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Accelerometer-Measured Physical Activity in Youth: Association with Adiposity-Related Health Indicators in NHANES 2003-2006

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Accelerometer-Measured Physical Activity in Youth: Association with Adiposity-Related Health Indicators in NHANES 2003-2006

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TABLE OF CONTENTS

ABSTRACT

BACKGROUND: Physical activity has numerous benefits to the cardiometabolic health in adults, yet there is a scarcity of objective evidence about early indicators in youth. Using data from multiple-day use of an accelerometer, we examined if reduced moderate and/or vigorous physical activity (MVPA) in children was associated with increased percent body fat (%BF) and adverse serum C-reactive protein (CRP) and lipid profiles.

METHODS: A cross-sectional analysis was conducted of 1876 participants (age 6-19) from the National Health and Nutrition Examination Survey annual surveillance survey in 2003-06 who wore an ActiGraph© Accelerometer Physical Activity Monitor for at least 10 hours daily for at least 4 days during a 7-day study period. Accelerometer counts were transformed into total minutes of moderate and vigorous intensity physical activity minutes per day. Participants were classified according to: having met or not the American College of Sports Medicine (ACSM) guideline of ≥ 60 minutes of daily MVPA; and, sex and age group (6-11, 12-17, 18-19) specific quartiles of mean MVPA minutes per day. Main outcome was %BF as measured by Holtain© skinfold calipers; exploratory dependent variables were CRP and lipid profiles. Analyses also were stratified by body mass index (BMI) percentile strata: Normal (< 85^{th}), Overweight (85^{th} to < 95^{th}) and Obese (≥95^{th}).

RESULTS: Children 6-11 years were much more likely to meet the ASCM guideline (27.4%; 160/718) compared to those 12-17 (2.5%; 23/925) and 18-19 years (1.7%; 4/239). Children who met the guideline had a lower mean %BF compared to those who engaged in ≥ 60 minutes per MVPA but for only 4-6 days, or, those who engaged in less than 60 minutes MVPA per day (16.9%, 18.2%, 23.4%, respectively, P<.001). This trend was observed in each of the Normal, Overweight, and Obese strata (P <.001 for both). Regarding quartiles of MVPA irrespective of

number of days, increasing sex-age quartiles of MVPA were associated with reduced mean %BF (25.5%, 21.9%, 21.1%, 17.1%, respectively, $p < .001$) in the total study sample. This trend was maintained in both Normal and Overweight strata ($P < .001$, respectively) but did not reach statistical significance in Obese children ($P = .23$). While we found that serum High Density Lipoprotein was significantly higher in the top quartile of MVPA (56.9) compared to the lowest two strata (53.3, 53.8, respectively; $P < .004$ for both), we produced no evidence of a relationship between MVPA and serum levels of CRP, Low Density Lipoprotein, Triglycerides or Total Cholesterol.

CONCLUSIONS: Adherence to the ACSM daily MVPA guideline is relatively low, especially after age 11. Children who reached the ACSM guideline had the lowest levels of body fat. There appears to be an inverse dose-response of MVPA in relation to %BF across quartiles of MVPA and independent of excess body weight.

LIST OF TABLES AND FIGURES

1.0 INTRODUCTION

1.1 Health Benefits of Physical Activity in Youth

Participation in regular physical activity (PA) has numerous benefits to ones current and future health. Being physically active provides lifelong health benefits including weight management, increased strength and endurance, and improved psychosocial health (US Department of Health and Human Services (HHS), 2014). Promotion of PA in youth is becoming a public health priority in response to the obesity epidemic and as evidenced by the "Let's Move" campaign that was launched by First Lady Michelle Obama in 2010 (Letsmove.gov, 2015). This program was developed as part of the first federally approved Physical Activity Guidelines for Americans released by the United States Department of Health and Human Services (HHS, 2014). According to a recent Institute of Medicine report on Fitness Measures and Health Outcomes in Youth (IOM, 2012), poor fitness levels in youth are associated with adverse health outcomes such as obesity or diabetes, which are risk factors for future cardiovascular disease (American Academy of Pediatrics (AAP), 2011). Children and adolescents are experiencing rapid bouts of change physiologically, skeletally, and developmentally during growth and maturation (Wilmore, Costill & Kenney, 2008). To reach their full growth and developmental potential, key elements of age-appropriate PA is necessary to achieve positive health outcomes such as healthy weight, bone health, and muscle development (HHS, 2014; Nettle & Sprogis, 2011).

1.2 Physical Activity Guidelines for Youth

The 2008 Physical Activity Guidelines call for children and adolescents to engage in at least 60 minutes per day of moderate to vigorous intensity PA and to include vigorous intensity

PA, resistance exercise, and bone-loading activity at least 3 days per week (HHS, 2014). The guidelines establish the minimum amount of PA necessary to achieve health-related benefits from daily exercise of moderate to vigorous intensity. The American College of Sports Medicine (ACSM) outlines aerobic exercise recommendations in the context of FITT: Frequency (i.e., typical times per week), Intensity (i.e., light, moderate, vigorous), Time (i.e., typical duration per event), and Type (i.e., strength, endurance). Individual exercise intensity varies with level of fitness. Moderate-intensity PA requires a moderate amount of effort and noticeably elevates heart rate and respiratory rate. Vigorous-intensity PA requires increased effort with substantial elevation in heart rate and respiratory rate (ACSM, 2014). The ACSM recommendations for aerobic activity fully align with the 2008 Physical Activity Guidelines listed above, and, moderate to vigorous intensity activities include running, brisk walking, swimming, dancing, and bicycling (ACSM, 2014) with the goal being to participate in physical activities that are developmentally appropriate, enjoyable, and promote life-long health benefits (HHS, 2014).

1.3 Physical Activity and Health Indicators

The association of PA with positive health outcomes and improved cardiometabolic health including blood pressure control, reduced insulin sensitivity, and improved lipid profiles is well documented in adults (Fischer, Berntsen, Perstrup, Eskildsen, & Pedersen, 2007; Kokkinos & Myers, 2010; Warnberg, Cunningham, Romeo, & Marcos, 2010). While improved cardiometabolic risk factors in youth are predicted to have positive long-term effects on health outcomes (Carson & Janssen, 2011), the actual association with PA in youth is not as well documented in children (Belcher, et al., 2014). These metabolic risk factors not only include elevated blood pressure, altered lipid levels, and central adiposity, but also increased levels of markers associated with chronic low-level systemic inflammation such as C-reactive protein (CRP) and interleukin-6 (Sacheck, 2008). There is some evidence of a causal relationship

between the rise in obesity and increased prevalence of metabolic risk factors in children and adolescents (Biro & Wien, 2010). Children with obesity are at increased risk for diseases previously not diagnosed until adulthood including hypertension, hyperlipidemia, and type 2 diabetes (AAP, 2006). Obesity places children and adolescents at risk of physiologic manifestations secondary to increased adiposity. Decreased levels of PA below a certain threshold may contribute to the obesity epidemic due to an energy imbalance, lowered basal metabolic rate, resulting in increased fat mass (AAP, 2011; Harrington, 2013). This may also be explained by calorie dense, high fat diets (Brownell, Schwartz, Puhl, Henderson, & Harris, 2009), decreased PA in school (AAP, 2011), increased sedentary behavior, or all factors combined.

Inflammatory markers have been shown to be associated with obesity, including acute phase proteins and pro-inflammatory cytokines. CRP, as an acute phase reactant, is a sensitive marker of inflammation and has been identified as a strong predictor of cardiovascular risk for adults (Ridker, 2003). The American Heart Association identifies CRP as the most clinically useful of the markers of inflammation to assess risk for coronary disease (Pearson et al., 2003; Warnberg, et al., 2010). Chronic low-grade systemic inflammation is associated with cardiovascular disease and type 2 diabetes (Danesh et al., 2004; Duncan et al., 2003; Parrett, Valentine, Arngrimsson, Castelli, & Evans, 2010; Petersen & Pedersen, 2005). Several parameters of the inflammatory reaction can be measured in plasma. Healy (2011) showed that sedentary time was correlated with elevated CRP in United States (US) adults by examining the associations of objectively measured sedentary time.

Physical activity as a modifiable risk factor for obesity offers a potential therapeutic approach to mitigate inflammation associated with excess adiposity and promotes anti-inflammatory effects (Warnberg, et al., 2010). Most of the research examining the influence of

PA on low-grade inflammation has studied the general adult population and athletes (Ford, 2002; Gaesser, Angadi, Ryan, & Johnston, 2012). Warnberg and colleagues (2010) reviewed large population cohort studies, such as the National Health and Nutrition Examination Survey (NHANES), the Nurses' Health Study II, and the Women's Health Study, found evidence of an inverse, independent dose-response relationship between plasma CRP and level of PA in both men and women. Few studies examining the relationship between PA and inflammatory markers in youth have been reported (Andersen, Riddoch, Kriemer & Hills, 2011).

More recent data support the importance of promoting PA to potentially modify inflammation associated with overweight and obesity in youth. Sadeghipour (2010) found Body Mass Index (BMI) was the most powerful predictor of serum concentration of CRP in children, thus emphasizing the importance of controlling body weight and preventing the progression to chronic cardiovascular disease. McVean, Carrel, Eickhoff, and Allen (2009) concluded in a sample of 75 non-obese children ages 11-14 with a BMI < 95th percentile that low levels of PA and higher body fat are associated with inflammation, thus higher levels of CRP.

Freedman and colleagues (2009), found 70% of children (n=200) with a BMI for age between the 85th and 94th percentiles had a moderate or higher level of body fatness. However, 30% had body fatness within the range of normal weight (<85th percentile). BMI among normal weight children was not considered to be diagnostic of body fatness and not a valid predictor of percent body fat (%BF) (Bray, 2002; Freedman et al., 2009). There are limited studies on whether normal weight children who do not engage in moderate to vigorous PA (MVPA) show early signs of adverse health outcomes.

1.4 Objectively Measured Physical Activity Versus Self-report

Measuring PA in children is difficult due to their natural inclination to run, jump and play in bouts and sporadic periods (Holman, Carson, & Janssen, 2011). Identification of the type, frequency, and duration of PA during childhood and adolescence are important to determine associations with positive health outcomes (Rowland, 2007). Estimates of PA and sedentary behavior have been based on self-report measures (Platat, Wagner, Klumpp, Schweitzer, & Simon, 2006; Saunders, Prince, & Tremblay, 2011). One such commonly used questionnaire is the International Physical Activity Questionnaire (IPAQ), which provides a comprehensive measure of activity (Celis-Morales et al., 2012). However, PA data derived from self-report are subject to potential response preference. Celis-Morales, et al. (2012), use of the IPAQ led to significant over-reporting of PA and under-reporting of sedentary behavior.

Due to the challenges of self-report, an increasing number of studies using objectively measured PA are in the literature, many with small samples (Nettlefold, McKay, Naylor, Bredin, & Warburton, 2012) and few from large, population-based samples. Troiano and colleagues (2008) reported on accelerometer measured PA using data from the NHANES 2003-2004 in a representative sample of US children, adolescents, and adults. NHANES reported that 42% of children 6-11 year, 8% of 12-15 year, and 7.6% of 16-19 year accumulated 60 mins of MVPA on most days of the week (Troiano et al., 2008). An accelerometer is an activity monitor worn on the body designed to detect forward movement and transmit output data on duration and intensity of PA (Bonomi, 2009). The use of accelerometry-based activity monitors to measure free-living PA in youth has been increasing in the literature (Bornstein, Beets, Byun, & Welk, 2011). Ekeland et al., (2012) conducted a pooled analysis of 14 studies between 1998 and 2009 comprising 20,871 children (age 4-18) from the International Children's Accelerometry Database. The authors concluded that higher MVPA time by children and adolescents was

associated with better cardiometabolic risk factors regardless of the amount of sedentary time (Ekelund et al., 2012). Belcher et al., (2014) examined self-report versus accelerometer measured MVPA from NHANES 2003-06 survey data in children and adolescents 12-17 year and biomarkers including BMI, waist circumference, triceps and subscapular skinfolds, blood pressure, lipids, CRP, insulin and glycohemoglobin. The authors did not include a measure of %BF as an obesity-related biomarker in youth. Additionally, Belcher et al., (2014) did not include the 6-11 age group in their study.

1.5 Problem Statement and Research Aims

The use of accelerometry provides an objective measure of PA and may better reflect relationships between PA and health outcomes than self-report (Loprinzi, et al., 2012; Ekelund et al., 2012). Assessing the association between objectively measured PA and health indicators in youth ages 6-19 years in relation to PA guidelines provides an opportunity to clarify potential targets for intervention, given the long-latency of chronic diseases. Moreover, we hypothesize that, among those who do not engage in adequate PA, adverse health indicators will be present in normal weight children as well as those who are obese or overweight. Hence, Aim 1 is to determine if there are adverse associations between reduced PA and %BF across the BMI spectrum. Aim 2 is to assess if metabolic effects typically seen in adulthood, such as elevated CRP and altered lipid levels including measures of total cholesterol, triglycerides, LDL and HDL also are present in children. The Institute of Medicine Committee on Fitness Measures and Health Outcomes in Youth, mentioned above, suggests that investigations of PA include BMI as an estimate of body weight, skinfold thickness at the triceps and subscapular skin folds as indicators of underlying fat proportion, and waist circumference as an indicator of abdominal fat. Measures of body composition can be influenced by factors such as level of PA, age and diet (IOM, 2012).

2.0 METHODS

2.1 Study Population

This study sample was derived from the Nutrition Health and Nutrition Examination Survey (NHANES) 2003-2004 and 2005-2006 cycles. Since 1999, NHANES has been a continuous survey designed to assess the health and nutritional status of children, adolescents, and adults in the United States. NHANES is a complex, multi-stage, probability sample representative of the civilian, non-institutionalized United States population. Participants are interviewed in their homes and subsequently examined in mobile examination centers (MEC) across 15 geographic locations. The survey was approved by the National Center for Health Statistics ethics review board and informed consent was obtained from all participants prior to data collection. Written child assent was obtained from children aged 7-11 years, written informed consent was obtained from children 12 years or older and written parental consent was obtained for those younger than 18 years of age. Detailed survey operations manuals, consent documents, brochures of the NHANES 2003-2004 and 2005-2006, and all relevant documentation can be found at www.cdc.gov/nchs/nhanes.htm.

2.2 Eligibility and Exclusion Criteria

Of the 10,485 children 6-19 years in the NHANES 2003-06 cycles, 2844 were randomly selected to wear the accelerometer for a 7-day period. Of these, 1876 wore the accelerometer for at least 10 hours per day for at least 4 days (Fig. 1), which is the NHANES default definition of valid days for analysis of monitor data (National Cancer Institute, 2014). NHANES excluded individuals who used a wheelchair for mobility (CDC, 2011). Participant characteristics

regarding age, gender, ethnicity, and medical history regarding asthma were obtained from a questionnaire during a household interview (CDC, . Three age categories were defined: children (6-11 years), adolescents (12-17 years), and older teens (18-19 years).

2.3 Physical Activity Variables

PA was measured by the Actigraph© accelerometer (Actigraph 7164; Actigraph, LLC, Fort Walton Beach, FL; CDC, 2011), which is a single axis monitor that has been programmed to detect normal human motion, records integrated acceleration as an activity count, and provides an objective estimate of intensity of movement. Survey participants were instructed to wear the activity monitor on a waist belt for 7 days during waking hours. The monitors were removed before going to bed. The device is not waterproof so that the participants were to remove the monitor during water sports or bathing (CDC, 2011). At the end of a full 7 days of wear, the monitor was mailed in an envelope provided by the study investigators. Summary PA data were calculated into mean minutes per day of either moderate or vigorous activity per day, and the combined total, using SAS software code provided by the National Cancer Institute (2014), a public-use protocol (http://riskfactor.cancer.gov/tools/nhanes_pam/).

As stated, we followed the NHANES default validation threshold for analyzable PA data: a valid day is a day in which the subject wore the monitor for 10+ hours; and a person with valid data for analyses wore the monitor for 4+ valid days. Two index variables were constructed: Met Daily Guideline (mean of $\geq$ 60 mins per day for seven days, mean of $\geq$ 60 mins per day for 4-6 days and mean < 60 mins per day for all days); and, age-sex specific quartiles of mean accumulated MVPA per day. MVPA quartiles were obtained separately for males and females in three age categories (age 6-11, 12-17, 18-19 years), and consolidated into a single variable.

The distribution and quartiles of mean minutes of MVPA per day by each age and sex category are found in Supplemental Table A.

2.4 Anthropometric and Biochemical Variables

Body composition measures for height, weight and skinfold measurement were collected in the MEC for purposes of assessing growth and body fat distribution. Standing height was an assessment of vertical size. Weight was measured in pounds with a Toledo© digital scale and converted to kilograms in the automated system. Skinfolds were measured on the right side of the body using Holtain© skinfold calipers. Triceps and subscapular skinfolds were measured to the nearest 0.1millimeter. Detailed procedure descriptions can be found in the NHANES procedure manuals www.cdc.gov/nchs/nhanes.htm. BMI was calculated from measured height and weight at the MEC (CDC, 2004). BMI calculated as the ratio of weight to the square of height (kg/m2) was used to classify normal, overweight, and obese categories among children and adolescents. The sex-specific cut points were: normal <85th percentile; overweight >85th and < 95th percentile; and, obese as ≥95th percentile (CDC, 2014). Percent body fat was calculated using Slaughter equations based on caliper measurements of triceps and subscapular skinfolds (Slaughter et al., 1988; Gurka et al., 2010; Hoffman, Toro-Ramos, Sawaya, Roberts, & Rondo, 2012). Participants missing triceps (n=77) and subscapular (n=151) skinfold data were excluded from analyses.

Males: $1.21^{*}(\text{triceps} + \text{subscapular}) - 0.008^{*}(\text{triceps} + \text{subscapular})^{2} - 1.7$
Females: $1.33^{*}(\text{triceps} + \text{subscapular}) - 0.013^{*}(\text{triceps} + \text{subscapular})^{2} - 2.5$

If the sum of the triceps and subscapular measurements are > 35, however, the following equations are suggested (Dezenberg, Nagy, Gower, Johnson & Goran, 1999):

Males: $0.783^{*}(\text{triceps} + \text{subscapular}) + 1.6$
Females: $0.546^{*}(\text{triceps} + \text{subscapular}) + 9.7$

Serum samples for CRP were obtained during examination at the MEC from participants 6 years of age and older. CRP levels were measured and reported to the nearest hundredth. Additionally, lipid measurements including total cholesterol, triglycerides, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were obtained from blood samples at the MEC. These measures were chosen based on their availability in the NHANES dataset and are indicators of cardiometabolic risk (Daniels & Greer, 2008). Triglycerides and LDL data were not obtained on participants <12 yrs. Trained personnel took all measurements at the MEC visit. Detailed procedure manuals can be found at www.cdc.gov/nchs/nhanes.htm.

2.5 Statistical Analysis

The primary independent variable of interest was objectively measured PA from the accelerometer. The average number of valid minutes per day was calculated to identify participants who met the 60+ minutes of MVPA daily defined by ACSM. The main outcome variable was %BF with secondary analyses of CRP and lipid profiles (i.e., total cholesterol, triglycerides, LDL and HDL). One-Way Analysis of Variance (ANOVA) or independent t-Tests were performed to compare mean levels of the outcome variables across categories of MVPA. SPSS Ver. 11.5 (SPSS, Inc., Chicago, IL) was used to generate descriptive and inferential statistics. Statistical significance was determined using p value of < 0.05.

3.0 RESULTS

3.1 Study Sample

Participant characteristics are reported in Table 1. In comparison to excluded children (i.e., did not wear the monitor or did not wear monitor for enough time), there were a

comparable percentage of males and females in both groups. There were slightly more Mexican Americans in the study sample compared to those excluded (34.3% vs 30.4%, respectively, P< .001). Individuals who wore the monitor, however, were younger (P<.001) and tended to have lower % body fat compared to the individuals with no PA data (P< .001). In comparison to all NHANES participants, there was a tendency for the study sample to have lower levels of serum CRP (P=.05), and Triglycerides (P=.02). They also tended to have lower Total Cholesterol, LDL and HDL but these levels did not reach statistical significance (P=.15, P=.12 and P=.16, respectively). Children included in the study had a comparable prevalence of asthma to those who did not have valid wear time (16.5% vs 16.7%, respectively, P=.98).

3.2 Daily MVPA and %BF

Overall, 9.9% (187/1882) of the sample spent a mean of ≥ 60 mins of MVPA per day for the full 7 day study period (Table 2). Males were more likely (11.9%; 112/945) than females (8.0%; 75/937) to have met the ACSM daily guidelines. Children 6-11 years were far more likely to have done so (22.3%; 160/718) compared to children 12-17 years (2.5%; 23/925) and 18-19 years (0.7%; 4/239).

As seen in Table 3, in the full sample, mean %BF was greater in those who engaged in MVPA < 60 mins per day on average compared to individuals who met the recommended level per day (23.4% vs. 16.9%, respectively, P<.001 Bonferroni pairwise comparison test). Those who exercised a mean of ≥ 60 mins per day but only for 4-6 days (18.2%, Bonferroni P<.001). The difference in %BF between the two higher MVPA groups, however, did not reach statistical significance (16.9% vs. 18.2%, respectively, Bonferroni P=.29). Similar trends were observed when stratifying by BMI category (Table 3). For example, among normal weight children, %BF

among those who met the weekly guideline was substantially lower than those who exercised < 60 mins per day on average (14.1% vs. 19.2%, respectively, Bonferroni P<.001).

3.3 Quartiles of Daily MVPA in relation to Percent Body Fat

When assessing daily MVPA in quartiles (Table 4), an inverse dose-response relationship was observed for the full sample as well as in each BMI stratum. For example, for all participants, %BF varied across quartiles of activity (25.5%, 21.9%, 21.1% and 17.1%, F=67.3, P<.001). Pairwise comparisons revealed significant differences in % BF except between Q2 and Q3. Among the normal weight children, %BF in each successive MVPA quartile was significantly lower (21.5%, 18.2%, 16.6% and 14.3%, F=87.7, P<.001). A similar inverse trend was observed among overweight children (F=16.2, P<.001) yet the difference in %BF between Q1 and Q2 was not statistically significant (31.0% vs. 29.2%, Bonferroni P=.67). Although there was a suggested inverse relationship between %BF and MVPA quartiles among obese children (34.4%, 35.2% and 34.1%), this trend was not statistically significant (F=1.5, P=.22).

3.4 Quartiles of Daily MVPA in relation to Serum CRP and Lipid Levels

No relationship was observed between MVPA quartiles with serum CRP (.22, .19, .20, .15, respectively, F=0.88, P=.45), total Lipids (F=1.51, P=.22), LDL (F=.40, P=.76) or Triglycerides (F=.39, P=.57). While the overall trend of increasing HDL level across MVPA quartiles did not reach statistical significance (53.5, 53.8, 54.7, 56.9, respectively, F=6.03, P=.22), post-hoc pairwise comparisons revealed statistically significant differences between Q1 and Q4 (Bonferroni P=.001) and Q2 and Q4 (Bonferoni P=.004).

4.0 DISCUSSION

4.1 Overview

To the best of our knowledge, our study is the first to report an inverse relationship between MVPA and %BF using the continuous NHANES 2003-06 accelerometer data sets. This effect was maintained among normal and overweight children. We contribute to the literature by demonstrating dose-effects when assessing MVPA according to PA guidelines as well as quartiles of activity. In contrast, we showed no such associations with CRP and lipid lipo-protein levels with the possible exception of HDL in which our findings demonstrated a positive impact of increasing MVPA.

4.2 Consistency with Prior Research

Our findings are consistent with Stevens et al. (2007), a study of adolescent American girls in sixth and eighth grades, who found an inverse association between objectively measured PA and reductions in %BF but no association was observed with BMI (Stevens et al., 2007). An association with %BF, and not BMI, may be reflective of differences in body composition changes of girls and boys during adolescence (Must, Barish, & Bandini, 2009). Pubertal changes in adolescent girls are associated with increases in %BF during this stage of growth and development (Stevens et al., 2007).

Our null findings with respect to CRP are inconsistent with some prior evidence, yet only a limited number of studies to date have examined the relationship between PA and inflammatory markers in youth. The Columbia University Bio-Markers Study of children and young adults, ages 6 to 24 years old, showed an inverse correlation between cardiovascular

fitness level and CRP. However, this finding was more pronounced in boys than girls (Isasi et al., 2003). An investigation of 1,520 youths in Quebec conducted, found that vigorous PA was protective of elevated CRP in boys, but CRP and PA was not related in girls (Sabiston et al., 2010). Perhaps we did not find an association because we combined moderate and vigorous PA in classifications. Similar to our study, a recent study by Belcher et al., (2014) using data from NHANES 2003-06 in youth ages 12-17, found neither self-report or accelerometer measures to be associated with total cholesterol or CRP.

Our findings of a lack of elevation in lipids among youth are consistent with some cross-sectional data published to date. In a review of several large-scale prospective youth-based cohorts, Magnussen and colleagues (2013) noted that lipid levels in youth are generally low despite the concomitant adverse risk factors such as poor diet or physical inactivity. In The Amsterdam Growth and Health Longitudinal Study, for example, although increases in body fat were present in adolescence, elevated triglycerides did not emerge until 20 years (Ferreira, van de Laar, Prins, Twisk, & Stehouwer, 2012). This study was a 24-year investigation of 373 children (mean age of 13.1 at baseline) with 2-8 follow-up visits.

Nonetheless, there appears to be a range of lipid levels in youth, and relatively higher values were found to be important predictors of pre-clinical markers of cardiovascular disease in adulthood in a number of studies (Magnussen, Smith, & Juonala, 2013). Specifically, The Amsterdam Growth and Health Longitudinal Study reported that elevated central fatness in adolescence predicted carotid stiffness and metabolic syndrome by the end of the study period. Similarly, higher lipid levels in youth predicted greater carotid intimal-medial thickness in adulthood in the Bogalusa Heart Study (Li et al., 2003) and were linked with adult onset of cardiovascular disease in the Muscatine Study (Davis, Dawson, Riley & Lauer, 2001).

To our knowledge, there have been very few studies of accelerometer-based studies of MVPA among youth in relation to concurrent cardiometabolic profiles and evidence thus far is mixed. As stated previously, Ekeland et al., (2012) conducted a pooled analysis of 14 studies comprising 20,871 children (age 4-18) from the International Children's Accelerometry Database in which they concluded that higher MVPA time by children and adolescents was associated with better cardiometabolic risk factors regardless of the amount of sedentary time (Ekelund et al., 2012). Belcher et al., (2014), in an investigation of accelerometer-measured MVPA from NHANES 2003-06 data among 12-17 year olds, found only weak links between greater MPVA and lipid biomarkers among boys, and no associations among girls. Evidence of a link between childhood PA and adult cardiometabolic risk factors appears to be more robust and extensive. The longitudinal European Youth Heart Study, for example, found that higher objectively-measured PA was not linked to clinically elevated lipid levels at baseline but that PA in childhood did predict reduced arterial stiffness 12 years later, particularly among those who maintained a stable, or increased, level of MVPA from youth to adulthood (Reid-Larsen, Grontved, Kristensen, Froberg, & Andersen, 2015). Similarly, the Young Finns Study reported that higher PA in youth predicted lower carotid intimal-medial thickness in adulthood (Juonala, et al., 2010)

Despite a mixed story of lipid levels in childhood, evidence of pre-clinical or disease outcomes in adulthood, however, have prompted calls for incorporation of PA assessment in the pediatric clinic (Daniels, Pratt & Hayman, 2011). Future research should explore potential methodological differences across studies as explanatory factors of divergent results. For example, it might be possible that concurrent adverse lipid profiles might be found among the children who are at the extreme of physical inactivity and obesity, given recent evidence from the Bogalusa Heart Study of substantial heterogeneity of cardiometabolic risk factors even among obese children (Li et al., 2011).

4.3 Clinical and Public Health Implications

Measuring percent %BF in children may provide an alternative assessment of overweight and obesity. According to Laurson, Eisenmann, and Welk (2011b), %BF may be a better predictor of excess body fat than is BMI, as it accounts for the physical growth changes of the child and adolescent. Methods such as skinfold thickness measurements are considered noninvasive and without excess cost (Laurson, Eisenmann, & Welk, 2011a) yet incorporation into routine practice could be challenging logistically.

Our observation of a dose-effect even among children of normal weight suggests that reliance on BMI alone for adiposity status might obscure underlying accumulation of body fat in children seeming to be without excess body weight. Conversely, our results of a dose-effect of reduced %BF in overweight and obese children in relation to quartiles of MVPA suggests that PA can ameliorate an adverse health indicator, and, reveals the importance of not classifying everyone who did not meet the guideline as sedentary. Utilizing the Slaughter equation to measure %BF can provide clinically useful information by using skin fold thickness measurements, which can allow for measurement of %BF when other technologies such as dual-energy X-ray absorptiometry are unfeasible or cost-prohibitive.

There are evidence directly linking modifiable youth risk factors such as lipid levels, blood pressure and obesity on preclinical cardiometabolic changes in adulthood (Magnussen, Smith, & Juonala, 2013; Magnussen, Smith, & Juonala, 2014). Health improvement activities such as MVPA may be important in modifying participant progression of their cardiometabolic profile into adulthood such as improvements in future vascular and cardiometabolic health.

While we did not produce evidence related to a key inflammatory marker and adverse lipids, we did produce suggestive findings of variation of HDL level among youth in relation to exercise.

Obesity and the accumulation of excess adipose tissue is difficult to reverse once it occurs so future public health initiatives need to focus on prevention efforts (Cunningham, 2014; Gortmaker et al., 2011), including reducing sedentary time (Dolinsky, Brouwer, Evenson, Siega-Riz, & Ostbye, 2011; Tremblay et al., 2011) and incorporating PA into the school day at all grade levels (Schuna, Lauersdorf, Behrens, Liguori, & Liebert, 2013).

4.4 Strengths and Limitations

A key asset of this study is the use of data from NHANES, the largest continuously run health survey of the United States population in existence for more than forty years. The large, nationally representative sample in the NHANES data set allowed for the examination of multiple markers and measures (i.e., CRP, lipid profiles) in a young, healthy cohort with validated procedures. However, while the NHANES data set provides a representative sample of the US population, limitations are due to the fact that this is a cross-sectional study and causation cannot be determined. In 1999, the survey became a continuous program that focuses on a variety of health measurements to meet emerging population health needs (CDC, 2012). The ability of NHANES to continuously examine trends is mixed: while it allows for the expansion of study variables, such as new inflammatory biomarkers, the survey content may change every two years.

Although another strength of our investigation is the use of accelerometer data, compared to the more error prone self-report, there are limitations to use of these objective data. For example, the accelerometer is not able to capture data on water sports. Additionally,

there are challenges in accelerator data due to the use of different coding methods, variability in cut points and activity levels (Hearst, Sirad, Lytle, Dengel, & Berrigan, 2012; Troiano, McClain, Brychta, & Chen, 2014). We employed the coding scheme provided by NIH. Nor could we assess MET-Mins (i.e., Metabolic Equivalent of Task), which would have allowed more precision in assessing energy expenditure. The accelerometer cannot distinguish different levels of moderate and vigorous activity (e.g. running versus very brisk walk).

4.5 Future Research

Future studies, as recommended by the IOM Committee on Fitness Measures and Health Outcomes in Youth, should include body composition measures of skinfold, waist circumference and BMI (IOM, 2012). The findings of Sabiston et al., (2010) of a relationship between vigorous PA and inflammatory markers in youth, support our recommendation that future studies isolate vigorous and moderate activity. Obesity has been characterized as an inflammatory condition that can lead to the development of chronic diseases such as cardiovascular disease (CVD) and type 2 diabetes (Sacheck, 2008). Prevention of systemic inflammatory processes at an early age is of great public health importance, but whether PA can independently modify inflammation in youth remains an important question (Sacheck, 2008). Better understanding of PA guidelines relative to inflammation could provide public health targets for the appropriate type, amount, and intensity (Holman, 2011). Studies have identified other inflammatory biomarkers not available for study in children in the NHANES data set that may have a relationship to PA in children such as interleukin 6, plasma leptin and tumor necrosis factor ∝ (Loprinzi et al., 2012; Platat et al., 2006).

Regarding our null findings about lipid levels, future research comparing extremes of PA and excess body weight might reveal differences in outcomes. For example, it might be

productive to compare lipid profiles in obese children who engage in very low levels of MVPA with children who are of normal and exercise at or above the ACSM guidelines. Similarly, examination of associations between minutes spent in sedentary time and cardiometabolic risk factors may identify youth at risk for chronic diseases. While, we did not explore associations between non-valid wearers of PA monitor, comparisons with study participants who completed at least 4 valid days of PA monitoring may reveal findings suggestive of the beneficial effects of different levels of PA. Additional suggestions for future research include: compare %BF and BMI percentile as outcomes; and, explore differences in the relationship of MVPA and study outcomes by race/ethnicity. Lastly, as no PA recommendations are included in the Physical Activity Guidelines for children younger than 6 years of age (Pate, 2012), we did not investigate this perspective. Yet, according to Pate (2012), there remains a need to study and construct guidelines for children in this age group.

4.6 Summary

Childhood obesity has grown at an alarming rate, with one-third of United States (US) children overweight or obese in 2008 (National Center for Health Statistics, 2012). The monitoring of PA, adiposity and cardiovascular risk marker trends in children and adolescence, and into adult life, may identify that increasing overall PA levels starting in childhood leads to greater health benefits and a reduction of chronic disease in adulthood (Owen et al., 2010). Setting national standards and prioritizing PA guidelines for youth can have far reaching positive health outcomes for their future health and wellness.

TABLE 1 Characteristics of Study Sample (n=1876) compared to excluded Participants (n=8244) in NHANES 2003-06

	Excluded[1,2] n=8244	Wore Monitor[2] n=1876	*P*-Value[3]
Sex			
Female	4156 (50.4%)	934 (49.8%)	.63
Male	4088 (49.6%)	942 (50.2%)	
Age Group			
6-11	2548 (30.9%)	711 (37.9%)	
12-17	4231 (51.3%)	919 (49.0%)	.001
18-19	1465 (17.8%)	246 (13.1%)	
Race/Ethnicity			
Mexican American	2504 (30.4%)	644 (34.3%)	
Other Hispanic	300 (3.6%)	52 (2.8%)	
Non-Hispanic W	2336 (28.3%)	450 (24.0%)	.001
Non-Hispanic B	2755 (33.4%)	619 (33.0%)	
Other	349 (4.2%)	111 (5.9%)	
Sex-Specific % Body Fat			
Q1	1820 (24.7%)	447 (26.2%)	
Q2	1789 (24.3%)	472 (27.7%)	.001
Q3	1837 (25.0%)	426 (25.0%)	
Q4	1908 (25.9%)	361 (21.2%)	
C-reactive Protein			
Q1 [<0.01]	1802 (24.6%)	447 (26.7%)	
Q2 [0.02-0.04]	1792 (24.5%)	437 (26.1%)	.05
Q3 [0.05-0.14]	1804 (24.6%)	383 (22.9%)	
Q4 [>0.15]	1928 (26.3%)	405 (24.2%)	
Total Cholesterol			
Q1 [<142]	1795 (24.8%)	432 (26.1%)	
Q2 [143-160]	1818 (25.1%)	405 (24.4%)	.15
Q3 [161-179]	1710 (23.6%)	418 (25.2%)	
Q4 [>180]	1925 (26.6%)	402 (24.3%)	
Triglycerides			
Q1 [<52]	753 (23.1%)	130 (26.0%)	
Q2 [53-70]	765 (23.4%)	122 (24.4%)	.02
Q3 [71-93.75]	714 (21.9%)	123 (24.6%)	
Q4 [>94]	1034 (31.7%)	125 (25.0%)	
LDL[4]			
Q1 [<71]	655 (20.7%)	127 (25.5%)	
Q2 [72-88]	850 (26.9%)	126 (25.3%)	.12
Q3 [89-105]	822 (26.0%)	125 (25.1%)	
Q4 [>106]	835 (26.4%)	121 (24.2%)	
HDL[5]			
Q1 [<45]	347 (28.7%)	428 (25.8%)	
Q2 [46-53]	314 (26.0%)	426 (25.7%)	.16
Q3 [54-63]	300 (24.8%)	411 (24.8%)	
Q4 [>64]	248 (20.5%)	392 (23.7%)	
Asthma			
Yes	1374 (16.7%)	309 (16.5%)	.98
No	6861 (83.2%)	1565 (83.4%)	

1 *Includes participants not selected for PAM, those who declined, or those who had less than 4 valid days*
2 *Data missing for some participants for certain variables (e.g., CRP).*
3 *Pearson Chi-Square Tests*
4 *Low-density Lipoprotein (LDL*
5 *High-density Lipoprotein (HDL)*

TABLE 2 Mean Minutes of MVPA per Day by Age and Sex

		>= 60m MVPA Mean per Day 7 days	>= 60m MVPA Mean per Day 4 to 6 days	< 60m MVPA Mean per Day	TOTALS
MALE	**6-11**	88 78.6%	196 70.3%	68 12.3%	352 37.2%
	12-17	20 17.9%	55 19.7%	391 70.6%	466 49.3%
	18-19	4 3.6%	28 10.0%	95 17.1%	127 13.4%
		(112)	**(279)**	**(554)**	**(945)**
FEMALE	**6-11**	72 96.0%	161 90.4%	133 19.4%	366 39.1%
	12-17	3 4.0%	10 5.6%	446 65.2%	459 49.0%
	18-19	0 0.0%	7 3.9%	105 15.4%	112 12.0%
		(75)	**(178)**	**(684)**	**(937)**
ALL	**6-11**	160 85.6%	357 78.1%	201 16.2%	718 38.2%
	12-17	23 12.3%	65 14.2%	837 67.6%	925 49.1%
	18-19	4 2.1%	35 7.7%	200 16.2%	239 12.7%
		(187)	**(457)**	**(1238)**	**(1882)**

TABLE 3 Daily MVPA in relation to Percent Body Fat[1]

	FULL SAMPLE n=1723[2]		NORMAL[3,6] n=1231		OVERWEIGHT[4,6] n=271		OBESE[5,6] n=207	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
>= 60m MVPA Mean per Day 7 days	185	16.9 (7.2)	148	14.1 (3.9)	21	24.7 (5.8)	16	32.1 (5.4)
>= 60m MVPA Mean per Day 4 to 6 days	442	18.2 (8.1)	329	14.9 (4.6)	66	24.2 (6.5)	45	32.5 (7.6)
< 60m MVPA Mean per Day	1090	23.4 (9.7)	754	19.2 (6.9)	184	29.3 (7.2)	146	37.1 (8.0)

[1] *n=153 missing data on skinfold measurement; % BF calculated using Slaughter equations for skinfold thickness for males and females*

[2] *One-Way ANOVA F=76.9, P < .001; 7 days vs. 4-6 days (P=.29); 7 days vs. < 60 mns (P<.001); 4-6 days vs. < 60 mns (P<.001)*

[3] *One-Way ANOVA F=83.7, P < .001; 7 days vs. 4-6 days (P=.53); 7 days vs. < 60 mns (P=.001); 4-6 days vs. < 60 mns (P<.001)*

[4] *One-Way ANOVA F=15.4, P < .001; 7 days vs. 4-6 days (P=.79); 7 days vs. < 60 mns (P=.004); 4-6 days vs. < 60 mns (P<.001)*

[5] *One-Way ANOVA F=7.9, P < .001; 7 days vs. 4-6 days (P=.99); 7 days vs. < 60 mns (P=.012); 4-6 days vs. < 60 mns (P<.001)*

[6] *Post hoc Bonferroni tests to correct for multiple comparisons.*

TABLE 4 Quartiles of Mean Minutes of MVPA per Day in relation to Percent Body Fat

	FULL SAMPLE n=1723[2]		NORMAL[3,6] n=1231		OVERWEIGHT[4,6] n=271		OBESE[5,6] n=207	
	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Q1	442	25.5 (9.2)	297	21.5 (7.1)	86	31.0 (5.8)	58	37.4 (7.7)
Q2	396	21.9 (9.1)	286	18.2 (6.2)	59	29.2 (6.5)	49	35.2 (8.1)
Q3	408	21.1 (9.6)	275	16.6 (5.7)	64	25.4 (7.2)	66	35.5 (8.1)
Q4	471	17.1 (8.0)	373	14.3 (4.5)	62	24.1 (6.6)	34	34.1 (8.1)

[1] *n=153 missing data on skinfold measurement; % BF calculated using Slaughter equations for skinfold thickness for males and females*

[2] *One-Way ANOVA F=67.3, P < .001; Q1 vs. Q2 (P<.001); Q1 vs. Q3 (P<.001); Q1 vs. Q4 (P<.001); Q2 vs. Q3 (P=1.00)*

[3] *One-Way ANOVA F=87.7, P < .001; Q1 vs. Q2 (P<.001); Q1 vs. Q3 (P<.001); Q1 vs. Q4 (P<.001); Q2 vs. Q3 (P=.006)*

[4] *One-Way ANOVA F=16.2, P < .001; Q1 vs. Q2 (P=.67); Q1 vs. Q3 (P<.001); Q1 vs. Q4 (P<.001); Q2 vs. Q3 (P=.012)*

[5] *One-Way ANOVA F=1.5, P < .22; P > 0.31 for all pairwise comparisons.*

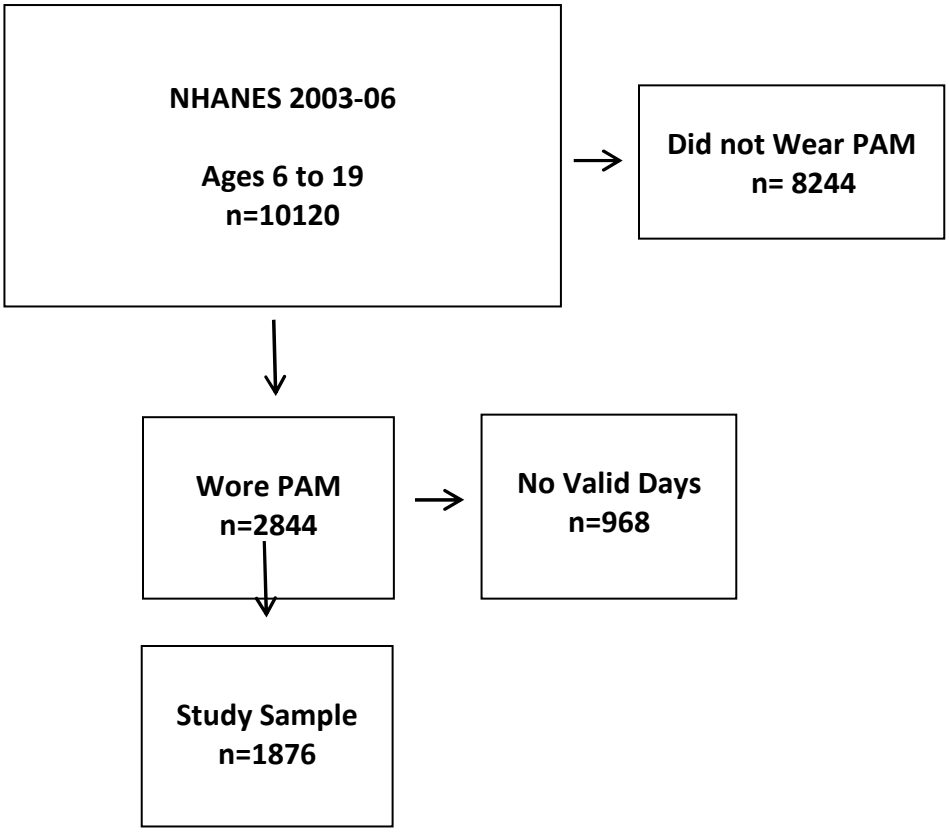
[6] *Post hoc Bonferroni tests to correct for multiple comparisons.*

TABLE 5 CRP and Lipid Levels in relation to Quartiles of Mean Minutes of MVPA

	CRP[1,6,7]	TOTAL LIPIDS[2,6]	HDL[3,6,8]	LDL[4,6,10]	TRIGLYCERIDES[5,9]
	n= 1677	n=1662	n=1662	n=502	n=503
Q1	0.22 (.76)	159.7 (27.4)	**53.3 (13.5)**	88.9 (25.2)	82.9 (52.5)
Q2	0.19 (.51)	162.3 (30.7)	53.8 (12.3)	91.4 (28.0)	83.1 (44.2)
Q3	0.20 (.58)	162.1 (28.1)	54.7 (13.2)	88.4 (22.7)	82.2 (42.7)
Q4	0.15 (.67)	162.7 (29.6)	**56.9 (13.3)**	91.0 (23.4)	74.8 (43.0)

[1] *One-Way ANOVA F=0.88, P =.45; P < .22; P > 0.65 for all pairwise comparisons.*
[2] *One-Way ANOVA F=1.51, P =.22; P > 0.22 for all pairwise comparisons.*
[3] ***One-Way ANOVA F=6.03, P =.22; Q1 vs. Q4 (P = 0.001); Q2 vs. Q4 (P = 0.004); Q3 vs. Q4 (P = 0.16); P > .69 for all other pairwise comparisons.***
[4] *One-Way ANOVA F=0.40 P < .76; P > 0.99 for all pairwise comparisons.*
[5] *One-Way ANOVA F=0.39, P < .57; P > 0.99 for all pairwise comparisons.*
[6] *Post hoc Bonferroni tests to correct for multiple comparisons.*
[7] *C-reactive protein (CRP)*
[8] *High-Density Lipoprotein (HDL)*
[9] *Low-Density Lipoprotein (LDL)*

Fig. 1 Flowchart of Inclusions and Exclusions



Supplemental Table A

Distribution of Mean Minutes of Daily Moderate to Vigorous Physical Activity Expenditure by Age and Sex

		MALES	FEMALES
All Ages	***n***	945	937
	Mean	63.29	77.06
	Median	51.17	72.001
	Range	0.50–248.67	7.00-354.29
	Q1	< 27.17	< 40.90
	Q2	27.17-51.17	40.90-65.57
	Q3	51.18-88.57	65.58-84.08
	Q4	> 88.57	> 84.08
6-11	***n***	352	366
	Mean	103.47	77.06
	Median	98.30	72.00
	Range	13.29–248.67	7.00-354.29
	Q1	< 51.42	< 40.90
	Q2	51.42-75.67	40.90-65.57
	Q3	75.68-103.02	65.58-84.08
	Q4	> 103.02	> 84.08
12-17	***n***	466	459
	Mean	37.67	19.48
	Median	31.41	15.25
	Range	0.50- 143.00	0.40-133.00
	Q1	< 20.92	< 9.23
	Q2	20.92-31.00	9.23-17.80
	Q3	31.01-50.38	17.81-27.68
	Q4	> 50.38	> 27.68
18-19	***n***	127	112
	Mean	45.94	26.32
	Median	43.57	20.75
	Range	5.50-134.50	2.67-89.50
	Q1	< 24.29	< 13.59
	Q2	24.30-39.05	13.59-23.45
	Q3	39.06-59.27	23.46-43.40
	Q4	> 59.27	> 43.40

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