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24-hour movement behaviors among US adolescents: a cross-sectional analysis using time diary data

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Bachelor of Science
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2018

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ABSTRACT

24-hour movement behaviors among US adolescents: a cross-sectional analysis using time diary data

By Hannah Behringer

Background:

The benefits of physical activity (PA) during adolescence are well-documented, and sedentary behavior (SB) has been established as a risk factor independent of PA. In the context of the movement continuum, this study aims to characterize and evaluate correlates of activity patterns from sleep to moderate to vigorous physical activity (MVPA). Durations of activity types within movement categories were also examined.

Methods:

Time diary data from 631 adolescents (10-18 years of age) participating in the 2014 Child Development Supplement wave of the Panel Study of Income Dynamics were used. Participants completed open-ended, 24-hour time-use surveys for one weekday and weekend day. Activities were categorized into groups, and metabolic equivalent of task (MET) values were assigned to each group, informing assignment to SB, light physical activity (LPA), or MVPA. Total daily energy expenditures (TDEE) and durations of each activity category were calculated. Multiple linear regression was used to examine associations between demographic characteristics and movement behaviors.

Results:

Average TDEE was 1423 MET-minutes for weekday and 1457 for weekend days, and MVPA levels were 69 and 139 minutes, respectively. Durations of SB were 677 minutes for weekday and 466 for weekend data. Significant gender differences were limited for broad movement categories, but girls spent more time lying (20 vs. 8 minutes for weekday). Boys consistently reported more time playing computer games (16 vs. 68 minutes for weekday) and sports/games (11 vs. 29 minutes for weekday). Differences by age group were observed for sleep and SB, and lower activity levels were observed among Black adolescents, particularly girls. There were also gender differences in the directions of associations of both income and weight with activity levels.

Conclusions:

Overall, 24-hour movement behaviors among US adolescents aligned with guidelines, but disparities were present, including lower activity levels among Black adolescents. Gender and age differences in duration of types of activities such as sports and computer games suggest variation in how activity duration is accumulated. Future research is needed to clarify these associations, which may inform development of targeted interventions for reducing SB and increasing PA, such as addressing barriers to sports participation among girls.

Main Takeaways

On average, adolescents reported adequate levels of sleep, SB, LPA, and MPVA.

- Girls had higher LPA but lower energy expenditure and MVPA on weekends
- Older adolescents reported more SB but lower energy expenditure and MPVA on weekends
- Black adolescents reported significantly lower energy expenditure and MVPA

Notable gender and age differences were observed in the types of activities recorded

- Within SB, girls reported more time lying while boys had more time playing computer games
- Girls also reported less time participating in sports and games
- Older adolescents spent more time lying and in quiet play and less time in active play

Associations between activity patterns and race, weight, and income may exist within gender strata

- Income and high activity were inversely related among girls, but positively among boys
- Associations between activity and weight status may also differ between boys and girls
- Greater SB and lower MVPA was found among Black girls compared to White girls

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I. INTRODUCTION

Background

Physical activity levels in the United States are a critical public health challenge. It is well-documented that many children and adults do not meet the amounts of daily activity recommended by the US Centers for Disease Control and Prevention (CDC) [1]. Coupled with high levels of sedentary behavior, the costs associated with poor movement habits are substantial. Low levels of physical activity have been estimated to account for 10% of premature deaths in the US and are associated with $117 billion in annual healthcare costs [2,3]. physical activity also has important implications for quality of life. In addition to having brain health benefits, it can play an important role in preventing chronic diseases, and it has been shown to improve quality of life among those that have chronic conditions. Importantly, it is becoming clear that physical activity and sedentary activity have independent effects on health. When comparing groups that report similar levels of physical activity, those with more sedentary time tend to have worse health outcomes[4]. Analyzing movement patterns in the context of the movement continuum, which illustrates the range of movement between sleep and intense exercise, is becoming increasingly important for moving movement research forward. This provides a more holistic understanding of how populations spend their time and how these activity behaviors may affect health outcomes [5].

A 2020 analysis reported that only 23% of children and adolescents (up to age 17), who are in an important period of physical, social, and emotional development, are not meeting the recommended levels of physical activity. This study also found that only 8.8% of this age meet guidelines for PA, sleep, and screen time [1]. Data from the national Youth Risk Behavior Survey indicates concerning trends for adolescent screen time, sedentary behavior, and physical activity.

For instance, the percentage of high school students reporting video game or computer usage for more than three hours per day (outside of school and work) more than doubled from 2003 to 2019 [6]. Engaging in regular activity levels during adolescence has important mental and physical health benefits, including building strong bones, improving cardiorespiratory and muscular fitness, controlling weight, and reducing symptoms of anxiety and depression. In addition, adolescent movement behavior has significant long-term health effects, such as reduced risk of developing conditions such as type 2 diabetes, obesity, cancer, heart disease, and osteoporosis later in life [7]. Thus, it is important to understand the determinants of these movement behaviors and determine how to best encourage adolescents to sit less and move more.

Factors contributing to adolescent activity levels are numerous and interconnected. Relatively consistent trends have been observed when comparing movement between genders, with boys generally reporting higher activity levels than girls [6,8,9]. In addition, consistent negative associations between age and physical activity levels have been observed among adolescents [10], while increases in sedentary behavior between ages 13-16 have been observed [11]. However, analyses and comparisons of complete movement behavior among these groups are still quite limited. Most studies focus solely on physical activity or sedentary behavior rather than considering comprehensive patterns, which may not capture a complete picture of movement habits. In addition, previous work has been limited by generalizability, data collection methods, and small sample sizes [12]. Much remains unclear about additional determinants of movement in this age group. Other factors that have been explored are socioeconomic status (SES), race/ethnicity, and weight and weight perception, although these associations are not yet clear. Emerging areas of interest are those related to socioecological models of health behavior, including built environment, parental attitudes and influences, and others.

Study objectives and significance

The primary aim of this study is to describe 24-hour movement patterns of US adolescents. Previous research has focused on evaluating either physical activity or sedentary, and few studies have described movement levels across the continuum. The Panel Study of Income Dynamics (PSID) is a nationally representative panel survey of US families that began collecting data in 1968. The Child Development Supplement (CDS) sub study of the PSID and includes a time diary component for a subset of its study population, which provides valuable information about how children and adolescents spend their time. While there are myriad approaches to collecting activity data, the use of time diaries presents notable strengths. This method involves participants recording descriptions and durations of their activities throughout the entire day. This approach has been identified as a useful method due to the open-ended nature and ability to capture information about the context of activity in addition to frequency and duration. As health behavior research moves towards examining complete movement composition rather than focusing on physical activity versus inactivity, time diary methods can play an important role in advancing our understanding of these relationships.

Using the CDS time diary data, this study aims to characterize the movement of this population from sleep to moderate to vigorous physical activity and examine potential correlates of activity patterns. Using a nationally representative sample and time diary data, this study will provide important insights into activity behaviors of US adolescents, including possible gender and age differences. Improving these behaviors is a public health priority, and the CDS data provides a valuable opportunity to more fully understand how adolescents spend their time and move throughout the day and provide opportunities for targeted interventions.

II. LITERATURE REVIEW

Movement continuum

When considering the health implications of physical activity and inactivity levels, is important to incorporate the entire movement continuum, which illustrates the range of movement between sleep and intense exercise. Metabolic equivalent tasks (METs) can be used to quantify activities along this continuum. Activities above 3 METs are considered as moderate to vigorous physical activity, those within the range of 1.5 – 3 METs are classified as light physical activity, and sedentary behaviors are those requiring less than 1.5 METs. An MET of 0.9 is typically assigned to sleep. Individuals can engage in high levels of moderate to vigorous physical activity as well as high levels of sedentary behavior, and there is growing evidence that behaviors along different parts of this scale may have different physiological implications - effects of sedentary behavior may not necessarily be the opposite of physical activity. Thus, it is important to describe and measure these differences, as opposed to examining levels of physical activity or exercise alone [5].

Importance of physical activity

Physical health

Physical activity has been established as one of the most important health-promoting behaviors for individuals of all ages. Those who engage in recommended levels of physical activity have a lower risk of developing cardiovascular disease, type 2 diabetes [13], and some cancers [14]. It also helps strengthen bones and muscles, control blood pressure and cholesterol levels, and can play a role in weight management [3]. In addition, higher levels of physical activity are associated with a lower risk of premature mortality from any cause, with evidence of a dose-response relationship [15,16]. Furthermore, it has been estimated that 10% of premature deaths are associated with insufficient physical activity in the United States [2].

Participating in sufficient physical activity during childhood also provides many health benefits, including improved bone health [17], weight status, cardiorespiratory and muscular fitness, and cardiometabolic health [3]. A recent examination of objectively measured physical activity and cardiometabolic indicators among adolescents found that meeting the CDC physical activity guidelines was associated with lower cardiometabolic risk factors and adiposity.[18] These outcomes occur through a variety of mechanisms. Childhood and adolescence are critical periods of bone development, and mechanical load during this time is an effective way to build bone strength through improved bone mass and structural skeletal adaptations. It has been established that just before puberty is when the skeleton is most sensitive to mechanical loading. However, it is not yet understood how different activities affect bone development [19].

The relationships between physical activity, sedentary behavior, diet, fitness, and weight status are complex. physical activity contributes to healthy levels of cardiorespiratory fitness (CRF), which may mediate the pathway between physical activity and weight and cardiovascular outcomes,[20] but as previously mentioned, among individuals with similar fitness levels, those who are more sedentary tend to have worse health outcomes. Additionally, it has been found that active overweight and obese persons have an approximately 50% lower NCD risk compared to those who are normal weight but unfit [21]. Therefore, it is important to examine movement across the continuum and target both physical activity and sedentary behavior and increase CRF levels to offset adverse health effects of overweight and obesity.

There is also some evidence that, in addition to short-term health benefits, physical activity levels during youth may have implications for health and activity levels later in adolescence [22] and during adulthood [23,24]. Habits developed during adolescence may translate to patterns during adulthood, as lifestyle choices are often established through this critical period of development; however, the magnitude of the effect of physical activity during adolescence on adult physical activity has been found to be moderate [12]. Quality investigations of direct associations between physical activity in adolescence and morbidity in adulthood are still limited, but there has been some indication that children active during childhood may have sustained associations with better bone health.[19,25] In addition, a large cohort study observed a reduced risk of breast cancer among participants who engaged in at least seven hours of sports or exercise during ages 5-19.[26] Results of studies that examined physical activity during childhood or adolescence and cardiovascular disease risk factors have been mixed. However, it has been suggested that measurement problems could be contributing to the lack of observed effects, as fitness during adolescence has been found to affect cardiometabolic health indicators[27-30] and fitness during adulthood. [31] Insufficient physical activity combined with other unhealthy behaviors, such as poor diet and lack of sleep, can contribute to excess weight gain, and obesity in childhood has been associated with obesity in adulthood.[32] More research, particularly longitudinal data, is needed to elucidate these relationships and mechanisms.

Mental health

In addition to the many physical benefits, maintaining an active lifestyle has also been associated with numerous mental health outcomes in both adults and youth. Importantly, physical activity in adolescence has been linked to better mental health. A large prospective study found an inverse relationship between physical activity and depressive symptoms during early adolescence,[33] which aligned with a recent cross-sectional study using data from the National Survey of Children's Health (NSCH). This study also linked physical activity to anxiety during childhood and adolescence[34], as did a randomized control trial demonstrated that physical activity reduced anxiety sensitivity, which is a precursor of panic attacks and panic disorder.[35] Recently, a meta-analysis examined the role of exercise on reducing both psychological ill-being and improving psychological well-being in children and adolescents and found small but significant effects for both. However, it was noted that different types of physical activity may affect mental health in different ways and that there may be potential mediators and moderators of this relationship [36]. physical activity has also been linked to improved cognition in adolescents [37,38], although there are still gaps in the evidence as some studies have reported mixed or inconclusive evidence.[39]

A growing body of work has examined effects of physical activity on academic outcomes, including grades and standardized test scores, but these results have also been mixed, with some reporting positive associations and other reporting none. [38-40] It has been suggested that aerobic fitness may mediate this relationship.[41]

Cerebral blood flow and circulating levels of certain hormones are increased by physical activity, which has been suggested as a pathway through which it may positively affect mood, self-confidence, and concentration, while also controlling anxiety, stress and anger. This mechanism may also play a role in cognitive development [42]. In addition, evidence has been found for the pathway of physical activity improving self-perception and consequently, self-esteem. However, there are still relatively few studies examining neurobiological and behavioral mechanisms, and more research is needed to evaluate the pathways between physical activity and mental health and cognition in young people.[43]

Another potential benefit of physical activity under exploration is its association with positive sleep outcomes. However, evidence for this relationship is still developing, particularly among adolescents.[44] Social health and physical activity has not yet been studied extensively, but there is evidence that participation in sports during childhood and adolescence may not only have positive psychological effects but also provide social health benefits.[45] This may be through the development of social skills, teamwork, and leadership. It has also been found that physical activity is associated with lower levels of risk-taking behaviors such as smoking and alcohol consumption.[46]

Health implications of sedentary behavior

Sedentary behavior is also emerging as a risk factor for many adverse physical and mental health outcomes, distinct from a lack of physical activity and acting through different pathways [5,47]. Meeting physical activity guidelines while still engaging in large amounts of sedentary time has been associated with increased all-cause mortality compared to those with similar amounts of physical activity but less sitting time[4]. Sedentary time during younger years has also been linked with adulthood health outcomes. For instance, a prospective birth cohort study reported that television viewing during childhood and adolescence was associated with higher BMI, lower cardiorespiratory fitness, and increased cigarette smoking and serum cholesterol in adulthood.[48] Examining activity in the context of the movement continuum and conceptualizing sedentary behavior independent of physical activity can provide a more comprehensive understanding of the different physiological responses of the two different behaviors, identify determinants of these behaviors in different populations, inform appropriate measurement, and guide interventions to improve each [5].

Adolescent activity patterns in the United States

Current guidelines and adherence

Physical activity in the United States is a significant public health concern, and levels among adolescents are no exception. Current CDC recommendations, developed in 2018 using the available scientific literature, are that children and adolescents from 5-17 years of age engage in 60 minutes or more of moderate-to-vigorous physical activity (at least 3.0 METs) every day. This is based on sufficient evidence that health benefits meaningfully accrue with 60 minutes of moderate-to-vigorous physical activity per day in this age group. It is also recommended that on at least 3 days of the week children and adolescents should partake in vigorous activity, exercise that strengthens muscles, and exercise that strengthens bones [3]. This guideline begins at age 5 due to insufficient evidence surrounding specific physical activity benefits for children under 5. The World Health Organization (WHO) endorses the same guidelines.[49]

However, it is clear that most children in the US are not meeting these guidelines. A recent analysis using data from the NSCH found that only 23% of children up to age 17 met physical activity guidelines and 33% met screen time guidelines.[1] A 2016 CDC report using Youth Behavior Risk Surveillance System (YBRSS) data found that 27.1% of high school students met the physical activity guidelines and that 14.3% had not participated in at least 60 minutes of physical activity on at least one day during the previous seven.[6] Another study published in 2019 reported that only 5% of US high school students (3% of girls and 7% of boys) meet the optimal levels of physical activity, sleep, and screen time.[50] In the context of the movement continuum, it is important to examine each of these behaviors as they each have important independent implications for health.

Temporal trends

Limited data on temporal trends in childhood and adolescent physical activity in the United States exists, but the available data show mixed results.[51] There is some evidence to suggest that adolescent movement patterns over time have improved in some areas but have declined or remained at poor levels in other respects. For instance, data from YBRSS indicates that girls' participation in high school sports increased from 1971 to 2012, a promising pattern for reducing gender differences. However, the same study found that active commuting, high school physical education, and outdoor play (3-12 year-olds) have all declined during this time period.[52] One examination of participation in organized sports also found a stable to slight increase of sport participation in US youths aged 9-13 between 2002 and 2006.[53] Another study focused on physical education participation in 9-12 year-old children and did not observe a significant change in students attending physical education one day per week but did report a decline in students attending physical education 5 days a week from 1991 to 2003. It was estimated that in 2003, only 28.4% of students received physical education 5 days a week.[54] McDonald et al. reported a decrease in active transport to school among 5-14 year-olds from 47.7% to just 12.7% between 1969 and 2009.[55] A 2011 CDC report found that 19-38% of 12-17 year-olds in the US engage in at least 60 minutes of physical activity per day.[56] Contrasting results were reported in a 2013 study examining trends in physical activity among US adolescents between 2001 and 2009, which found that while the proportion of adolescents meeting physical activity recommendations was still low, there were improvements in physical activity levels during this period.[57]

Temporal trends in sedentary time show concerning patterns. A study using data from almost 10,000 adolescents (age 12-19) in the National Health and Nutrition Examination Survey

(NHANES) showed increasing levels of total hours per day of sitting time between 2001 and 2016. Between 2007 and 2016, there was an increase of almost 1 hour per day of sitting time, and this trend was comparable between most subgroups.[58] However, another study using nationally representative samples of students in grades 6-10 found that while most adolescents engaged in more than the 2 hours per day of screen-based sedentary behavior, some encouraging trends existed. Notably, the amount of time spent watching TV (at the time, the most prevalent sedentary behavior) decreased from 2001 to 2009.[57] Future studies will need to include sedentary behavior data that covers how contemporary adolescents spend their time, such as time on mobile phones and social media. Changes in many environmental and lifestyle factors in recent decades, including lower levels of active transport and screen time during both leisure and school or work activities, have contributed to the lower levels of physical activity and greater amounts of sedentary behavior. However, studies evaluating these patterns and changes among US adolescents remain limited.

Age

Physical activity levels tend to decrease with age throughout childhood and adolescence. Longitudinal analyses have observed significant decreases in physical activity between ages 9 and 15 years[10] as well as decreasing physical activity coupled with increasing sedentary activity between around 13-16 years of age.[11] Data from the 2015 national YBRSS indicated that prevalence of not having participated in at least 60 minutes of physical activity on at least one day in the seven before the survey was generally higher among high school students in higher grade levels. The same study also reported that younger high school students tended to be physically active for at least 60 minutes per day on five or more days.[6] One report found that 40% of children under 12 meet the recommendation of 60 minutes of physical activity per day while only 8% of adolescents (13-18 years old) meet this guideline.[59] Furthermore, a large, nationally representative cross-sectional study found a substantial age effect in meeting physical activity guidelines, observing that the prevalence of children meeting the recommended levels decline by 15.5% between ages 6-17 years.[1]

Gender

Gender has also been associated with differing levels of physical activity. Kann and colleagues reported that the prevalence of not having meeting the recommended 60 minutes of physical activity per day in the previous seven days was higher among high school females than high school males, and this pattern was consistent within race/ethnicity strata. This pattern was also observed for being physically active for at least 60 minutes per day on five or more days and on all seven days, attending physical education classes, and playing on at least one sports team. [6] A large, cross-sectional study using data from NSCH also found that being female was associated with a lower likelihood of meeting physical activity guidelines among youths.[1] Data from NHANES indicated that among adolescents aged 12-17, a greater percentage of males reported any moderate to vigorous physical activity across all race/ethnicity categories. Among those who were physically active, males also reported more daily minutes of activity.[8] In another analysis, males were found to have higher levels of moderate to vigorous physical activity in both middle school (11-13 years old) and high school (13.1-18 years).[9] The same study also reported that trends in moderate to vigorous physical activity from adolescence to adulthood differed significantly by sex, with males presenting a later decline in activity. Some research has also examined how different types of physical activity differ between gender. For example, one examination identified gender differences for the proportion of time spent across domains of moderate to vigorous physical activity. Girls reported more moderate to vigorous physical activity than boys in the transport category, while boys had more moderate to vigorous physical activity in school and leisure time.[60] However, there is limited evidence surrounding these differences in US adolescents.

Race and ethnicity

Some studies have reported differences in physical activity levels by race and/or ethnicity. Kann and colleagues observed that the prevalence of not having participated in at least 60 minutes of physical activity on at least one day in the previous seven days was higher among Black and Hispanic high school students than white students. Similar patterns were found for the prevalence of being physically active at least 60 minutes per day on five or more days during the previous seven days and all seven days. The same study also reported that the prevalence of having attended physical education classes daily was higher among Black and Hispanic students than among White students.[6] NHANES data from 2007-2016 indicated that being of a minatory race/ethnicity (Black, Hispanic, or other) was associated with lower moderate to vigorous physical activity among female adolescents but not male adolescents, after controlling for weight status (Armstrong). In addition, even after controlling for family income, it was found that physical activity was lower in Hispanic adolescents compared with their white counterparts.[57]

Miller and colleagues reported that trends in lower moderate to vigorous physical activity from adolescence to adulthood differed significantly by race/ethnicity. The authors highlight the importance of intersectionality and examining trends among subgroups, such as Hispanic females compared to Hispanic males and White females, as it is important to evaluate if interaction is present to determine groups that could have multiple challenges to achieving the recommended levels of lower physical activity. [9]

Socioeconomic status

Differences in physical activity levels among students from lower-income families have been observed, but the significance of this relationship has sometimes been attenuated once controlling for weight status.[61] Data from NHANES also showed that, after adjusting for weight status, lower income was also associated with lower activity among 12–17-year-old females but not for males.[8] A 2007 review found similar results. While teenagers of high socioeconomic status (SES) engaged in more physical activity than low-SES teenagers, this association is sometimes only observed among females. There was also some evidence to suggest that this association is stronger among older adolescents than in younger adolescents.[62]

A cross-sectional survey of students in grades 5-12 found that youths from low-SES families reported physical activity on fewer days of the week and lower sports participation. Barriers to sports participation including transportation and cost were more often reported among low-SES children.[63] For adolescents who receive little to no in-school physical activity, this could be an important area to target to improve equitable access to physical activity opportunities.

Weight and weight perception

While weight and BMI are often analyzed as outcomes of physical activity, it is important to consider the possible feedback loop that implicates BMI as a determinant of physical activity levels.[9] For instance, a recent cross-sectional analysis identified an association between adiposity in adolescents and meeting daily physical activity guidelines as well as daily moderate to vigorous physical activity levels.[18] Similarly, Friel and colleagues also observed that youths who were classified as overweight or obese by BMI were notably less likely to meet physical activity guidelines.[1] However, the direction of this relationship is not completely clear, and it may depend more on perception of weight rather than actual weight. It was found that, regardless of weight status, adolescents who perceive themselves as overweight have a stronger intention to lose weight, but do not actually improve eating or exercise habits, compared to those with the same weight status and gender. Furthermore, those who had a normal weight but perceived themselves as overweight were more likely to engage in potentially unhealthy methods of weight loss.[64] This suggests that it may be important to consider weight perception and weight as factors of adolescent physical activity to adjust interventions for encouraging healthy approaches to weight loss.

Other factors

Ecological models of physical activity determinants look beyond individual attributes and examine how psychosocial, environmental, and policy level factors contribute to activity levels. Environmental factors have been suggested as an important factor in youth physical activity. A study that examined the relationship of physical activity -related facilities and SES with overweight and physical activity levels found that the lower SES, which also tended to be high-minority, had reduced access to facilities, lower physical activity levels, and greater rates of overweight.[61] A recent examination using a nationally representative sample of adolescents and objectively-measured physical activity found an association between living in more walkable neighborhoods and moderate to vigorous physical activity.[65] Another aspect of environment that has been examined is living in rural areas. One study found that rural adolescents engaged in less in-school moderate to vigorous physical activity compared to those living in non-rural areas but found no differences in activity taking place at home or during weekends. Any differences in moderate to vigorous physical activity were mostly mediated by differences in neighborhood resources. This analysis also found lower screen time among rural adolescents.[66] There is certainly room for future research in this area as the importance of considering environmental context becomes more prominent, and there may be many other aspects of environment that may play a role in reaching physical activity guidelines.

Parental factors have also been examined as potential determinants of adolescent physical activity. This includes level of parental support as well as the health status and physical activity patterns of parents. Studies assessing the relationship between parental and child physical activity have been mixed, but evidence for parental support, such as praise, watching physical activity participation, transport to physical activity, and encouragement, is stronger. Effect sizes for specific parental support activities have been limited, suggesting that the aggregation of supportive actions may be more important.[67] In addition, a recent meta-analysis did not find sufficient evidence that caregiver involvement plays an important role in interventions for improving child and adolescent physical activity.[68] Variation in how parental support and physical activity has been measured creates challenges for synthesizing past work. Similar to other potential correlates, more research is required.

Additional psychosocial factors and their relationships with adolescent physical activity levels have been examined. One study of several psychosocial correlates of moderate to vigorous physical activity among underserved adolescents found that motivation and self-efficacy were significant among girls and motivation among boys.[69] However, another investigation reported no psychosocial correlates among girls, but that self-efficacy was significant among boys,[70] suggesting that these relationships are still unclear. One study found that support from family and friends, more enjoyable physical activity, self-efficacy, and perception of more competition benefits and less lack of interest were associated with higher levels of physical activity, and that these correlations were similar among normal and overweight adolescents [71].

Measuring physical activity

Objective methods

There are a range of available methods of measuring physical activity, but objective measurement through monitoring devices can provide the most accurate and complete data. Instruments such as accelerometers, pedometers, and heart rate monitors can provide information about activity intensity, volume, and duration. There is currently no gold-standard wearable monitor for free-living settings, and the decision of which device to use depends on study components, such as the aspect of physical activity being studied, target population, budget and logistics, and necessary precision [72].

Pedometers have been used for many years and have become popular through fitness tracking consumer devices such as the Fitbit. They have traditionally tracked movement, but newer models have added additional features that have yet to be evaluated. Traditional pedometers have been found to be reliable and it has been proposed that the most accurate placement for pedometers is the ankle [73]. Pedometers offer a relatively low-cost objective means of measuring physical activity and can quantify ambulatory movement during walking and running using an easily understood metric. A disadvantage is that they cannot measure non-ambulatory activities, posture, and energy expenditure. In addition, they rely on proprietary algorithms to determine number of steps [72].

Accelerometers are more complex than pedometers, as they measure accelerations in gravitational units. These accelerations are processed and calibrated to known criterion measure to determine levels (duration and frequency) of sedentary activity and light, moderate, and vigorous physical activity. It is still up to debate which techniques are best for processing, and there has been a wide range of correlations due to type of monitor being used, placement on the body, activities studied, and context [72]. Advantages of using accelerometers include detailed and precise physical activity measurement that can be monitored over long periods of time. However, similar to pedometers, many algorithms to quantify physical activity are proprietary and can lack ability to detect non-ambulatory activities [72,74].

Heart rate monitors are the most common direct measure used in free-living settings, and there is a strong relationship between heart rate and energy expenditures during moderate and vigorous physical activity. These devices are viable options for activities such as cycling or weightlifting that may not be measured well using accelerometry or pedometers. However, limitations are the need to account for blood pressure medication and discomfort that may occur due to wearing devices for extended periods of time. Some research has employed multi-sensor systems that combine several physiological and mechanical techniques, which can provide additional precision. While pedometers, accelerometers produce an objective measurement of activity, they are expensive, difficult to use in large-scale studies, and are not without methodologic challenges.

Self-report and observational methods

Several options exist for measuring physical activity through self-report. They offer a low burden, low-cost option for collecting activity information, with several validated options available. Global questionnaires are simple tools that often consist of only one to four questions, perhaps asking if participants do or do not regularly participate in a certain amount of physical activity. It is a simple and easy tool to gather information for a large sample but lacks the detail to help establish a dose-response relationship.[72]

Short-term recalls ask participants to report the frequency, duration, and intensity of types of physical activity in which they engaged in the last week or month. Activity type can consider intensity or domain, such as transportation, occupation, or leisure-time. Scores are calculated using frequency, intensity, and duration of the types of physical activity, and intensities are then quantified as METs to provide summary scores.[72] This method allows researchers to assess adherence to guidelines and examine dose-response relationships. A significant limitation is challenges related to recall bias.[72] The Physical Activity Questionnaire (PAQ), along with its complementary self-report instruments for youth (PAQ-C) and adolescents (PAQ-A), is a commonly used short-term recall due to its well-established psychometric properties and useful measurement characteristics.[75] More detailed recall questionnaires are also employed to gather more comprehensive physical activity data. Limitations of self-report questionnaires are that they are susceptible to recall and social desirability biases and that they are less robust in measuring light or moderate activity and are limited by the questions and language used.[76]

physical activity logs require participants to check activities in which they engaged throughout the day or during discreet time periods during the day. Advantages of this method is that it is a relatively simple task and participants do not have to recall activity duration. However, it does require a detailed account of physical activity information at the end of the day, which creates a substantial participant burden. Time diaries are similar, as they require individuals to record detailed information about various aspects of physical activity throughout the day, including domain, body position, duration, and social context. New methods now use smartphones or computers to make completing diaries more convenient. They allow researchers to collect a wide breadth of information but similar to logs, they are quite burdensome to participants.[72] It has been found that self-report methods are more accurate when describing high-intensity physical activity but not when reporting low- to moderate- intensity physical activity.[77,78]

A third method is direct observation, in which an observer monitors and records subject physical activity. This can be useful in young populations and when contextual information may be important to collect. However, it is usually only useful when activity is limited to a certain space, such as a playground or classroom, the lack of objective measurement, and a relatively large time requirement.[76]

Selecting a method of measurement depends on a variety of factors and can be a challenging process. Considerations include budget and human resources available, outcomes of interest and type of data to be collected, and the population of interest (e.g., age, level of burden, number of subjects). In every study collecting physical activity data, strengths and limitations of each tool should be carefully considered and anticipated to proactively decrease likelihood of measurement error. Pettee-Gabriel, et al., created a conceptual model for selecting a tool based on four components (population characteristics, study characteristics, instrument characteristics, and activity characteristics).[79] It has also been proposed that properly defining and classifying sedentary behavior when selecting and implementing a physical activity assessment tool will improve its utility.[72] There is still much more to learn about these methods, which will surely adapt over time.

Utility and benefits of time-use surveys

Time-use surveys or diaries provide an informative source of behavioral epidemiology data. These data collection tools allow researchers to examine how individuals spend time in different daily activities and how these patterns vary across demographic groups. Respondents write the activity and the time at which they started and ended the activity. Then, activities can be classified and coded into consistent categories based on the specific activity, such as playing soccer, and as sedentary, light physical activity, moderate physical activity, and vigorous physical activity. This allows researchers to find total amount of time spent in each activity and number of bouts to examine movement patterns in greater depth. Important details about reported activities such as domain, frequency, and context of daily activity can be captured from time-use surveys, which is not possible with more traditional self-report measures nor objective measures. Other advantages of time-use data compared to alternate self-report methods are minimization of recall bias and reporting errors. Time-use methods can be applied to population surveillance, observational, and intervention studies to provide information on movement patterns. As activity research shifts from focusing on physical activity levels independently to composition of activity behavior across the day [5,80], time-use data will become increasingly important as we strengthen our understanding of movement patterns.

Metabolic Equivalent of Task

To quantify energy expenditure of physical activity and determine where different activities fall along the movement continuum, metabolic equivalent tasks, or METs, are used as a metric. An MET is a ratio of working metabolic rate relative to resting metabolic rate, with 1.0 MET corresponding to resting metabolic rate. To standardize this classification of energy costs associated with PA, The Compendium of Physical Activities was created. It links types of activities with their corresponding MET values is based on existing literature and pooled data of energy expenditure measurements. The first version was published in 1993, and periodic updates have been provided. The most recent version was published in 2011, and in 2018 a Youth Compendium was published.[81] It has been widely used in research and in practice to describe physical activity.

Conceptual Framework

Activity among US adolescents

Adolescence is a critical life stage for the development of healthy habits. Engaging in physical activity and avoiding excessive sedentary time are modifiable behaviors that can have important health implications, both physical and mental. As discussed in the previous section, health effects associated with activity patterns during adolescence may be both short-term and long-term. That is, while adolescent physical activity can improve adolescent health, it may also play a role in adulthood health. It has also been suggested that achieving sufficient activity levels during childhood and adolescence may be related to adult activity.[82]

It is also becoming clear that physical activity and sedentary behavior have independent effects on well-being, highlighting the importance of assessing activity along the movement continuum. Collecting comprehensive data on these behaviors will be critical for improving our understanding of movement and health and determining groups that may be particularly susceptible. For instance, individuals that report high amounts of sedentary time in addition to low physical activity levels may be identified to inform future research and guide interventions.

In the US, evidence has shown that adolescents tend to not meet guidelines for physical activity in addition to engaging in high levels of sedentary activity. As the use of technology and screens continues to increase for both work and leisure, along with other factors that facilitate sedentary lifestyles, there is concern that youth populations will develop poor activity patterns that could persist into adulthood.[83] In addition, further declines in physical activity and increases in sedentary behavior were observed throughout the COVID-19 pandemic. Thus, it is critical that we improve our understanding of this health behavior to improve the current and future health of adolescents.

Factors Influencing Adolescent Physical Activity Levels

Despite the many studies that have examined physical activity levels in adolescent populations, much uncertainty remains surrounding correlates of movement patterns. While it is clear that movement patterns are complex behaviors dictated by many sociocultural, environmental, psychosocial factors and more, some factors have been consistently associated with adolescent physical activity levels. As detailed in the literature review, boys meet physical activity guidelines more often than girls, and physical activity tends to decline with age. However, the age at which these gender differences begin to appear is unclear. Older adolescent girls tend to have the lowest physical activity levels but determining when this divergence begins can inform proactive intervention.

It has also been indicated that non-white and lower-SES adolescents report lower levels of physical activity, but the evidence for these associations is less consistent. Weight and perhaps more importantly, weight perception, have also been identified as factors that may affect adolescent physical activity participation. Another area of interest surrounds environmental factors, such as access to green spaces, sidewalk availability, and living in urban versus rural environments. Ecological models consider these contextual factors affect activity levels. This also often includes psychosocial factors, including parental support and self-efficacy. These developments illustrate the multidimensionality of activity behavior. Interaction and mediation pathways may also exist between these variables, which are still under investigation but also contribute to the complex nature of movement behavior. For instance, non-white girls may be at additional risk of low physical activity compared to white females and non-white males.[9]

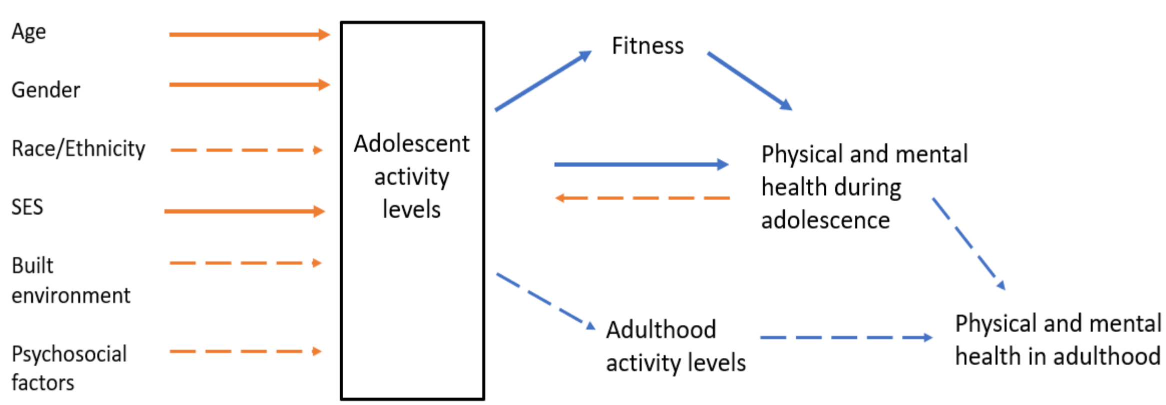
As evidence surrounding many patterns and correlates of adolescent activity in the US remains unknown or unclear, there is merit in elucidating these relationships to inform future research and interventions to improve movement habits among youths. Many previous studies have used self-report methods such as global questionnaires or short-term recalls. While these methods are useful for gathering a high-level overview of physical activity patterns, it is important to examine additional details about reported activity, including domain, bouts, and context. Time-use surveys are a useful tool for understanding 24-hour activity and movement behavior and relationships with health outcomes.

Study objectives

This study aims to build upon existing evidence by describing activity levels among US adolescents in the context of the movement continuum. Data from 24-hour time-use diaries from the 2014 Child Development Supplement (CDS) of the nationally representative Panel Study of Income Dynamics (PSID) is used to characterize activity patterns according to METs. Although available data are cross-sectional, which does not allow for examination of causal relationships, the open-ended CDS time diaries paired with demographic data collected through PSID allow adolescent movement habits to be characterized and compared across various demographic groups. Objectives of the study are to describe 24-hour movement behaviors of US adolescents, compare activity levels between boys and girls and at different ages, and assess potential correlates of activity including SES, race and ethnicity, and weight status.

Visual Representation of Conceptual Framework

The solid arrows indicate relationships that are well-established, and the dotted arrows represent hypothesized associations subject to further examination. Associations represented by orange arrows will be examined in this study.



III. METHODS

Data

Data source and study population

The dataset used for this analysis comes from the Panel Study of Income Dynamics (PSID), a large, ongoing longitudinal household survey based at the University of Michigan. PSID began in 1968 with a nationally representative sample comprising 18,000 individuals from 5,000 families and has continuously collected data about employment, income, education, child development, health, and many other topics. The original households included in the study constitute a national probability sample of US households in 1967, a combination of two independent samples. The first is a cross-sectional sample drawn by the Survey Research Center (SRC), which was a national sample based on stratified multistage selection of the civilian noninstitutional population and provided 2,930 initial interviews. The second sample is from the Survey of Economic Opportunity (SEO), from which the PSID successfully interviewed 1,872 low-income families. As the PSID was initially developed to study poverty and income dynamics, the original sample oversampled low-income families [84].

The sample has naturally grown as children and grandchildren from the original families are invited to participate. Immigrant samples have been added in recent decades to ensure the sample resembles the changing US population. As of 2019, the sample had grown to more than 24,000 individuals from 9,500 families. Data were originally collected annually but switched to a biennial schedule in 1997 [84].

In 1997, the Child Development Supplement (CDS) was added to the PSID. Up to two children per household ages 0-12 were added at this time, and these individuals were followed over three waves ending in 2007-2008. CDS was redesigned as a steady-state study in 2014 and included all eligible children born since 1997 in PSID households that completed the core PSID interview in 2013. These children were to be interviewed every 5-6 years with another wave planned for 2019, but data collection was delayed due to COVID-19. Thus, the present analysis uses data from CDS-2014. Sample eligibility criteria for this wave were that the family participated in the 2013 Core PSID survey, the child's reported birth year was 1997-2013, the child was classified as belonging to the PSID sample, the child was not classified as a household head or the spouse/partner of a household head, and the child was not deemed to be eligible for the original CDS study. A total of 5,816 children were eligible and information was collected in full for 4,333 of these children. In addition to the main CDS component, 50% of households were selected to participate in an in-home visit to provide additional information, including completion of time-use diaries over two days[85].

Data collection

CDS collects a variety of information about the children included related to health status, cognition, behavior, use of media, home environment, education, and more. Interviewers first contacted families and completed an initial screening. Most CDS information was collected via phone call. Primary caregivers completed two phone interviews. One is about the household and neighborhood environment and family characteristics, and the other is about the child's health, behavior, and education. Children ages 8-17 completed separate, independent interviews about their health, future plans, social life, electronic use, and more.[85]

The in-home component included time diaries completed by children on two randomly assigned, nonconsecutive days (one weekday and one weekend). Time diaries were open-ended, where parents and children recorded the child's activity over 24 hours, indicating the times at which each activity began and ended. Respondents were also asked to report where the child was, who was participating in the activity with the child, who was in the same location but not directly involved, and what else the child was doing at the time, if anything. PSID researchers then classified and coded all recorded activities into specific activity types, such as an organized sports practice, computer or phone use, or attending an organization meeting. Time diaries have been extensively validated as reliable methods for representing how children and adults spend their time [86] and have been shown to be more accurate than self-reported average daily or weekly activity time.[86,87]

Sample weights were calculated to reflect differential selection probabilities and nonresponse and allow researchers to generalize results to all children in the US that fit the CDS-2014 selection criteria and caregivers. A separate weight was constructed for the subsample of children that completed the in-home supplement. The selection process for this component was probability-based, but it is noted that all participants did not have an equal chance of selection. The CDS-2014 User Guide provides details about the methods used to calculate these sample weights.

Variables

Demographics

Demographic variables of interest included sex, age at time of time diary completion, race, ethnicity, total household income for 2012 and if this met the 2012 Census Needs Standard, highest level of education completed by the household head, weight status, and weight perception. The sex variable was obtained from the main PSID data file. Age of participants at the time of completing the weekday diary and when completing the weekend diary was obtained using participants' dates of birth and the recorded date of each diary.

Race and ethnicity variables were collected in the demographics survey, where the caregiver indicated their children's' race and ethnicity. Respondents were permitted to indicate multiple races, but only the first mention was used for this study. Missing values for the race variable were limited, so they were included in the "other" category. Missing data for ethnicity was substantial, so a "missing" category was created for this variable.

Household income and 2012 Census Needs standard, which is a standardized threshold for livable income based on family size, were gathered from the main PSID file. Household income was collected in 2013 about the 2012 tax year and includes the taxable income of all family members, transfer income, and social security income. This was compared to the 2012 census needs variable to create a new binary variable indicating if the individual's family met the needs or not. Years of education completed by the household head was also obtained from the main PSID file and recorded in number of years.

BMI was calculated through measures collected by the PSID interviewer during the in-home supplement, and weight status of children was determined by percentiles of BMI-for-age. Those under the fifth percentile were classified as underweight, percentile 5-85 were normal weight, percentile 85-95 were at risk for overweight, and those above percentile 95 were deemed overweight. Children were weighed on a scale and stood against a wall or door to measure height. Children over the age of 10 were asked "how do you think of yourself in terms of weight?" Possible answers included very underweight, slightly underweight, about the right weight, slightly overweight, and very overweight.

Survey variables, including weights, clusters, and strata, were also used. Weights for children included in the in-home supplement and time diary subset were included in the CDS dataset. Cluster and strata variables were included in the main PSID dataset and included in the analyses.

Time diaries

Each row of data in the time diary file corresponded to one individual, with the time in seconds spent in each activity in the columns. All activities were included in the analysis in order to capture a complete understanding movement throughout the day. The activity variables included in this dataset were created by PSID researchers who categorized all open-ended questions. The activities included in the weekend and weekday diaries are identical. Participants were given a target date for when to complete each diary, decided between the primary caregiver and the PSID interviewer, and indicated on which day it was actually completed. Participants in the same household were given the same target dates. While it was suggested that primary caregivers assist with or complete the time diary for younger children, time diary instructions indicated that teenagers could complete the diaries on their own.

Data preparation and cleaning

Analytic sample

All data cleaning and analyses were performed in SAS 9.4 (Cary, N.C.). Datasets were downloaded from the PSID website in multiple datasets, which were merged by a family identifier variable and an individual identification variable to contain all variables of interest. The CDS data was subset to include only those who were eligible for and completed time diaries, which was a total of 1566 participants out of the 4333 total children in the CDS sample. Age was provided as age at time of weekday diary and at time of weekend diary, so only those who were at least 10 years old at the time of completing both diaries were included. A new variable for mean age was created by averaging the ages at the time of completing each diary. This was used to classify individuals into age categories of 10-12, 13-15, and 16-18 years. These cutoffs were used due to differing energy expenditure based on age outlined in the Compendium of Youth Physical Activity. [81]

Activity classification and MET assignment

Time diary activity data was first converted from seconds to minutes. Using the Youth Compendium of Physical Activities, [81] activities in the time diaries were assigned to one of the sixteen activity categories in the compendium. For example, time diary activities related to participation in team or individual sports were assigned to the "Sports/games" group, chores were assigned to the "Housekeeping/work" group, and homework and reading were assigned to the "Quiet play/schoolwork/television (sitting)" group. Variables for the sum of each of these activity groups were created. Using the corresponding METs for specific activities within each group outline by Butte and colleagues, average METs for each group were calculated for each age group for each activity group. This informed classification of activity group variable to sedentary behavior, light physical activity, or moderate-to-vigorous physical activity. There were several variables for travel time in the time diaries, but mode of travel was not specified (e.g., walking, biking, driving), so these were summed to create a variable for total travel time that was not assigned to a movement category. There were also several variables related to occupation for which the nature of the work was not specified, so these were also not assigned to an activity level. Once each time diary activity was assigned to a compendium category, new variables representing the total time recorded for each of the compendium categories were created. Sleep was included as a separate variable.

Since METs for each activity varied by age group, the data was divided into three subsets to assign appropriate METs to each movement category variable. Variables were created for weekend and weekday total daily energy expenditure, measures in MET-minutes, and minutes spent in sleep, sedentary behavior, light physical activity, moderate-to-vigorous physical activity, and travel. Energy expenditure variables were created by multiplying the time spent in each compendium category by the MET value assigned to that category and summing of the products for all categories. The other activity variables were calculated by summing the total minutes spent in the compendium categories that were classified as moderate-to-vigorous physical activity, for instance, based on their METs. New variable names were kept consistent so that the datasets could be recombined to create the final analytic dataset.

Statistical analyses

Descriptive statistics

Survey weight, clusters, and strata variables were included with SAS survey procedures in all analyses to account for the survey design and resulting probability selections when calculating standard errors. The alpha level was set to 0.05 for all analyses. Descriptive statistics for demographics of the overall population were first calculated, reporting the mean or percentage and standard error. Median was reported for income due to the presence of an outlier. These characteristics were then compared between boys and girls and among the three age groups. For the comparison between sexes, t-tests were used for continuous variables and adjusted Pearson chi-square tests were used to compare distribution among categorical variables. When comparing continuous variables between the three age groups, ANOVA was used. Chi-square was again used for examining equal distribution among categorical variables.

Analyses of movement patterns

Time spent in each of the compendium of physical activity categories for the weekday and weekend diaries was calculated for the total study population. Independent sample t-tests were used to assess differences in these variables between boys and girls, and ANOVA was used to make comparisons among the age categories. Multiple linear regression models were employed to assess the relative difference in weekday and weekend total daily energy expenditure and time spent in sleep, sedentary behavior, light physical activity, and moderate-to-vigorous physical activity while accounting for multiple variables, including age category, sex, race, ethnicity, household income, level of parental education, weight status, and weight perception. P-values were used to assess the statistical significance of the associations.

Finally, the sample was stratified by sex based on a priori research to evaluate correlates of movement patterns among girls and among boys. Multiple linear regression models for the outcomes of weekday and weekend total daily energy expenditure and minutes spent in sedentary behavior, light physical activity, and moderate-to-vigorous physical activity were repeated (with the omission of the sex variable) to conduct this subgroup analysis. Coefficient estimates and p-values are reported for all models.

VI. RESULTS

Study characteristics

Table 1 displays weighted characteristics of the study sample. The final analytic sample included 631 adolescents, of which 38.2% were 10-12 years old, 35.0% were 13-15, and 26.9% were 16-18. Gender was approximately evenly represented (48.4% female). Adolescents were about two thirds White and 15% (95% CI [9.55%, 19.75%]) Black, and 17.6% (95% CI [12.63%, 22.49%]) were of Hispanic ethnicity. However, a majority (60.4%) did not have data for ethnicity. About half were categorized as normal weight and half perceived themselves as "about the right weight". The mean total household income in 2012 was 99,621 USD (95% CI [56,824, 141,819]), with a median of 69,976. A large majority (86.1% (95% CI [80.88%, 91.35%]) of the sample met the census needs threshold in 2012. On average, household heads completed 13.6 (95% CI [13.18, 14.09]) years of education. Unweighted descriptive statistics and differences in demographic characteristics between gender and age groups are displayed in the appendix.

Table 1 here

Movement patterns

Total daily energy expenditure

Metabolic equivalent of task (METs), the ratio of working metabolic rate relative to resting metabolic rate, can be used to measure of energy expenditure. An MET of 1.0 is associated with rest and above 6.0 METs is considered vigorous activity. On average, adolescents reported total daily energy expenditure of 1423 (95% CI [1378, 1468]) and 1457 (95% CI [1381, 1532]) MET-minutes on weekdays and weekends, respectively (Table 2). Average energy expenditures were similar between genders on the weekday, but significantly higher among boys on the weekend (1305 vs. 1599 MET-minutes) (Table 3). Comparisons of movement patterns among age groups are provided in Table 4. Average daily energy expenditure differed significantly only for the weekend (1562 for ages 10-12, 1474 minutes for ages 13-15, and 1285 for ages 16-18).

Table 2 and Figures 1 and 2 here, followed by Tables 3 and 4

Multiple linear regression analyses indicated a significant association with total daily energy expenditure by gender only on the weekend (Table 5). On average, boys exerted 280 more daily MET-minutes on weekend days than girls. No significant associations with age category were present in the linear regression analyses. Black adolescents reported 128 fewer MET-minutes on the weekday compared to their White counterparts. Adolescents in the underweight category reported 196 fewer weekday MET-minutes compared to those categorized as normal weight. With an increase of family income of 10,000 USD, there was a small but statistically significant decrease in daily energy expenditure (1 MET-minute).

Table 5 and Table 6 here

Sleep

Average sleep duration was nine hours (95% CI [8.7, 9.3]) on weekdays and 10.5 hours (95% CI [10.2, 10.7]) on weekend days (Table 2). While there were no significant differences by gender, we did observe variation among age categories. Average weekday and weekend sleep was 569 and 655 minutes for those in the 10-12 age group, 513 and 604 minutes for the 13-15 group, and 532 and 620 minutes for 16–18-year-old adolescents (Table 4).

Few differences were observed in the regression analyses of sleep correlates (Table 6). Boys reported 32 more minutes of sleep on the weekday, and adolescents 13-15 years of age had 43 fewer minutes of nightly weekend sleep compared to those 10-12 years of age. Hispanic adolescents had 42 fewer minutes of average nightly weekday sleep compared to non-Hispanic.

Sedentary time

Sedentary time consisted of lying, quiet play, schoolwork, television watching, and computer games. Average total duration was 11.3 hours (95% CI [10.9, 11.7]), or about 47% of the day on weekdays (Figure 1) and 7.8 hours (95% CI [7.4, 8.2]) (one third of the day) on weekend days (Figure 2). Table 2 also includes duration of activity types that comprise each movement category. The quiet play, schoolwork, and television activity group contributed most of adolescents' sedentary time, with 620 out of the 677 weekday minutes and 377 out of the 466 weekend day minutes.

No gender differences for overall sedentary time were observed in the descriptive analyses, but some differences were identified when looking at activity types within movement categories (Table 3). Weekday and weekend lying durations were greater among girls (20 minutes vs. 8 minutes and 23 minutes vs. 8 minutes, respectively) and computer game play time was greater among boys for both types of days (16 minutes vs 68 minutes and 26 minutes vs 118 minutes, respectively). Girls spent significantly more time in the quiet play, schoolwork, and television activity group (639 vs. 602 minutes) and standing (68 minutes vs. 49 minutes) on the weekday.

Sedentary time also differed for the three age groups for both weekday and weekend data (Table 4). Durations were 647 and 447 minutes for ages 10-12, 713 and 512 minutes for ages 13-15, and 671 and 435 minutes for ages 16-18. Significant differences in duration by activity type among the age groups were observed for lying and quiet play for both weekday and weekend data (3 minutes, 18 minutes, and 25 minutes).

Results from multiple linear regression analyses indicated no significant differences by age nor gender in sedentary time. Correlations between family income with both weekday and weekend sedentary time were statistically significant, with higher income associated with a less than one minute reduction (Table 7). No significant differences were identified between genders and age groups in the regression results.

Table 7 and Table 8 here

Light physical activity

The light physical activity category consisted primarily of standing, which contributed over 98% of total duration, but also included weightlifting. Adolescents reported 59 minutes (95% CI [53, 65]) and 51 minutes (95% CI [46, 56]) of light physical activity on weekdays and weekend days, respectively (Table 2). Light physical activity was the only movement category for which significant gender differences were observed in the descriptive analyses. Girls spent an average of 68 and 59 minutes in this category on weekdays and weekend days, respectively, while the corresponding durations for boys were 49 and 44 minutes (Table 3). No differences were found between age groups.

Multiple linear regressions of light physical activity resulted in significant correlations by gender for both weekday and weekend, with boys reporting 17 and 16 fewer minutes, respectively (Table 8). A small (0.4 minutes) but significant decrease in light physical activity was found for each additional year of education for the household head.

Moderate to vigorous physical activity

Moderate to vigorous physical activity included housekeeping and work, calisthenics, sports and games, dance and aerobics, bike and scooter riding, active play, swimming, walking, and running. Housekeeping and work, sports/games, and active play each contributed about a third of the total moderate to physical activity duration for weekdays and about one third, and 35%, 17%, and 32% of the average weekend duration, respectively. Average duration of moderate to vigorous physical activity was 69 minutes (95% CI [58, 79]) on weekdays and 139 minutes (95% CI [123, 154]) on weekend days, while the medians were 31 minutes and 105 minutes, respectively (Table 2). Boys spent more time in moderate to vigorous physical activity only on weekend days (121 minutes vs. 156 minutes) (Table 3). Boys spent more time playing sports and games on both types of days (11 minutes vs. 29 minutes for weekday, 14 minutes vs 34 minutes for weekend).

Weekday and weekend moderate to vigorous physical activity duration differed among the three age groups; durations were 81 and 160 minutes for ages 10-12, 54 and 132 minutes for ages 13-15, and 71 and 116 minutes for ages 16-18, respectively (Table 4). Upon examination of activity type, active play was different for both day types, with the youngest group reporting the highest duration. Walking and running duration were also significantly different, with the oldest group spending the most time in these activities.

In multiple linear regression analyses of moderate to vigorous physical activity duration, no associations with gender nor age group were observed (Table 9). For both weekday and weekend, average daily moderate to vigorous physical activity was lower among Black adolescents (by 36 and 47 minutes, respectively) and among those in the “other” race category (51 minutes) for the weekend when compared to White adolescents. Lower daily weekend moderate to vigorous physical activity was also observed among underweight (61 fewer minutes) and at risk for overweight (31 fewer minutes) adolescents when compared to those classified as normal weight. Income was significantly associated with weekend moderate to vigorous physical activity, with an increase of 10,000 USD associated with a less than one minute decrease.

Table 9 here

Stratified analyses

Total daily energy expenditure

Multiple linear regression results stratified by gender are displayed in Tables 10 through 14. Among girls, daily energy expenditure differed among age groups only for weekday data (Table 10). Girls ages 13-15 had 105 fewer MET-minutes than girls ages 10-12. The average daily energy expenditure among Black adolescent girls was lower than that of White girls by 126 for weekday and 188 MET-minutes for weekend data. Girls in the "other" race category had 261 fewer weekend MET-minutes than White girls. Daily weekend energy expenditure among underweight girls was significantly higher than girls of normal weight (290 MET-minutes). In addition, there was a small but significant association between family income and weekend energy expenditure with a higher income resulting in a 1.1 fewer MET-minutes.

Among boys, weekday energy expenditure was found to be lower by 193 MET-minutes for boys of "other" race compared to White boys. Hispanic ethnicity was associated with lower energy expenditures for both weekday and weekend data (222 and 517 MET-minutes, respectively). There were differences among weight categories for the weekend data, with underweight, at risk for overweight, and overweight boys reporting 345, 239, and 273 fewer MET-minutes, respectively, when compared to normal wight boys. Family income increase of 10,000 USD was associated with an increase of 22 MET-minutes for weekend days.

Table 10 here

Sleep duration

Stratified regressions for sleep duration showed that Black girls had 85 more minutes of weekend sleep compared to White girls (Table 11). In addition, girls who were underweight slept 76 more minutes than girls of normal weight on weekdays. There were significant increases with both family income on both types of days (0.57 and (0.11 minutes), but a small decrease in weekend sleep (-1.0 minute) with a one-year increase in education of the household head. Among boys, the only significant associations were based on weight status. Boys who were underweight, at risk for overweight, and overweight reported 79, 67, and 47 respective fewer minutes of weekday sleep when compared to boys categorized as normal weight.

Table 11 here

Sedentary time

Black race was significantly associated with increased average sedentary time among girls (78 minutes) but not among boys (Table 12). No age differences were observed among either of the gender strata. Being underweight was associated with lower weekday sedentary time among girls (191 minutes) but higher duration in boys (92 minutes). In addition, family income and household head years of education were associated with lower sedentary time on weekdays (0.6 minutes and 3 minutes, respectively) but increased time on weekend days (0.5 minutes and 3 minutes) only among girls.

Table 12 here

Light physical activity duration

Differences in average durations of light physical activity were limited in the stratified analyses. The only significant association among girls was found for household head years of education (-0.6 minutes for weekday and -0.4 for weekend) (Table 13). Among boys, family income was associated with a small increase, but years of education was related to a modest decrease. Black race was significantly associated with an increase in both weekday and weekend light physical activity among boys (14 minutes and 20 minutes, respectively).

Table 13 here

Moderate to vigorous physical activity duration

Among girls, associations with lower average daily moderate to vigorous physical activity duration were observed for Black race (44 minutes lower for weekday and 52 minutes lower for weekend) compared to White (Table 14). Girls in the “other” race category were also found to have 67 fewer minutes on the weekend. Boys in this category were found to have 49 fewer minutes on weekdays than White boys. In addition, Hispanic adolescent boys reported 59 fewer minutes of weekday moderate to vigorous physical activity than non-Hispanic boys. No significant differences between weight categories were observed among girls. Among boys, underweight was associated with 85 fewer minutes and being at risk for overweight with 62 fewer minutes of daily weekend duration. Among girls, higher income was associated with a slight decrease (0.15 minutes) in duration of moderate to vigorous physical activity.

Table 14 here

V. DISCUSSION

Main findings

This study aimed to describe and examine correlates of activity patterns of US adolescents in the context of the movement continuum using data from 24-hour time diaries. The introduction of 24-hour movement guidelines[88] has emphasized the importance of applying an integrated approach to assessing the composition of movement throughout the day, from sleep to moderate to vigorous physical activity.[89] Adolescents engaged in over an hour of daily moderate to vigorous physical activity, were sedentary for less than half of the day, and reported over eight hours of sleep. While gender and age differences were limited when comparing durations of sedentary time and moderate to vigorous physical activity, differences were observed for several of the activity types. In addition, we found that associations between activity patterns and race, weight, and income may exist within gender strata.

On average, adolescents in this study reported above one hour of moderate to vigorous physical activity on weekdays and about two hours on weekdays, consisting mostly of housekeeping and work, sports and games, and active play. This total meets current recommendations that children and adolescents engage in in 60 minutes of moderate to vigorous physical activity per day. [49] Previous studies evaluating 24-hour movement patterns in children and adolescents have found daily moderate to vigorous physical activity mainly within the range of 45-60 minutes [89-92]; however, these examinations have largely used accelerometry to measure physical activity, which tends to provide lower estimates compared to self-report methods.[93] One study that also employed a 24-hour recall and used MET-minutes as a measure of total daily energy expenditure found that adolescent boys had 137 and girls had 107 minutes of daily moderate to vigorous physical activity. These values fall in between the present estimates for weekday and weekend moderate to vigorous physical activity. In addition, we found total daily energy expenditures of 1423 and 1457 MET-minutes, lower than that reported by Maher (above 2300 MET-minutes).[94] Furthermore, an examination of health behavior using 2007 PSID CDS time diary data reported 106 minutes of daily active leisure[95], highlighting that these methods may indeed result in higher activity estimates. It should also be noted that median moderate to vigorous physical activity values were substantially lower than the means, indicating that at an individual level, fewer than half of adolescents met physical activity guidelines. There were several individuals, some of whom were siblings reporting similar durations, that reported very high durations of certain moderate to vigorous physical activity activities, suggesting that activity may be highly variable in this population.

Adolescents spent close to 50% of the 24-hour period in in sedentary time on the weekdays, mainly accumulating this time thorough quiet play, schoolwork, and television. However, we found that on weekends, sedentary time comprised only about a third of adolescents' days, closer to rates observed in a compositional analysis by Dumuid and colleagues.[91] Past results examining these differences have been mixed, with some finding higher sedentary time on weekends compared to weekdays,[96,97] while others have reported the opposite.[28,98,99] One consideration is that school time was not detailed in the present time diary variables and was thus classified as sedentary time, contributing to much of the weekday sedentary time. Differences in approaches to activity measurement and activity classification may at least partially account for these discrepancies, but literature evaluating total sedentary time is currently limited. Current recommendations only provide a specific target (< 2 hours) for recreational screen time,[88] so many analyses have only examined this component of sedentary behavior.[89,92]

On average, adolescents met sleep guidelines of 9-12 hours for those 10-12 years old and 8-10 hours for ages 13-18.[100] Previous literature on gender differences in adolescent sleep has been mixed,[101-103] and our findings of no significant gendered differences in sleep patterns further indicate that there may be more nuance within this relationship. In the multiple linear regression, the two older age groups reported less sleep than the 10–12-year-old group, but this difference was only significant among 13-15 year old adolescents. This runs contrary to most existing work that has often reported decreases in sleep throughout adolescence [101,104], but the middle age group still reported an average of above eight hours on both weekdays and weekends.

Our examination of gender associations revealed comparable durations of moderate to vigorous physical activity between boys and girls. This could be attributed to our inclusion of all forms of physical activity, including household activities and chores rather than solely sports participation or other exercise. We found that boys engaged in sports and games for about 20 minutes longer than girls on both weekdays and weekends, highlighting the importance of evaluating different activity types across the entire day. Sports participation among girls has improved in recent decades but may still be present,[6] and rates of increases have not been equal across race and ethnicity.[105] While similar total moderate to vigorous physical activity levels are encouraging from a physical health standpoint, type of physical activity could also have implications for social and emotional health.[106] It is important that programs continue to advocate for girls' participation in sports.[107] No gender differences were observed in overall sedentary time, but girls reported about 15 more minutes spent lying and boys had more time playing computer games, with 50 more minutes reported on weekday and about 90 more on weekend days. Examining activities comprising sedentary time can inform more detailed examinations of these effects and tailored interventions to best address this important component of the movement continuum in young people.

Previous studies have suggested that physical activity tends to decrease while sedentary time tends to increase with age,[59,108,109] but these patterns were not consistently observed in the present analysis. While not statistically significant, the middle age group (13-15) generally had the least moderate to vigorous physical activity and highest sedentary time, a notable combination that may merit further investigation. In addition, we found age differences in types of activities. For instance, time spent lying increased with age and active play generally decreased. There were also differences in the quiet play and schoolwork category, with the 13–15-year-old group reported the longest durations, followed by 10-12. This variation may have been due to the variety of activities included in this category, as younger children may have reported more quiet play while schoolwork time may increase with age. Examining these differences provides valuable information about how different age groups are spending their time and thus how to best improve movement outcomes.

Multiple linear regression analyses allowed us to examine additional potential correlates of movement behaviors. Black race was found to be associated with about 40 fewer minutes of moderate to vigorous physical activity, and upon stratifying by gender, this relationship only persisted among girls. Importantly, this group also had lower overall total daily energy expenditure and over 70 minutes more sedentary time compared to White girls. This is consistent with a recent study that observed more pronounced gender disparities in physical activity among Black high school students.[110] Previous research looking at sedentary time is more limited, but data from the National Health and Nutrition Examination Survey has suggested that Black adolescents may engage in more sedentary behavior.[58] Paired with the present findings, further examinations of this potential interaction at this pivotal stage of life are warranted, particularly given the importance of health habits formed during childhood on future health.[23,24,82] We did not observe significant difference between Hispanic and non-Hispanic girls, as has also been reported[110] but did observe lower daily energy expenditure and moderate to vigorous physical activity among Hispanic boys compared to non-Hispanic boys. Lower physical activity levels have also been reported among Hispanic adolescents overall.[8] However, a substantial proportion of adolescents did not have ethnicity data, limiting our ability to draw meaningful conclusions.

Additional associations were observed among weight categories, particularly when stratifying by gender. Different patterns were observed for underweight between genders; girls classified as underweight reported higher energy expenditure and lower sedentary time while underweight boys reported lower energy expenditure and higher sedentary time when compared to those in the normal weight category. Associations between being at risk for overweight or overweight and physical activity levels were only observed among boys, contrary to previous findings that have suggested weight or physical appearance may play more of a role in this relationship among girls.[111]

While some significant correlations were identified between income and parental education and activity outcomes, the direction of these estimates varied, and the effect sizes were generally too small to be meaningful in practice. Current evidence is mixed, and our results somewhat align with a study that used both 24 hours recall and pedometers found no differences in total moderate to vigorous physical activity by income and only small differences in step counts.[94] However, another reported that physical activity increased with income but only among females.[8] While the current examination did not assess this relationship, there is also evidence that higher household income is an important factor for participation in organized sports.[63,112]

Limitations and future directions

It is important to acknowledge the limitations of the current investigation. Time-use surveys are not an objective measure of physical activity intensity and energy expenditure. However, they are subject to less recall bias than other subjective means of physical activity data collection [87] and capture valuable information about type of activity. Future work could integrate data from accelerometry and time-use surveys to validate activity duration and intensity. In addition, there were several steps in the translation of time diary recordings into the included outcomes that required subjective categorization of variables. Some variables in the time use data did not objectively align with the activity categories outlined in the Youth Compendium of Physical Activity.[81] When assigning MET values to activity categories, an average was applied to all time diary activities falling into the compendium category, so if activities comprising more or less of the durations had a true MET that was much higher or lower than the assigned average, this could distort the estimate MET-minutes. Based on the MET assignment, some categories were on the border of classification as sedentary behavior versus light physical activity or light physical activity versus moderate to vigorous physical activity, affecting estimates of energy expenditure or durations of movement categories.

Another limitation is that type of travel was not included in the time diaries. There was information about where participants were going, but not the mode of travel. Thus, we cannot examine the role that active or inactive travel may have played in this study. In addition, occupational activities were not specified, and school time was coded as one variable, which was ultimately classified into the schoolwork and sedentary categories. We therefore are unable to include potential physical education time or active learning, important contributors to physical activity in this age group.[113] For many of the time diary variables, additional details, such as participants standing or sitting during activities, would inform more objective categorization of activities. The analyses were also limited by missing data in several of the demographic categories. In addition, MET-minutes was used to measure total daily energy expenditure, but there are many factors, including age, body composition, and others, that contribute to this metric. More comprehensive measures of energy expenditure could be explored in future work. Lastly, many comparisons were conducted in this paper, introducing the potential for issues surrounding multiple testing.

Future research in this area with additional datasets should ensure that mode of travel and school day activity are included in order to develop a more complete characterization of adolescent movement patterns throughout the day. In addition, future analyses of the CDS time diary data could include additional comparisons among subgroups and more specific activity categories to elucidate some of the present findings. A formal examination of the adolescents with the highest activity levels is an important next step to assess the validity of the current estimates. Next steps should also include combining weekday and weekend data to examine weekly activity patterns.

Strengths

Despite these limitations, there are notable strengths of this investigation. This was a relatively large sample of time diary data from a nationally representative, ongoing panel study. The large sample allowed for comparisons between gender and age groups. While time diary methods are subjective, they provide detailed measures of daily movement behavior that cannot be gathered from device-measured activity. The diary was open-ended with no predetermined time increments, allowing respondents to complete the diary as closely to their actual activity patterns with less recall and social desirability bias than other recall methods.[87] The use of time-diary data provides valuable information about type of activities and allowed for characterization of complete movement patterns of the sample, rather than just screen time, sports participation, or other commonly used activity outcomes. Gaining a more complete picture of the balance between time spent in different activity can inform our identification of groups that may be particularly at risk (e.g., low physical activity and high sedentary time). There is ample evidence that evaluating combinations of activities in the context of the movement continuum merits further attention as it captures valuable information that evaluating movement behaviors in isolation.[88]

Furthermore, while differences in sedentary time and moderate to vigorous physical activity were limited between boys and girls, analyses of activity type revealed variations that may have implications for adapting interventions to specific populations. Finally, collection of time diary data on both a randomly selected school day and weekend day provided insights into how activity patterns may differ during different parts of the week.

Conclusions & Public Health Implications

Meeting combined recommendations for sleep, sedentary behavior, and physical activity outlined in 24-hour movement guidelines has been associated with better physical and mental health outcomes,[89,90]. This study further emphasizes the merits of investigating activity in the movement continuum framework and contributes to our current understanding of the composition of these activities among US adolescents in the context of 24-hour movement behaviors. Using time diary data, we found that on average, adolescents report over an hour of daily moderate to vigorous physical activity, were sedentary for less than half of the day, and had over eight hours of nightly sleep. In addition, while differences in overall moderate to vigorous physical activity and sedentary time between girls and boys and age groups were limited, types of activities contributing to sedentary time and physical activity time differed, indicating the importance of evaluating how these minutes are accumulated when conducting movement behavior research. As certain types of physical activity such as sports may provide other social and cognitive benefits, additional research is needed to understand these relationships.

While some adolescents are meeting guidelines, further work is required to address disparities in achieving healthy 24-hour movement guidelines. Notably, we identified both low physical activity and high sedentary time among Black females. Identifying groups with suboptimal movement metrics and examining types of activities that comprise these movement categories will be critical in informing tailored interventions that will effectively benefit different subgroups, such as addressing barriers to sports participation among girls. Reducing sedentary behavior and increasing physical activity will play a critical role in addressing the growing public health burden of physical and mental health-related challenges among adolescents and prevent future development of obesity and chronic disease.

VI. REFERENCES

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VII. TABLES & FIGURES

Table 1. Weighted characteristics of adolescents completing time diary component of the CDS (n=631)

Characteristics	Mean or %	SE
Gender		
Female	48.38	3.02
Male	51.62	3.02
Age category		
10-12	38.17	2.62
13-15	34.96	2.53
16-18	26.87	2.49
Race		
White	67.53	3.35
Black	14.65	2.50
Other	17.82	2.54
Ethnicity		
Hispanic	17.56	2.42
Not Hispanic	22.00	2.33
Missing	60.43	2.90
Child weight status [a]		
Underweight	1.98	0.69
Normal	46.89	3.55
At-risk for overweight	11.93	1.30
Overweight	20.56	2.54
Missing	18.63	3.05
Child's weight perception [b]		
Very underweight	2.36	0.70
Slightly underweight	11.79	2.04
About the right weight	51.62	3.14
Slightly overweight	18.95	3.01
Very overweight	3.87	1.41
Missing	11.41	1.72
Total household income (USD), mean	99,621	20,888
Median	69,976	5,236
Census needs [c]		
Below Census needs	13.89	2.57
At or above Census needs	86.11	2.57
Years of education completed by household head	13.64	0.22

Note. All results are survey-adjusted.

[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.

[b] Children were asked "How do you think of yourself in terms of weight?"

[c] 2012 total household income compared to standardized 2012 income needs based on family size and US Census data.

Table 2. Mean total daily energy expenditure (MET-min) and duration of daily weekday and weekend activities (min/day) among US adolescents

	Weekday		Weekend	
	Estimate	SE	Estimate	SE
Total daily energy expenditure, mean	1423	22.13	1457	37.14
Total daily energy expenditure, median	1328	19.52	1315	46.16
Sleep	539.4	9.52	627.8	7.13
Sedentary time	676.4	12.48	466.2	11.37
Lying (not sleeping)	13.69	3.57	15.14	2.03
Quiet play/schoolwork/television (sitting)	619.62	10.97	377.50	9.32
Computer games (sitting)	43.13	5.15	73.54	6.50
Light physical activity	59.16	2.81	51.10	2.56
Standing	58.44	2.82	51.00	2.55
Weightlifting	0.73	0.53	0.11	0.08
Moderate to vigorous physical activity, mean	68.78	5.14	138.7	7.73
Moderate to vigorous physical activity, median	30.70	6.95	104.8	8.49
Housekeeping/work	22.61	2.88	48.70	5.82
Calisthenics/gymnastics	2.43	0.85	1.07	1.22
Sports/games	20.17	3.34	24.14	3.74
Dance/aerobics	0.96	0.42	2.36	0.88
Bike riding	0.51	0.13	4.06	1.20
Active Play	20.49	3.05	43.96	5.30
Swimming	0.67	0.36	3.76	1.73
Walking	2.55	0.70	11.38	1.47
Running	0.82	0.57	0.34	0.27
Travel	64.36	12.48	75.22	5.60

Note. All results are survey-adjusted. T-tests were used to compare minutes between boys and girls, and ANOVA was used to compare minutes among age groups. MET = metabolic equivalent of task.

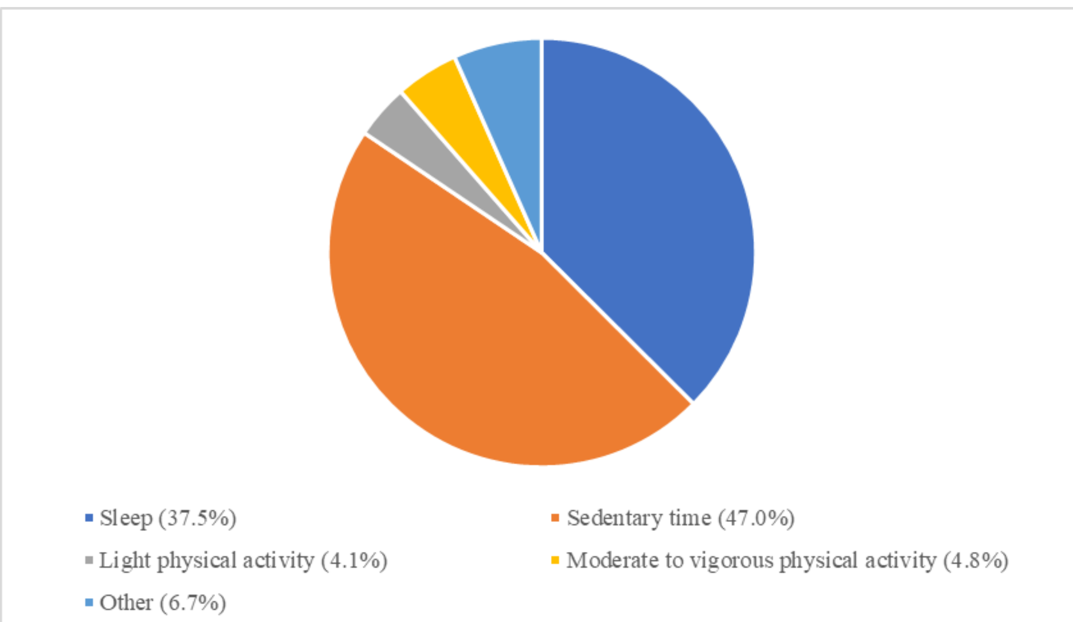

Figure 1. Average 24-hour weekday activity behavior composition of US adolescents. "Other" category includes unspecified travel and occupational time.

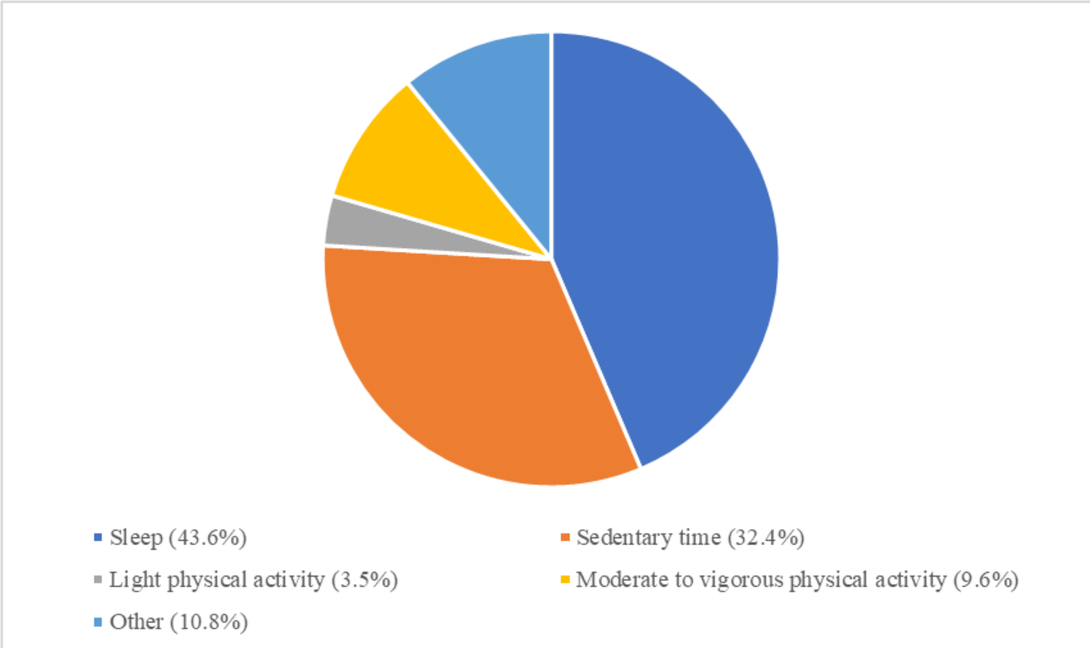

Figure 2. Average 24-hour weekend activity behavior composition of US adolescents "Other" category includes unspecified travel and occupational time.

Table 3. Mean total daily energy expenditure (MET-min) and duration of weekday activities (min/day) among US adolescents by gender.

	Weekday					Weekend				
	Girls (n=314)		Boys (n=317)			Girls (n=314)		Boys (n=317)		
	Mean	SE	Mean	SE	p	Mean	SE	Mean	SE	p
Total daily energy expenditure, mean	1430	35.14	1415	36.86	0.77	1305	42.26	1599	70.52	0.002
Total daily energy expenditure, median	1329	22.89	1325	36.89		1195	60.59	1402	75.52	
Sleep	524.6	11.9	553.3	12.9	0.06	641.2	14.09	615.21	10.90	0.17
Sedentary time	675.0	16.2	677.8	15.51	0.87	442.8	16.6	488.1	20.40	0.12
Lying (not sleeping)	19.89	5.61	7.90	2.66	0.02	22.91	4.24	7.87	2.41	0.001
Quiet play/schoolwork/television (sitting)	638.90	14.79	601.55	14.50	0.049	393.58	14.57	362.42	16.19	0.19
Computer games (sitting)	16.24	4.19	68.34	9.95	<0.001	26.33	4.49	117.79	13.42	<0.001
Light physical activity	68.11	4.26	50.77	3.96	0.004	58.88	4.01	43.81	3.14	0.003
Standing	68.11	4.26	49.37	3.90	0.002	58.88	4.01	43.59	3.12	0.002
Weightlifting	0.00	0.00	1.41	1.04	0.18	0.00	0.00	0.22	0.16	0.19
Moderate to vigorous physical activity, mean	67.05	9.03	70.41	7.82	0.79	120.5	7.59	155.7	13.57	0.02
Moderate to vigorous physical activity, median	30.44	10.07	30.17	8.70		103.5	12.62	110.1	19.44	
Housekeeping/work	26.94	5.14	18.55	4.59	0.26	51.06	8.87	46.49	5.68	0.60
Calisthenics/gymnastics	2.76	1.49	2.11	1.11	0.73	2.37	0.88	4.36	2.03	0.39
Sports/games	10.97	2.86	28.79	5.95	0.01	13.98	3.37	33.66	6.54	0.01
Dance/aerobics	1.98	0.87	0.11	0.01	0.03	4.89	1.86	0.00	0.00	0.01
Bike riding	0.35	0.23	0.65	0.31	0.50	3.23	2.20	4.83	2.67	0.65
Active Play	22.67	4.60	18.45	4.17	0.47	32.01	5.13	55.17	11.27	0.09
Swimming	0.51	0.42	0.81	0.59	0.68	2.77	1.72	4.68	2.86	0.56
Walking	2.46	0.76	2.64	1.07	0.88	12.04	2.49	10.75	2.75	0.73
Running	1.17	1.10	0.50	0.41	0.57	0.56	0.55	0.13	0.09	0.44
Travel	66.56	4.89	62.30	5.29	0.48	78.33	9.11	72.31	7.95	0.60

Note. All results are survey-adjusted. T-tests were used to compare minutes between boys and girls, and ANOVA was used to compare minutes among age groups. MET = metabolic equivalent of task.

Table 4. Mean total daily energy expenditure (MET-min) and duration of activities (min/day) among US adolescents by age group.

	Weekday							Weekend						
	10-12 (n=255)		13-15 (n=236)		16-18 (n=140)			10-12 (n=255)		13-15 (n=236)		16-18 (n=140)		
	Mean	SE	Mean	SE	Mean	SE	p	Mean	SE	Mean	SE	Mean	SE	p
Total daily energy expenditure, mean	1444	35.11	1383	33.86	1445	59.66	0.19	1562	64.53	1474	62.08	1285	85.75	<0.001
Total daily energy expenditure, median	1325	35.26	1309	23.12	1330	65.94		1402	76.88	1326	55.96	1129	85.91	
Sleep	568.7	9.10	512.9	16.50	532.4	25.33	<0.001	654.8	11.56	603.9	15.86	620.5	14.29	<0.001
Sedentary time	646.5	12.75	713.4	18.97	671.0	26.08	<0.001	446.6	13.88	511.7	20.86	434.8	26.17	<0.001
Lying (not sleeping)	6.82	4.20	11.70	5.10	26.06	9.85	<0.001	2.90	2.34	17.72	4.39	24.92	7.32	<0.001
Quiet play/schoolwork/television (sitting)	601.32	14.64	656.69	21.32	597.40	21.00	<0.001	367.68	16.39	411.09	21.00	347.74	22.64	0.001
Computer games (sitting)	38.36	7.31	45.00	8.86	47.49	13.92	0.54	72.98	11.24	82.90	13.82	62.15	13.71	0.28
Light physical activity	57.33	4.14	57.15	2.96	64.37	7.64	0.11	52.64	3.94	49.27	4.18	51.29	4.06	0.65
Standing	57.33	4.15	55.36	2.66	64.01	7.64	0.06	52.64	3.94	49.06	4.14	51.15	4.05	0.62
Weightlifting	0.00	0.00	1.79	1.48	0.37	0.37	0.048	0.00	0.00	0.22	0.21	0.13	0.14	0.72
Moderate to vigorous physical activity, mean	81.04	9.26	53.85	8.4	70.79	10.86	0.005	160.5	11.66	132.2	11.85	116.2	17.89	<0.001
Moderate to vigorous physical activity, median	59.73	9.06	9.42	4.78	29.74	13.24		129.2	9.73	93.58	14.50	59.77	23.64	
Housekeeping/work	24.74	5.16	22.58	5.79	19.64	4.84	0.55	50.08	6.85	46.76	7.40	49.27	12.66	0.89
Calisthenics/gymnastics	2.31	1.86	2.47	1.32	2.53	1.37	0.99	1.62	0.87	3.99	2.15	5.15	3.19	0.43
Sports/games	23.90	7.48	13.97	2.62	22.94	7.79	0.07	30.08	2.55	21.88	6.84	3.25	9.11	0.25
Dance/aerobics	0.88	0.57	0.70	0.60	1.42	1.23	0.83	1.17	0.54	5.49	2.55	0.00	0.00	0.01
Bike riding	1.03	0.43	0.32	0.32	0.00	0.00	0.15	6.14	3.01	4.89	3.61	0.00	0.00	0.06
Active Play	27.84	6.73	14.44	4.77	17.94	6.00	0.03	58.84	9.72	43.25	8.84	23.75	8.78	<0.001
Swimming	0.51	0.30	0.00	0.00	1.76	1.32	0.13	4.33	2.74	0.20	0.21	7.56	5.11	0.08
Walking	2.15	0.74	1.70	0.89	4.24	2.08	<0.001	9.82	2.69	9.57	1.90	15.94	5.76	<0.001
Running	0.00	0.00	0.16	0.16	2.86	2.07	<0.001	0.00	0.00	0.19	0.13	1.01	0.98	0.007
Travel	64.45	5.15	64.19	4.87	64.46	8.01	0.99	80.75	9.09	61.23	9.14	85.53	9.41	0.01

Note. All results are survey-adjusted. T-tests were used to compare minutes between boys and girls, and ANOVA was used to compare minutes among age groups. MET = metabolic equivalent of task.

Table 5. Correlates of weekday and weekend total daily energy expenditure (MET-min) among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	6.09 (50.80)	0.91	279.6 (96.79)	0.006
Age category (ref = 10-12)				
13-15	-61.73 (38.42)	0.11	15.47 (96.31)	0.87
16-18	25.50 (69.41)	0.71	-142.85 (127.6)	0.27
Race (ref=white)				
Black	-128.2 (49.43)	0.01	-138.6 (106.4)	0.20
Other	-61.07 (83.60)	0.47	-175.2 (110.7)	0.12
Ethnicity (ref=not Hispanic)				
Hispanic	-143.97 (95.57)	0.14	-377.3 (141.7)	0.01
Missing	-28.74 (67.29)	0.67	-241.5 (98.09)	0.02
Weight status (ref=normal) [a]				
Underweight	-196.18 (96.65)	0.048	-242.6 (137.4)	0.08
At risk for overweight	-35.37 (78.70)	0.66	-102.1 (72.23)	0.16
Overweight	-83.53 (58.44)	0.16	-190.0 (98.33)	0.06
Missing	16.11 (95.17)	0.87	23.23 (103.7)	0.82
Family income [b]	-1.0 (0.31)	0.003	-0.2 (0.28)	0.47
Household head years of education	-4.50 (4.13)	0.28	3.91 (3.74)	0.30

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
MET = metabolic equivalent of task
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 6. Correlates of weekday and weekend mean sleep duration among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	31.70 (14.35)	0.03	-29.56 (17.86)	0.10
Age category (ref = 10-12)				
13-15	-41.06 (23.31)	0.08	-42.89 (21.16)	0.048
16-18	-26.90 (27.01)	0.32	-27.84 (22.13)	0.21
Race (ref=white)				
Black	-5.82 (13.03)	0.66	40.03 (25.30)	0.12
Other	3.21 (27.97)	0.91	-65.28 (28.64)	0.03
Ethnicity (ref=not Hispanic)				
Hispanic	-42.05 (16.81)	0.02	38.90 (25.08)	0.13
Missing	-34.09 (18.50)	0.07	10.64 (17.92)	0.56
Weight status (ref=normal) [a]				
Underweight	-24.68 (37.87)	0.52	14.50 (44.08)	0.74
At risk for overweight	-17.48 (21.37)	0.42	38.90 (25.79)	0.14
Overweight	-13.97 (12.88)	0.28	22.84 (18.87)	0.23
Missing	-0.87 (26.83)	0.97	12.95 (28.72)	0.65
Family income [b]	0.57 (0.67)	<0.001	0.13 (0.06)	0.02
Household head years of education	2.51 (2.03)	0.22	-0.47 (0.62)	0.45

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 7. Correlates of mean weekday and weekend sedentary time among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	-0.19 (16.44)	0.99	51.11 (28.43)	0.08
Age category (ref = 10-12)				
13-15	34.93 (21.04)	0.10	60.54 (30.44)	0.05
16-18	3.83 (23.85)	0.87	-15.70 (33.35)	0.64
Race (ref=white)				
Black	47.82 (24.66)	0.06	65.39 (37.37)	0.09
Other	45.00 (31.31)	0.16	67.61 (36.42)	0.07
Ethnicity (ref=not Hispanic)				
Hispanic	20.70 (32.19)	0.52	-19.32 (35.79)	0.59
Missing	55.02 (20.35)	0.01	-7.91 (27.56)	0.78
Weight status (ref=normal)				
Underweight	20.09 (61.31)	0.74	84.86 (86.16)	0.33
At risk for overweight	34.90 (28.47)	0.23	41.31 (34.81)	0.24
Overweight	15.76 (16.03)	0.33	4.90 (24.64)	0.84
Missing	-52.38 (27.89)	0.07	-50.38 (39.51)	0.21
Family income [a]	-0.57 (0.06)	<0.001	0.42 (0.13)	0.002
Household head years of education	-2.05 (1.80)	0.26	1.78 (1.63)	0.28

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] per every $10,000 increase in annual income
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 8. Correlates of mean weekday and weekend light physical activity duration among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	-17.24 (5.76)	0.004	-16.13 (4.78)	0.001
Age category (ref = 10-12)				
13-15	-0.47 (6.28)	0.94	-7.67 (7.06)	0.28
16-18	5.04 (8.20)	0.54	-5.69 (7.22)	0.43
Race (ref=white)				
Black	1.05 (6.69)	0.88	7.31 (6.49)	0.27
Other	5.72 (8.65)	0.51	8.51 (8.84)	0.34
Ethnicity (ref=not Hispanic)				
Hispanic	5.57 (7.11)	0.44	6.29 (7.34)	0.40
Missing	0.34 (7.31)	0.96	6.19 (6.89)	0.37
Weight status (ref=normal)				
Underweight	-3.00 (10.48)	0.78	7.17 (17.11)	0.68
At risk for overweight	-9.18 (7.22)	0.21	1.30 (8.64)	0.88
Overweight	2.34 (6.75)	0.73	-5.16 (4.33)	0.24
Missing	-2.02 (9.60)	0.83	-8.65 (6.75)	0.21
Family income [a]	0.03 (0.04)	0.34	0.02 (0.02)	0.13
Household head years of education	-0.12 (0.20)	0.58	-0.38 (0.18)	0.04

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 9. Correlates of mean weekday and weekend moderate to vigorous physical activity duration among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	3.85 (12.18)	0.75	30.45 (16.22)	0.07
Age category (ref = 10-12)				
13-15	-15.10 (8.22)	0.07	-9.26 (16.97)	0.59
16-18	2.67 (14.06)	0.85	-21.34 (23.00)	0.36
Race (ref=white)				
Black	-36.13 (12.46)	0.006	-46.55 (22.84)	0.047
Other	-22.13 (16.61)	0.19	-50.71 (21.69)	0.02
Ethnicity (ref=not Hispanic)				
Hispanic	-31.58 (19.18)	0.11	-38.00 (34.26)	0.27
Missing	-26.56 (15.07)	0.08	-32.28 (18.19)	0.08
Weight status (ref=normal) [a]				
Underweight	-34.14 (20.23)	0.10	-61.46 (34.38)	0.08
At risk for overweight	-13.18 (14.64)	0.37	-31.14 (13.56)	0.03
Overweight	-11.96 (13.89)	0.39	-22.03 (22.41)	0.33
Missing	23.12 (21.94)	0.30	9.92 (22.74)	0.66
Family income [b]	-0.02 (0.06)	0.75	-0.19 (0.07)	0.005
Household head years of education	-0.47 (0.37)	0.21	0.38 (1.04)	0.72

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 10. Correlates of mean weekday and weekend total daily energy expenditure (MET-min) among US adolescents, stratified by gender.

	Girls (n=314)				Boys (n=317)			
	Weekday		Weekend		Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Age category (ref = 10-12)								
13-15	-104.92 (49.70)	0.04	173.9 (123.7)	0.17	-13.33 (75.27)	0.86	-180.1 (174.2)	0.31
16-18	-45.76 (101.8)	0.65	-137.6 (131.4)	0.30	65.02 (95.76)	0.50	-262.1 (153.5)	0.09
Race (ref=white)								
Black	-125.77 (59.61)	0.04	-188.4 (82.11)	0.03	-70.15 (82.71)	0.40	1.51 (161.1)	0.99
Other	52.33 (114.75)	0.65	-260.9 (122.5)	0.04	-193.1 (86.34)	0.03	-96.50 (201.8)	0.63
Ethnicity (ref=not Hispanic)								
Hispanic	-60.17 (110.1)	0.59	-190.5 (153.8)	0.22	-222.4 (106.58)	0.04	-516.7 (201.6)	0.01
Missing	114.6 (79.68)	0.16	-380.8 (129.4)	0.004	-158.4 (82.18)	0.06	-3.73 (143.6)	0.98
Weight status (ref=normal) [a]								
Underweight	-264.1 (206.1)	0.21	289.7 (99.48)	0.005	-62.60 (92.26)	0.50	-344.7 (143.8)	0.02
At risk for overweight	-72.76 (84.33)	0.39	54.06 (108.9)	0.62	143.79 (98.94)	0.15	-239.4 (93.41)	0.01
Overweight	-35.33 (63.84)	0.58	-68.18 (104.0)	0.52	-74.74 (62.48)	0.24	-272.5 (125.9)	0.04
Missing	-4.28 (107.3)	0.97	-24.10 (109.9)	0.83	129.5 (139.2)	0.36	272.5 (156.0)	0.09
Family income [b]	-1.1 (0.23)	<0.001	-0.1 (0.25)	0.61	13.1 (6.80)	0.06	21.6 (8.91)	0.02
Household head years of education	-7.79 (1.99)	<0.001	2.84 (3.21)	0.38	9.34 (8.77)	0.29	5.33 (10.59)	0.62

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model. MET = metabolic equivalent of task.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 11. Correlates of mean weekday and weekend sleep duration among US adolescents, stratified by gender.

	Girls (n=314)				Boys (n=317)			
	Weekday		Weekend		Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Age category (ref = 10-12)								
13-15	-35.82 (29.69)	0.23	-51.13 (38.36)	0.19	-43.05 (37.87)	0.26	-33.23 (21.83)	0.13
16-18	-1.28 (34.34)	0.97	-21.94 (40.41)	0.59	-59.34 (37.14)	0.12	.25.34 (20.59)	0.22
Race (ref=white)								
Black	-19.46 (18.09)	0.29	84.48 (35.13)	0.02	9.19 (12.64)	0.47	-4.06 (34.46)	0.91
Other	-18.78 (36.79)	0.61	-97.35 (45.36)	0.04	39.05 (36.73)	0.29	-10.73 (24.79)	0.67
Ethnicity (ref=not Hispanic)								
Hispanic	-51.86 (30.84)	0.10	38.38 (43.13)	0.38	-39.41 (19.99)	0.05	25.86 (33.08)	0.44
Missing	-60.27 (24.64)	0.02	-11.61 (31.34)	0.71	-2.16 (31.51)	0.95	13.43 (22.51)	0.55
Weight status (ref=normal) [a]								
Underweight	75.73 (31.83)	0.02	-74.15 (52.45)	0.16	-79.32 (31.77)	0.02	33.41 (61.28)	0.59
At risk for overweight	7.33 (22.11)	0.74	46.00 (34.79)	0.19	-67.18 (32.54)	0.04	14.15 (35.18)	0.69
Overweight	13.39 (21.36)	0.53	-5.04 (35.18)	0.89	-46.75 (15.83)	0.005	45.54 (36.19)	0.21
Missing	4.60 (41.45)	0.91	24.66 (47.46)	0.61	-13.21 (21.39)	0.54	-18.97 (25.04)	0.45
Family income [b]	0.57 (0.08)	<0.001	0.11 (0.07)	0.10	0.84 (1.77)	0.64	-1.02 (1.53)	0.51
Household head years of education	3.76 (1.09)	0.001	-0.96 (0.46)	0.04	-4.61 (2.78)	0.10	0.90 (1.66)	0.59

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model. MET = metabolic equivalent of task.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 12. Correlates of mean weekday and weekend sedentary time among US adolescents, stratified by gender.

	Girls (n=314)				Boys (n=317)			
	Weekday		Weekend		Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Age category (ref = 10-12)								
13-15	3.48 (26.12)	0.89	63.48 (35.22)	0.08	67.87 (44.46)	0.02	47.44 (46.17)	0.31
16-18	-32.43 (34.56)	0.35	0.70 (45.21)	0.99	59.56 (33.39)	0.08	-35.09 (50.14)	0.49
Race (ref=white)								
Black	78.73 (32.63)	0.02	70.18 (35.45)	0.05	11.36 (25.97)	0.66	42.30 (49.58)	0.40
Other	49.51 (48.75)	0.31	87.87 (47.89)	0.07	44.16 (35.24)	0.22	20.90 (54.03)	0.70
Ethnicity (ref=not Hispanic)								
Hispanic	-22.02 (46.24)	0.64	-48.91 (35.54)	0.17	68.19 (35.35)	0.06	22.32 (55.55)	0.69
Missing	66.16 (27.50)	0.02	-7.49 (38.92)	0.85	29.58 (31.91)	0.36	8.81 (36.23)	0.81
Weight status (ref=normal) [a]								
Underweight	-191.64 (39.89)	<0.001	135.92 (78.00)	0.09	91.51 (37.93)	0.02	41.44 (119.29)	0.73
At risk for overweight	6.23 (29.24)	0.83	-5.83 (29.09)	0.84	61.60 (49.74)	0.22	89.63 (57.65)	0.13
Overweight	-13.70 (28.13)	0.63	-4.09 (36.76)	0.91	32.04 (20.60)	0.13	-4.58 (35.75)	0.90
Missing	-54.79 (40.44)	0.18	-83.47 (45.65)	0.07	-72.53 (35.74)	0.048	-33.79 (40.44)	0.41
Family income [b]	-0.6 (0.06)	<0.001	0.48 (0.09)	<0.001	-4.04 (2.18)	0.07	-3.54 (3.22)	0.28
Household head years of education	-2.97 (1.18)	0.02	3.44 (0.96)	0.001	3.98 (2.68)	0.14	-2.63 (3.12)	0.40

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 13. Correlates of mean weekday and weekend light physical activity duration among US adolescents, stratified by gender.

	Girls (n=314)				Boys (n=317)			
	Weekday		Weekend		Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Age category (ref = 10-12)								
13-15	-6.96 (9.04)	0.44	-8.60 (14.07)	0.54	10.36 (8.04)	0.20	-5.53 (7.96)	0.49
16-18	21.27 (15.42)	0.17	-1.64 (12.28)	0.89	-9.48 (5.71)	0.10	-11.36 (7.80)	0.15
Race (ref=white)								
Black	-7.62 (10.95)	0.49	0.94 (8.26)	0.91	13.88 (5.52)	0.02	20.08 (6.14)	0.002
Other	6.46 (12.47)	0.61	10.65 (15.91)	0.51	12.07 (7.57)	0.12	10.02 (10.00)	0.32
Ethnicity (ref=not Hispanic)								
Hispanic	7.47 (12.07)	0.54	8.49 (9.33)	0.37	-5.77 (9.04)	0.53	-2.50 (11.09)	0.82
Missing	6.63 (9.45)	0.49	10.03 (11.85)	0.40	-11.09 (9.20)	0.23	0.80 (8.94)	0.93
Weight status (ref=normal) [a]								
Underweight	-1.74 (11.83)	0.88	-16.01 (11.94)	0.19	0.14 (14.53)	0.99	25.40 (20.53)	0.22
At risk for overweight	2.24 (10.29)	0.82	6.62 (13.65)	0.63	-15.33 (9.07)	0.10	-4.50 (7.63)	0.56
Overweight	4.89 (8.37)	0.56	-4.02 (6.23)	0.52	3.63 (10.55)	0.73	-2.22 (8.45)	0.79
Missing	2.40 (16.12)	0.88	-17.61 (10.27)	0.09	-3.32 (7.56)	0.66	6.18 (10.75)	0.57
Family income [b]	-0.004 (0.04)	0.94	0.02 (0.02)	0.40	1.43 (0.79)	0.08	1.52 (0.46)	0.002
Household head years of education	-0.57 (0.19)	0.005	-0.44 (0.20)	0.03	0.17 (0.35)	0.64	-1.21 (0.51)	0.02

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

Table 14. Correlates of mean weekday and weekend moderate- to-vigorous physical activity duration among US adolescents, stratified by gender.

	Girls (n=314)				Boys (n=317)			
	Weekday		Weekend		Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Age category (ref = 10-12)								
13-15	-8.30 (14.73)	0.58	13.63 (24.78)	0.58	-25.21 (14.06)	0.08	-43.44 (37.16)	0.25
16-18	0.82 (17.56)	0.96	-31.45 (22.94)	0.19	-8.65 (16.17)	0.60	-33.19 (37.82)	0.38
Race (ref=white)								
Black	-43.63 (15.54)	0.007	-52.44 (16.54)	0.003	-20.83 (20.00)	0.30	-28.42 (31.23)	0.37
Other	-6.27 (23.01)	0.79	-66.93 (22.86)	0.005	-48.66 (18.33)	0.01	-36.45 (38.80)	0.35
Ethnicity (ref=not Hispanic)								
Hispanic	1.38 (24.72)	0.96	14.05 (35.74)	0.70	-59.05 (25.29)	0.02	-72.25 (37.90)	0.06
Missing	-7.99 (15.75)	0.61	-56.40 (21.71)	0.01	-34.45 (21.17)	0.11	11.40 (32.92)	0.73
Weight status (ref=normal) [a]								
Underweight	-3.40 (30.13)	0.91	24.96 (21.67)	0.25	-28.50 (22.53)	0.21	-85.27 (38.56)	0.03
At risk for overweight	-20.68 (14.26)	0.15	2.42 (25.33)	0.92	18.93 (21.63)	0.39	-62.42 (22.83)	0.01
Overweight	3.51 (18.19)	0.85	0.94 (25.23)	0.97	-18.41 (15.39)	0.24	-42.10 (24.95)	0.10
Missing	13.99 (17.58)	0.43	7.53 (20.10)	0.71	54.33 (35.69)	0.13	47.51 (34.02)	0.17
Family income [b]	-0.02 (0.04)	0.68	-0.15 (0.05)	0.001	2.48 (1.54)	0.11	2.33 (1.93)	0.23
Household head years of education	-0.56 (0.39)	0.16	-0.06 (0.83)	0.94	0.31 (1.38)	0.82	2.75 (2.43)	0.26

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.

APPENDIX

Table A1. Unweighted characteristics of adolescents completing time diary component of the CDS (n=631)

Characteristics	% or mean (± SD)
Gender	
Female	49.76
Male	50.24
Age category	
10-12	40.41
13-15	37.40
16-18	22.16
Race	
White	42.31
Black	46.28
Other	11.41
Ethnicity	
Hispanic	6.66
Not Hispanic	29.64
Missing	63.71
Child weight status [a]	
Underweight	2.54
Normal	46.43
At-risk for overweight	13.47
Overweight	22.35
Missing	15.21
Child's weight perception [b]	
Very underweight	2.38
Slightly underweight	10.46
About the right weight	54.20
Slightly overweight	18.54
Very overweight	2.69
Missing	11.73
Total household income (USD), mean	73,803 (± 253,634)
Median	48,000
Census needs [c]	

Below Census needs	23.30
At or above Census needs	76.70
Years of education completed by household head	13.76 (± 8.73)

[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.

[b] Children were asked "How do you think of yourself in terms of weight?"

[c] 2012 total household income compared to standardized 2012 income needs based on family size and US Census data.

Table A2. Weighted characteristics of adolescents completing time diary component of the CDS by gender and age group.

	Gender							Age group						
	Total (n = 631)		Girls (n=314)		Boys (n=317)			10-12 (n=255)		13-15 (n=236)		16-18 (n=140)		
Characteristics	Mean or %	SE	Mean or %	SE	Mean or %	SE	p	Mean or %	SE	Mean or %	SE	Mean or %	SE	p
Race							0.04							<0.001
White	67.53	3.35	63.21	4.58	71.58	3.94		76.82	3.71	65.12	4.61	57.49	5.51	
Black	14.65	2.50	14.03	2.53	15.23	3.31		14.92	3.34	13.92	2.86	15.20	3.40	
Other	17.82	2.54	22.76	4.47	13.19	1.98		8.26	1.85	20.96	4.31	27.31	4.55	
Ethnicity							0.42							<0.001
Hispanic	17.56	2.42	17.12	3.85	17.98	2.98		21.84	4.07	9.26	3.29	22.29	4.51	
Not Hispanic	22.00	2.33	25.48	3.40	18.74	3.19		48.11	5.46	7.52	2.91	3.77	1.65	
Missing	60.43	2.90	57.40	4.10	63.28	4.67		30.05	5.08	83.23	4.18	73.94	4.48	
Child weight status [a]							0.003							0.17
Underweight	1.98	0.69	1.15	0.66	2.76	1.17		1.22	0.71	4.04	1.53	0.39	0.29	
Normal	46.89	3.55	36.82	4.34	56.33	5.14		46.93	5.07	48.23	5.96	45.10	4.87	
At-risk for overweight	11.93	1.30	15.25	2.68	8.82	1.92		12.50	2.43	12.24	2.64	10.70	2.57	
Overweight	20.56	2.54	24.25	3.45	17.10	3.36		24.39	3.68	18.25	3.99	18.13	4.86	
Missing	18.63	3.05	22.53	3.66	14.99	3.39		14.96	4.34	17.24	2.70	25.67	5.45	
Child's weight perception [b]							0.06							0.01
Very underweight	2.36	0.70	1.01	0.90	3.64	1.06		4.99	1.34	1.27	1.23	0.06	0.06	
Slightly underweight	11.79	2.04	7.66	2.61	15.66	3.03		12.34	3.64	10.64	2.98	12.49	4.42	
About the right weight	51.62	3.14	50.63	4.82	52.55	3.61		38.78	4.92	62.01	4.93	56.35	4.88	
Slightly overweight	18.95	3.01	24.55	4.22	13.70	3.00		24.79	4.70	13.33	4.20	17.95	4.07	
Very overweight	3.87	1.41	4.36	2.04	3.42	1.70		2.27	0.85	5.21	2.50	4.41	3.34	
Missing	11.41	1.72	11.80	2.47	11.04	2.39		16.83	3.73	7.54	2.46	8.74	2.00	

Total household income (USD), mean	99,621	20,888	112,163	38,778	87,285	6,897	0.47	85,753	8,499	73,100	5.527	152,705	65,165	0.049
Median	69,976	5,236	68,403	7,326	75,669	9,544		79,894	8,869	58,113	6,790	74,592	9,786	
Census needs [c]							0.01							0.88
Below Census needs	13.89	2.57	19.03	4.27	9.07	2.25		14.71	4.20	14.47	3.00	11.96	4.98	
At or above Census needs	86.11	2.57	80.97	4.27	90.93	2.25		85.29	4.20	85.53	3.00	88.04	4.98	
Years of education completed by household head	13.64	0.22	13.92	0.84	13.37	0.37	0.56	13.67	0.42	13.16	0.29	14.22	1.37	0.31

Note. All results are survey-adjusted. Adjusted Pearson chi-square test used for comparisons across categorical variables. To compare family income and parental education, t-tests and ANOVA were used for gender and age groups, respectively.

[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5^{th} percentile, normal = 5-85^{th} percentile, at risk for overweight = 85-95^{th} percentile, overweight = above 95^{th} percentile.

[b] Children were asked “How do you think of yourself in terms of weight?”

[c] 2012 total household income compared to standardized 2012 income needs based on family size and US Census data.

Table A3. Correlates of mean weekday and weekend travel time among US adolescents (n=631).

	Weekday		Weekend	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex (ref=female)				
Male	-3.53 (5.56)	0.53	-7.13 (10.21)	0.49
Age category (ref = 10-12)				
13-15	2.00 (6.01)	0.74	-25.72 (16.04)	0.12
16-18	3.80 (7.25)	0.60	-1.94 (15.76)	0.90
Race (ref=white)				
Black	-7.80 (8.55)	0.37	-43.78 (12.28)	0.001
Other	-16.59 (9.52)	0.09	-23.00 (11.64)	0.05
Ethnicity (ref=not Hispanic)				
Hispanic	-3.03 (10.13)	0.77	13.10 (16.43)	0.43
Missing	-0.52 (7.65)	0.95	20.71 (16.75)	0.22
Weight status (ref=normal) [a]				
Underweight	29.35 (19.19)	0.13	-56.66 (10.59)	<0.001
At risk for overweight	14.39 (8.04)	0.08	3.40 (15.05)	0.82
Overweight	15.40 (8.01)	0.06	-2.48 (13.81)	0.86
Missing	1.23 (7.95)	0.88	18.66 (23.77)	0.44
Family income [b]	0.09 (0.03)	0.002	-0.10 (0.09)	0.30
Household head years of education	0.33 (0.19)	0.10	-0.25 (0.51)	0.62

Note. All results are survey-adjusted. Estimates obtained from multiple linear regression model.
[a] Weight status of child determined by percentiles of BMI-for-age. Underweight = under 5th percentile, normal = 5-85th percentile, at risk for overweight = 85-95th percentile, overweight = above 95th percentile.
[b] per every $10,000 increase in annual income.