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The Effect of Physical Activity Bout Patterns on Metabolic Syndrome Risk Factors in Youth: National Health and Nutrition Examination Survey 2003–2006

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Abstract

Background: Research suggests that accumulating moderate to vigorous physical activity (MVPA) in longer continuous bouts may have beneficial effects on metabolic syndrome risk factors. The objective of this study was to examine the independent associations of MVPA bout patterns on metabolic syndrome risk factors among a nationally representative sample of youth.

Methods: Results are based on 3165 children and adolescents (6–18 y old) from the 2003–2006 National Health and Nutrition Examination Survey. Accelerometers measured MVPA accumulated in bouts of: <5, 5 to 10, and 10 minutes over 7 days. Participants were categorized into quartiles based on percentage of each bout duration. Sensitivity analysis was conducted using 3 versions of MVPA cut points for youth. A series of general linear models were used to compare metabolic syndrome risk factors between groups.

Results: Youth participating in longer continuous bouts of MVPA had lower body mass index percentile ($P < .02$), waist circumference (WC) ($P < .01$), WC percentile ($P < .02$), and waist to height ratio ($P < .01$) than youth participating in shorter bouts of MVPA. When analyzed for interactions between MVPA and bout pattern quartile, only 1 cut point showed a significant interaction for WC and WC percentile.

Conclusion: Longer continuous bouts of MVPA had beneficial effects on body anthropometrics and weight status, although these effects may be moderated by total MVPA.

Keywords

accelerometry; epidemiology; metabolic health; pediatrics

Increasing prevalence of obesity and metabolic syndrome risk factors (METsRF) has become a serious public health concern for children and adolescents over the past 30 years. The most recent estimates show 17% of children and adolescents aged 2–17 years old are obese¹ and 26.4% to 45.6% of children and adolescents have at least 1 “at risk” or “high risk” METsRF as defined by the Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents.^{2,3} Youth with METsRF are not only at an increased risk of developing type 2 diabetes and cardiovascular disease in adulthood,^{4,5} but are also at risk of developing metabolic syndrome, which has been shown to be a strong predictor of all-cause mortality.⁶

Inadequate amounts of physical activity and low cardio-respiratory fitness are associated with clustered and individual METsRF in children and adolescents,^{7–9} with 1 study reporting that adolescents accumulating at least 88 minutes of moderate to vigorous physical activity (MVPA) per day have the lowest metabolic syndrome continuous risk score.¹⁰ Although the relationship between individual and clustered METsRF, physical activity, and cardiorespiratory fitness is well reported, the studies exploring the effect of how the MVPA is accumulated, or the bout patterns of MVPA on individual and clustered METsRF are more conflicted.^{11–15} Some studies suggest that MVPA accumulated in bouts of 5 to 10 continuous minutes or longer are independently associated with lower waist circumference (WC)¹¹ and lower likelihood of being overweight,¹³ while other studies show no effects MVPA bouts on any METsRF.^{14,15}

Previous studies had several limitations that could explain these inconsistent outcomes, such as different MVPA cut points, grouping subjects by attainment of a set bout duration rather than a holistic approach to the physical activity patterns, not accounting for the residual effect of MVPA beyond controlling statistically, and developing index scoring for METsRF variables rather than reporting on each risk factor individually. The objective of this study was to examine the effects of MVPA bout patterns on individual METsRF in children and adolescents.

Methods

Study Population

Subject data for this cross-sectional, observational design were collected from the Centers for Disease Control and Prevention 2003–2004 and 2005–2006 National Health and Nutrition Examination Survey (NHANES). The NHANES is a series of population studies examining health and nutritional status of children, adolescents, and adults through interviews, surveys, and physical examinations.

Participants in this investigation were normal healthy children and adolescents aged 6–18 years who wore an accelerometer on the waist and completed blood laboratory assessments in the morning session as per NHANES 2003–2004 and 2005–2006 protocols.¹⁶ To be included, subjects were required to have at least 1 day of 10 hours per day of valid accelerometer wear time and all necessary covariates. All participants provided written consent and assent and research ethics approval was granted by the National Center for

Health Statistics. The overall study population was 20,470 individuals, and we excluded participants <6 or ≥18 years of age and pregnant women, leaving 5943 individuals (eligible sample). Those with insufficient accelerometer data were further excluded, thus, data from 3165 subjects were available for analyses. For the analysis of triglycerides, glucose, and insulin, 2038 children aged 6–11 years were excluded for being nonfasted at the time of blood sample data collection.

Physical Activity

Physical activity was assessed by an ActiGraph AM-7164 (Fort Walton Beach, FL) accelerometer over 7 consecutive days on a custom-fitted elastic strap around the waist, over the right hip. Accelerometer data were summed and stored at 60-second time intervals or “epochs.” Subjects were provided with materials describing the monitor and instructed on how and when to wear the accelerometer by trained member of the research staff. Subjects were instructed to remove accelerometers for water activities such as swimming and bathing/showering and also when sleeping. Accelerometer data were reviewed by NHANES collaborators and screened for outliers and unreasonable values. Nonwear time was identified as ≥60 consecutive minutes with 0 counts per minute (cpm), with allowance for 1 to 2 minutes of accelerometer counts between 0 and 100. Sedentary time was classified as worn time with accelerometer counts <100. To account for a form of selection bias which may come with choosing 1 specific accelerometer cut point for our analysis, light, moderate, and vigorous physical activity intensities are presented using 3 different age specific cut points: (1) the 2005 Freedson cut points¹⁷ using the metabolic equivalent (MET) values for MVPA described by Troiano et al¹⁸; (2) the 2005 Freedson cut points using the MET values for MVPA described by Saint-Maurice et al¹⁹; and (3) the 2008 Evenson cut points²⁰ for MVPA. Once MVPA cut points were applied, total MVPA time was classified into one of the bout categories described by Mark and Janssen¹³:

1. Sporadic: 1 to 4.9 minutes of continuous MVPA
2. Short: 5 to 9.9 minutes of continuous MVPA
3. Medium-long: ≥10 minutes of continuous MVPA

Subsequently, the proportion of total MVPA from sporadic, short, and medium to long bouts was calculated.

Metabolic Syndrome Risk Factors

For the purpose of this study, METsRF were grouped into categories of weight status/body anthropometrics (body mass index [BMI]), WC, waist to height ratio, serum lab values (total, LDL [low-density lipoprotein] and HDL [high-density lipoprotein] cholesterol, triglycerides, glucose, and insulin), and blood pressure. All METsRF measurements were collected by a trained research team member in the NHANES mobile examination center. Weight was measured in kilograms using a digital weight scale, while wearing a standard examination gown. Height was measured on a calibrated stadiometer with a 4-body part contact point position against the backboard. Weight and height were used to calculate BMI (measured in kilogram per square meter), which was used to determine age and sex specific BMI percentile.²¹ Abdominal WC was measured at the level of the iliac crest to the nearest

0.1 cm and was used to determine waist to height ratio and age and sex specific percentile for WC.²²

Serum blood samples used to analyze total cholesterol, LDL and HDL cholesterol, and triglycerides were processed, stored, and shipped to Johns Hopkins Medical Center in Baltimore, MD for analysis, while samples used to analyze fasting glucose and insulin were processed, stored, and shipped to the University of Missouri in Columbia, MO for analysis. Triglycerides, glucose, and insulin were only collected in subjects who were fasting at the time of measurement. Triglyceride, glucose, and insulin values for subjects <11.9 years were not included in this analysis. The direct immunoassay method was used to determine HDL cholesterol. Triglycerides and total cholesterol were measured in serum, enzymatically, through a series of coupled reactions using cholesteryl ester hydrolase, cholesterol oxidase, and peroxidase (for total cholesterol) and lipase, glycerokinase, glycerophosphate oxidase, and peroxidase (for triglycerides).¹⁶ Then, the LDL cholesterol was calculated using the Friedewald calculation.²³

The hexokinase method was used to determine fasting glucose concentrations. Fasting insulin concentrations were determined using an immunoenzymometric method in NHANES 2003–2004 and the enzyme-linked immunosorbent assay method in NHANES 2005–2006.¹⁶ Blood pressure was measured for 3 to 4 times after resting quietly in the sitting position for a minimum of 5 minutes by a trained blood pressure examiner.²⁴

Covariates

Interviewer-administered questionnaires obtained the following covariates: age (y), sex, race (non-Hispanic white and other), poverty–income ratio, head of household education level (that is, high school or less, associate degree/some college, and college/graduate degree), and physical disability that would limit walking activity (yes/no) and asthma (yes/no). Dietary intake was assessed by a 24-hour diet recall coupled with US Department of Agriculture food composition data. Data obtained from 24-hour recall were used to calculate diet quality index scores using the Healthy Eating Index-2015 (HEI-2015).²⁵ The HEI-2015 is a measure of diet quality developed by the US Department of Agriculture that assesses conformance to the dietary guidelines for Americans.²⁶ The HEI-2015 provides a point value based on how well a person meets the dietary guidelines, expressed as a percentage per 1000 kcals. To account for possible seasonal variation in physical activity and METsRF, assessment date were dichotomized into 6-month time periods when the examination was performed (November 1 through April 30 and May 1 through October 31).

Statistical Analysis

To obtain population-representative findings, 2-year sample weights for each NHANES cycle were combined to provide 4-year weights for the 2003–2006 survey periods. Examination weights were reweighted based on age, sex, and race/ethnicity to account for the nonrandom absence of participants in our analysis sample.

Pearson correlations were computed to examine the relationship between percentage of total MVPA accumulated in sporadic, short, and medium-long bouts. Potential evidence of multicollinearity was found ($r = .95$) between the variables. Therefore, the principal

component analysis was performed with an orthogonal rotation (eg, varimax) to extract each subject's estimated bout pattern component score. Then, participants were categorized into quartiles based on individual bout pattern component scores.

Due to this study being observational, participants cannot be randomized to a specific bout pattern profiles; therefore, differences in respondent characteristics, which in a randomized trial would be assumed to be null, might explain the observed effects. Therefore, propensity score weighting was utilized to eliminate the differences in the observed characteristics (eg, age, sex, total MVPA, etc) between participants in each quartile group. Covariates included in the propensity score model included categorical variables for sex (male/female), age (6–9, 10–13, and 14–18 y), asthma (yes/no), physical disability (yes/no) assessment period (November 1 through April 30 and May 1 through October 31), and quartiles of HEI-2015 total scores, poverty–income ratio, sedentary time, light activity and moderate to vigorous activity. Missing values for covariates in the propensity score model were treated as a separate category. The obtained propensity score weights were then combined with the 2-year sample weights by multiplying the 2 weights together. Weights that were more than 5 times the mean weighted value (weight limit) were considered an outlier weight, and that weight was trimmed by making it equal to the weight limit. To show how comparable the quartiles were after applying the propensity score weights, a calculation was made of the maximum standardized mean difference for each variable used to create the weights (Table 1), and absolute maximum standardized differences greater than 0.20 are moderate effect size differences²⁷ and to obtain a more robust estimation the covariates with lingering imbalances (absolute maximum standardized differences >0.20) were added to the final models.

A series of general linear models were conducted to compare the associations of the following variables between the identified quartiles: WC, BMI percentile, blood pressure, total LDL and HDL cholesterol, triglycerides, glucose, and insulin. Linear contrast tests were used to examine the linear trends across different bout patterns. Serum blood values and blood pressure outcomes were controlled for BMI percentile. Finally, total MVPA was dichotomized at the median value and interaction terms were added to the model to determine whether associations between bout pattern quartiles varied by high versus low MVPA. All main effects, interactions, and trends were considered significant at a $P < .05$. Analyses were conducted using R²⁸ and SAS (version 9.4; SAS Inc, Cary NC). The propensity score weights were fitted using the R package Twang²⁹ and PROC FACTOR, PROC MODECLUS, PROC SURVEYFREQ, SURVEYMEANS, and SURVEYREG procedures implemented in SAS were used to account for sampling strata, the primary sampling unit, and individual combined propensity and sampling weights.

Results

The participants' descriptive and demographic data are displayed in Table 2. The participants' characteristics of the analysis sample were similar to all potentially eligible participants (Table 1). In brief, the sample had a mean age of 12.2 years and was 48.9% female. Approximately 62% of the sample was considered non-Hispanic white, with the

remaining considered 38% minority status. The subjects were health weight status with an average BMI percentile of 63.5.

Table 3 shows the physical activity and accelerometer characteristics of each accelerometer cut point by quartile with quartile 1 representing shorter, more sporadic MVPA bout patterns and quartile 4 representing longer, continuous MVPA bout patterns. Using the Evenson²⁰ cut points, the sample averaged 41.7 minutes per day of MVPA, which was comprised of 30.8 minutes per day of moderate intensity physical activity, and 10.9 minutes per day of vigorous intensity physical activity. Roughly 93.5% of total MVPA was spent in sporadic bouts, 4.8% in short bouts, and 1.7% in medium-long bouts. The males were more active than the females (males = 48.5 min/d and females = 34.5 min/d of MVPA) and males generally participated in longer bouts of MVPA (males = 4.7% and 1.9%, females = 4.4% and 1.4% of short and medium-long bouts, respectively).

When the sample was analyzed using the Freedson et al¹⁷ cut points and MET values for MVPA described by Saint-Maurice et al,¹⁹ the sample averaged 34.03 minutes per day of MVPA, which was comprised of 31.3 minutes per day of moderate intensity physical activity and 2.6 minutes per day of vigorous intensity physical activity. Roughly 94% of total MVPA was spent in sporadic bouts, 4.5% in short bouts, and 1.5% in medium-long bouts. The males were more active than the females (males = 39.1 min/d and females = 29.2 min/d of MVPA) and males generally participated in longer bouts of MVPA (males = 4.5% and 1.7%, females = 4.2% and 1.2% of short and medium-long bouts, respectively).

Finally, using the Freedson et al¹⁷ cut points and MET values for MVPA described by Troiano et al¹⁸ the sample averaged 50.4 minutes per day of MVPA, which was comprised of 43.7 minutes per day of moderate intensity physical activity and 6.6 minutes per day of vigorous intensity physical activity. Roughly 92.9% of total MVPA was spent in sporadic bouts, 5.1% in short bouts, and 2% in medium-long bouts. The males were more active than the females (males = 57.0 min/d and females = 43.2 min/d of MVPA) and males generally participated in longer bouts of MVPA (males = 5.2% and 2.3%, females = 4.8% and 1.6% of short and medium-long bouts, respectively).

Metabolic Syndrome Risk Factor by MVPA Cut Point

Table 4 displays the differences in METsRF by MVPA bout quartile based on the Evenson, Freedson/Saint-Maurice, and Freedson/Troiano cut points for MVPA.^{17,18,20} Regardless of MVPA cut point, there was a significant trend where those who participated in longer continuous bouts of MVPA had lower BMI percentile, lower WC percentile, and lower waist to height ratio than those who participated in the shorter continuous bouts of MVPA. Using Freedson/Saint-Maurice cut points, there were also significant differences in absolute WC in centimeters, systolic blood pressure, and glucose. When the quartiles were compared using the Freedson/Troiano cut points, there were also differences in absolute WC. Regardless of MVPA cut point, there were no differences in diastolic blood pressure, total HDL or LDL cholesterol, triglycerides, or insulin by bout pattern quartile.

To further explore if the difference in MVPA total minutes per day between quartiles moderates the observed associations, the sample was dichotomized at the median value of

MVPA within each cut point. BMI percentile, absolute and relative WC, and waist to height ratio were analyzed to determine if interactions were present between bout pattern quartile and those who had differing levels of MVPA (Table 5). For both the Evenson and Freedson/Saint-Maurice cut points, there were no significant interactions between MVPA and bout pattern quartile for BMI percentile, absolute and relative WC, or waist to height ratio. Interactions were present for both absolute and relative WC within the Freedson/Troiano cut points, with no other significant interactions present.

Discussion

The results of this study suggest that children and adolescents who participate in longer continuous bouts of MVPA have lower body anthropometrics and weight status (WC percentile, waist to height ratio, and BMI percentile) than youth who participate in shorter continuous bouts of MVPA. These themes remained significant regardless of which accelerometer cut point or MET value for MVPA were used.

We found notable differences in minutes per day of MVPA between bout pattern quartiles. For the Evenson, Freedson/Saint-Maurice, and Freedson/Troiano cut points, there was a mean difference of 21.8, 17.7, and 40.7 minutes per day between quartiles 1 and 4, respectively, suggesting that children and adolescents who exercise in longer bouts of MVPA, also accumulate more minutes of MVPA. Although we controlled for MVPA within the statistical model, further analysis was warranted to confirm that the differences in METsRF outcomes by bout pattern quartile was not moderated by the differences in MVPA.

It should be noted, that although we attempted to control for the differences in minutes per day of MVPA between bout patterns quartiles, there is no guarantee that the influence of MVPA was fully accounted for, and these results should be interpreted with some caution. For both the Evenson and Freedson/Saint-Maurice cut points, there were no significant interactions between MVPA (dichotomized at median) and bout pattern quartile for any of the body anthropometrics or weight status variables. This suggests that the association of bout profiles and these weight-related outcomes do not differ between individuals with high or low levels of total MVPA. When we looked at interactions between MVPA and bout pattern quartile using the Freedson/Troiano cut points, we found significant interactions in both absolute and relative measures of WC. Although WC decreased across quartiles of bouted MVPA for both high and low levels of total MVPA, the association was stronger in those with higher total MVPA. This finding may be explained by residual confounding of total MVPA. However, the finding of an inverse association with WC across bout profiles regardless of total MVPA group (high/low) provides evidence that bouts may still play a role for WC outcomes.

Not surprisingly, our sensitivity analysis revealed some differences in outcomes depending on which cut point and MET value for MVPA were applied, suggesting that not all MVPA cut points are the same and may provide different outcomes. The Freedson/Saint-Maurice cut points also showed a significant trend for systolic blood pressure and fasting glucose (although the differences for these 2 are not clinically significant). Both the Freedson/Saint-Maurice and Freedson/Troiano cut points showed a significant trend for absolute WC, which

was not present in the analysis using the Evenson cut points. We suggest that future investigations, if they decide to use a cut point for MVPA, apply more than 1 in their analysis to confirm their results are generalizable.

In regard to the effects of bout patterns on METsRF, the results of this investigation are similar to the results of other studies, where longer continuous bouts of MVPA have an effect on weight status and anthropometrics but not on other METsRF in children or adolescents.^{11–14,30} Stone et al¹² measured short (>4 s) and long (≥ 5 min) bouts of exercise in a sample of forty-seven, 8–10 year old, boys and found that moderate intensity exercise in longer bouts had the strongest negative relationship with absolute WC. Only using the Freedson/Troiano cut points, Willis et al¹¹ measured sporadic, short, and medium-long MVPA bout patterns in a smaller sample of 396 children ($M_{age} = 7.6$ y) and concluded that youth participating in longer bouts of MVPA has lower absolute WC and BMI percentile compared with shorter bouts of MVPA. Mark and Janssen¹³ investigated if sporadic, short, and medium-long bouts of MVPA could predict overweight in 8–17 year old youth from NHANES 2003–2006. The authors found that youth who were in the highest quartile for medium-long bouts of MVPA were the least likely to be over-weight compared with the lowest quartile.¹³ Finally, Trost et al³⁰ studied 187 youth with and without obesity and found that obese youth had significantly fewer bouts of 5, 10, and 20 continuous minutes of MVPA per week compared with their nonobese peers.

Furthermore, this study acknowledges that different bout patterns of MVPA have no significant effect on cholesterol, triglycerides, blood pressure, or measures of glucose metabolism in children and adolescents. Consistent with the finding of this study, studies on bout patterns in children and adolescents by Willis et al,¹¹ and Holman et al¹⁴ show no notable differences between MVPA bouts accumulated sporadically or longer duration on selected METsRF. Despite this, longer bouts of MVPA may have benefits beyond a healthier WC and weight status. Studies have shown that youth who participate in 5 or more bouts of 10 minutes of MVPA have favorable health risk behaviors³¹ (ie, sexual behaviors, cigarette smoking, alcohol consumption, illegal drug use, school truancy, etc.) and physical activity prescribed in longer continuous bouts may be related to increased adherence to an exercise program.³² The effects of physical activity prescribed in bouts on intervention adherence have yet to be studied specifically in youth.

This investigation offers many methodological advantages over previous studies measuring MVPA bout patterns in youth. Previous studies investigating bout patterns typically used only 1 cut point for MVPA to investigate their primary outcomes. With the existence of many different intensity-related cut points for youth and lack of consensus on cut point selection in the current literature, researchers must choose from cut points that differ in estimates of physical activity intensity and time.^{33,34} To address the cut point conundrum,³³ this study used both the Evenson cut points as well as the Freedson cut points. The Evenson and Freedson cut points were chosen due to higher accuracy for light, moderate, and vigorous intensity physical activities in children and adolescents.³⁴ Within the Freedson cut points, 2 different age-specific MET values for MVPA were applied. The results revealed some similar themes regardless of which cut point was chosen and also found some notable differences. We feel that the similarities in body anthropometrics and weight status results,

regardless of cut point, speak to the strength of the results of this study. Furthermore, we completed additional propensity score weighted analysis to further investigate and control for the influence of total MVPA on our main outcomes, which to our knowledge, has not been performed in previous studies of physical activity bouts in youth. Finally, rather than dichotomizing the sample by youth who met vs did not meet a specific MVPA bout durations (eg, 5, 10, or 20 min), the subjects were placed in quartiles by those who exercised in shorter or longer continuous bouts by the total percentage of MVPA accumulated in sporadic, short, and medium-long durations of physical activity. This holistic approach to bout physical activity was first described by Mark and Janssen.¹³ Using the 3 different durations of continuous physical activity to group subjects into quartiles allowed for more freedom to compare youth with different overall patterns of physical activity.

Limitations and Future Directions

This study does have some weaknesses, which should be addressed. Initially, the cross-sectional nature of this investigation does not allow for this study to determine whether the shorter continuous bouts of MVPA is a result of higher weight status, or the higher weight status is a result of the shorter bouts of continuous MVPA. Longitudinal studies are needed to determine causality in the development of obesity in youth. In addition, although the sample was controlled for age, there were no data available to determine pubertal stage. Pubertal stage, independent of age, may have significant effects on physical activity and energy expenditure.^{35,36} Similarly, the wide age range of this study (6–18 y old) includes both younger children who have less control over their physical activity environment, combined with older adolescents who mostly make physical activity volume and pattern choices for themselves. Future studies should explore the effects of aging from childhood through adolescence and puberty status on patterns of physical activity by sex. The accelerometer was only worn for 7 days, of which only 1 day of valid wear time was required to be included in the analysis. This 1-week snapshot of objectively measured physical activity may not be an adequate representative sample of normal habitual physical activity and may have missed other forms of physical activity, such as cycling, swimming, and weight training as some examples. In addition, the accelerometers in this study were limited to 60-second epochs based on the 2003–2006 NHANES study protocol. Shorter epochs may reveal additional, shorter patterns of physical activity, especially in the younger subjects. This study did not consider the impact of sleep, which may have significant effects on METsRF, especially weight status. Also, youth aged 6–11 years old were excluded from analysis that required a fasting state at the time of the blood draw.

Conclusion

Accumulating MVPA in longer continuous bouts may have a beneficial effect on body anthropometric and weight status in children and adolescents. This relationship is not maintained for WC after controlling for MVPA when using the Freedson/Troiano MVPA cut points. Longer continuous bouts of MVPA do not have an effect on other METsRF. Youth who participate in longer continuous bouts of MVPA, also accumulate more minutes per day of MVPA. Future investigations are needed to determine if the effects of MVPA bout patterns on METsRF are similar in children compared with adolescents. Also, studies are

needed to determine if prescribing physical activity in longer bouts is an effective intervention strategy for weight management in children and adolescents.

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Table 1

Maximum Standardized Effect Sizes for Unweighted and Propensity Score Weighted Covariates

Characteristics	Evanson cut points		Freedson/Saint-Maurice		Freedson/Saint-Maurice	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size
Female	0.79	0.22 ^a	0.67	0.12	0.76	0.17
Minority	0.43	0.12	0.40	0.19	0.37	0.19
Asthma (no)	0.09	0.05	0.06	0.03	0.11	0.11
Asthma (yes)	0.09	0.05	0.06	0.03	0.12	0.11
Asthma (missing)	0.03	0.04	0.03	0.05	0.03	0.03
Physical disability (yes)	0.12	0.07	0.13	0.06	0.10	0.07
HEI-2015 quartile 1	0.17	0.09	0.20	0.04	0.20	0.04
HEI-2015 quartile 2	0.10	0.07	0.02	0.08	0.15	0.10
HEI-2015 quartile 3	0.09	0.06	0.08	0.10	0.05	0.03
HEI-2015 quartile 4	0.20	0.05	0.22	0.06	0.24	0.13
HEI-2015 missing	0.14	0.09	0.13	0.16	0.12	0.08
PIR quartile 1	0.12	0.09	0.07	0.05	0.09	0.11
PIR quartile 2	0.07	0.08	0.09	0.07	0.10	0.12
PIR quartile 3	0.09	0.05	0.06	0.04	0.06	0.04
PIR quartile 4	0.14	0.06	0.13	0.07	0.13	0.10
PIR missing	0.11	0.07	0.11	0.08	0.13	0.13
Age (6–9 y)	0.33	0.13	0.33	0.20	0.66	0.15
Age (10–13 y)	0.11	0.11	0.14	0.13	0.26	0.07
Age (14–18 y)	0.38	0.06	0.40	0.07	0.69	0.19
MVPA quartile 1	1.73	0.26 ^a	1.62	0.21 ^a	1.90	0.26 ^a
MVPA quartile 2	0.60	0.18	0.51	0.14	0.43	0.12
MVPA quartile 3	0.59	0.05	0.54	0.05	0.56	0.06
MVPA quartile 4	1.12	0.28 ^a	1.13	0.25 ^a	0.99	0.24 ^a
Sedentary time quartile 1	0.23	0.14	0.23	0.11	0.43	0.19
Sedentary time quartile 2	0.08	0.08	0.05	0.05	0.09	0.08

Characteristics	Evenson cut points				Freedson/Saint-Maurice				Freedson/Saint-Maurice			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size	Maximum standard effect size
Sedentary time quartile 3	0.16		0.06		0.21		0.05		0.26		0.07	
Sedentary time quartile 4	0.20		0.05		0.12		0.10		0.35		0.05	
LPA quartile 1	0.34		0.07		0.33		0.09		0.40		0.13	
LPA quartile 2	0.17		0.04		0.16		0.19		0.17		0.07	
LPA quartile 3	0.08		0.04		0.16		0.05		0.20		0.13	
LPA quartile 4	0.36		0.14		0.36		0.22 ^a		0.26		0.10	
Assessment period	0.14		0.02		0.13		0.03		0.12		0.12	

Abbreviations: HEI, Healthy Eating Index; LPA, light physical activity; MVPA, moderate to vigorous physical activity; PIR, poverty-income ratio.

^a Absolute maximum standardized differences greater than 0.20 are considered to be moderate effect size differences and to obtain a more robust estimation these covariates were included in the final models.

Population-Weighted Characteristics of the Eligible Sample and the Analysis Sample of US youth 6 to 18 years (NHANES 2003–2006)

Table 2

Descriptive variables	Eligible sample				Analysis sample			
	N	Mean, %	95% CL	N	Mean, %	95% CL		
Age, y	5943	12.3	12.0	12.5	3165	12.2	11.9	12.4
Female, %	2951	48.9	47.4	50.5	1568	48.9	46.6	51.2
Minority, %	4373	38.6	32.9	44.3	2358	38.4	31.5	45.2
Weight, kg	5902	51.8	50.6	53.0	3151	51.3	49.9	52.6
Height, cm	5900	152.7	151.6	153.8	3150	152.5	151.4	153.6
BMI, %ile	5897	63.6	62.0	65.2	3149	63.5	61.4	65.7
PIR	5676	2.6	2.4	2.8	3037	2.6	2.5	2.8
HEI-2015 total score	5597	51.1	50.1	52.1	3013	52.5	51.4	53.6
Asthma								
Yes	999	16.8	15.5	18.1	520	15.7	13.9	17.5
No	4936	83.1	81.8	84.4	2639	84.1	82.4	85.9
Missing	8	0.1	0.1	0.2	6	0.1	0.0	0.3
Physical disability								
Yes	294	4.7	4.0	5.3	155	4.4	3.5	5.3
No	5647	95.3	94.6	96.0	3010	95.6	94.7	96.5
Missing	2	0.03	0.00	0.08	0	0.0	0.0	0.0

Abbreviations: %ile, percentile; BMI, body mass index; CL, confidence limits; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey; PIR, poverty-income ratio.

Table 3
Average Accelerometer Data of the Analysis Sample of US Youth 6–18 Years (NHANES 2003–2006) by Cut Points

Variable	Quartile 1 (n = 791)		Quartile 2 (n = 791)		Quartile 3 (n = 792)		Quartile 4 (n = 791)	
	Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL
Evenson								
Wear time, min/d	845.4	832.8	857.9	850.4	838.4	862.4	859.9	838.8
Average intensity, cpm	423.9	399.3	448.5	466.4	445.9	486.9	537.0	513.0
MVPA bouts, %								
Sporadic (<5 min)	98.9	98.8	99.0	96.1	96.0	96.2	92.8	92.9
Short (5–9.9 min)	1.0	0.9	1.0	3.3	3.1	3.4	5.3	5.5
Medium-long (10 min)	0.2	0.1	0.2	0.6	0.5	0.7	1.9	2.1
Sedentary, min/d	451.2	435.5	466.9	446.9	434.6	459.3	449.9	432.6
LPA, min/d	363.3	351.9	374.7	364.2	354.6	373.8	357.3	347.8
MVPA, min/d	30.9	28.2	33.6	39.3	36.4	42.1	45.3	42.8
Variable	Quartile 1 (n = 789)		Quartile 2 (n = 793)		Quartile 3 (n = 792)		Quartile 4 (n = 791)	
	Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL
Freedson/Saint-Maurice								
Wear time, min/d	851.9	838.6	865.2	851.7	840.3	863.1	844.8	829.3
Average intensity, cpm	423.9	398.2	449.6	478.5	456.3	500.7	502.6	481.2
MVPA bouts, %								
Sporadic (<5 min)	99.3	99.2	99.3	96.6	96.5	96.7	93.4	93.2
Short (5–9.9 min)	0.7	0.6	0.8	2.8	2.7	2.9	5.1	4.8
Medium-long (10 min)	0.1	0.1	0.1	0.6	0.5	0.6	1.5	1.3
Sedentary, min/d	454.9	440.4	469.5	446.4	434.8	458.0	442.2	425.9
LPA, min/d	372.3	360.6	384.0	372.6	362.1	383.0	366.3	356.8
MVPA, min/d	24.7	22.2	27.1	32.7	30.5	35.0	36.3	34.1
Variable	Quartile 1 (n = 790)		Quartile 2 (n = 791)		Quartile 3 (n = 791)		Quartile 4 (n = 791)	
	Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL
Freedson/Troiano								
Wear time, min/d	842.6	828.1	857.1	844.3	832.3	856.3	849.6	832.7
Average intensity, cpm	389.4	369.6	409.2	449.8	429.5	470.2	504.7	486.4

Variable	Quartile 1 (n = 791)			Quartile 2 (n = 791)			Quartile 3 (n = 792)			Quartile 4 (n = 791)		
	Mean	95% CL		Mean	95% CL		Mean	95% CL		Mean	95% CL	
MVPA bouts, %												
Sporadic (<5 min)	99.0	98.9	99.0	95.6	95.5	95.8	91.9	91.8	92.1	85.0	84.2	85.8
Short (5–9.9 min)	0.9	0.8	1.0	3.5	3.3	3.6	5.8	5.6	6.1	10.1	9.5	10.7
Medium-long (10 min)	0.2	0.1	0.2	0.9	0.8	1.0	2.2	2.0	2.5	4.9	4.2	5.5
Sedentary, min/d	465.3	447.1	483.5	451.2	435.6	466.9	439.6	419.7	459.4	444.9	431.9	457.8
LPA, min/d	348.5	340.4	356.7	347.1	338.0	356.2	352.7	341.4	364.0	348.1	340.7	355.4
MVPA, min/d	28.8	25.8	31.8	46.0	42.1	49.8	57.4	53.6	61.1	69.5	63.8	75.1

Abbreviations: CL, confidence limits; cpm, counts per minute; LPA, light physical activity; MVPA, moderate to vigorous physical activity; NHANES, National Health and Nutrition Examination Survey.

Adjusted Means (95% CL) for Continuous METsRF Variables Across Quartiles of MVPA Bout Patterns in US Youth 6–18 Years (NHANES 2003–2006) by Median Split of MVPA

Table 4

Variable	Quartile 1				Quartile 2				Quartile 3				Quartile 4				<i>P</i> _{trend}
	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL		
Evenson cut points																	
BMI, ^a %ile	784	65.5	61.6	69.4	789	65.1	61.4	68.7	787	61.2	57.4	65.0	789	61.0	57.7	64.3	.023 *
WC, ^a cm	774	75.1	73.3	76.9	779	74.0	72.2	75.8	779	72.0	70.6	73.4	780	73.4	71.6	75.3	.051
WC, ^a %ile	706	60.3	56.9	63.7	734	60.4	56.5	64.3	741	56.4	52.6	60.1	714	56.2	53.0	59.5	.013 *
Waist to height ratio ^a	706	0.49	0.48	0.50	735	0.49	0.48	0.50	743	0.48	0.47	0.48	714	0.47	0.46	0.48	.001 *
Systolic BP, ^b mm Hg	482	108.1	106.7	109.6	417	108.8	107.3	110.4	407	108.0	106.3	109.8	484	106.2	104.5	107.9	.094
Diastolic BP, ^b mm Hg	482	58.2	56.1	60.3	417	59.1	57.0	61.3	407	58.5	55.6	61.4	484	58.7	56.3	61.1	.81
Total cholesterol, ^b mg/dL	699	162.2	157.0	167.3	714	159.5	153.8	165.3	695	162.6	157.6	167.5	725	155.4	149.7	161.2	.18
HDL cholesterol, ^b mg/dL	699	50.4	48.7	52.2	714	50.7	48.2	53.2	695	52.8	51.4	54.1	725	51.9	49.2	54.6	.21
LDL cholesterol, ^b mg/dL	293	91.7	85.2	98.2	269	93.3	85.6	101.0	272	95.3	87.2	103.3	327	85.3	77.5	93.1	.20
Triglycerides, ^b mg/dL	294	99.5	78.4	120.5	269	91.1	75.6	106.5	273	84.4	76.5	92.2	327	84.4	71.9	96.8	.12
Glucose, ^b mg/dL	246	89.7	87.8	91.6	196	91.2	87.7	94.8	198	89.7	87.4	92.1	266	91.8	89.9	93.7	.31
Insulin, ^b uU/mL	239	12.4	11.0	13.8	192	13.3	11.6	15.0	195	13.2	10.9	15.6	264	13.6	11.5	15.7	.21
Freedson/Saint-Maurice cut points																	
BMI, ^c %ile	781	66.9	62.8	71.0	792	65.4	62.6	68.3	788	61.0	57.4	64.7	788	59.2	55.8	62.7	.002 *
WC, ^c cm	770	75.8	73.9	77.7	781	74.4	72.9	75.8	781	72.5	71.4	73.6	780	71.9	70.1	73.7	<.001 *
WC, ^c %ile	711	61.6	57.8	65.4	737	60.8	58.1	63.5	735	56.7	53.3	60.2	712	54.0	50.9	57.1	<.01 *
Waist to height ratio ^c	712	0.49	0.48	0.50	737	0.49	0.48	0.49	737	0.48	0.47	0.48	712	0.47	0.46	0.48	<.01 *
Systolic BP, ^d mm Hg	462	108.3	106.6	110.0	405	108.8	107.0	110.6	435	108.4	106.9	109.9	488	106.1	104.4	107.7	.029 *
Diastolic BP, ^d mm Hg	462	58.5	56.1	60.8	405	58.3	56.3	60.3	435	58.9	56.6	61.3	488	57.9	55.1	60.8	.85

Variable	Quartile 1				Quartile 2				Quartile 3				Quartile 4				<i>P</i> _{trend}
	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>n</i>	Mean	95% CL	<i>P</i> _{trend}	
Total cholesterol, ^d mg/dL	469	159.9	154.8	165.0	398	161.1	156.5	165.7	403	160.4	155.8	165.0	566	159.0	153.7	164.4	.79
HDL cholesterol, ^d mg/dL	469	51.0	49.0	53.0	398	50.4	48.2	52.5	403	51.6	49.2	54.0	566	52.7	50.4	55.0	.13
LDL cholesterol, ^d mg/dL	224	86.7	81.1	92.3	180	90.2	83.8	96.5	204	93.3	86.1	100.5	281	88.0	80.2	95.7	.58
Triglycerides, ^d mg/dL	225	92.1	80.6	103.5	181	93.0	76.2	109.8	204	94.1	85.7	102.5	281	82.7	74.1	91.3	.15
Glucose, ^d mg/dL	230	90.2	88.8	91.6	184	89.3	87.4	91.2	208	94.0	89.1	98.9	284	91.3	87.7	94.8	.04
Insulin, ^d uU/mL	223	13.1	11.5	14.8	180	12.5	10.7	14.3	206	13.1	10.5	15.6	281	13.6	11.4	15.8	.59
Freedson/Troiano cut points																	
BMI, ^e %ile	781	69.7	65.1	74.3	790	62.7	59.0	66.3	786	62.1	58.7	65.6	790	58.8	55.9	61.6	.01*
WC, ^e cm	769	77.0	75.4	78.7	778	74.1	72.4	75.9	779	73.1	71.9	74.4	784	72.7	71.6	73.8	<.001*
WC, ^e %ile	700	66.4	62.8	70.0	731	59.4	55.9	62.9	740	58.3	54.8	61.9	722	52.5	49.9	55.1	<.001*
Waist to height ratio ^e	700	0.5	0.5	0.5	732	0.5	0.5	0.5	742	0.5	0.5	0.5	722	0.5	0.5	0.5	<.001*
Systolic BP, ^f mm Hg	519	107.1	105.9	108.4	443	108.0	106.2	109.8	392	107.6	106.0	109.1	434	108.1	106.3	109.9	.41
Diastolic BP, ^f mm Hg	519	57.7	55.5	59.8	443	59.5	57.7	61.3	392	58.0	55.0	61.0	434	58.5	56.2	60.8	.80
Total cholesterol, ^f mg/dL	594	164.2	158.7	169.6	427	159.2	153.6	164.8	342	162.9	157.0	168.8	471	156.4	151.9	160.9	.059
HDL cholesterol, ^f mg/dL	594	50.9	48.4	53.4	427	50.2	47.6	52.7	342	52.9	50.6	55.1	471	52.3	49.5	55.1	.11
LDL cholesterol, ^f mg/dL	280	91.7	83.5	100.0	202	89.9	83.1	96.7	173	94.5	85.3	103.8	233	86.2	78.2	94.2	.40
Triglycerides, ^f mg/dL	281	101.5	80.7	122.3	203	89.0	77.6	100.4	173	84.2	74.9	93.6	233	82.6	71.1	94.1	.093
Glucose, ^f mg/dL	287	90.3	88.7	91.8	208	92.2	87.9	96.5	174	92.0	89.3	94.6	236	90.5	88.7	92.4	.91
Insulin, ^f uU/mL	278	12.0	10.4	13.5	204	12.4	10.4	14.4	173	14.2	11.6	16.9	234	11.7	10.3	13.1	.79

Abbreviations: %ile, percentile; BMI, body mass index; BP, blood pressure; CL, confidence limits; HDL, high-density lipoprotein; LDL, low-density lipoprotein; METsRF, metabolic syndrome risk factors; MVPA, moderate to vigorous physical activity; NHANES, National Health and Nutrition Examination Survey; WC, waist circumference. Note: Triglycerides, glucose, and insulin were only collected on subjects aged 12–17.9 years and who fasted at the time of data collection.

^aPropensity score weighted and additionally controlled for sex and quartile of MVPA;

^bAdditionally controlled for BMI %ile.

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^c Propensity score weighted and additionally controlled for quartiles of MVPA and light physical activity.

^d Additionally controlled for BMI %ile.

^e Propensity score weighted and additionally controlled for quartiles of MVPA..

^f Additionally controlled for BMI %ile.

* Statistical significance at $P < .05$.

Table 5

Adjusted Means (95% CL) for Continuous METsRF Variables Across Quartiles of MVPA Bout Patterns in US Youth 6–18 Years (NHANES 2003–2006) by Median Split of MVPA

Variable	Quartile 1		Quartile 2		Quartile 3		Quartile 4		<i>P</i> _{Interaction}
	Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL	
Evenson cut points									
BMI, ^a %ile									.57
MVPA < 38.3 min/d	68.4	65.0 71.8	66.2	62.3 70.0	63.6	57.9 69.2	62.1	54.8 69.5	
MVPA 38.3 min/d	62.0	54.2 69.9	64.3	59.5 69.1	58.9	54.1 63.6	59.5	56.2 62.8	
WC, ^a cm									.91
MVPA < 38.3 min/d	79.7	77.8 81.5	77.6	75.6 79.5	75.5	73.2 77.8	77.3	74.0 80.6	
MVPA 38.3 min/d	71.1	67.2 75.1	70.8	68.0 73.6	68.1	66.5 69.7	69.4	67.6 71.2	
WC, ^a %ile									.66
MVPA < 38.3 min/d	65.3	62.0 68.5	63.1	58.3 67.9	60.3	54.2 66.4	60.2	53.4 67.0	
MVPA 38.3 min/d	56.2	49.2 63.2	58.5	53.7 63.3	52.2	47.8 56.6	52.3	48.1 56.4	
Waist to height ratio ^a									.81
MVPA < 38.3 min/d	0.50	0.49 0.51	0.49	0.48 0.50	0.48	0.47 0.50	0.48	0.46 0.50	
MVPA 38.3 min/d	0.48	0.46 0.51	0.48	0.47 0.50	0.47	0.46 0.48	0.47	0.46 0.47	
Freedson/Saint-Maurice cut points									
BMI, ^b %ile									.97
MVPA < 31.0 min/d	68.4	65.4 71.3	67.0	62.6 71.4	61.6	57.1 66.1	59.4	52.1 66.8	
MVPA 31.0 min/d	66.3	57.8 74.9	64.5	59.6 69.3	60.5	54.5 66.4	58.7	55.5 61.8	
WC, ^b cm									.68
MVPA < 31.0 min/d	77.2	75.3 79.1	75.8	74.1 77.6	74.1	72.6 75.7	72.2	69.5 74.9	
MVPA 31.0 min/d	74.9	70.6 79.2	73.0	70.7 75.4	70.8	69.0 72.7	71.1	69.5 72.8	
WC, ^b %ile									.81
MVPA < 31.0 min/d	63.7	60.2 67.2	63.3	59.0 67.7	59.9	55.1 64.7	54.9	48.1 61.7	
MVPA 31.0 min/d	62.2	54.7 69.7	59.2	54.2 64.1	53.7	48.3 59.0	52.6	49.1 56.1	
Waist to height ratio ^b									.59

Variable	Quartile 1		Quartile 2		Quartile 3		Quartile 4		<i>P</i> _{interaction}			
	Mean	95% CL	Mean	95% CL	Mean	95% CL	Mean	95% CL				
MVPA < 31.0 min/d	0.50	0.49	0.51	0.49	0.49	0.50	0.49	0.48	0.50	0.47	0.46	0.49
MVPA 31.0 min/d	0.48	0.46	0.50	0.48	0.47	0.49	0.47	0.46	0.47	0.46	0.46	0.47
Freedson/Troiano cut points												
BMI, ^c %ile												.49
MVPA < 40.4 min/d	68.8	66.0	71.6	64.9	60.4	69.4	63.9	59.1	68.7	58.6	52.4	64.8
MVPA 40.4 min/d	73.6	61.8	85.5	60.5	55.8	65.3	60.8	56.6	65.0	58.2	54.4	62.0
WC, ^c cm												.004*
MVPA < 40.4 min/d	81.6	80.2	83.1	80.4	78.7	82.1	79.2	77.3	81.0	77.1	74.9	79.4
MVPA 40.4 min/d	77.3	73.0	81.6	68.3	65.6	71.0	66.8	65.0	68.5	66.2	64.4	68.0
WC, ^c %ile												.001*
MVPA < 40.4 min/d	66.2	63.0	69.4	64.6	60.8	68.5	61.8	56.4	67.1	54.1	48.7	59.5
MVPA 40.4 min/d	74.9	67.4	82.4	54.9	49.6	60.2	55.0	50.6	59.3	49.1	44.7	53.5
Waist to height ratio ^c												.077
MVPA < 40.4 min/d	0.50	0.49	0.51	0.49	0.48	0.50	0.48	0.47	0.50	0.47	0.45	0.48
MVPA 40.4 min/d	0.52	0.50	0.55	0.48	0.46	0.49	0.47	0.47	0.48	0.46	0.46	0.47

Abbreviations: %ile, percentile; BMI, body mass index; BP, blood pressure; CL, confidence limits; METsRF, metabolic syndrome risk factors; MVPA, moderate to vigorous physical activity; NHANES, National Health and Nutrition Examination Survey; WC, waist circumference. Note: Triglycerides, glucose, and insulin were only collected on subjects aged 12–17.9 years and who fasted at the time of data collection.

^aPropensity score weighted and additionally controlled for sex and MVPA.

^bPropensity score weighted and additionally controlled for MVPA and light physical activity.

^cPropensity score weighted and additionally controlled for MVPA.

* Statistical significance at $P < .05$.