Cardiometabolic Correlates of Physical Activity and Sedentary Patterns in U.S. Youth

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ABSTRACT

JENKINS, G. P., K. R. EVENSON, A. H. HERRING, D. HALES, and J. STEVENS. Cardiometabolic Correlates of Physical Activity and Sedentary Patterns in U.S. Youth. *Med. Sci. Sports Exerc.*, Vol. 49, No. 9, pp. 1826–1833, 2017. **Introduction**: Daily or weekly averages of physical activity and sedentary behavior could mask patterns of behavior throughout the week that independently affect cardiovascular health. We examined associations between day-to-day physical activity and sedentary behavior latent classes and cardiovascular disease (CVD) risk factors in U.S. youth. **Methods**: Data were from 3984 youth ages 6–17 yr from the National Health and Nutrition Examination Survey (2003–2006) and from previously published accelerometry latent classes characterizing average counts per minute and percent of wear time in moderate-to-vigorous physical activity (MVPA) and sedentary behavior. Multiple linear regression was used to examine associations of the classes with waist circumference, systolic and diastolic blood pressure, HDL-C and LDL-C, triglycerides, glucose, and insulin. **Results**: Participants spent 50.4% of the day in sedentary behavior and 5.3% of the day in moderate-to-vigorous physical activity. Average counts per minute were 516.4 for a 7-d period. Significant differences in CVD risk factors were between extreme classes with few differences observed in intermediate classes. Youth in latent class 4 (highest average counts per minute) had lower systolic blood pressure (-4.11 mm Hg, 95% confidence interval [CI] = -7.74 to -0.55), lower glucose (-4.25 mg·dL^{-1}, 95% CI = -7.84 to -0.66]), and lower insulin (-6.83 μU·mL^{-1}, 95% CI = -8.66 to -4.99]) compared with youth in class 1 (lowest average counts per minute). Waist circumference was lower for the least sedentary class (-2.54 cm, 95% CI = -4.90 to -0.19) compared with the most sedentary class. Some associations were attenuated when classes were adjusted for mean physical activity or sedentary level. **Conclusions**: There is some indication that patterns, in addition to the total amount of physical activity and sedentary behavior, may be important for cardiovascular health in youth. Longitudinal studies are needed to examine associations between physical activity and sedentary behavior patterns and changes in CVD risk factors. **Key Words**: ACCELEROMETRY, CARDIOVASCULAR DISEASE, RISK FACTORS, NHANES, LATENT CLASS, PEDIATRICS

Cardiovascular disease (CVD) affects nearly 86 million Americans, and that number is expected to rise to nearly 116 million by 2030 (17). Clinical presentation of CVD largely appears in middle age, but the process of atherosclerosis begins in childhood (8) and is accelerated in the presence of risk factors such as obesity, high blood pressure, high cholesterol, and diabetes (1,20). Approximately 50% of youth in the United States have at least one CVD risk factor (12). These risk factors have been shown to track from childhood to adulthood (2,9,13,24) but can be reduced by adherence to a healthy lifestyle (1,8,20).

The American Heart Association, the World Health Organization, and the *2008 Physical Activity Guidelines for Americans* have emphasized the importance of physical activity for heart health and recommend that children and adolescents engage in at least 60 min of physical activity each day with most coming from moderate to vigorous intensity (16,19,27). Studies of U.S. children show higher average time in moderate-to-vigorous physical activity (MVPA) has been associated with lower waist circumference, systolic blood pressure, and higher HDL-C (4,21). Despite the benefits of MVPA, only 8% of adolescents and 42% of children obtain the recommended amount of physical activity with 50% of their waking hours engaged in sedentary behaviors (25).

The current physical activity guidelines (19) were developed primarily based on studies using self-reported physical activity, which is susceptible to recall and social desirability bias (10,18,19,22). Accelerometers record acceleration in

small units of time and are not affected by these two sources of bias. Data are usually summarized into daily or weekly averages, but these summary measures potentially mask patterns of behavior over time that may independently affect cardiovascular health.

Latent class analysis (LCA), a data-driven statistical method, has been used in previous studies to describe patterns, or classes, of physical activity and sedentary behavior in children and adolescents (6,14,15,23), but the studies are limited by the use of self-report data or (14,15) a combination of self-report and accelerometry data (23). Further, previous LCA studies of physical activity did not include children of younger ages (14,15,23). Previous work has used accelerometry (without self-report) to derive day-to-day physical activity and sedentary behavior latent classes in youth ages 6–17 yr (6), but the relationships between the latent classes and the CVD risk factors were not explored. Therefore, the purpose of this study was to examine accelerometry-derived day-to-day physical activity and sedentary behavior latent classes with CVD risk factors in U.S. children and adolescents. We hypothesized that children and adolescents with more active or less sedentary patterns would have better health outcomes than children with the least active or most sedentary patterns.

METHODS

Study population. The National Health and Nutrition Examination Survey (NHANES) is a cross-sectional survey using a complex multistage probability sampling design to select a representative sample of the United States. Data were collected initially during home interviews, followed by physical examinations in a mobile examination center. NHANES data for the 2003–2004 and 2005–2006 cycles were available for 5607 youth ages 6–17 yr. Youth who did not have accelerometer data ($n = 577$) were excluded, resulting in 5030 youth eligible for analysis. The participant's parent or guardian provided informed consent, and the participant provided assent before data collection. Consenting and assenting documents are available for 2003–2004 (http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/brochures03_04.htm) and 2005–2006 (http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/brochures05_06.htm). The project was reviewed by the University of North Carolina at Chapel Hill Institutional Review Board and classified as exempt.

Excluded participants. Of the 5030 participants ages 6–17 yr with accelerometer data, participants were further excluded for the following reasons: accelerometer was not calibrated upon return ($n = 351$), failed to wear the accelerometer for ≥ 8 h·d^{-1} on ≥ 3 d ($n = 681$), taking diabetic medication ($n = 8$), and had outlying values for fasting glucose or average counts per minute ($n = 6$). The total number of participants used in this analysis in 3984.

Physical activity and sedentary behavior latent classes. Details of the design of the latent classes have been previously published (6) and are available for application (7). Briefl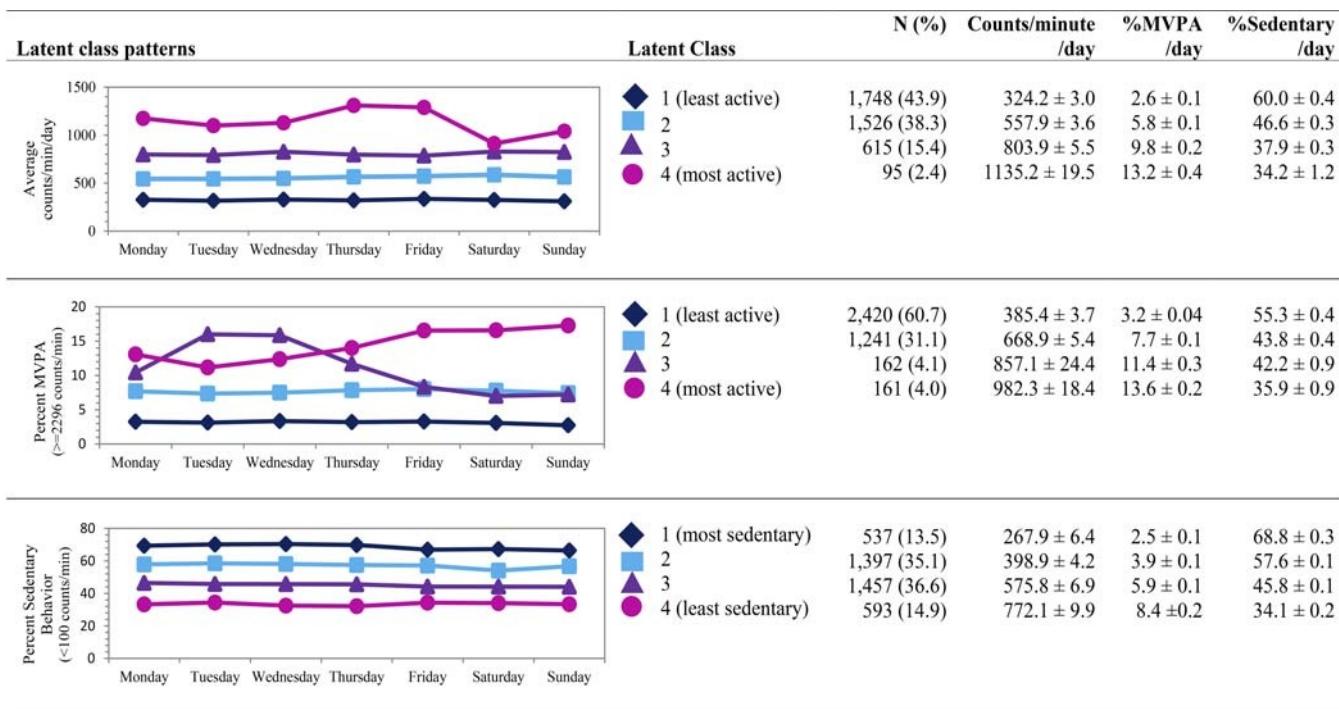y, participants were instructed to wear the ActiGraph accelerometer (model 7164) on their right hip for 7 d, during waking hours when not engaged in water-based activities. Accelerometer data were used to derive latent classes characterizing average counts per minute, and percent of wear time spent in MVPA and sedentary behavior. Average counts per minute describes the "average intensity" of physical activity. Cut points of ≥ 2296 and <100 counts per minute were used to define MVPA and sedentary behavior, respectively (5,6). Percent of total wear time spent in MVPA and in sedentary behavior were calculated and used as indicators in the LCA. Each participant was assigned to one of four classes based on the highest posterior class membership probability using maximum likelihood methods.

Detailed characteristics and shapes of the latent classes have been previously described (6). Figure 1 shows the distribution of participants by latent class membership. Youth in class 1 of the average counts per minute and MVPA latent classes were "least active," whereas youth in class 4 were "most active." Youth in class 1 of the sedentary behavior latent classes were "most sedentary," whereas youth in class 4 were "least sedentary." Latent classes 1, 2, and 3 of average counts per minute were constant across the week, differing in average intensity, whereas class 4 shows a non-monotonic increase in average counts per minute late in the week. MVPA latent classes 1 and 2 were constant across the week, whereas class 3 shows a higher percentage of time spent in MVPA earlier in the week and class 4 shows a higher percentage of time spent in MVPA late in the week. Sedentary behavior latent classes were constant across the week, differing primarily in percentage of wear time spent in sedentary behavior. It should be noted that classification in one set of classes does not determine classification in a different set of classes. For example, a participant in the most active MVPA class (i.e., class 4) may not be in the most active average counts per minute class.

CVD risk factors. CVD risk factors were measured by trained and certified staff. We explored associations with waist circumference, systolic and diastolic blood pressure, HDL-C, LDL-C, triglycerides, glucose, and insulin. Up to four measurements for systolic and diastolic blood pressure were completed in youth ≥ 8 yr. The first reading was dropped, and the remaining readings were averaged. Youth ≥ 12 yr of age were asked to fast ≥ 8 h before blood collection for LDL-C, triglycerides, glucose, and insulin. Fasting status was confirmed by self-report at the time of the examination.

Covariates. Age (continuous), gender, race/ethnicity (non-Hispanic White, non-Hispanic Black, Mexican American, and others), and socioeconomic status were included as covariates. Poverty-to-income ratio (PIR), an index for the ratio of total family income to poverty level, was used as an indicator of socioeconomic status.

Statistical analyses. The association of physical activity and sedentary behavior with each CVD risk factor was evaluated using three multiple linear regression models. Model 1 examined continuous average counts per minute and continuous percent of time spent in MVPA and in sedentary

Latent class patterns	Latent Class	N (%)	Counts/minute /day	%MVPA /day	%Sedentary /day
(Average counts/min/day graph)	1 (least active)	1,748 (43.9)	324.2 ± 3.0	2.6 ± 0.1	60.0 ± 0.4
	2	1,526 (38.3)	557.9 ± 3.6	5.8 ± 0.1	46.6 ± 0.3
	3	615 (15.4)	803.9 ± 5.5	9.8 ± 0.2	37.9 ± 0.3
	4 (most active)	95 (2.4)	1135.2 ± 19.5	13.2 ± 0.4	34.2 ± 1.2
(Percent MVPA graph)	1 (least active)	2,420 (60.7)	385.4 ± 3.7	3.2 ± 0.04	55.3 ± 0.4
	2	1,241 (31.1)	668.9 ± 5.4	7.7 ± 0.1	43.8 ± 0.4
	3	162 (4.1)	857.1 ± 24.4	11.4 ± 0.3	42.2 ± 0.9
	4 (most active)	161 (4.0)	982.3 ± 18.4	13.6 ± 0.2	35.9 ± 0.9
(Percent Sedentary Behavior graph)	1 (most sedentary)	537 (13.5)	267.9 ± 6.4	2.5 ± 0.1	68.8 ± 0.3
	2	1,397 (35.1)	398.9 ± 4.2	3.9 ± 0.1	57.6 ± 0.1
	3	1,457 (36.6)	575.8 ± 6.9	5.9 ± 0.1	45.8 ± 0.1
	4 (least sedentary)	593 (14.9)	772.1 ± 9.9	8.4 ± 0.2	34.1 ± 0.2

FIGURE 1—Distribution of participants by latent class membership based on accelerometer measured average intensity (counts per minute), percent wear time in MVPA, and sedentary behavior, NHANES 2003–2006 (*n* = 3984). Adapted and used with permission from Evenson KR, Wen F, Hales D, Herring AH. National youth sedentary behavior and physical activity daily patterns using LCA applied to accelerometry. *Int J Behav Nutr Phys Act*. 2016;13(1):5.

behavior with each CVD risk factor. Model 2 examined the latent classes of counts per minute, percent of MVPA, and percent of sedentary behavior with each CVD risk factor. Model 3 combined models 1 and 2, examining the independent association of the latent classes and each CVD risk factor after controlling for the corresponding continuous measure of physical activity or sedentary behavior. For models 1 and 3, functional forms of the continuous measures of physical activity and sedentary behavior were explored using linear, quadratic, cubic, and restricted cubic splines with knots at percentiles 5, 27.5, 50, 72.5, and 97.5. Wald's *F* tests were used to compare linear combinations and to determine the best form. To account for the differential probabilities of selection, estimates were weighted to the 2000 census using 4-yr sample weights provided by NHANES. All models are adjusted for age, sex, race/ethnicity, and PIR. Analyses were conducted using survey procedures of SAS statistical software, version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Characteristics of the 3984 youth used in this analysis are presented in Table 1. Mean age was 11.5 years, 51.0% were male, 60.2% were non-Hispanic white, and mean PIR was 2.6, indicating a household income of 160% above the poverty threshold. Youth spent 50.4% of an average day in sedentary behavior and 5.3% of an average day in MVPA. Average intensity was 516.4 counts.

Unadjusted means of each CVD risk factor by latent class are presented in Table, Supplemental Digital Content 1, Distribution of participants by latent class membership, http://links.lww.com/MSS/A951. Mean waist circumference and systolic blood pressure tend to lower across latent classes as youth tend to become more active or less sedentary. Mean HDL-C was higher as youth tend to become more active or less sedentary. LDL-C, triglycerides, glucose, and insulin means tend to lower with more active average counts per minute or percent of MVPA classes. Glucose and insulin levels tend to be higher as youth tend to be less sedentary.

Average intensity. Adjusted associations for average counts per minute with CVD risk factors are shown in Table 2. Model 1 shows adjusted associations between continuous average counts per minute and CVD risk factors. Quadratic and cubic terms for counts per minute were added to the model examining waist circumference, and a quadratic term for counts per minute was added to the model examining diastolic blood pressure. Average counts per minute was significantly associated with lower systolic blood pressure, triglycerides, and insulin and higher HDL-C. For every additional unit of average counts per minute, triglycerides was lower by 0.03 mg·dL^{-1} (95% confidence interval = −0.06 to −0.00) and HDL-C was higher by 0.01 mg·dL^{-1} (0.00–0.01). Model 2 shows adjusted associations between the average counts per minute latent classes and the CVD risk factors. The latent classes were inversely associated with waist circumference, systolic blood pressure, glucose, and insulin and positively

TABLE 1. Characteristics of the overall study population and remaining sample after exclusions, among youth ages 6 to 17 years old, NHANES 2003–2006.

	Overall[a] (n = 5607)	Analytic Sample[b] (n = 3984)	P[c]
Age, mean ± SE, yr	12.17 ± 0.06	11.48 ± 0.09	0.01
Gender, n (%)			0.08
Male	2804 (51.16)	2001 (51.00)	
Female	2803 (48.84)	1983 (49.00)	
Race/ethnicity, n (%)			0.02
Non-Hispanic White	1469 (61.16)	1007 (60.15)	
Non-Hispanic Black	1902 (14.82)	1332 (14.74)	
Mexican American	1776 (12.44)	1331 (13.33)	
Other	460 (11.58)	314 (11.79)	
PIR, mean ± SE	2.13 ± 0.06	2.64 ± 0.08	0.3
Accelerometer activity, mean ± SE			
% MVPA per day	5.32 ± 0.09	5.32 ± 0.09	0.6
% Sedentary per day	51.40 ± 0.28	50.36 ± 0.33	0.9
Counts per minute	505.35 ± 5.43	516.35 ± 5.73	0.6
CVD risk factors, mean ± SE			
Waist circumference (cm)	74.72 ± 0.28	72.41 ± 0.42	0.6
Systolic blood pressure (mm Hg)	106.28 ± 0.37	106.00 ± 0.37	0.01
Diastolic blood pressure (mm Hg)	56.66 ± 0.46	56.67 ± 0.46	0.9
HDL cholesterol (mg·dL^{-1})	54.42 ± 0.30	54.19 ± 0.38	0.6
LDL cholesterol (mg·dL^{-1})	88.90 ± 0.60	87.85 ± 1.26	0.8
Triglycerides (mg·dL^{-1})	83.52 ± 1.37	87.39 ± 2.05	0.3
Glucose, plasma (mg·dL^{-1})	92.23 ± 0.46	91.90 ± 0.37	0.6
Insulin (μU·mL^{-1})	13.31 ± 0.38	11.64 ± 0.35	0.01

[a]Particpants ages 6–17 yr participating in the 2003–2006 NHANES survey.
[b]Participants were excluded for the following reasons: did not have accelerometer data (n = 577), accelerometer was not calibrated upon return (n = 351), failed to wear accelerometer for ≥8 h·d^{-1} on ≥3 d (n = 681), taking diabetic medication (n = 8), and had outlying values for fasting glucose or average intensity (n = 6).
[c]P value test differences between the overall sample and the analytic sample.

associated with HDL-C. Waist circumference was significantly lower for each class (class 2, −2.22 cm [−3.28 to −1.16]; class 3, −5.31 cm [−6.92 to −3.70]; and class 4, −8.13 cm [−9.47 to −6.79]) compared with class 1. This relationship is further described in Figure 2, which shows adjusted means of the latent classes by CVD risk factor. Mean waist circumference is lower in latent classes with higher average counts per minute. Systolic blood pressure was lower for class 3 (−2.11 mm Hg [−3.61 to −0.60]) and class 4 (−4.14 mm Hg [−7.74 to −0.55]) compared with class 1. HDL-C was higher for class 3 (3.54 mg·dL^{-1} [1.66–5.42]) compared with class 1. Glucose was lower for class 4 (−4.25 mg·dL^{-1} [−7.84 to −0.66]) and insulin was lower for class 4 (−6.83 μU·mL^{-1} [−8.66 to −4.99]) compared with class 1. When comparing extreme classes (class 4 vs class 1), Figure 2 shows mean waist circumference, mean systolic blood pressure, mean glucose, and mean insulin was lower in class 4, which is characterized by high average counts per minute and an increase in counts per minute late in the week, compared with class 1, which is characterized by low average counts per minute that is consistent from day to day. After adjustment for continuous average counts per minute in model 3 (not shown), the latent classes maintain their significant associations with systolic blood pressure (P = 0.01), glucose (P = 0.03), and insulin (P = 0.02), although marginally attenuated.

MVPA. Adjusted associations for MVPA with CVD risk factors are shown in Table 3. Model 1 shows adjusted associations between continuous percent of wear time in MVPA and CVD risk factors. A quadratic term for percent of wear time in MVPA was added to models examining waist circumference, diastolic blood pressure, and glucose. Percent of wear time in MVPA was significantly associated with lower waist circumference, systolic blood pressure, triglycerides, and insulin and higher HDL-C. For every additional unit of percent of wear time in MVPA, systolic blood pressure was

TABLE 2. Associations between continuous counts per minute (model 1), counts per minute latent classes (model 2), and CVD risk factors in youth: NHANES 2003–2006.

		Model 1[a,b]		Model 2[a,c]					
		Counts Per Minute		Latent Class 2 vs Class 1		Latent Class 3 vs Class 1		Latent Class 4 vs Class 1	
Outcome	N	β	95% CI	β	95% CI	β	95% CI	β	95% CI
WC[d]	3775	0.01	−0.02 to 0.04	**−2.22**	**−3.28 to −1.16**	**−5.31**	**−6.92 to −3.70**	**−8.13**	**−9.47 to −6.79**
SBP	3237	**0.00**	**−0.01 to 0.00**	0.30	−0.66 to 1.26	**−2.11**	**−3.61 to −0.60**	**−4.14**	**−7.74 to −0.55**
DBP[e]	3237	−0.01	−0.02 to 0.01	−1.22	−3.13 to 0.69	−1.65	−4.05 to 0.75	−1.50	−4.68 to 1.68
HDL-C	3423	**0.01**	**0.00 to 0.01**	0.89	−0.29 to 2.07	**3.54**	**1.66 to 5.42**	4.07	−1.05 to 9.19
Glucose	1026	0.00	−0.01 to 0.00	0.67	−1.20 to 2.53	−0.78	−3.30 to 1.73	**−4.25**	**−7.84 to −0.66**
LDL-C	1286	−0.01	−0.02 to 0.01	−0.85	−7.18 to 5.48	−1.35	−9.36 to 6.66	**−13.27**	**−23.95 to −2.58**
Triglycerides	1288	**−0.03**	**−0.06 to 0.00**	−8.14	−16.93 to 0.64	**−16.71**	**−31.55 to −1.87**	−14.61	−35.26 to 6.05
Insulin	1007	**0.00**	**−0.01 to 0.00**	−1.38	−3.37 to 0.62	−0.87	−4.09 to 2.34	**−6.83**	**−8.66 to −4.99**

Bold associations have a P value <0.05.
CI, confidence interval; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.
[a]Adjusted for age, sex, race/ethnicity, and PIR.
[b]Model 1 are associations between the continuous measure of counts per minute and the CVD risk factors. Beta estimate and 95% CI of linear term is shown.
[c]Model 2 are associations between the counts per minute latent classes and the CVD risk factors. Classes 2, 3, and 4 are compared with class 1 (least active class).
[d]Model 1 also includes the quadratic and cubic terms for counts per minute.
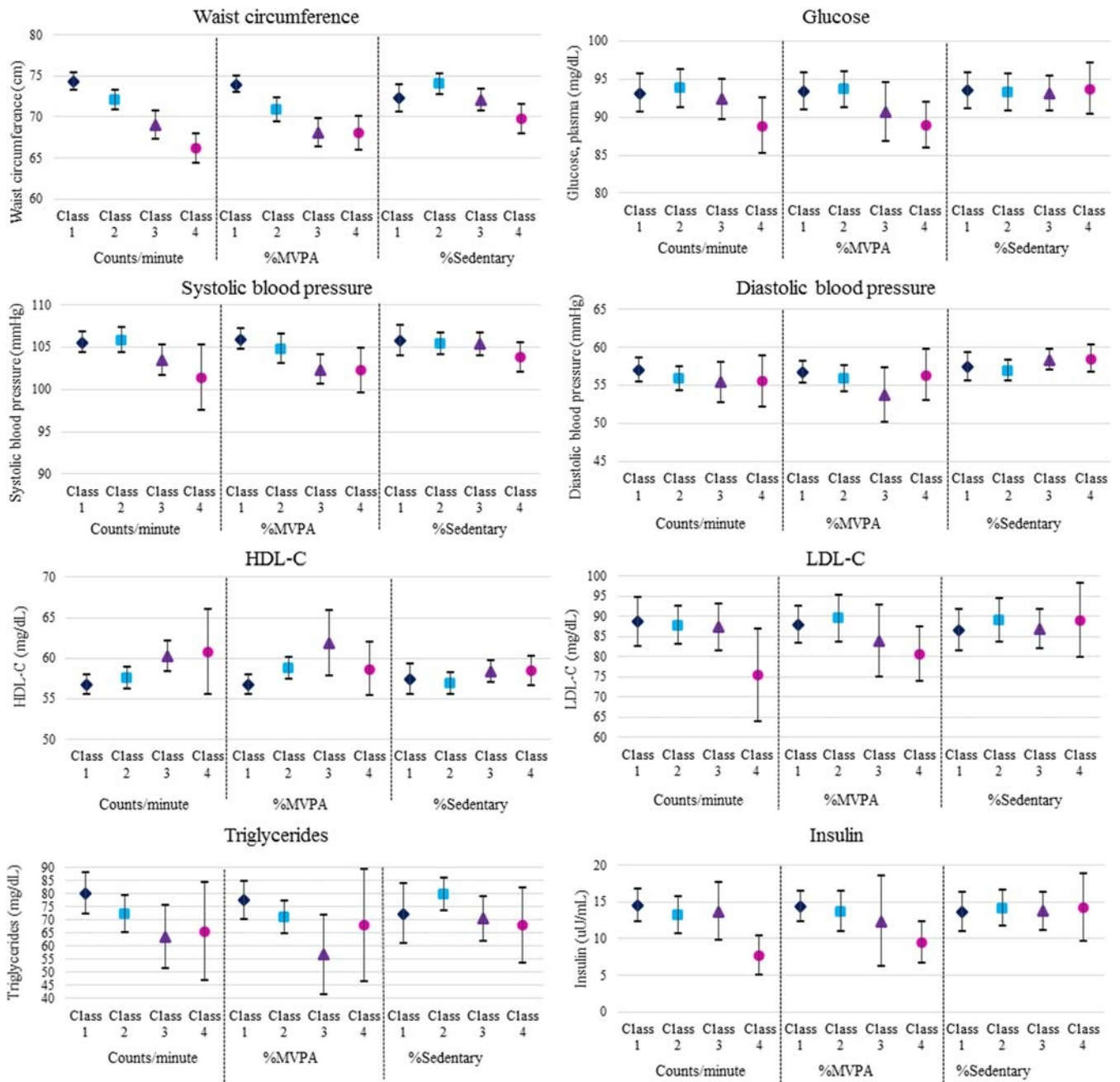[e]Model 1 also includes the quadratic term for counts per minute.

FIGURE 2—Adjusted means and 95% confidence intervals of CVD risk factors comparing the counts per minute, percent MVPA, and sedentary behavior latent classes to the least active or most sedentary class (class 1).

lower by 0.27 mm Hg (−0.41 to −0.13), triglycerides were lower by 2.08 mg·dL^{-1} (−3.89 to −0.27), insulin was lower by 0.31 μU·mL^{-1} (−0.59 to −0.03), and HDL-C was higher by 0.47 mg·dL^{-1} (0.25–0.69). Model 2 shows adjusted associations between the percent of MVPA latent classes and the CVD risk factors. The latent classes were inversely associated with waist circumference, systolic blood pressure, glucose, LDL-C, and insulin and positively associated with HDL-C. Waist circumference was significantly lower for each class (class 2, −3.09 cm [−4.28 to −1.90]; class 3, −5.92 cm [−7.64 to −4.21]; and class 4, −5.95 cm [−7.80 to −4.09]) compared with class 1. Systolic blood pressure was lower

for class 3 (−3.59 mm Hg [−5.29 to −1.89]) and class 4 (−3.68 mm Hg [−6.22 to −1.14]) compared with class 1. HDL-C was higher for class 2 (1.99 mg·dL^{-1} [0.86–3.12]) and class 3 (5.12 mg·dL^{-1} [0.91–9.34]) compared with class 1. Insulin was lower for class 4 (−4.95 μU·mL^{-1} [−6.63 to −3.28]) and glucose was lower for class 4 (−4.39 mg·dL^{-1} [−6.40 to −2.39]) compared with class 1. These associations were attenuated after further adjustment for percent of wear time in MVPA in model 3 (not shown).

Sedentary behavior. Table 4 shows adjusted associations for sedentary behavior with CVD risk factors. Adjusted associations between continuous percent of wear time in

TABLE 3. Associations between continuous MVPA percent wear time (model 1), MVPA latent classes (model 2), and CVD risk factors in youth: NHANES 2003–2006.

		Model 1[a,b]		Model 2[a,c]					
		%MVPA		Latent Class 2 vs Class 1		Latent Class 3 vs Class 1		Latent Class 4 vs Class 1	
Outcome	N	β	95% CI	β	95% CI	β	95% CI	β	95% CI
WC[d]	3775	−1.09	−1.66 to −0.52	−3.09	−4.28 to −1.90	−5.92	−7.64 to −4.21	−5.95	−7.80 to −4.09
SBP	3237	−0.27	−0.41 to −0.13	−1.16	−2.47 to 0.15	−3.59	−5.29 to −1.89	−3.68	−6.22 to −1.14
DBP[d]	3237	−0.32	−0.96 to 0.32	−0.85	−2.66 to 0.96	−2.95	−6.22 to 0.32	−0.36	−3.57 to 2.86
HDL-C	3423	0.47	0.25 to 0.69	1.99	0.86 to 3.12	5.12	0.91 to 9.34	1.95	−1.36 to 5.25
Glucose[d]	1026	0.16	−0.48 to 0.80	0.21	−1.70 to 2.13	−2.72	−6.12 to 0.67	−4.39	−6.40 to −2.39
LDL-C	1286	−0.38	−1.23 to 0.46	1.49	−4.77 to 7.75	−4.11	−13.88 to 5.67	−7.30	−14.52 to −0.08
Triglycerides	1288	−2.08	−3.89 to −0.27	−6.62	−13.92 to 0.68	−20.82	−37.42 to −4.21	−9.69	−33.65 to 14.27
Insulin	1007	−0.31	−0.59 to −0.03	−0.72	−2.66 to 1.21	−2.09	−7.24 to 3.06	−4.95	−6.63 to −3.28

CI, confidence interval; %MVPA, percent of wear time in MVPA per day; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.
Bold associations have a *P* value <0.05.
[a]Adjusted for age, sex, race/ethnicity, and PIR.
[b]Model 1 are associations between the continuous measure of %MVPA and the CVD risk factors. Beta estimate and 95% CI of linear term is shown.
[c]Model 2 are associations between the %MVPA latent classes and the CVD risk factors. Classes 2, 3, and 4 are compared with class 1 (least active class).
[d]Model 1 also includes the quadratic term for %MVPA.

sedentary behavior and CVD risk factors are presented in model 1. A quadratic term for percent of sedentary behavior was added to the model examining waist circumference. Percent of wear time spent in sedentary behavior is significantly associated with waist circumference and HDL-C. HDL-C was lower by 0.07 mg·dL^{-1} (−0.13 to −0.01) for each additional unit of percent of wear time in sedentary behavior. Model 2 shows adjusted associations between the percent of sedentary behavior latent classes and the CVD risk factors. Waist circumference was higher for class 2 (1.73 cm [0.13–3.33]) and lower for class 4 (−2.54 cm [−4.90 to −0.19]) compared with class 1. This overall significant association was maintained in model 3 (not shown) after further adjustment for percent of wear time in sedentary behavior (*P* = 0.004).

DISCUSSION

This study of U.S. children and adolescents examined the association between day-to-day patterns of physical activity and sedentary behavior with several CVD risk factors. A key observation from the analysis is that classes with higher average intensity of physical activity or higher percentage of MVPA had beneficial associations with several CVD risk factors and classes with a lower percentage of sedentary behavior were associated with lower waist circumference only. For many risk factors, the associations attenuated after controlling for total average physical activity or sedentary behavior. However, some associations remained significant after controlling for these variables. These findings indicate that some behavioral patterns of physical activity may lower certain CVD risk factors beyond the amount of physical activity attained. The overall study findings highlight the importance of the amount of physical activity and sedentary behavior for cardiovascular health, and also suggest some contribution of daily pattern.

Previous studies have used bouts (i.e., extended periods of physical activity or sedentary behavior) as an alternative way to construct patterns of physical activity and sedentary behavior and then examined these patterns with CVD risk factors (3,11,26). Willis et al. (26) classified nearly 400 youth ages 6 to 9 yr based on MVPA bouts using latent profile analysis and reported that youth who accumulate a higher percentage of both short bouts (5 to <10 min in length) and medium-to-long bouts (≥10 min) had lower waist circumference compared with youth who accumulate a lower percentage of short and medium-to-long bouts. Another study examined MVPA accumulated in bouts of five consecutive minutes or more and MVPA accumulated in less than five consecutive minutes (i.e., sporadic MVPA) with CVD risk factors using the NHANES

TABLE 4. Associations between continuous sedentary percent wear time (model 1), sedentary latent classes (model 2), and CVD risk factors in youth: NHANES 2003–2006.

		Model 1[a,b]		Model 2[a,c]					
		%SED		Latent Class 2 vs Class 1		Latent Class 3 vs Class 1		Latent Class 4 vs Class 1	
Outcome	N	β	95% CI	β	95% CI	β	95% CI	β	95% CI
WC[d]	3775	0.55	0.17–0.93	1.73	0.13 to 3.33	−0.25	−2.02 to 1.51	−2.54	−4.90 to −0.19
SBP	3237	0.05	0.00–0.10	−0.37	−1.91 to 1.16	−0.38	−1.88 to 1.12	−1.95	−4.11 to 0.21
DBP	3237	0.23	−0.05 to 0.50	−0.20	−1.96 to 1.56	−1.54	−3.17 to 0.08	−1.42	−3.92 to 1.07
HDL-C	3423	−0.07	−0.13 to −0.01	−0.56	−2.52 to 1.40	0.90	−1.04 to 2.85	1.03	−1.10 to 3.16
Glucose	1026	0.01	−0.06 to 0.09	−0.30	−1.65 to 1.05	−0.48	−1.95 to 1.00	0.21	−3.16 to 3.57
LDL-C	1286	0.04	−0.21 to 0.03	2.41	−4.05 to 8.88	0.21	−6.09 to 6.50	2.45	−8.29 to 13.19
Triglycerides	1288	0.38	−0.19 to 0.95	7.51	−3.73 to 18.75	−1.83	−13.29 to 9.63	−4.40	−20.50 to 11.70
Insulin	1007	0.04	−0.04 to 0.13	0.44	−2.05 to 2.93	0.06	−1.93 to 2.05	0.55	−3.39 to 4.50

CI, confidence interval; SED = sedentary behavior; %SED = percent of wear time in sedentary behavior per day; WC = Waist circumference; SBP = systolic blood pressure; DBP = diastolic blood pressure.
Bold associations have a *P* value <0.05.
[a]Adjusted for age, sex, race/ethnicity, and PIR.
[b]Model 1 are associations between the continuous measure of %SED and the CVD risk factors. Beta estimate and 95% CI of linear term is shown.
[c]Model 2 are associations between the %SED latent classes and the CVD risk factors. Classes 2, 3, and 4 are compared with class 1 (most sedentary class).
[d]Model 1 also includes the quadratic term for %SED.

data of more than 2700 youth ages 6–19 yr (11). Their results indicate that youth obtaining ≥ 14 m·d^{-1} of total MVPA (i.e., MVPA bouts and sporadic MVPA) had lower odds of a high cardiometabolic risk score, high waist circumference, and high systolic blood pressure compared with youth obtaining <14 min·d^{-1} of total MVPA (11). Although the accumulation of MVPA bouts each day provides insight into the patterns in which youth may obtain the daily recommendation of physical activity for cardiometabolic benefits, daily bouts summarize MVPA into a single average measure and do not tell us if variability in MVPA across the week or maintaining a consistent level of MVPA from day to day is beneficial for cardiometabolic health. Our analysis showed that weekly patterns that maintain a higher percentage of MVPA or higher average intensity are associated not only with lower waist circumference and systolic blood pressure but also with lower glucose, insulin, and higher HDL-C, before controlling for time spent in MVPA. Patterns across the week rather than patterns averaged into a summary measure highlight the importance of maintaining day-to-day physical activity behaviors for cardiometabolic health.

Previous work using LCA identified four distinct patterns for average intensity, MVPA, and sedentary behavior based on average counts per minute per day and percent of wear time in MVPA and sedentary behavior, respectively, in a nationally representative sample of youth (6). Evenson et al. demonstrated that youth cluster together based on distinct physical activity and sedentary behavior patterns, thus warranting further exploration into how the patterns differentially affect health outcomes. Our results indicate that youth participating in more activity or less sedentary behavior had more favorable CVD risk factors. For example, compared with the least active MVPA class (class 1), youth in classes 2, 3, and 4 accumulated 4%, 8%, and 10% more MVPA per day, respectively, resulting in more favorable CVD risk factors among classes with a higher percentage of MVPA per day. An interesting finding is that although class 2 accumulated a consistent level of MVPA across the week, a day-to-day pattern that is similar to class 1, class 3, and class 4 varies across the week and is associated with differing combinations of CVD risk factors. Youth in class 3 accumulate a higher percentage of MVPA Monday through Thursday and a lower percentage of MVPA Friday through Sunday, but youth in class 4, the most active class, accumulate a lower percentage of MVPA Monday through Thursday and a higher percentage of MVPA Friday through Sunday. Both classes are significantly associated with lower waist circumference and systolic blood pressure when compared with class 1. However, class 3 is also significantly associated with HDL-C and triglycerides, but class 4 is associated with glucose and insulin. Although this may be an artifact of how youth with similar behaviors cluster together, the results suggest that the manner in which youth accumulate weekly activity may support different biologic mechanisms, and further research could focus on specific weekly patterns that are associated with long-term cardiovascular health.

There has been increasing research using accelerometry to explore extended bouts of sedentary behavior with health outcomes. A study using NHANES data examined sedentary behavior in more than 2500 participants ages 6–19 yr and did not find extended bouts of sedentary behavior (≥ 30 min) and percentage of wear time spent in sedentary behavior to be predictors of a high cardiometabolic risk score (3). The same study did not find significant associations between sedentary behavior and waist circumference or systolic blood pressure (3). Although our results do not indicate a significant association between the sedentary classes and the systolic blood pressure, we did find a significant association between sedentary classes and waist circumference. This could be because our classes account for sedentary behavior each day rather than an average daily pattern across the week.

Collectively, our study along with previous research highlights the importance of accumulating higher amounts of physical activity and reducing the amount of time in sedentary behavior. Strengths of the current study include use of a large, nationally representative sample of U.S. children and adolescents, which increases generalizability, assessment of physical activity and sedentary behavior by accelerometry, a data-driven statistical approach to derive day-to-day patterns of physical activity and sedentary behavior, and examination of multiple CVD risk factors. Several limitations to this study are noteworthy. Proportions across classes vary, making some comparisons more extreme than others. Specifically, the MVPA and the average intensity referent class (class 1) represents 60% and 44% of the population, respectively, but class 4 represents 4% and 2.4% of the population. Although the results identify a large proportion of youth who could improve their cardiometabolic health from interventions targeting weekly activity and sedentary behaviors, the results are cross-sectional, which inhibits our ability to establish temporality. In addition, the accelerometer protocol excluded use during water-based activities, and it is possible some activities were not accounted for when developing the physical activity variables. Lastly, nearly 30% of children and adolescents were excluded from the analysis because of missing or invalid accelerometry data, or outlying risk factor or physical activity values. Comparison of youth included and excluded (Table 1) indicate differences in some sociodemographic variables and CVD risk factors. Participants included in the analytic tend to be younger, have a lower mean systolic blood pressure, and have a lower mean insulin compared with the overall sample. The analytic sample also has a smaller percentage of non-Hispanic Whites and a larger percentage of Mexican Americans.

LCA modeling identifies physical activity or sedentary behaviors that are associated with cardiovascular health, but may provide more information than simpler summary measures. We showed some indication that patterns, in addition to amount of physical activity and sedentary behavior may be important. Longitudinal studies could further improve our understanding of the effect of physical activity and sedentary behavior latent classes on CVD risk factors. Promotion strategies should continue to encourage increases in physical

activity and reductions in sedentary behavior in children and adolescents for overall cardiovascular health.

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