International Journal of Physical Activity and Health

Volume 3 | Issue 2 Article 4

5-9-2024

Physical Activity in Underserved Preadolescents: Characterization of Accumulation and Patterns

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Recommended Citation
Behar, Alma I.; Mahar, Matthew T.; Norman, Gregory; Elder, John P.; Pratt, Michael; Dionicio, Patricia; and Crespo, Noe C. (2024) "Physical Activity in Underserved Preadolescents: Characterization of Accumulation and Patterns," *International Journal of Physical Activity and Health*: Vol. 3: Iss. 2, Article 4.
DOI: https://doi.org/10.18122/ijpah.3.2.4.boisestate
Available at: https://scholarworks.boisestate.edu/ijpah/vol3/iss2/4

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Abstract

Objectives: The increasing rates of physical inactivity and sedentary behaviors among youth are a significant public health concern. The greatest disparities in physical activity (PA) are experienced by underserved (racial/ethnic minority, low-income) youth. This study aimed to characterize accelerometer-measured PA behaviors in a sample of low-income, predominantly Latino, preadolescents. *Methods:* Participants wore wrist worn GENEActiv accelerometers for 7 days. PA levels were classified as sedentary (< 50 mg), light (50-150 mg), moderate (> 150-500 mg), vigorous (> 500 mg), and MVPA (≥ 150 mg). Time spent in PA levels and sedentary time (ST), prevalence of meeting MVPA guidelines, and PA volume were estimated from accelerometer data. Three-way between-group multivariate analyses of variance examined adjusted differences between age, sex, and weight status groups across activity outcomes. *Results:* Participants (N=68, M_{age}= 9.45 ± 1.73 years) spent an average of 103 minutes/day in MVPA and 50% of participants met MVPA guidelines. They also spent 65% of their wake time at a sedentary level. Participants engaged in more total PA ($p < .001$) on weekdays than weekends. Older participants (10-12 years) spent more min/day in ST ($p < .01$) and had lower PA volume ($p < .01$) than younger participants (6-9 years). Girls spent more time in bouts of MVPA ($p < .01$) and had higher PA volume ($p = 0.1$) than boys. *Conclusions:* The findings of this study indicate that preadolescents spent a high proportion of time being sedentary and still met MVPA guidelines. More research is needed to understand the underlying causes of PA and ST patterns found in this study.

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http://doi.org/10.18122/ijpah.3.2.4.boisestate

Physical Activity in Underserved Preadolescents: Characterization of Accumulation and Patterns

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Keywords: Youth activity, sedentary time, accelerometer, Hispanic/Latinos

Introduction

Physical activity (PA) among youth plays a critical role in the prevention of negative health outcomes, such as overweight/obesity, metabolic syndrome, diabetes, and cardiovascular disease (Anderson & Durstine, 2019). Yet, the majority of youth ages 16-17 are considered insufficiently active (Katzmarzyk et al., 2018). Only 24% of youth meet the current guidelines of 60 minutes or more of daily moderate-to-vigorous PA (MVPA) (Merlo et al., 2020). A study of nationally representative data from the National Survey of Children's Health (NSCH) recently found that the prevalence of daily PA among youth decreased significantly from 24% in 2016 to 19% in 2020 (Lebrun-Harris et al., 2022). In addition to declines in PA,

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current prevalence estimates point to rapid increases in youth sedentary behavior (SB), with SB making up a substantial portion (between 50-60%) of their waking day (Barnett et al., 2018). A large study in a representative sample of 6-17-year-old youth in the U.S. recently found that youth spent 52% of their waking day being sedentary, spending slightly less time in light intensity PA (45% of the time), and spending less than 4% of their time in MVPA (Carson et al., 2019). The prevalence of PA and SB in youth also vary by days of the week. Studies show that youth are generally less physically active and more sedentary on weekend days (Saturday-Sunday) compared to weekdays (Monday-Friday) (Bachner et al., 2021; Keane et al., 2017).

Research points to existing differences in youth PA and SB defined by age, sex, race/ethnicity, and socioeconomic status (SES), placing specific populations at increased risk of PA-related health disparities. Youth PA levels decrease with age starting in preadolescence (between ages 9-12 years) (Katzmarzyk et al., 2018; Katzmarzyk et al., 2017). Lower PA levels have also been observed among girls compared to boys (Chen et al., 2021), and among youth with overweight/obesity compared to those with healthy weight (Cooper et al., 2015). The greatest disparities in PA, however, are experienced by racial/ethnic minority youth from low-income backgrounds (i.e., underserved youth). Specifically, Hispanic/Latino youth engage in disproportionately lower levels of activity (Evenson et al., 2019), and higher levels of SB compared to their non-Hispanic White peers (McDonald et al., 2018). Currently, only 25% of Hispanic/Latino youth meet daily PA guidelines (Merlo et al., 2020). This is important as research shows that low levels of PA are associated with an increased prevalence of overweight and obesity among Hispanic/Latino youth, particularly those ages 6-11 years (Isasi et al., 2016; Katz et al., 2021). As such, underserved youth represent a high-risk group with regard to physical inactivity, SB, and related health outcomes, emphasizing the need to improve PA-promoting efforts in this particular population (Craike et al., 2018).

Understanding the accumulation and patterns of PA behaviors among underserved youth can help inform PA interventions to address disparities in PA-related health outcomes. Self-reported activity measures (e.g., surveys) have been widely used in population-level research (Merlo et al., 2020) as they are a low-cost and convenient method for assessing PA behaviors. However, self-reported data may be biased, as parents tend to overestimate their children's PA . Objective measures of PA, such as accelerometers, overcome the limitations of self-report measures because they provide time-stamped PA intensity data, have low participant burden, and reliably distinguish activity intensity levels from sedentary time in youth (Antczak et al., 2021; Duncan et al., 2020).

Recent advances in accelerometer measurement techniques have resulted in additional information (e.g., bout lengths, PA volume), which is useful for describing youth PA profiles. PA bouts provide information on episodes of sustained activity of a specified minimum duration and intensity (Mark & Janssen, 2009). PA volume (i.e., average magnitude of dynamic acceleration) takes the frequency, intensity, and duration of periods of activity and summarizes them into a single metric representing the accumulated volume of activity within a 24-hour period (Chaput et al., 2014; Rowlands et al., 2019). Although public health efforts have primarily focused on the promotion of MVPA in youth, research suggests that the total amount of PA is more indicative of overall health than is any single component (e.g., high intensity PA). For example, total PA (i.e., activity of light, moderate, and vigorous intensities) is positively associated with various physical, psychological, and cognitive health indicators among youth aged 5-17 years (Poitras et al., 2016). PA recommendations have also traditionally focused on MVPA performed in a continuous manner. However, research supports that both bouted and non-bouted MVPA can improve a variety of health outcomes (Willis et al., 2015). A recent study in a nationally representative sample of youth ages 6-18 years found that longer continuous bouts of MVPA had beneficial effects on body anthropometrics (e.g., BMI percentile, waist circumference) (White et al., 2019).

As such, accelerometers are increasingly being used in epidemiological and clinical research to assess PA and SB patterns in youth (Cooper et al., 2015; Evenson et al., 2019; Fraysse et al., 2019). However, few studies have used accelerometers to gain a clearer understanding of PA patterns among underserved Hispanic/Latino youth (Eyre & Duncan, 2013). This study aimed to characterize and describe various domains of accelerometer-measured PA (sedentary time, total PA, PA intensities, average acceleration) and examine differences by child age, sex, and weight status in a sample of predominantly Latino preadolescents from low-income backgrounds. Based on the existing youth PA literature, we hypothesized that (1) participants in this sample would be insufficiently active; (2) participants would be less active on weekends compared to weekdays; (3) a small proportion of participants would meet current MVPA guidelines; and (4) PA levels would be greater among participants who were younger (vs. older), boys (vs. girls), and had healthy weight (vs. overweight/obesity).

Methods

Study Design, Participants, and Procedures

The present study utilized baseline data from the *Athletes for Life* study (AHA 14SDG20490382, NCT03761589), a randomized controlled trial that tested the efficacy of a 12-week, behavioral intervention on parent and child cardiovascular fitness (Szeszulski et al., 2020). Primary participants were children ages 6-11 years from a community in South Phoenix, Arizona characterized by a large proportion of lower-income and underserved populations. Children had to be between the ages of 6-11 years to be included in the *Athletes for Life* study. Exclusion criteria included: (1) presence of a mental or physical condition that is contraindicated to participating in sports/exercise, (2) having a chronic condition that limits mobility, or (3) taking medications that influence body composition. Community partners (e.g., recreation centers, community clinics) assisted with the recruitment of study participants through emails and flyers distributed in their facilities and in local public schools. *Athletes for Life* study procedures and intervention components are described in detail elsewhere (Szeszulski et al., 2020). Child assent to participate was obtained before any data collection. Data collected at baseline included child anthropometric measurements (height and weight), child accelerometer-measured PA, and parent self-reported questionnaire to assess the child's sociodemographic characteristics. Children were given a toy worth approximately $5 for completing each round of data collection (0, 12, and 24 weeks) and for wearing the accelerometer. The *Athletes for Life* study was conducted between September 2014 and March 2018 following Institutional Review Board (IRB) approval from Arizona State University (ASU).

Study Measures

The present study uses child accelerometry-measured PA data, anthropometric data, and demographic data collected only at baseline (pre-intervention).

Accelerometer-Measured Child PA and SB. Child activity data was collected from *N*=104 participants prior to the 12-week intervention using GENEActiv accelerometers. GENEActiv is a waterproof triaxial accelerometer with a dynamic range of +/- 8g (i.e., gravity estimator of normal everyday activity) (Activinsights, Cambridgeshire, UK) and has been validated with children (Fairclough et al., 2016). GENEActiv has demonstrated high technical reliability and validity in determining time spent in activity intensities and in distinguishing PA from SB in children (Duncan et al., 2020). The commercial GENEActiv software (version 2.2) was used to initialize accelerometers to collect unfiltered, triaxial acceleration data at a sampling frequency of 40 Hz (i.e., collect acceleration data 40 times per second in each of the three axes). Accelerometers were initialized at the baseline timepoint and set to start recording data at 12AM of the following day. Participants were instructed to wear the accelerometer on their preferred wrist for 7 consecutive days, 24 hours per day to improve compliance and minimize missing data due to non-wear (Antczak et al., 2021; Fairclough et al., 2016; Rowlands et al., 2016).

For the current study, raw accelerometer data files were read into R software and summarized using the GGIR package version 2.6-0 (Migueles, Rowlands, et al., 2019), which calculates acceleration metrics, i.e., the vector of magnitude of acceleration corrected for gravity (Euclidean Norm minus 1 g, ENMO). Accelerometer data processing steps were followed as described in the GGIR package vignette (https://cran.r-project.org/web/packages/GGIR/vignettes/GGIR.html#1_Introduction). Non-wear time was computed using detection procedures by Van Hees and colleagues (Van Hees et al., 2013). Using GGIR defaults, a block is classified as non-wear time when the standard deviation of the 60-minute window is less than 13 mg (milli-gravity units of acceleration) and the value range of a 60-minute window is less than 50 mg for at least two of the three axes of acceleration (*x*, *y*, *z*). GGIR then imputes the missing data based on average ENMO values from similar timepoints on other days and provides the *number of valid hours* to determine valid wear time and *non-wear percentage per day*. PA levels were classified as sedentary (<50 mg), light (50-150 mg), moderate (>150-500 mg), vigorous (>500 mg), and MVPA (≥150 mg). PA classification criteria were based on published intensity cut points for wrist worn GENEActiv accelerometers in preadolescents ages 7-11 years (Hildebrand et al., 2014), which have been used in previous accelerometer studies with youth populations (Antczak et al., 2021; Fairclough et al., 2016; Rowlands et al., 2018; Sanders et al., 2019). Sedentary time (ST) was separated from sleep using the nocturnal sleep detection algorithm in GGIR (van Hees et al., 2018). Activity data were considered for preliminary analyses if post-calibration error was less than 0.02 *g* and valid data were present for every 15-minute period in a 24-hour cycle (even when data were scattered over multiple days). Participants also needed a minimum of 1 day where the GENEActiv recorded sufficient wear time (Rowlands et al., 2016). ENMO was averaged over 5-second epochs, as done in previous studies with preadolescents ages 6-12 years (Antczak et al., 2021; Cooper et al., 2015). A shortest possible epoch length (between 1-5 seconds) is recommended to capture short bursts of MVPA due to the sporadic activity of children (Altenburg et al., 2021).

Child BMI. Height (cm) and weight (kg) measures were conducted using a portable stadiometer and electronic scale (SECA) to compute child Body Mass Index (BMI) and BMI cut-points based on the CDC Growth Charts (Kuczmarski, 2002). BMI percentile ranges were used to classify participants into the following weight status categories: 1=Underweight (< 5th percentile), 2=Healthy Weight (> 5th – 85th percentile), 3=Overweight (> 85th – 95th percentile), 4=Obesity (> 95th percentile).

Demographics Characteristics. Data on child and household demographic characteristics included date of birth, sex, race/ethnicity, country of birth, household monthly income, and receipt of public assistance (i.e., SNAP/EBT/Food Stamps, WIC, TANF).

Statistical Analysis

Accelerometer compliance was assessed by computing mean valid wear time (hours) and mean valid days. Time spent across PA intensity levels (sedentary, light, moderate, and vigorous) was estimated from accelerometer data by dividing total minutes spent at each level by the total minutes in the child's waking period. Total PA was computed by combining total time (minutes) spent in light, moderate, and vigorous intensities. MVPA was assessed using an intensity threshold of 150 mg based on 5-second epochs. A variable for total MVPA minutes was computed by combining total minutes spent in moderate intensity and total minutes spent in vigorous intensity into a single variable. Participants were categorized as meeting recommended MVPA guidelines if they achieved 60 or more minutes of MVPA on *all* days of the measurement period (Fairclough et al., 2016; Sanders et al., 2019). The average time spent in bouts of MVPA was assessed for three duration categories: sporadic MVPA bouts (≥ 1 and < 5 mins.), short MVPA bouts (≥ 5 and < 10 mins.), and medium-to-long MVPA bouts (≥ 10 mins.) (Mark & Janssen, 2009; Willis et al., 2015). Various bout lengths were examined to identify how the estimated accumulation of minutes of MVPA was affected by bout length criteria. Bouts of MVPA were identified as 1-, 5- or 10-minute time windows that start with a 5-second epoch value equal to or greater than 150 mg, and for which 80% of subsequent 5-second epoch values are equal to or higher than the 150 mg threshold (Migueles, Rowlands, et al., 2019). The summary measure ENMO mg (average per day) was used as an indicator of average magnitude of dynamic wrist acceleration (i.e., PA volume, mg) over the measurement period (Rowlands et al., 2016). PA volume is a novel measure that provides an additional description of an individual's PA profile.

Descriptive statistics (means, standard deviations) were used to summarize participant PA. Pearson product-moment correlations were used to explore relationships among PA variables. Differences in accelerometer compliance by categories of participant age (6-9 yrs. vs. 10-12 yrs.), sex (male vs. female), and weight status (healthy weight vs. overweight/obesity) were assessed using independent-samples *t*-tests. Independent samples *t*-tests compared differences in PA intensity levels and MVPA bout durations by age, sex, and weight status. Chi-square tests for independence explored differences by age, sex, and weight status between children who met MVPA guidelines vs. those who did not meet recommended guidelines. A three-way between-groups multivariate analysis of variance (MANOVA) tested differences between age, sex, and weight status groups across several PA outcomes simultaneously (i.e., 2 x 2 x 2 factorial design). Eight dependent variables were used, and the independent variables were age, sex, and weight status. Factorial MANOVA with a Bonferroni correction controlled for risk of a Type I error given the multiple statistical tests conducted. Therefore, results from MANOVA's univariate analyses are considered significant at the ≤ .01 alpha value. The relationship between the independent variables (age, sex, weight status) on each dependent variable was evaluated using effect size statistics, which represent the proportion of the variance in the dependent variable that can be explained by each independent variable. Two-way (age^{x}sex, age^{x}weight, sex^{x}weight) and three-way (age^{x}sex^{x}weight) interactions were specified in the model. Significance for all other statistical tests was set at $p < .05$. All analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 28.0 (SPSS, Inc. Chicago, Illinois).

Results

Preliminary Analysis

Out of the 104 participants who wore the GENEActiv devices, 27 were excluded (6 declined to take part in accelerometry measures and 21 used malfunctioning accelerometers which did not record PA data). This resulted in 77 raw data files containing unfiltered, time- and date-stamped triaxial acceleration data (x, y, z), in gravitational units (g), complete with negative sign indicating directionality. Next, GGIR output files were inspected, and 4 cases were excluded due to accelerometer calibration errors, indicating that the accelerometers did not record data and/or the child had zero hours of valid data; therefore, no PA variables were computed for these 4 cases. No extreme outliers were identified in the GGIR output files (i.e., abnormally high values were not detected by GGIR program). Five additional cases were excluded from analyses due to missing data from key variables (i.e., one case had < 1 valid accelerometer day, and four cases had age, sex, height, and/or weight data missing).

Sample Characteristics

The final analytical sample was 68 preadolescents (56% female, 44% male) between the ages of 6 and 12 years, and with at least one day of valid accelerometer data. Participants were predominantly Hispanic/Latino (94%) and were born in the U.S. (93%). Over 54% of participants had overweight (> 85th – 95th percentile) or obesity (> 95th percentile) and almost 40% of participant's households reported receiving some form of public assistance (Table 1). Over 98% of participants (n=67) had at least 3 days of valid accelerometer data, and over 97% had at least 1 weekend day of accelerometer data. The average number of valid days was 6.8 days ($M_{\text{Wear Time}}$= 11.3 ± 3.6 hours/day). Older participants (ages 10-12 years) had more valid days of accelerometer data compared to younger participants (ages 6-9 years) (M= 7.2 ± 1.1 vs. M= 6.4 ± 1.5; M_{Δ}= 0.8 days, p= .01), and participants with overweight/obesity had significantly fewer valid hours per day compared to those with healthy weight (M= 10.6 ± 2.9 vs. M= 12.1 ± 4.3; M_{Δ}= -1.5 hours/day, p= .02). There were no significant sex differences in accelerometer wear compliance.

Table 1. Sociodemographic Characteristics of the Sub-Sample of Athletes for Life Study Participants Who Completed Accelerometry Measures (N=68).

	N (%) or M ± SD
Child characteristics:	
Age	9.45 ± 1.73
Sex	
Female	38 (55.9%)
Male	30 (44.1%)
Hispanic/Latino (*% yes*)	64 (94.1%)
Country of Birth	
U.S.	63 (92.6%)
Mexico	5 (7.4%%)
Weight Status [a]	
Underweight (< 5th)	2 (2.9%)
Healthy weight (> 5th – 85th)	29 (42.6%)
Overweight (> 85th – 95th)	9 (13.2%)
Obesity (> 95th)	28 (41.2%)
BMI % [a]	74.73 ± 28.90
Household characteristics:	
Household total monthly income (n=61)	
$0 - $2999	33 (54.1%)
$3000 - $5000+	14 (23.0%)
Don't know	14 (23.0%)
Public assistance recipients (*% yes*)	27 (39.7%)

[a] CDC BMI percentile for age-and-sex.

Characterization of Youth PA

Correlation coefficients (Table 2) showed moderate, negative associations between sedentary time and all PA variables, as well as significant positive associations between key PA variables.

Table 2. Pearson Product-Moment Correlations between Child Activity Measures.

	1	2	3	4	5	6	7	8
1. Total PA	1	-.73**	.83**	.78**	.63**	.37**	.29*	.70**
2. Sedentary time		1	-.49**	-.69**	-.61**	-.44**	-.27*	-.69**

3. Light PA	1	.29*	.15	-.07	-.12	.22
4. MVPA		1	.91**	.72**	.64**	.94**
5. $MVPA^{1\text{-}5mbt}$			1	.69**	.45**	.85**
6. $MVPA^{5\text{-}10mbt}$				1	.62**	.72**
7. $MVPA^{10mbt}$					1	.70**
8. PA volume						1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Within a 24-hour day window (i.e., 1440 min/day), participants spent an average of 927 min/day in wake time and an average of 513 min/day in sleep period time. They spent approximately 65% of their wake time in ST, 24% in light PA intensity, 9% in moderate PA intensity, and 2% of the time in vigorous PA intensity (Table 3). Participants spent between 43 and 187 min/day in MVPA and spent significantly more time in sporadic bouts (≥ 1 and < 5 mins.) compared to medium-to-long bouts (≥ 10 mins.) ($p < .001$) and to short bouts (≥ 5 and < 10 mins.) ($p < .001$). Average PA volume during wake time was 73.2 mg (i.e., light PA intensity).

Table 3. Descriptive Statistics of Accelerometer-Measured Child Activity.

	Min.	Max.	M ± SD
Waking Time [a]			
Hours per day	13.5	17.8	15.5 ± 0.8
Minutes per day	809.3	1070.6	927.0 ± 45.3
Sleep Period Time [a]			
Hours per day	6.2	10.5	8.6 ± 0.8
Minutes per day	369.4	630.7	513.0 ± 45.3
Time Spent in Intensity Levels (mean mins/day)			
Sedentary time	427.5	749.5	597.8 ± 65.9
Light PA	157.1	315.3	226.1 ± 33.7
Moderate PA	38.2	151.6	85.9 ± 22.1
Vigorous PA	0.7	46.0	17.2 ± 11.2
Total PA (mean mins/day) [b]			
Light, Moderate, and Vigorous PA	225.8	448.7	329.2 ± 51.4
MVPA (mean mins/day) [b]			
MVPA	43.0	187.1	103.1 ± 30.2
MVPA bouts lasting ≥ 1 and < 5 mins	6.5	57.2	23.6 ± 9.9
MVPA bouts lasting ≥ 5 and < 10 mins	0	19.5	5.2 ± 4.3
MVPA bouts lasting ≥ 10 mins	0	51.8	8.9 ± 11.1
PA Volume (mean mg/day) [b]			
PA volume	43.6	126.4	73.2 ± 19.0
PA volume by intensity level [c]			
Sedentary	12.5	22.1	16.9 ± 1.7
Light	83.3	91.0	87.6 ± 1.5
Moderate	213.6	267.5	240.2 ± 10.9
Vigorous	640.6	1176.4	915.6 ± 121.3
Average Acceleration (mean mg/day) [d]	29.6	81.1	48.5 ± 11.5

[a] Duration of day window is 1440 minutes, which includes both waking time and sleep period time.
[b] Activity during waking hours of 24-hour day window.
[c] Sedentary: < 50 mg; Light: 50-150 mg; Moderate: >150-500 mg; Vigorous: >500 mg.
[d] Average acceleration per 24-hour cycles.

Half of participants (n=34) in this sample met the recommended guidelines of ≥ 60 minutes of MVPA on all days. Chi-square tests for independence (with Yates Continuity Correction) indicated no differences in age (χ^2

(1, *n*=68) = .24, *p*= .63, *phi*= .09), sex (χ^2 (1, *n*=68) = .54, *p*= .46, *phi*= -.12), or weight status (χ^2 (1, *n*=68) = .95, *p*= .33, *phi*= -.15) between participants who met current MVPA guidelines versus those who did not. Among those who did not meet the recommended guidelines, the number of days in which they did achieve at least 60 minutes of MVPA ranged between 2-6 days (*M*= 5.9 days). Only 1 participant had zero days of at least 60 minutes of MVPA; 13 participants achieved ≥ 60 minutes of MVPA on 1-4 days; and 20 participants achieved ≥ 60 minutes of MVPA on 5-6 days.

Overall, participants engaged in more PA on weekdays (Monday-Friday) compared to weekend days (Saturday-Sunday) in terms of total PA (*M*= 337.2 ± 53.5 vs. *M*= 312.6 ± 64.4; M_Δ= 24.6 min/day, *p*< .001), light PA (*M*= 231.3 ± 35.1 vs. *M*= 215.1 ± 42.1; M_Δ= 16.2 min/day, *p*< .001), MVPA (*M*= 105.9 ± 30.9 vs. *M*= 95.5 ± 36.5; M_Δ= 10.4 min/day, *p*<.01), and 1-5-minute MVPA bouts (*M*= 24.8 ± 10.3 vs. *M*= 20.6 ± 12.1; M_Δ= 4.1 min/day, *p*< .001). The average PA volume during waking time also was lower on weekends, with average PA intensity shifting from a light PA level (50.3 mg/day) to a sedentary level (44.7 mg/day) (*p*< .001). Differences were not statistically significant for sedentary time (*p*= .07), 5-10-minute MVPA bouts (*p*= .45), or 10-minute MVPA bouts (*p*=. 39) by days of the week.

Differences between Age, Sex, and Weight Status Groups Across PA Outcomes

We report partial eta squared (Pη^2) effect size statistic for the multivariate tests of factorial MANOVA due to this study's small sample size and relatively unequal N values in group categories. Based on Pillai's Trace (*V*) criterion, the combined dependent variables were significantly different by levels of age [*V*= 0.37, *F*(7, 54)= 4.52, Pη^2= 0.37] (*p*<.001), and sex [*V*= 0.25, *F*(7, 54)= 2.54, Pη^2= 0.25] (*p*= .03), but not by levels of weight status [*V*= 0.16, *F*(7, 54)= 1.43, Pη^2= 0.16] (*p*= .21). The interactions between age and weight [*V*= 0.27, *F*(7, 54)= 2.89, Pη^2= 0.27] (*p*= .01) and between sex and weight [*V*= 0.22, *F*(7, 54)= 2.18, Pη^2= 0.22] (*p*= .05) were also significant, showing that the relationship between weight status and PA varies with levels of age and sex. There were no significant interactions between age and sex (*p*= .28), or between age, sex, and weight status (*p*= .24).

To investigate the association of each independent variable and their interactions on the individual dependent variables, univariate *F*-tests using an alpha level of ≤ .01 were performed. Pair-wise comparison of estimated marginal means adjusted for multiple analyses (Table 4), followed by univariate *F*-tests, showed significant age differences in sedentary time, 1-5-minute MVPA bouts, and PA volume. Compared to 6-9-year-old participants, 10-12-year-olds spent significantly more time being sedentary (*p* <.01), less time in 1-5-minute MVPA bouts (*p* <.01) and had lower PA volume (*p* <.01). Age had no significant influence on total PA, light PA, MVPA, 5-10-minute MVPA bouts, or 10-minute MVPA bouts. There were significant sex differences in MVPA bout durations and PA volume. Compared to boys, girls spent more time in 1-5-minute MVPA bouts (*p*= .01), in 5-10-minute MVPA bouts (*p* <.01), and in 10-minute MVPA bouts (*p* <.01). Girls also had higher PA volume (*p*= .01). Sex was not significantly associated with ST, total PA, light PA, or MVPA. There were no significant differences by weight in any of the individual dependent variables, although the sex^{x}weight interaction was statistically significant for 10-minute MVPA bouts [*F*(1, 60)= 9.88, Pη^2= 0.14] (*p*< .01). There were no statistically significant interactions between age^{x}sex, age^{x}weight, or age^{x}sex^{x}weight on any of the individual dependent variables.

Table 4. Age, Sex, and Weight Category Differences in Sedentary and Physical Activity Intensities and Profiles.

Variables	Categories		M ± SEM [a]	M_Δ	*p*-value [b]
ST	***Age***	***6-9 yrs.***	***572.9 ± 11.2***	***-48.1***	***<.01***
		10-12 yrs.	***620.9 ± 11.3***		
	Sex	Male	598.2 ± 12.1	2.7	.87
		Female	595.6 ± 10.5		
	Weight	Healthy	595.3 ± 12.0	-3.1	.85
		OW/OB	598.5 ± 10.6		
Total PA	Age	6-9 yrs.	340.9 ± 9.1	24.6	.06
		10-12 yrs.	316.3 ± 9.2		

	Sex	Male Female	324.2 ± 9.7 333.0 ± 8.5	-8.8	.50
	Weight	Healthy OW/OB	328.2 ± 9.7 329.1 ± 8.5	-0.9	.95
Light PA	Age	6-9 yrs. 10-12 yrs.	229.9 ± 6.0 223.0 ± 6.0	6.9	.42
	Sex	Male Female	230.3 ± 6.4 222.6 ± 5.6	7.7	.37
	Weight	Healthy OW/OB	222.5 ± 6.4 230.4 ± 5.6	-7.9	.36
MVPA	Age	6-9 yrs. 10-12 yrs.	111.0 ± 5.0 93.3 ± 5.0	17.7	.02
	Sex	Male Female	93.9 ± 5.3 110.4 ± 4.6	-16.5	.02
	Weight	Healthy OW/OB	105.6 ± 5.3 98.7 ± 4.7	7.0	.33
MVPA$^{1-5mbts}$	***Age***	***6-9 yrs. 10-12 yrs.***	***27.0 ± 1.5 19.6 ± 1.6***	***7.3***	***< .01***
	Sex	***Male Female***	***20.4 ± 1.7 26.1 ± 1.4***	***-5.7***	***.01***
	Weight	Healthy OW/OB	24.7 ± 1.6 21.9 ± 1.5	2.8	.22
MVPA$^{5-10mbts}$	Age	6-9 yrs. 10-12 yrs.	6.0 ± 0.7 4.2 ± 0.7	1.8	.07
	Sex	Male Female	3.6 ± 0.7 6.5 ± 0.6	-3.0	< .01
	Weight	Healthy OW/OB	5.7 ± 0.7 4.4 ± 0.6	1.2	.21
MVPA^{10mbts}	Age	6-9 yrs. 10-12 yrs.	8.1 ± 1.7 8.1 ± 1.7	0.02	.99
	Sex	***Male Female***	***4.5 ± 1.8 11.8 ± 1.5***	***-7.3***	***< .01***
	Weight	Healthy OW/OB	10.7 ± 1.8 5.6 ± 1.6	5.0	.04
PA Volume	***Age***	***6-9 yrs. 10-12 yrs.***	***79.6 ± 2.9 65.4 ± 2.9***	***14.2***	***< .01***
	Sex	***Male Female***	***66.7 ± 3.1 78.4 ± 2.7***	***-11.7***	***.01***
	Weight	Healthy OW/OB	76.2 ± 3.1 68.9 ± 2.7	7.3	.08

[a] Adjusted for multiple comparisons. [b] Bolded and italicized: Mean difference significant at the .01 level.

Discussion

This study described domains of accelerometer-measured PA and examined differences by age, sex, and weight status among a sub-set of underserved preadolescents. The average minutes accumulated in sedentary time in this sample was greater than nationally representative accelerometry data, which show that youth ages 6-17 years spend approximately 400 min/day in ST (approximately 50-52% of wake time) (Carson et al., 2019). However, the current study's results are similar to recent studies using GENEActiv accelerometers which found that youth spent an average of 515 min/day (61% of waking time) (Keane et al., 2017) and

681 min/day (Fraysse et al., 2019) being sedentary. During wake time, participants in this study spent an average of 5.5 hours per day in total PA. Similar to national accelerometry data (Carson et al., 2019), most of the active time was spent at a light intensity. This finding is also consistent with a study that used wrist worn GENEActiv monitors which found that youth ages 8-11 years accumulated 235 min/day in light PA (Keane et al., 2017). In the current study, roughly 11% of participant's waking time was spent in total MVPA. Approximately 23% of total MVPA was spent in sporadic bouts, 5% in short bouts, and 9% in medium-to-long bouts. This is also consistent with nationally representative accelerometer data, which found most of the MVPA bouts were less than 5 minutes compared to long bout durations (White et al., 2019). Participants also engaged in significantly more PA on weekdays compared to weekend days, which is similar to previous PA studies (Bachner et al., 2021; Sanders et al., 2019). During weekdays, participants accumulated 25 more minutes of total PA, 16 more minutes of light PA, 11 more minutes of MVPA, and 4 more minutes of sporadic (< 5-min) MVPA bouts compared to weekend days.

Overall, participants averaged 73.2 mg/day of dynamic PA acceleration, and the average volume of activities accumulated over 24-hour cycles (i.e., during sleep period time and waking time) was 48.5 mg/day. Recent research studying the utility and interpretation of accelerometer metrics indicate that any time accumulated above 100 mg (i.e., above the intensity of a slow walk) is considered "active time"(Rowlands et al., 2019). As such, the average acceleration found in our study is representative of sedentary-to-very low activity, as the mean value did not exceed the 150 mg threshold representing MVPA (Hildebrand et al., 2014; Rowlands et al., 2016; Sanders et al., 2019). Recent accelerometer studies using wrist-worn monitors have found similar average acceleration values among youth ages 8-13 years (Fairclough et al., 2019; Rowlands et al., 2019). The proportion of participants who met MVPA guidelines in this study is higher than national accelerometry data (Katzmarzyk et al., 2017). Yet, our finding is similar to that from a recent study which found that 50.3% of youth ages 9-10 years engaged in at least 60 minutes of MVPA per day (Fairclough et al., 2019). Recent accelerometer studies among youth using the wrist-worn GENEActiv monitor have also applied the 7-day measurement period guideline to their samples. These studies found that the MVPA guidelines were met by 86.9% of youth ages 9-10 years (Fairclough et al., 2016), 32% of youth ages 10-12 years (Caillaud et al., 2022), and 22.1% of youth ages 8-11 years (Keane et al., 2017). Participants in the current study also engaged in significantly more PA on weekdays compared to weekend days, which is consistent with previous research (Sanders et al., 2019).

The current study showed that younger participants were less sedentary and more active compared to older participants. Significant age differences in child ST and PA are largely consistent with previous accelerometer-based research with youth in the U.S. A recent study by Evenson and colleagues (2019) with Hispanic/Latino youth ages 8-16 years found that higher levels of MVPA occurred among 8-10-year-olds than 15-16-year-olds. Conversely, higher levels of ST occurred among 15-16-year-olds than 8-10-year-olds (Evenson et al., 2019). Contrary to previous studies, we found no significant differences in total MVPA by child weight status (Elmesmari et al., 2018). We did find a significant interaction between sex and weight status for medium-to-long MVPA bouts (≥ 10 min), suggesting that the influence of weight status on time spent in medium-to-long MVPA bouts is significantly different for boys than it is for girls. That is, girls with healthy weight spent substantially more time in MVPA bouts ≥ 10 minutes compared to healthy weight boys and compared to participants with overweight/obesity.

This study also found that girls in this study were generally more active than boys. Overall, girls accumulated more min/day of short and medium-to-long MVPA bouts and had a higher PA volume, compared to boys. These findings are largely inconsistent with those from previous accelerometer studies that have found that boys are more physically active than girls (Cooper et al., 2015; White et al., 2019), spend more time in MVPA (Keane et al., 2017), participate in longer bouts of MVPA (Mark & Janssen, 2009; White et al., 2019), and have higher PA volume (mg) (Fairclough et al., 2019) compared to girls. A study among adolescent girls ages 11-12 years found higher accelerometer based MVPA values compared to other international studies, with girls accumulating an average of 82 min/day of MVPA, and over 90% meeting recommended PA guidelines (Bachner et al., 2021). However, this study included only girls so a comparison to their male counterparts could not be made. A study by Silva et al. (2011) among Portuguese youth ages 10-13 years examined seasonal variations in MPVA between boys and girls and found that girls accumulated more MVPA minutes during the winter compared to boys (121 min/day vs. 99 min/day) (Silva et al., 2011). Similar to our findings, a study of youth ages 8-17 years found that girls spent a higher percentage of time in sporadic MVPA bouts (lasting ≥ 1 and < 5 mins) compared to boys (i.e., 71.7% vs. 60.4% of total MVPA) (Mark & Janssen, 2009). Another study of children ages 6-9 years also found that girls spent more of their overall MVPA in sporadic bouts compared to boys (92.4% vs. 89.3%) (Willis et al., 2015).

The finding that girls in this study were more physically active than boys was surprising. It is possible that our results are due to selection bias of healthy, active girls who chose to enroll in the study. Knowledge about the physical contexts (e.g., indoor/outdoor locations), domains (e.g., leisure, transportation), and types (e.g., jumping rope, playing sports) of participants' activity would provide a better understanding of the PA behaviors of girls in this sample and may also help explain this finding. For example, a study among Portuguese children showed significant gender differences in domain-specific time spent in MVPA (Pizarro et al., 2017). They found that over 54% of girls' MVPA was in the transportation domain, compared to 35.2% of boys' MVPA, and most of boys' MVPA was spent in school and leisure domains. Other studies also found that girls accumulate a significant amount of light PA during leisure time and more MVPA time in active transport (e.g., walking or biking), at home, and other locations (Kelso et al., 2021). Based on these earlier studies, it is possible that girls in our sample may have accumulated more PA in specific contexts, domains, or types of activities compared to boys, although this cannot be determined as these data were not collected as part of the larger study.

Study Limitations

The current study was a secondary analysis of data obtained from a sub-sample of participants recruited into a larger fitness- and nutrition-focused randomized controlled trial, which limited our ability to assess additional variables of interest. For example, information about participants' accelerometer placement (i.e., dominant vs. non-dominant wrist) was not collected. Thus, we were unable to compare our results with previous accelerometer studies that have wrist-specific results. Wrist placement is important as previous studies have found that the GENEActiv accelerometer yields higher ENMO (mg) values when worn on the dominant wrist . Wrist placement is also an important factor related to accelerometer data collection which may impact sleep, sedentary time, and PA estimations (Migueles, Cadenas-Sanchez, et al., 2019). Our study had a small sample size, which restricted our ability to control for additional potential factors such as accelerometer wear time (Evenson et al., 2019) and seasons (Silva et al., 2011), which are known to influence youth PA. Our study also includes a specific sample of preadolescents (ages 6-12 years, primarily Hispanic/Latino of Mexican background), which limits our ability to examine differences with other racial/ethnic groups. Although our findings are relevant for similar populations, they are not necessarily representative of other Hispanic/Latino preadolescents from different sub-groups (e.g., Puerto Rican, Dominican) or geographic locations. Additionally, inferences made regarding PA behavioral patterns in this study may depend upon the chosen raw data processing methods. Our study's accelerometer data were collected at a sampling frequency of 40 Hz over 5-second epochs as part of the protocol, which is substantially lower than previous youth accelerometry studies (Caillaud et al., 2022; Keane et al., 2017). Our use of 5-second epochs may have also detected additional, shorter patterns of PA, especially among younger participants (Altenburg et al., 2021). It is possible that by using a shorter epoch length in our study, we could have overestimated MVPA values and/or have light PA classified as ST. The prevalence of meeting MVPA guidelines can also vary depending on the cut points used (Migueles, Cadenas-Sanchez, et al., 2019). Another potential limitation in this study involves selection bias. It is possible that our study sample consists of generally active youth, girls in particular, who may have been more motivated to enroll in the study. Therefore, the PA values found in our study sample may not be representative of other preadolescents in this community.

Study Strengths

Despite potential limitations, the use of accelerometry allows comparison of our sample with national accelerometry data and with findings from other studies in which accelerometry has been used as an objective measure of youth PA. The majority of participants wore the accelerometer for the full measurement period. Thus, the good compliance found in our study provides confidence that the data are representative of daily activity for participants in our sample. Our findings also highlight the importance of assessing different dimensions of accelerometer-measured youth activity. Youth PA-promoting efforts have focused on increasing MVPA (i.e., meeting MVPA guidelines). Yet, MVPA accounts for the smallest portion of the 24-hour period, even among youth who are highly active (Chaput et al., 2014). Evidence is growing on the health benefits of light PA (Agbaje, 2023) and MVPA bouts (White et al., 2019; Willis et al., 2015). Recent research in this area has also focused on investigating associations between novel accelerometer metrics (e.g., PA volume) and health indicators in youth (Fairclough et al., 2019).

Conclusions

In this study, predominantly Hispanic/Latino preadolescents living in a low-income environment had higher levels of MVPA and ST than national averages. Importantly, our findings indicate that preadolescents can spend a high proportion of time being sedentary and still meet MVPA guidelines. Yet, the average amount of time participants spent in ST is concerning given the evidence of the associations between sedentary behaviors and the increased risk for obesity and other negative health outcomes (Barnett et al., 2018). This is especially important in a population that experiences pervasive disparities in childhood obesity and cardiometabolic risk factors (Katz et al., 2021). Given the cross-sectional design of this study, longitudinal studies with larger participant samples and across a greater variety of racial/ethnic minorities and income backgrounds would add strength to the study findings. More research is needed to understand the underlying causes of the patterns revealed by our study findings, for instance, the high sedentary values, and the higher prevalence of PA among girls compared to boys. Future studies can also expand on this research through the use of real-time methodologies (Dunton, 2017) to provide important insights into the proximal social and physical contexts that influence youth PA and sedentary behaviors (e.g., physical location, social company) as they occur in real time.

Acknowledgments/Author's Notes

We are grateful to the *Athletes for Life* study team for their support and contributions throughout the project period. We are especially thankful to the families who participated in the study for their time and dedication in the completion of accelerometer and survey measures. The research presented in this paper received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. Dr. Behar was supported with PhD scholarships for this dissertation research.

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