Joint Associations of Moderate-to-Vigorous Physical Activity and Sedentary Time with Adiposity and Cardiometabolic Risk Factors in Adolescents

MÓNICA SUÁREZ-REYES[1,2], ROBBIE A. BEYL[1], PETER T. KATZMARZYK[1], and AMANDA E. STAIANO[1]

[1]*Pennington Biomedical Research Center, Baton Rouge, LA; and* [2]*Escuela de Ciencias de la Actividad Física, el Deporte y la Salud, Universidad de Santiago de Chile, Santiago, CHILE*

ABSTRACT

SUÁREZ-REYES, M., R. A. BEYL, P. T. KATZMARZYK, and A. E. STAIANO. Joint Associations of Moderate-to-Vigorous Physical Activity and Sedentary Time with Adiposity and Cardiometabolic Risk Factors in Adolescents. *Med. Sci. Sports Exerc.*, Vol. 57, No. 7, pp. 1319–1325, 2025. **Purpose:** This study aims to explore the joint associations of moderate-to-vigorous physical activity (MVPA) and sedentary time (ST) with adiposity and cardiometabolic risk factors in adolescents. **Methods:** A cross-sectional study was conducted on 309 participants (10–16 yr old). Measurements included accelerometer-measured MVPA and ST, anthropometrics, body composition, and cardiometabolic risk factors. MVPA and ST were categorized as high or low based on median values (MVPA 27.7 $min \cdot d^{-1}$, ST 597.7 $min \cdot d^{-1}$). General linear models assessed associations of MVPA and ST with adiposity and cardiometabolic risk factors, adjusted for covariates. **Results:** We observed significant inverse associations between MVPA and adiposity measures. Thus, participants in the low MVPA category, compared with those in the high category, had higher body mass index (BMI; 2.23 units), *z*-BMI (0.43 units), waist circumference (6.1 cm), fat mass (4.6 kg), body fat (3.9%), and visceral fat (0.13 L), indicating that higher MVPA is linked to healthier body composition. No significant associations were found between ST and adiposity. MVPA was also negatively associated with some cardiometabolic risk factors, whereas ST showed no significant associations. **Conclusions:** This study highlights the need to prioritize increasing MVPA among adolescents to support healthy body composition and improve cardiometabolic health. Although ST did not show significant associations, it remains important to limit sedentary behaviors due to their potential contribution to negative health outcomes later in life. **Key Words:** BODY COMPOSITION, LIFESTYLE HABITS, SEDENTARY BEHAVIOR, YOUTH HEALTH

Physical activity and sedentary behavior are two lifestyle habits that share the day's waking hours. Their interaction impacts various aspects of health, particularly in adolescence, a critical phase where establishing healthy behaviors is essential for long-term well-being. Physical activity is defined as any bodily movement that increases energy expenditure above resting energy expenditure (1). Sedentary time (ST) is defined as the time spent in sedentary behaviors (any waking behavior with an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining, or lying posture) (2). Given the evidence on the association between physical activity with positive health outcomes at early ages (3), the World Health Organization (WHO) recommends that children and adolescents younger than 18 yr accumulate an average of 60 min of moderate-to-vigorous physical activity (MVPA) daily (1). The evidence regarding the association between time spent in sedentary behaviors and health outcomes is less clear, and recommendations are currently nonspecific about the amount of time youth or adults should spend in sedentary behavior.

When studying the health effects of physical activity and sedentary behavior in children and adolescents, adiposity and cardiometabolic risk factors are two of the most reported outcomes (3); however, these behaviors have been mostly studied separately. At young ages, favorable associations have been reported between greater amounts and higher intensities of physical activity with adiposity and cardiometabolic health (3,4). The evidence on the association of sedentary behavior

Address for correspondence: Amanda E. Staiano. Ph.D., Pennington Biomedical Research Center, 6400 Perkins Rd, Baton Rouge, LA 70808; E-mail: Amanda.Staiano@pbrc.edu
Submitted for publication July 2024.
Accepted for publication January 2025.

0195-9131/25/5707-1319/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000003663

with adiposity and cardiometabolic health is less clear (5). Many studies have shown small or no associations (6,7). Strizich et al. (8), a study of Latino children observed that MVPA was positively associated with more favorable levels of several markers of cardiometabolic health (e.g., high-density lipoprotein cholesterol (HDL-C), triglycerides, and insulin). However, these associations were no longer significant after adjusting for ST and adiposity.

Rather than analyzing the associations among physical activity, sedentary behavior, and health outcomes separately, considering both behaviors together is closer to what is observed in real life (9). Studies in adults have shown that MVPA is protective against high levels of ST regarding health risk factors, measured either with accelerometry (10) or self-report (11). However, less is known about whether the joint associations of both behaviors observed in the adult population are similar in younger populations. This study aims to explore the joint associations of MVPA and ST with adiposity and cardiometabolic risk factors in adolescents.

METHODS

Participants. Participants aged 10 to 16 yr were enrolled in the TIGER Kids study (Translational Investigation of Growth and Everyday Routines in Kids; NCT02784509) between 2016 and 2018. This cross-sectional analysis utilized baseline data. Adolescents were recruited from Baton Rouge (Louisiana, United States) through various means of convenience sampling, including email lists, health fairs, schools, and social media campaigns. The eligibility criteria included body weight <226.8 kg (to meet size requirements of magnetic resonance imaging (MRI) and dual-energy x-ray absorptiometry (DXA) machines), ability to understand instructions and complete study procedures, not being pregnant, not consuming a medically restricted diet, and no significant physical or mental impairments hindering movement or accelerometer use. Out of the 342 initially enrolled participants, 309 were included in the present study. Among the exclusions, 2 were due to missing weight data, 3 for missing DXA data, 12 for missing MRI data, 5 for missing blood measurements, and 11 for missing valid accelerometer data. Pennington Biomedical Research Center's Institutional Review Board approved the study (IRB No. 2016-028).

Procedures. After obtaining written informed consent from the parent/guardian and written assent from the adolescent, an accelerometer was provided to the adolescent to be worn on their hip for 7 d. After 7 d, the adolescent attended a clinical visit after an overnight fast (12 h). The visit included anthropometric measurements, body composition assessment, questionnaires, a blood draw, and blood pressure measurements. Parents completed a demographic form that included the adolescent's date of birth, sex, and race/ethnicity. All questionnaires were completed and managed using Research Electronic Data Capture (REDCap), an electronic data capture tool hosted by Pennington Biomedical Research Center (12,13). REDCap is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture, 2) audit trials for tracking data manipulation and export procedures, 3) automated export procedures for seamless data downloads to common statistical packages, and 4) procedures for data integration and interoperability with external sources.

Anthropometric measures and puberty status. Anthropometry was recorded to the nearest 0.1 cm for height and 0.1 kg for weight. Each measurement was taken twice, with the average used for analysis. If the two values differed by more than 0.5 units, a third was taken to replace the outlier. Standing height was assessed ensuring participants stood upright and with their head aligned with the Frankfort Horizontal Plane. Both height and weight were assessed with participants wearing a gown and without shoes.

Age and sex-adjusted body mass index (BMI) was calculated ($kg \cdot m^{-2}$) and converted to percentiles using R version 4.2.3 and *cdcanthro* package for the 2020 CDC Growth Charts for the United States (available from: www.cdc.gov/growth-chart-training/hcp/computer-programs/r-programs.html). Thus, overweight status was defined as a BMI at ≥85th percentile and obesity status at ≥95th percentile. Trained research staff measured waist circumference in duplicate at the natural waist, mid-way between the inferior border of the rib cage, and the superior aspect of the iliac crest with clothing moved out of the way. A third measure occurred if the measurements differed by more than 0.5 cm. Waist circumference percentiles ≥90th for sex and age were classified as abdominal obesity (14). Self-ratings of puberty status were collected based on Tanner stages of development (15).

Body composition. A whole-body DXA scan using a GE iDXA scanner (GE Medical Systems, Milwaukee, WI) was used to estimate fat mass. The amount of fat mass relative to the total body weight determined the body fat percentage. Abdominal MRI scans were performed on a General Electric Signal Excite (3.0 Tesla; GE Medical Systems, Waukesha, WI) scanner. The images were captured with IDEAL-IQ imaging software, acquiring 28 slices spaced 4.78 cm apart, from the liver's highest point to the bottom of the right kidney. A trained technician analyzed the images using ANALYZE® software package (CNSoftware, Rochester, MN), manually outlining the visceral fat. The number of pixels was multiplied by voxel width and height for each slice to calculate the area in cm^2. This area was then multiplied by the number of slices (28 slices), along with the voxel depth and 0.000001, to determine visceral fat volume in liters.

Physical activity and ST. Physical activity and ST were measured using an accelerometer (ActiGraph GT3X+; Actigraph, Ft. Walton Beach, Pensacola, FL) worn on an elastic belt around the hip in the left midaxillary line. The accelerometers were initialized to collect data at a frequency of 80 Hz, while the Idle sleep mode was disabled. Participants were instructed to wear the accelerometer for 24 $h \cdot d^{-1}$ (except for water-based activities) for at least 7 d including 2 weekend days. Sleep time was identified using a previously published algorithm and removed from the analysis (16). Non-wear time was determined as intervals of at least 20 consecutive minutes of zero activity intensity counts. Only days with ≥10 h of awake wear time were considered, and the analysis included participants with at least 4 valid days including 1 weekend day. Activities with <25 counts per 15 s were considered sedentary behavior,

whereas activities with ≥574 counts per 15 s were considered MVPA and were applied only to the vertical axis (*Y*) (17). These cutoff points provide an acceptable classification accuracy for different physical activity intensities and perform well among children and adolescents of a wide age range (18). Participants who averaged 60 min of daily MVPA across available days were classified as physically active following the WHO recommendations (1).

Cardiometabolic risk factors. Resting blood pressure was measured using a sphygmomanometer, and the average of two systolic blood pressure (SBP) and diastolic blood pressure (DBP) measurements was used to calculate the mean arterial pressure (MAP) (MAP = ((2 × DBP) + SBP)/3). Previously described cutoff points by sex, age, and height were used to determine high blood pressure (19). A fasting blood sample was drawn using venipuncture. The blood sample was used to measure HDL-C, triglycerides, glucose, insulin, and high-sensitivity C-reactive protein (Hs-CRP). HDL-C was assayed via a Trinity DXC600. A Beckman Coulter obtained serum triglyceride and glucose, and an immunoassay on a Siemens Immulite 2000–determined insulin level. The homeostasis model assessment of insulin resistance (HOMA-IR) was computed using the following equation: (fasting glucose concentration multiplied by fasting insulin concentration) divided by 405. Previously described cutoff points were used to determine risk in children (low HDL-C <40 $mg \cdot dL^{-1}$, high triglycerides ≥130 $mg \cdot dL^{-1}$, high fasting glucose ≥100 $mg \cdot dL^{-1}$) (20,21). There is no commonly accepted reference value for HOMA-IR in youth (22).

Analysis. The Shapiro–Wilk test was used to determine the normal distribution of continuous variables. Almost all variables had a nonnormal distribution, except for BMI *z*-score, SBP, MAP, and ST, which had normal distributions. For consistency, all continuous variables are presented as medians and interquartile range (IQRs). Categorical variables are presented as frequencies and percentages. A composite cardiometabolic risk factor score was derived by summing the standardized residuals (age, sex, race, and puberty status) for waist circumference, MAP, HDL-C, triglycerides, glucose, and HOMA-IR. In the case of HDL-C, because it is inversely related to risk, the standardized residual is multiplied by −1. Thus, the score is a continuous value, with lower values indicating a better cardiometabolic profile and higher values indicating a poorer cardiometabolic profile. The construction of this composite *z*-score has been previously described (23). MVPA and ST were expressed in minutes per day and split into high and low categories using their median values (MVPA = 27.7 $min \cdot d^{-1}$; ST = 597.7 $min \cdot d^{-1}$). The median was used to determine high/low MVPA and ST categories because only 1 in 10 adolescents met the MVPA recommendations, so an active/inactive split would have caused an imbalance in the sample. Because no guidelines exist for ST, the median was also a suitable benchmark for ST. The general linear model was used to determine the associations of MVPA (high vs low), ST (high vs low), and their interaction with adiposity and cardiometabolic risk factors. Values were expressed as estimated marginal means (EMM; 95% confidence intervals (CI)), and adjusted for age, sex, race, and accelerometer awake wear time (BMI, *z*-BMI, waist circumference, fat mass, and body fat) and age, sex, race, accelerometer awake wear time, and BMI (SBP, DBP, MBP, HDL-C, triglycerides, glucose, *z*-score cardiometabolic risk factor, and Hs-CRP). In addition, binary logistic regression models were used to compute the odds ratios (95%) for the adjusted associations between the group combining high/low MVPA and high/low ST with the risky conditions (i.e., overweight or obesity, abdominal obesity, high blood pressure, low HDL-C, high triglycerides, and high glucose). The high MVPA/low ST was considered the reference group for this analysis. SPSS version 29 was used for the analysis. A P value <0.05 was considered statistically significant.

RESULTS

The general characteristics of the sample are presented in Table 1. Almost 60% of the adolescents were identified by their parents as non-Hispanic White, whereas approximately one-third were identified as African American. The prevalence of overweight or obesity was approximately 50%, whereas the prevalence of cardiometabolic risk factors fluctuated between 2.3% and 29.4%, with high glucose and abdominal obesity being the least and most common, respectively. Regarding physical activity, only 1 out of 10 adolescents met the recommendation of

TABLE 1. General characteristics of the sample (n = 309).

Age (yr)	12.8 (11.3–14.5)
Girls, *n* (%)	165 (53.4)
Race, *n* (%)	
Non-Hispanic White	181 (58.6)
African American	105 (34.0)
Other	23 (7.4)
BMI ($kg \cdot m^{-2}$)	22.2 (18.6–27.2)
BMI *z*-score	0.96 (–0.04 to 1.84)
BMI percentile	83.1 (48.6–96.7)
Fat mass (kg)	17.9 (11.1–26.9)
Body fat (%)	33.1 (24.7–40.8)
Visceral fat (L)	0.44 (0.27–0.72)
Waist circumference (cm)	73.5 (65.0–88.0)
SBP (mm Hg)	107.0 (101.0–113.0)
DBP (mm Hg)	65.0 (59.0–72.0)
MAP (mm Hg)	79.0 (74.0–84.3)
HDL-C ($mg \cdot dL^{-1}$)	52.1 (44.8–60.3)
Triglycerides ($mg \cdot dL^{-1}$)	62.0 (45.0–92.5)
Glucose ($mg \cdot dL^{-1}$)	87.0 (83.0–91.0)
HOMA-IR	2.1 (1.1–3.7)
z-Score cardiometabolic risk factors	–0.57 (–2.36 to 1.50)
Hs-CRP ($mg \cdot dL^{-1}$)	0.50 (0.19–1.80)
Accelerometer awake/wear time ($min \cdot d^{-1}$)	866.4 (819.7–904.3)
MVPA ($min \cdot d^{-1}$)	27.7 (19.9–42.8)
MVPA (%)	3.4 (2.3–5.0)
ST ($min \cdot d^{-1}$)	597.7 (535.8–637.9)
ST (%)	69.5 (63.9–74.1)
Weight status, *n* (%)	
Underweight	9 (2.9)
Normal weight	149 (48.2)
Overweight	47 (15.2)
Obesity	104 (33.7)
Abdominal obesity ≥p90, *n* (%)	91 (29.4)
High blood pressure ≥p90, *n* (%)	54 (17.5)
Low HDL-C <40 $mg \cdot dL^{-1}$, *n* (%)	32 (10.4)
High triglycerides ≥130 $mg \cdot dL^{-1}$, *n* (%)	31 (10.0)
High glucose ≥100 $mg \cdot dL^{-1}$, *n* (%)	7 (2.3)
Physically active (≥60 $min \cdot d^{-1}$ MVPA), *n* (%)	31 (10.0)

Values are expressed as median and IQR or *n* (%). MVPA (%): time spent in MVPA (% of daily accelerometer awake/wear time). ST (%): time spent in ST (% of daily accelerometer awake/wear time).

TABLE 2. Associations of MVPA and ST with adiposity and cardiometabolic risk factors in adolescents (n = 309).

	High MVPA						Low MVPA					
	Low ST (n = 105)			High ST (n = 50)			Low ST (n = 49)			High ST (n = 105)		
	EMM	Lower	Upper	EMM	Lower	Upper	EMM	Lower	Upper	EMM	Lower	Upper
BMI (kg·m^{-2})	22.2	20.6	23.8	22.8	20.7	25.0	24.5	22.3	26.7	25.0	23.4	26.6
BMI z-score	0.57	0.27	0.87	0.75	0.35	1.16	1.06	0.64	1.48	1.13	0.83	1.43
Waist circumference (cm)	73.2	69.2	77.1	75.0	69.7	80.4	80.3	74.8	85.8	80.1	76.1	84.0
Fat mass (Kg)	17.3	14.4	20.3	19.0	15.1	23.0	22.1	18.1	26.2	23.4	20.4	26.3
Body fat (%)	29.2	27.0	31.4	31.4	28.5	34.4	33.9	30.9	37.0	34.5	32.3	36.7
Visceral fat (L)	0.47	0.35	0.58	0.54	0.39	0.68	0.62	0.46	0.77	0.64	0.53	0.76
SBP (mm Hg)	106.4	104.4	108.4	107.7	105.1	110.3	109.4	106.7	112.2	108.2	106.3	110.2
DBP (mm Hg)	63.6	61.6	65.6	64.4	61.8	67.1	66.3	63.5	69.0	66.6	64.6	68.6
MAP (mm Hg)	77.8	76.2	79.5	78.9	76.6	81.1	80.7	78.4	83.0	80.5	78.8	82.1
HDL-C (mg·dL^{-1})	54.6	52.1	57.1	52.7	49.4	56.1	54.6	51.2	58.1	55.0	52.4	57.5
Triglycerides (mg·dL^{-1})	68.9	57.9	79.9	82.1	67.4	96.8	69.3	54.1	84.4	80.4	69.4	91.3
Glucose (mg·dL^{-1})	86.8	85.0	88.7	86.8	84.4	89.3	87.8	85.3	90.3	89.1	87.3	91.0
HOMA-IR	2.2	1.8	2.7	2.3	1.7	2.9	3.1	2.4	3.7	3.1	2.6	3.5
Cardiometabolic risk factors z-score	−0.68	−1.20	−0.15	−0.09	−0.79	0.62	−0.05	−0.78	0.67	0.19	−0.33	0.71
Hs-CRP (mg·dL^{-1})	2.1	0.9	3.3	1.3	−0.3	2.9	2.2	0.5	3.9	2.7	1.5	3.9

Values are expressed as EMMs (95% CIs). BMI, z-BMI, waist circumference, fat mass, body fat, and visceral fat adjusted for age, sex, and race. SBP, DBP, median blood pressure, HDL-C, triglycerides, glucose, HOMA-IR, z-score cardiometabolic risk factors, and Hs-CRP adjusted for age, sex, race, and z-BMI.

≥60 min of MVPA on average per day. Time spent in MVPA represented 3% of daily accelerometer awake wear time, whereas time spent in ST represented almost 70% of daily accelerometer awake wear time.

Table 2 displays the values for adiposity measures and cardiometabolic risk factors across MVPA and ST categories, presented as EMM (95% CIs) adjusted for age, sex, race, and accelerometer awake wear time in the case of adiposity measures and age, sex, race, accelerometer awake wear time, and BMI in the case of cardiometabolic risk factors. Most adiposity measures were progressively higher from high MVPA/low ST to low MVPA/high ST. No specific pattern was observed for cardiovascular risk factors, except in the case of HOMA-IR, which was progressively higher across the MVPA and ST groups.

Associations between MVPA, ST, and the MVPA–ST interaction with adiposity and cardiometabolic risk factors are displayed in Figures 1 and 2. MVPA showed a significant and inverse association with all adiposity measurements after adjustment for age, sex, race, and accelerometer awake wear time. Consequently, participants in the high MVPA category, compared with those in the low category, had lower BMI (−2.23 units), z-BMI (−0.43 units), waist circumference (−6.1 cm), fat mass (−4.6 kg), body fat (−3.9%), and visceral fat (−0.13 L) (Figs. 1A–F). There were no significant associations observed for ST or the interaction of MVPA–ST with any adiposity variable. MVPA was significantly and negatively associated with some cardiometabolic risk factors after adjustment for age, sex, race, accelerometer awake wear time, and BMI (Figs. 2A–I). Those in the high MVPA category had lower values for DBP (−2.4 mm Hg), MBP (−2.2 mm Hg), and HOMA-IR (−0.81 units) compared with those in the low category, independently of ST. No association with MVPA, ST, or MVPA–ST interaction was observed for SBP, HDL-C, triglycerides, glucose, cardiometabolic risk factor z-score, or Hs-CRP.

Table 3 shows the computed odd ratios (OR; 95% CIs) of having high cardiometabolic risk factors (i.e., overweight or obesity, abdominal obesity, high blood pressure, low HDL-C, high triglycerides, high glucose) according to the groups

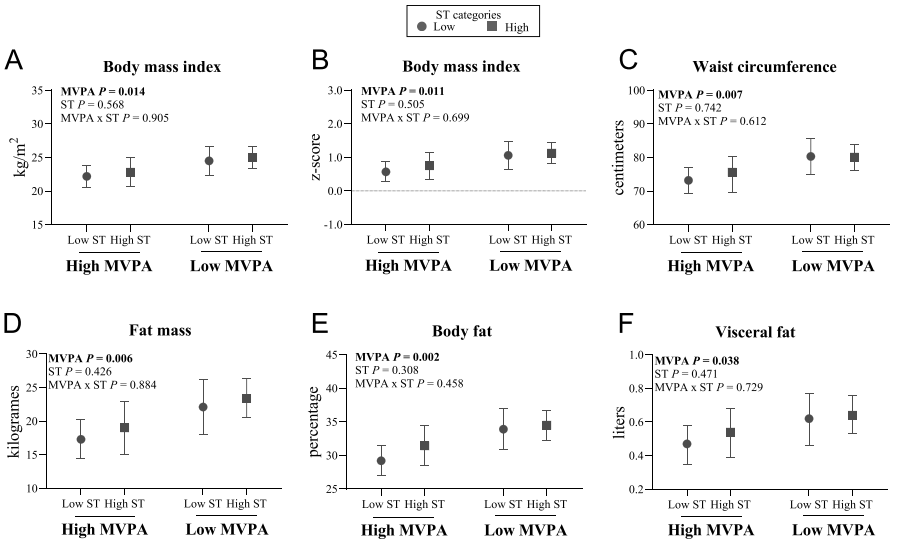

FIGURE 1—Differences in adiposity across MVPA and ST groups among adolescents. Values are expressed as EMMs (95% CIs) adjusted for age, sex, race, and accelerometer awake wear time.

combining high/low MVPA and high/low ST. The high MVPA/low ST was considered the reference. No statistically significant differences were observed between high and low ST within the high MVPA category. Both groups of high and low ST in the low MVPA category were between 2 and 3 times more likely to have overweight or obesity, and more than 3 times to have abdominal obesity compared with the reference (high MVPA/low ST) group. No associations were observed between low HDL-C, high triglycerides, or high glucose with group membership.

DISCUSSION

One of the key findings of this study is the differential associations of MVPA versus ST with adiposity and cardiometabolic risk factors. The negative associations between MVPA and adiposity measures underscore the importance of regular physical activity in maintaining healthy body composition in adolescence. However, the lack of significant associations between ST and adiposity suggests that ST is not directly related to adiposity in this age group. The study also revealed associations between MVPA and some cardiometabolic risk factors, including DBP and HOMA-IR.

MVPA, ST, and adiposity. The negative associations between MVPA and adiposity and the non-association between ST and adiposity observed here align with previous findings (24,25). In a large study of children and adolescents, Ekelund (24) performed a combined analysis of MVPA and ST, revealing that those who spent more time in MVPA had lower levels of adiposity, independent of ST. Subsequent studies with alternative adiposity measurements have supported these observations (4,25). Notably, the MVPA median value in our sample (27.7 min·d^{-1}) only corresponded to half of that recommended level for children and adolescents (1) and was lower than those reported in previous studies (24,25).

Kwon et al. (26), in their study involving adolescents from the Avon Longitudinal Study (UK), found no association between ST and adiposity in adolescents with different levels of MVPA, similar to our results. However, they identified a significant association between adiposity and time spent watching television. This highlights the importance of considering not only the duration of sedentary behavior but also the type of sedentary activity and its relationship with health. Unfortunately, objective measurements with an accelerometer do not allow for distinguishing the type of activity associated with ST (i.e., watching television, reading, etc.). In addition, Dowda et al. (27) based on data from an observational and longitudinal study in elementary school children, contrary to our observations, reported an association between ST and adiposity over time. However, this was observed only in children with obesity. This suggests that interventions to reduce ST would be more important among children with excess weight to limit the increase in adiposity and its deleterious effects on health. Adiposity is associated with adverse health effects that begin at an early age, contributing to the development of cardiometabolic diseases later in life (28). Therefore, identifying modifiable behaviors such as MVPA and ST and the extent to which they relate to adiposity has been identified as a gap that requires more research (29).

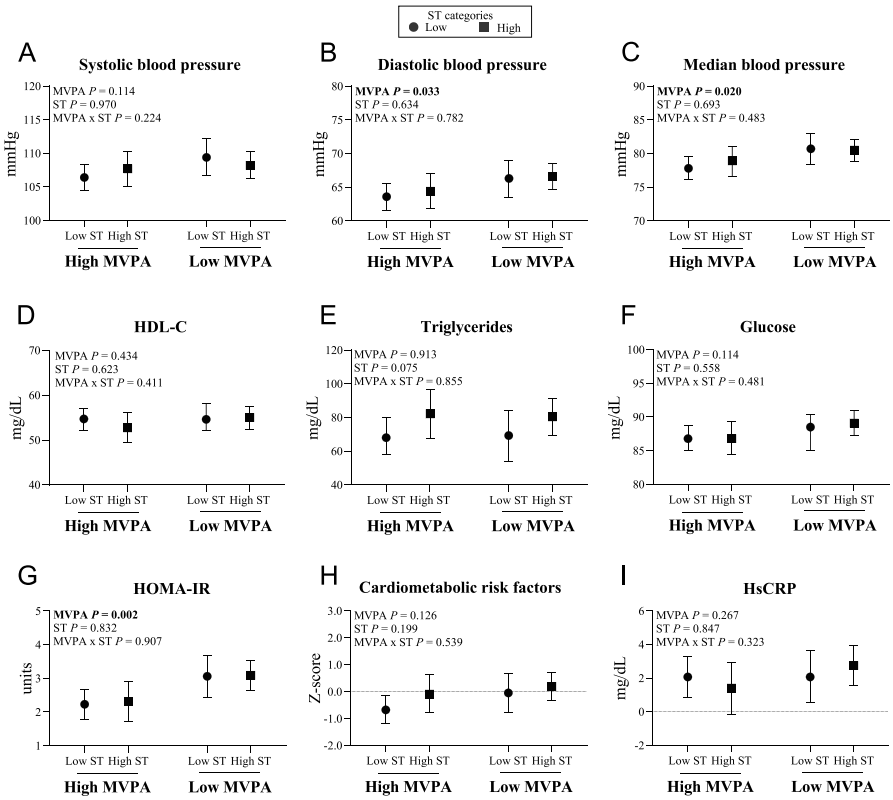

FIGURE 2—Differences in cardiometabolic risk factors across MVPA and ST groups among adolescents. Values are expressed as EMMs (95% CIs) adjusted for age, sex, race, accelerometer awake wear time, and BMI.

TABLE 3. OR and 95% CIs of having high values for cardiometabolic risk factors across MVPA and ST categories (n = 309).

	High MVPA				Low MVPA					
	Low ST (n = 105)	High ST (n = 50)			Low ST (n = 49)			High ST (n = 105)		
	REF	OR	Lower	Upper	OR	Lower	Upper	OR	Lower	Upper
Overweight or obesity	1.00	1.27	0.59	2.73	**3.21**	**1.47**	**7.04**	**2.02**	**1.07**	**3.81**
Abdominal obesity ≥p90	1.00	1.91	0.79	4.60	**3.20**	**1.38**	**7.43**	**3.55**	**1.73**	**7.27**
High blood pressure ≥p90	1.00	0.75	0.23	2.44	1.37	0.51	3.67	1.59	0.69	3.67
Low HDL-C <40 mg·dL^{-1}	1.00	1.60	0.46	5.57	1.68	0.45	6.25	0.84	0.27	2.65
High triglycerides ≥130 mg·dL^{-1}	1.00	1.48	0.36	6.07	1.85	0.52	6.60	2.18	0.74	6.45
High glucose ≥100 mg·dL^{-1}	1.00	2.14	0.11	41.76	4.01	0.30	53.57	2.76	0.23	32.60

Bold indicates statistical significance. Overweight or obesity and abdominal obesity adjusted for age, sex, race, and accelerometer awake/wear time. High blood pressure, low HDL-C, high triglycerides, and high glucose were adjusted for age, sex, race, accelerometer awake wear time, and BMI.

MVPA, ST, and cardiometabolic risk factors. We did not observe an association between MVPA and cardiometabolic risk factors expressed as composite risk z-score. When z-score components were analyzed individually, DBP, MBP, and HOMA-IR were associated with MVPA, independent of ST, whereas HDL-C, triglycerides, and Hs-CRP were not significantly associated with MVPA. Strizich et al. (8), in their study involving Hispanic and Latino young participants, reported associations between MVPA and most cardiometabolic risk factors. However, the associations were attenuated after adjustment for ST and BMI. On the other hand, Ekelund et al. (24) reported associations between MVPA and all cardiometabolic outcomes after adjusting for confounders, which remained statistically significant independent of ST. In such studies, MVPA levels were higher than those observed in our group of adolescents (i.e., ≥35 min·d^{-1} MVPA), with a larger sample. The discrepancy between these findings highlights the complexity of the interaction between MVPA and ST. Our analysis revealed no significant association between ST and cardiometabolic risk factors. This finding aligns with previous studies, which found no link between ST and cardiometabolic risk factors in children and adolescents based on prospective analyses (30,31). This contrasts with findings in adults, where ST is associated with a higher risk of adverse outcomes, including cardiovascular disease and mortality (32,33). The difference between adults and adolescents could be linked to the progressive development of cardiometabolic risk factors over time and shorter lifetime exposure. In adolescents, certain lifestyle habits, including the time spent in sedentary behaviors, may not have persisted long enough to manifest as diagnosable conditions. To understand how cardiometabolic risk factors develop from adolescence to adulthood, longitudinal studies with repeated measures of MVPA and ST are required.

The strengths of this study include the use of objective measurements of MVPA and ST with accelerometers, the use of DXA and MRI-derived adiposity measures, and the evaluation of a wide range of cardiometabolic risk factors. However, some limitations should be noted. Accelerometers cannot distinguish between sitting and standing, and there is a lack of contextual information about sedentary behavior. In addition, the cutoff points used to determine MVPA and ST are based on younger children (5–8 yr) compared with our sample (10–16 yr), which may lead to issues due to differences in age, maturation, and motor development (17). Nonetheless, the cutoff points established by Evenson et al. (17) are widely used and provide acceptable classification accuracy for the different physical activity intensities and perform well among children and adolescents. Other factors influencing adiposity and cardiometabolic risk factors, such as dietary factors, were not considered.

CONCLUSIONS

In conclusion, our results highlight the importance of encouraging adolescents to engage in MVPA to support healthy body composition. This was observed even when we considered high MVPA as more than 27.7 min·d^{-1}, corresponding to half the recommended amount at this age. Although ST did not show significance in our study, it remains pertinent to advocate for its limitation during adolescence due to its potential association with negative health outcomes later in life.

We thank the parents and adolescents who participated in the TIGER Kids Study. This study was supported by the United States Department of Agriculture (USDA) (3092-51000-056-04A; ClinicalTrials.gov: NCT02784509, PI: Amanda E. Staiano). This work was also partially supported by a NORC Center (P30DK072476, PI: Eric Ravussin) from the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) entitled "Nutrition, Obesity, and Metabolic Health through the Lifespan" and National Institute of General Medical Sciences (NIGMS) (U54 GM104940; PI; John Kirwan), which funds the Louisiana Clinical and Translational Science Center. M. S. R. is partly supported by the LAUNCHED program from NIDDK (U24 DK132740). P. K. was funded, in part, by the Marie Edana Corcoran Chair in Pediatric Obesity and Diabetes. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. The funding bodies did not play a role in the design of the study and data collection, analysis of data, and interpretation of data, or in writing the manuscript. The authors report no conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

Author Contributions: Conceptualization: M. S.-R., A. E. S., and P. T. K. Analysis and software: M. S.-R. and R. A. B. Funding acquisition: A. E. S. and P. T. K. Writing original draft: M. S.-R. Writing review and editing: M. S.-R., A. E. S., P. T. K., and R. A. B. Visualization: M. S.-R. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Ethics Considerations: Pennington Biomedical Research Center provided institutional review board and ethics approval (2016–028). Written consent of the parent/guardian and written assent of the adolescent were obtained at the first visit. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

REFERENCES

1. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451–62.
2. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary behavior research network (SBRN)—terminology consensus project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75.
3. Chaput JP, Willumsen J, Bull F, et al. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. *Int J Behav Nutr Phys Act*. 2020;17(1):141.
4. Poitras VJ, Gray CE, Borghese MM, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*. 2016;41(6 Suppl 3):S197–239.
5. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab*. 2016;41(6 Suppl 3):S240–65.
6. Biddle SJH, García Bengoechea E, Wiesner G. Sedentary behaviour and adiposity in youth: a systematic review of reviews and analysis of causality. *Int J Behav Nutr Phys Act*. 2017;14(1):43.
7. Cliff DP, Hesketh KD, Vella SA, et al. Objectively measured sedentary behaviour and health and development in children and adolescents: systematic review and meta-analysis. *Obes Rev*. 2016;17(4):330–44.
8. Strizich G, Kaplan RC, Sotres-Alvarez D, et al. Objectively measured sedentary behavior, physical activity, and cardiometabolic risk in Hispanic youth: Hispanic Community Health Study/Study of Latino Youth. *J Clin Endocrinol Metab*. 2018;103(9):3289–98.
9. Chaput JP, Olds T, Tremblay MS. Public health guidelines on sedentary behaviour are important and needed: a provisional benchmark is better than no benchmark at all. *Br J Sports Med*. 2018;54(5):308–9.
10. Ekelund U, Tarp J, Fagerland MW, et al. Joint associations of accelero-meter measured physical activity and sedentary time with all-cause mortality: a harmonised meta-analysis in more than 44 000 middle-aged and older individuals. *Br J Sports Med*. 2020;54(24):1499–506.
11. Stamatakis E, Gale J, Bauman A, Ekelund U, Hamer M, Ding D. Sitting time, physical activity, and risk of mortality in adults. *J Am Coll Cardiol*. 2019;73(16):2062–72.
12. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377–81.
13. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
14. Fernández J, Redden D. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatr*. 2004;145(4):439–44.
15. Tanner JM. Normal growth and techniques of growth assessment. *Clin Endocrinol Metab*. 1986;15(3):411–51.
16. Tudor-Locke C, Barreira TV, Schuna JM, Mire EF, Katzmarzyk PT. Fully automated waist-worn accelerometer algorithm for detecting children's sleep-period time separate from 24-h physical activity or sedentary behaviors. *Appl Physiol Nutr Metab*. 2014;39(1):53–7.
17. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci*. 2008;26(14):1557–65.
18. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc*. 2011;43(7):1360–8.
19. Flynn JT, Falkner BE. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. *Hypertension*. 2017;70(4):683–6.
20. Hannon TS, Arslanian SA. Obesity in adolescents. *N Engl J Med*. 2023;389(3):251–61.
21. Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, National Heart, Lung, and Blood Institute. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: summary report. *Pediatrics*. 2011;128(Suppl 5):S213–56.
22. Tagi VM, Giannini C, Chiarelli F. Insulin resistance in children. *Front Endocrinol (Lausanne)*. 2019;10:342.
23. Eisenmann JC. On the use of a continuous metabolic syndrome score in pediatric research. *Cardiovasc Diabetol*. 2008;7(1):17.
24. Ekelund U. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA*. 2012;307(7):704–12.
25. Kwon S, Burns TL, Levy SM, Janz KF. Which contributes more to childhood adiposity—high levels of sedentarism or low levels of moderate-through-vigorous physical activity? The Iowa Bone Development Study. *J Pediatr*. 2013;162(6):1169–74.
26. Kwon S, Ekelund U, Kandula NR, Janz KF. Joint associations of physical activity and sedentary time with adiposity during adolescence: ALSPAC. *Eur J Public Health*. 2022;32(3):347–53.
27. Dowda M, Saunders RP, Dishman RK, Pate RR. Association of physical activity, sedentary behavior, diet quality with adiposity: a longitudinal analysis in children categorized by baseline weight status. *Int J Obes (Lond)*. 2024;48(2):240–6.
28. Marketou ME, Buechler NS, Fragkiadakis K, et al. Visceral fat and cardiometabolic future in children and adolescents: a critical update. *Pediatr Res*. 2023;94(5):1639–47.
29. DiPietro L, Al-Ansari SS, Biddle SJH, et al. Advancing the global physical activity agenda: recommendations for future research by the 2020 WHO physical activity and sedentary behavior guidelines development group. *Int J Behav Nutr Phys Act*. 2020;17(1):143.
30. Stamatakis E, Coombs N, Tiling K, et al. Sedentary time in late childhood and cardiometabolic risk in adolescence. *Pediatrics*. 2015;135(6):e1432–41.
31. Skrede T, Steene-Johannessen J, Anderssen SA, Resaland GK, Ekelund U. The prospective association between objectively measured sedentary time, moderate-to-vigorous physical activity and cardiometabolic risk factors in youth: a systematic review and meta-analysis. *Obes Rev*. 2019;20(1):55–74.
32. Patterson R, McNamara E, Tainio M, et al. Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis. *Eur J Epidemiol*. 2018;33(9):811–29.
33. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc*. 2009;41(5):998–1005.