistical analysis: JL, CC. Administrative, technical, or material support: YC. Study supervision: YC.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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