Activity Levels for Four Years in a Cohort of Urban-Dwelling Adolescent Females

BONNY ROCKETTE-WAGNER[1], ALISON E. HIPWELL[2], ANDREA M. KRISKA[1], KRISTI L. STORTI[3], and KATHLEEN M. MCTIGUE[1,4]

[1]*Department of Epidemiology, University of Pittsburgh, Pittsburgh, PA;* [2]*Department of Psychiatry, University of Pittsburgh, Pittsburgh, PA;* [3]*Department of Kinesiology, Health, and Sport Science, University of Indiana, Indiana, PA; and* [4]*School of Medicine, University of Pittsburgh, Pittsburgh, PA*

ABSTRACT

ROCKETTE-WAGNER, B., A. E. HIPWELL, A. M. KRISKA, K. L. STORTI, and K. M. MCTIGUE. Activity Levels for Four Years in a Cohort of Urban-Dwelling Adolescent Females. *Med. Sci. Sports Exerc.*, Vol. 49, No. 4, pp. 695–701, 2017. **Purpose**: Evidence suggests that female adolescents and those living in urban environments may have lower physical activity (PA) levels compared with their peers. Yet few studies report PA for urban adolescent females, and there is no consensus regarding potential causes for low PA in this subgroup. We examined PA levels, in a large, diverse cohort of 14- to 17-yr-old urban-dwelling females and assessed the effect of socioeconomic, personal, and neighborhood/environmental factors on PA. **Methods**: One week of time-stamped step count data were collected on 926 girls from the Pittsburgh Girls Study at four annual visits. Valid recordings (worn at least 10 h on 3+ d) were examined and compared with normalized step count values from a U.S. population-representative sample. Relationships between important covariates and average steps per day were examined with regression models. **Results**: Adjusted mean ± SD step counts per day at baseline were 5614 ± 2434 after controlling for important covariates with less than 6% of girls achieving at least 10,000 steps per day. The girls from the Pittsburgh Girls Study accrued ~45% of their steps during school hours. Age-specific median step counts per day for study participants were similar to the 25th percentile of U.S. population normalized values and did not significantly change during follow-up. Non-Hispanic African American race/ethnicity was associated with higher average step counts per day; obesity and a recent childbirth were associated with lower average step counts per day. **Conclusions**: Step counts in this cohort of urban adolescent girls were considerably lower than expected for U.S. adolescent females. Targeted efforts to improve PA levels in urban youth should consider the importance of school-based activity while increasing PA opportunities outside of school. **Key Words:** TIME-STAMPED STEP COUNTS, SCHOOL-BASED ACTIVITY, METROPOLITAN, PEDOMETER

Low levels of physical activity (PA) have been associated with poor quality of life, the development of chronic diseases, and other negative health outcomes in youth (23,24). Currently, the U.S. Centers for Disease Control and the World Health Organization recommend 60 min$\cdot$d^{-1} of PA for youth (37,41). Compared with the general youth population, lower percentages of disadvantaged and urban youth appear to be meeting the recommendations (8,15,16,19). The known health benefits of PA support prioritizing the identification and characterization of these and other subgroups at high risk for inactivity. In addition, the recent Surgeon General's Call to Action, titled "Step It Up!"(38), highlighted the need to identify factors related to PA levels in these subgroups that may better inform targeted PA intervention efforts for those most in need of improvement.

For the last two decades, a consistent picture has emerged in which activity levels among youth decrease with increasing age and females are less active than males (18,22,36). For example, adolescent females 12–19 yr of age from the National Health and Nutrition Examination Survey (NHANES) recorded less steps per day on average compared with boys of similar age (9000 vs 11,000), and less when compared with both younger girls and boys (12,000 and 13,000 steps per day, respectively; 6–11 yr old) (36). Aspects of the built environment that vary across metropolitan settings have also emerged as factors that may lead to differences in PA levels across subgroups (8,16). In relation to this, one study reported that urban youth had significantly lower mean ± SD step counts per day compared with suburban and rural youth (10,856 ± 3706 vs 12,297 ± 3616 and 11,934 ± 3374, $P < 0.05$); with the lowest mean step counts per day in urban females (16). Furthermore, studies of environmental factors suggest that differences in opportunities to engage in PA in/outside of school and neighborhood safety (perceived and objectively recorded) may contribute to activity level variations across

Address for correspondence: Bonny Rockette-Wagner, Ph.D., Department of Epidemiology, University of Pittsburgh, 130 Desoto Street, 515, Parran Hall, Pittsburgh, PA 15261; E-mail: bjr26@pitt.edu.
Submitted for publication May 2016.
Accepted for publication October 2016.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.acsm-msse.org).

0195-9131/17/4904-0695/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000001152

metropolitan settings (10,12,33). Other factors highly correlated with metropolitan setting that may be related to activity levels include race/ethnicity and poverty (8).

Few studies report PA data specifically for adolescent females living in an urban environment (8,12,16,40) and even less do so using objective measures of PA (12,16,40), which may be more accurate and precise compared with subjective measures (e.g., questionnaires). The few published studies using objective measures have been cross-sectional studies of younger adolescent females (<13 yr of age), and none of these studies have examined urban cohorts with sufficient size or ethnic and socioeconomic diversity to fully explore the roles of race/ethnicity, environmental factors, poverty factors, and personal/lifestyle factors on PA levels within this population.

This article aims to describe PA levels in a large population-based, racially and socioeconomically diverse cohort of 14- to 17-yr-old urban-dwelling females followed during a 4-yr period using time-stamped step counts. The activity level of this cohort will be compared with known step goals and to published normalized population values for average step counts per day derived from female adolescents participating in NHANES. Finally, the effect of socioeconomic, personal/lifestyle, and neighborhood/environmental factors on step counts in this cohort will be examined.

METHODS

EPIDEMIOLOGY

Participants were recruited from the Pittsburgh Girls Study (PGS; begun in 1999). The PGS study design, methods, and primary results have been published (20). Briefly, 2451 girls comprising four age cohorts (5–8 yr in wave 1) were recruited from the 89 zip code–defined residential neighborhoods of Pittsburgh, Pennsylvania, using random household sampling techniques. In the 30 lowest-income neighborhoods, 100% of households were enumerated. Approximately 50% of households were randomly enumerated in the remaining neighborhoods. Overall, 83.7% of girls listed by the U.S. Census were identified. Of the 2992 eligible families identified, 2451 (82%) agreed to participate. Sampling weights were determined, based on the oversampling pattern, to maintain population representativeness. Before age 18 yr, written informed consent was obtained from the caregiver, and participants gave verbal assent. From age 18 yr onward, the young women provided written informed consents. The study was approved by the University of Pittsburgh institutional review board.

The PGS pedometer ancillary study began in assessment wave 10 (2010) at which time the girls were 14–17 yr old and continued to wave 13 (2013). A total of 1045 girls were recruited sequentially from PGS interview respondents in 2010 to determine objectively assessed PA levels, reported by pedometers, in this cohort. The mean retention rate of the original PGS sample was more than 90% in wave 10.

Data collection. Trained interviewers conducted separate annual in-home interviews for girls and caregivers at which socioeconomic and neighborhood perception variables were collected from caregivers. Ethnicity/race was defined as non-Hispanic (NH) African American, NH Caucasian, and all other because of the small numbers of caregivers reporting other ethnic/racial categories. Family poverty was defined as receiving public assistance (yes/no). In addition, single parent household (yes/no), living in a neighborhood with primarily single-family households (yes/no), and parent's education less than high school (yes/no) were also examined. Socioeconomic status (SES), as a composite variable, was calculated from parental education (less than high school), public assistance, and single parent household.

Neighborhood perception variables included measures of neighborhood safety, problems, convenience, appreciation, and neighbor helpfulness. Each measure was based on responses to established questions (26). In addition, neighborhood was characterized according to trained interviewers' perception about whether the participant's block was predominantly single-family housing. U.S. Census statistics (2010) for households below poverty (%) and households with less than a high school education (%) were based on 2010 postal zip code–defined neighborhoods.

Girls provided data on personal/lifestyle factors, including current smoking (yes/no), recent childbirth status (gave birth in the past year), and body mass index (BMI). BMI was calculated from interviewer-measured height and weight. Weight categories were defined using accepted age/gender-specific BMI cut points: normal and underweight (BMI <85th percentile), overweight (BMI ≥85th percentile, but <95th percentile), mild/moderate obesity (BMI ≥95th percentile but less than 1.2 × 95th percentile), and severe obesity (BMI ≥1.2 × 95th percentile) (9). Families were compensated for their participation.

PA measurement. PA data were collected using a reliable and valid pedometer, the Omron HJ-720ITC (Kyoto, Japan). Previously validated algorithms used in the HJ-720ITC convert recorded displacement along the two measurement axes into step counts (30). Data are output as time-stamped step counts in 1-h increments.

Monitors were distributed at the participants' interviews during four consecutive annual visits (waves 10–13). Participants wore the monitors on their waist for the 7 d after each interview visit. The identification of each recorded hour as worn/not worn was provided with the standard monitor output using proprietary algorithms. Data were screened for mailback time and monitor wear time. Girls were asked to rewear the monitor if they had <3 d of identifiable monitor wear. Valid days of monitoring were defined using the criteria of ≥10 h of wear time and a lower threshold of at least 150 steps (4). Girls with less than three valid days of recording were not included in the final analyses (1).

Statistical analyses. Population weights were used in all analyses. Chi-squared and Kruskal–Wallis tests were used to determine differences between PGS girls with/without valid pedometer data. The PGS population weighted values for average total steps per day by age at different percentiles of the distribution were compared with published normalized values to provide a context for step counts recorded in PGS. The normalized reference values were generated using step count data from a U.S. population-representative sample of females 14–20 yr of age (NHANES 2005–2006) (3).

Regression models were used to determine differences in step counts both between and within groups at baseline and longitudinally. Several *a priori* factors, monitor wear time, weekend day included (Saturday or Sunday) (yes/no), seasonal variation indicated as *recorded in winter* (December through March) (yes/no), and age cohort, were included in all models. In the case of missing values for neighborhood perception variables and socioeconomic variables, the previous years' values were carried over. A sensitivity analysis in which socioeconomic and neighborhood variables were not carried over did not change the findings.

Adjusted generalized linear regression models were used at baseline (PGS wave 10), and mixed models were used for longitudinal data analyses (PGS waves 10–13) to calculate values for least-square (adjusted) means and SE for average total steps per day. Significant differences across and between subgroups were established using ANCOVA and Tukey test, respectively. Linear mixed models were used to determine important predictors of step counts over the entire follow-up. Univariate models, including the *a priori* covariates, were run to determine the relationship between each demographic, lifestyle, neighborhood, and socioeconomic variable and average steps per day. Additional multivariable analyses included all potential predictors. A step-down approach was used to determine the most appropriate final model. Statistical analyses were conducted in SAS version 9.3 (SAS Institute, Cary, NC).

RESULTS

Baseline (PGS study wave 10) step counts. A subsample of 1045 of the original 2451 PGS girls were invited to participate in the pedometer study. There were no significant differences in key demographic and lifestyle factors between girls recruited/not recruited into the ancillary study (based on $P < 0.05$; data not shown). At baseline of the ancillary study (PGS wave 10), 926 (88.6%) of 1045 enrolled girls had complete pedometer data (≥3 d with ≥10 h of recording time and ≥150 steps; Table 1). Compared with girls without complete data, ancillary study participants with complete data were more likely to live in neighborhoods with more household incomes below poverty level (15.6% vs 20.7%, $P = 0.02$).

Of the 926 girls with complete pedometer data, 38.4% were NH Caucasian and 55.6% were NH African American. They were comparable with nationally representative samples of girls of similar age for reporting a pregnancy (2.3% vs 2.4%) (13) and reporting currently smoking (14.6% vs 15.7%) (17,19). The percentage from families receiving

TABLE 1. Demographic characteristic of PGS pedometer study participants at baseline (wave 10 assessment; *n* = 1045).

Variable	Without Complete PED Data, *N* = 119	With Complete PED Data, *N* = 926	*P*
Study cohort (%)			0.004[a]
5 (~age 14 yr)	14.4	23.8	
6 (~age 15 yr)	24.0	26.2	
7 (~age 16 yr)	26.0	28.4	
8 (~age 17 yr)	35.6	21.6	
Race (%)			0.77
NH African American	43.9	46.2	
NH Caucasian	48.6	47.2	
Mixed/other	7.5	6.6	
BMI percentile, median (IQR)	81.0 (54.9–94.4)	78.6 (51.9–93.6)	0.91
Previous birth (%)	1.7	2.3	0.23
Smoking, current (%)	16.5	14.6	0.60
Single parent house (%)	50.7	44.1	0.18
Parent less than high school education (%)	35.7	44.6	0.07
Public assistance, current (%)	34.4	34.5	0.98
SES, composite variable (%)			0.13
Low	48.8	41.0	
Middle	16.9	24.5	
High	34.4	34.5	
Neighborhood (%)			
Below poverty, median (IQR)[b]	15.6 (11.5–25.9)	20.7 (11.4–30.9)	0.02
Less than high school education, median (IQR)[b]	13.4 (4.0–18.8)	14.3 (13.0–11.9)	0.99

PED, pedometer.
[a]Based on chi-squared *P* value for differences, *P*-trend was not significant ($P = 0.49$).
[b]Neighborhood statistics based on 2010 census.

public assistance was similar to 2011 statistics for adolescents (11–15 yr) in the U.S. population (34.5% vs 32%) (6), whereas the percentage defined as overweight (BMI ≥85 percentile) was somewhat higher compared with NHANES 2009–2010 data for 12- to 19-yr-olds (43.9% vs 32.6%) (27).

Mean ± SD monitor wear time was 15.8 ± 1.9 $h \cdot d^{-1}$. Baseline (age 14–17 yr; PGS study year 10) step counts were relatively low (Table 2). The average unadjusted mean ± SD steps per day was 5614 ± 2434. The average median (interquartile range [IQR]) steps per day was 5368 (3866–7069). Only 5.3% of girls had at least 10,000 steps per day, which is an estimate of the steps needed to meet the 60-min activity goal of the Centers for Disease Control for adolescent females (34). On the basis of the commonly used 5000 steps per day cut point, 43.7% of the girls were considered inactive or sedentary at baseline (35).

NH African American girls recorded slightly more mean ± SD steps per day when compared with NH Caucasian girls (6087 ± 2373 vs 5244 ± 2426; Table 2). On the basis of 10,000 steps per day, 6.1% of NH African American girls would have been meeting the activity goal compared with 2.8% of NH Caucasian girls and 3.2% of girls reporting other racial/ethnic groups. The results of a comparison of adjusted least squares mean steps per day (models included cohort, monitor wear time, season of wear, and if a weekend day was recorded) between NH African American and NH Caucasian girls across SES groups suggested that step counts were higher for NH African American girls in all three SES groups reaching significance (Tukey test $P < 0.05$) in the lower and moderate SES groups (see Figure, Supplemental Digital Content 1, Adjusted means and SE for total

EPIDEMIOLOGY

TABLE 2. Mean ± SD daily activity at baseline (wave 10) for PGS girls with valid pedometer data (n = 926).

	Step Counts	Maximum Hourly Step Counts[a]	Percentage of Wear Hours with <100 Steps	Percentage of Inactive Girls[b]
All (n = 926)	5614 (2434)	1429 (639)	41.9 (15.9)	43.7
Age (yr)				
14 (n = 217)	5520 (2285)	1372 (583)	40.0 (15.2)	44.7
15 (n = 240)	5763 (2474)	1505 (697)	41.6 (16.1)	40.5
16 (n = 262)	5843 (2489)	1497 (649)	42.0 (15.4)	40.1
17 (n = 207)	5252 (2434)	1311 (594)	44.3 (16.9)	51.4
Race/ethnicity				
NH African American (n = 515)	6087 (2373)	1522 (563)	43.0 (15.1)	37.0
NH Caucasian (n = 356)	5244 (2426)	1357 (721)	40.3 (16.8)	48.6
All Other (n = 55)	5024 (2423)	1296 (659)	45.0 (16.3)	56.4

[a]Daily average for highest step counts recorded during an hour of the day.
[b]Population level value based on average step counts per day; inactive is defined as <5000 steps per day.

steps per day at wave 10 visit for NH African Americans and NH Caucasians across socioeconomic status groups, http://links.lww.com/MSS/A817).

Step counts per day were significantly lower ($P < 0.0001$) for girls who wore the monitors in winter (n = 474; median [IQR] = 5585 [3817–7404], December–March) compared with girls who wore the monitors during other months (n = 452; median [IQR] = 6341 [4774–8247]). Although activity levels were significantly higher on week days compared with weekend days ($P < 0.05$; data not shown), girls with a recorded weekend day did not have significantly more or less steps than girls without a recorded weekend day (n = 728; median [IQR] = 5348 [3866–6976]) vs (n = 198; median [IQR] = 5566 [3865–7506]; P = 0.32).

Diurnal activity patterns suggested that average step counts were significantly different across hours of the day for week days and weekend days (both $P < 0.0001$; see Figure Supplemental Digital Content 2, Median and interquartile range (IQR) for average pedometer steps by time of the day during the school year, http://links.lww.com/MSS/A818). On week days, median steps per hour quickly peaked near the start of the school day (8:00–9:00 a.m.; median [IQR] = 279 [100–530] steps) and again in the late afternoon (4:00–5:00 p.m. median [IQR] = 463 [230–754] steps). However, more steps overall were accrued from 8:00 a.m. to 3:00 p.m. (corresponding to school hours; median [IQR] = 2635 [1724–3589]) when compared with other periods of the day (12:00 a.m.–6:00 a.m., 6:00 a.m.–8:00 a.m., 3:00–7:00 p.m., and 7:00 p.m.–12:00 a.m.).

PGS step count values by age: comparison to NHANES. The number of records for the PGS sample (recorded for all waves; 10–13) was highest at age 17 yr (n = 754), as all four birth cohorts wore the pedometers at this age. Median (IQR) values for steps per day among PGS girls were quite stable over time (Fig. 1). At 14, 17, and 20 yr of age, median (IQR) step counts per day were 5177 (2209–10,243), 5116 (1776–10,458), and 4599 (1700–10,584), respectively.

Overall, total steps per day in PGS girls were lower than normalized step values from NHANES for girls of similar age (Fig. 1). PGS 14-yr-old girls at the 5th and 95th percentiles recorded an average of 444 and 1098 steps per day less than the normalized values for 14-yr-old girls at the 5th and 95th percentiles, respectively. For each age-group, the results suggest that the 50th percentile step count values in PGS girls were similar to the 25th percentile for normalized population step count values from NHANES. However, PGS

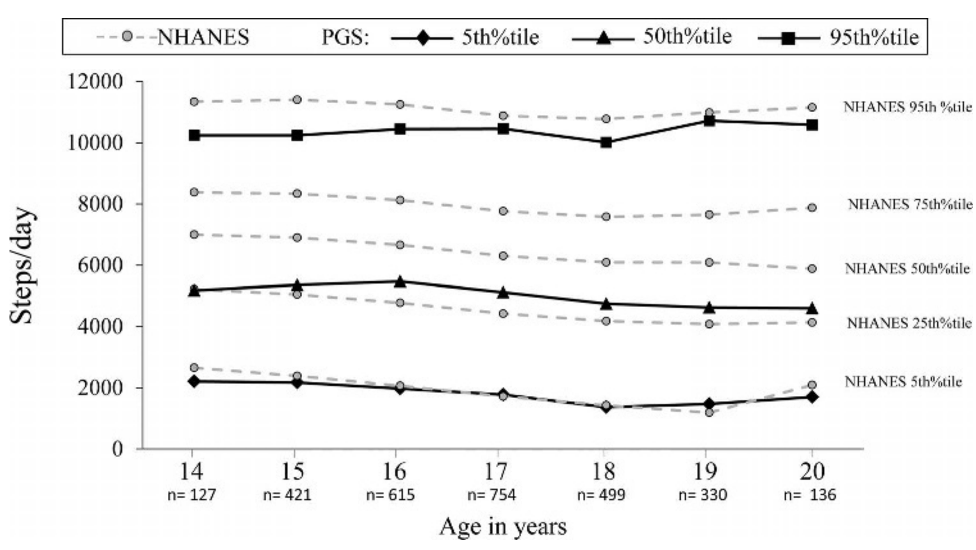

FIGURE 1—PGS cohort steps per day percentiles by age (collected during waves 10–13) and normalized steps per day percentiles from the NHANES 2005–2006 data. Note: NHANES data for ages 14–19 yr adapted from Barriera et al. 2015(2); NHANES 2005–2006 data for age 20 yr provided via personal correspondence with Dr. John M. Schuna.

step count values at the 5th and 95th percentiles tracked relatively closer to the normalized values at the U.S. population's 5th and 95th percentile.

Longitudinal PGS step count values: associations with personal and environmental factors. Longitudinal data from PGS was further examined with mixed models to account for repeated measures. Only girls with valid baseline data (n = 926) were included in the longitudinal analyses. A large proportion of these girls also provided data with ≥3 valid days, in subsequent waves: 832 (wave 11), 790 (wave 12) and 758 (wave 13) individuals, respectively. All models were adjusted for the *a priori* variables of monitor wear time, inclusion of a weekend day (yes/no), season of pedometer wear (winter/nonwinter), and age cohort. The adjusted mean ± SE estimates for average steps per day were 5623.2 ± 90.7, 5222.4 ± 102.7, 5585.7 ± 105.0, and 5315.7 ± 108.8, at PGS study wave assessments 10–13, respectively.

In the individual univariate models, which also contained the four *a priori* variables, significant predictors of average steps per day (P < 0.05) were race/ethnicity, weight category, recent birth, and all four socioeconomic variables (single-family home, neighborhoods with predominately single-family homes, parental education, and receiving public assistance). Six of seven neighborhood perception variables were significantly related to step counts (P < 0.05, data not shown); only neighborhood appreciation was not. Indicators of higher poverty and poorer neighborhood perception were generally associated with higher, not lower, step counts per day (data not shown). The relationship between weight categories and average steps per day was not monotonic; girls in the severely obese category recorded the lowest step counts per day followed by girls with normal/underweight BMI (data not shown).

Significant predictors of average steps per day in the final multivariable model (Table 3) were season of monitor use (winter vs nonwinter), average monitor wear time per day, birth cohort, race/ethnicity, recent child birth, body weight category, and whether the girl's home neighborhood was predominantly single-family housing (yes/no). Although step counts per day did not differ over time in this model (P = 0.62), there was a difference in step counts across birth cohorts, with steps decreasing with age. The strongest predictor of steps was "having given birth in the past year," which was associated with an average ± SE estimated reduction of 1476.3 ± 294.0 step counts per day (P < 0.0001). Girls identified as being severely obese had a significant average ± SE estimated reduction of 707.3 ± 190.0 step counts per day when compared with overweight girls (reference category; P-dif <0.001). NH African American ethnicity/race and living in a neighborhood with less single-family housing were associated with higher estimated step counts.

TABLE 3. Reduced multivariable model predicting average steps per day in PGS girls from pedometer measurement baseline (wave 10) to wave 13.

Variable	Estimate (SE)[a]	P
Intercept	−631.0 (739.7)	**0.39**
Worn in winter (yr)	−641.1 (102.9)	<**0.0001**
Average wear time (h·d^{-1})	303.08 (25.0)	<**0.0001**
Recording included weekend day (yr)	134.2 (125.9)	**0.29**
Time (~1-yr increment)	−22.5 (45.5)	**0.62**
Birth cohort (age at enrollment to PGS)		**0.01**
5 (~age 14 yr)	Reference	–
6 (~age 15 yr)	37.3 (137.7)	0.79
7 (~age 16 yr)	−87.7 (136.0)	0.52
8 (~age 17 yr)	−431.4 (153.8)	<0.01
Race		<**0.0001**
NH Caucasian	Reference	–
NH African American	662.0 (111.4)	<0.0001
All other	343.4 (210.0)	0.10
BMI weight category		**0.001**
Low to normal (<85th percentile)	−396.5	<0.01
Overweight (85th–94th percentile)	Reference	–
Mild/moderate obesity (95th percentile to <1.2 × 95th percentile)	−171.1 (195.5)	0.38
Severe obesity (≥1.2 × 95th percentile)	−707.3 (190.0)	<0.001
Recent childbirth; past year (yr)	−1476.3 (294.0)	<**0.0001**
Multifamily house (yr)	337.7 (120.0)	<**0.01**

[a]For categorical variables, estimate represents step count difference compared with reference group. For wear time, the estimate is the difference for each additional hour of the day and time is for each ~1-yr period between recordings.

DISCUSSION

This study is the first we are aware of to report objective PA data for urban adolescent females over a 4-yr period. The results of this study are in line with other studies of younger adolescents suggesting that urban females may be less active than other youth their age (8,16). For each year of pedometer recording, only approximately 5% of PGS girls recorded at least 10,000 steps per day; the suggested minimum number of steps needed to meet the 60-min·d^{-1} activity goal (34). Overall, daily step counts for PGS girls were lower than expected values, based on a nationally representative sample of girls of similar age. In addition, changes in step counts over the follow-up period were small and not significant in the PGS cohort.

These findings highlight the importance of school-based activity for these urban youths. On the basis of time-stamped pedometer data, school-based activity was important in this cohort, accounting for nearly 45% of recorded steps per day at baseline. The number of steps recorded during school hours was similar to other cohorts (32,39). However, school-based activity was a larger contributor to overall activity levels in this cohort, as the PGS girls reported lower step counts after school and on weekends compared with these other cohorts. The dominance of school-based activity in this sample may also suggest a lack of alternative PA options. Young urban females may benefit from the development of new opportunities for activity during the after-school period and on weekends.

PGS girls identifying as NH African American had slightly higher average step counts per day than girls identifying with other racial/ethnic groups. Previous studies have reported inconsistent findings for the differences in PA levels across racial/ethnic groups (7,15,21), with several recent studies supporting this study's findings of higher PA levels in African American youth compared with Caucasian youth of similar age (7,11). It should be noted that, although significant, the differences in step counts across racial/ethnic groups in PGS appear smaller than the differences between the PGS cohort, as a whole, and the normalized values for the U.S. population-representative sample, suggesting the relative importance of the urban environment on overall activity levels, regardless of race/ethnicity.

Reasons cited for why youth living in urban settings may have lower PA levels when compared with youth living in other metropolitan settings include less safe neighborhood environments and increased poverty (12,31). However, some urban youth studies have reported increased PA levels with increased poverty (7,29). One possible reason for this may be increases in transportation activity observed among those living below the poverty line (15,29). The association between higher poverty and poorer parental perception of neighborhood with higher PA levels in this cohort (although attenuated in the full model) may support the notion that disadvantaged youth may, of necessity, walk more for transportation.

Longitudinal changes in step counts (for 4 yr) were not significant in the PGS sample. Although the cross-sectional NHANES data show little difference in activity for adolescent girls across a similar age range, other longitudinal studies using objective PA measures have shown significant declines in activity levels during adolescence (5,14,28). Most of these longitudinal studies report MVPA, which cannot be separated out from total pedometer steps. For this reason, it is not possible to know whether MVPA levels could have similarly declined in the PGS girls across adolescence, despite the small overall changes in step counts.

A strength of this study compared with many previous studies was the use of an objective measure of PA. Objective measures, including pedometers, can provide more accurate assessments of PA than questionnaires. However, interpretations of step count comparisons between monitors, such as Omron monitors (PGS) and ActiGraph monitors (NHANES), should consider the possibility that differences in reported steps could be due to differences in monitor design and processing. Although some bias is likely, both the Omron and ActiGraph monitors have validated well against manual counting, recording 97.5% and 98.5% of steps, respectively, and have shown good agreement with each other (25). This would suggest a high degree of confidence in reported values from both monitors as well as cross-monitor comparisons.

The size and diversity of this cohort was advantageous and made it possible to examine the role of personal and environmental factors that may affect activity levels within the urban environment. Our study was also not confounded by the relationships between metropolitan setting and SES and metropolitan setting and race/ethnicity. However, without suburban and rural youth, it was not possible to gain a complete understanding of factors that may be contributing to low PA levels among youth living in urban settings, but not other metropolitan settings. Therefore, future efforts should seek to examine a large cohort, similar to the PGS, that also includes youth living in other metropolitan settings.

CONCLUSIONS

The overall low levels of PA in the PGS cohort suggest that adolescent girls living in urban environments should be considered a priority group for targeted PA improvement. The daily patterns of activity in the PGS girls suggest that future intervention efforts in similar urban adolescents should consider the potential importance of school-based activity. Increasing opportunities for activity outside of school, particularly on weekends, should also be considered a priority.

The authors greatly appreciate the support of the PGS staff and study participants. They also thank Dr. John M. Schuna for providing normalized step count data for 20-yr-olds from the NHANES 2005–2006 data.

This work was supported by the National Institutes of Health (grant nos. MH 081071 and MH056630). The sponsor had no role in the study design, collection, analysis or interpretation of data, writing of the report, or decision to submit the manuscript for publication.

B. R. W., A. E. H., A. M. K., K. L. S., and K. M. M have no conflicts of interest to report.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

EPIDEMIOLOGY

REFERENCES

1. Adams MA, Caparosa S, Thompson S, Norman GJ. Translating physical activity recommendations for overweight adolescents to steps per day. *Am J Prev Med*. 2009;37(2):137–40.
2. Barreira TV, Schuna JM Jr, Mire EF, et al. Normative steps/day and peak cadence values for united states children and adolescents: National Health and Nutrition Examination Survey 2005–2006. *J Pediatr*. 2015;166(1):139–43.
3. Barreira TV, Schuna JM Jr, Mire EF, et al. Normative steps/day and peak cadence values for united states children and adolescents: National Health and Nutrition Examination Survey 2005–2006. *J Pediatr*. 2015;166(1):139–43.
4. Cain KL, Sallis JF, Conway TL, Van Dyck D, Calhoon L. Using accelerometers in youth physical activity studies: a review of methods. *J Phys Act Health*. 2013;10(3):437–50.
5. Cameron C, Craig CL, Bauman A, Tudor-Locke C. CANPLAY study: secular trends in steps/day amongst 5–19-year-old Canadians between 2005 and 2014. *Prev Med*. 2016;86:28–33.
6. Crouse G, Waters A. *Welfare Indicators and Risk Factors*. Washington D.C.: Office of Human Services Policy, U.S. Department of Health and Human Services; 2014. p. 21.
7. Eyre EL, Duncan MJ. The impact of ethnicity on objectively measured physical activity in children. *ISRN Obes*. 2013;2013:757431.
8. Felton GM, Dowda M, Ward DS, et al. Differences in physical activity between black and white girls living in rural and urban areas. *J Sch Health*. 2002;72(6):250–5.
9. Flegal KM, Wei R, Ogden CL, Freedman DS, Johnson CL, Curtin LR. Characterizing extreme values of body mass index-for-age by

using the 2000 Centers for Disease Control and Prevention growth charts. *Am J Clin Nutr*. 2009;90(5):1314–20.
10. Gómez JE, Johnson BA, Selva M, Sallis JF. Violent crime and outdoor physical activity among inner-city youth. *Prev Med*. 2004;39(5):876–81.
11. Gortmaker SL, Lee R, Cradock AL, Sobol AM, Duncan DT, Wang YC. Disparities in youth physical activity in the United States: 2003–2006. *Med Sci Sports Exerc*. 2012;44(5):888–93.
12. Hager ER, Witherspoon DO, Gormley C, Latta LW, Pepper MR, Black MM. The perceived and built environment surrounding urban schools and physical activity among adolescent girls. *Ann Behav Med*. 2013;45(1 Suppl):S68–75.
13. Hamilton BE, Martin JA, Osterman MJ, Curtain SC. Births: Preliminary Data for 2014. *Natl Vital Stat Rep*. 2015;64(6):1–19.
14. Janz KF, Letuchy EM, Burns TL, Eichenberger Gilmore JM, Torner JC, Levy SM. Objectively measured physical activity trajectories predict adolescent bone strength: Iowa Bone Development Study. *Br J Sports Med*. 2014;48(13):1032–6.
15. Johnson TG, Brusseau TA, Darst PW, Kulinna PH, White-Taylor J. Step counts of non-white minority children and youth by gender, grade level, race/ethnicity, and mode of school transportation. *J Phys Act Health*. 2010;7(6):730–6.
16. Johnson TG, Brusseau TA, Vincent Graser S, Darst PW, Kulinna PH. Step counts of 10- to 11-year-old children by ethnicity and metropolitan status. *J Phys Act Health*. 2010;7(3):355–63.
17. Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE. Use of alcohol, cigarettes, and number of illicit drugs declines among U.S. teens. In: *University of Michigan News Service; National Press Release*. Ann Arbor (MI): University of Michigan; 2014. p. 35.
18. Kahn JA, Huang B, Gillman MW, et al. Patterns and determinants of physical activity in U.S. adolescents. *J Adolesc Health*. 2008;42(4):369–77.
19. Kann L, Kinchen S, Shanklin S, Flint KH, Hawkins J, Harris WA. Youth Risk Behavioral Surveillance—United States 2013. *Morb Mortal Wkly Rep*. 2014;4:35–7.
20. Keenan K, Hipwell A, Chung T, et al. The Pittsburgh Girls Study: overview and initial findings. *J Clin Child Adolesc Psychol*. 2010; 39(4):506–21.
21. Kimm SY, Glynn NW, Kriska AM, et al. Decline in physical activity in black girls and white girls during adolescence. *N Engl J Med*. 2002;347(10):709–15.
22. Kimm SY, Glynn NW, Kriska AM, et al. Longitudinal changes in physical activity in a biracial cohort during adolescence. *Med Sci Sports Exerc*. 2000;32(8):1445–54.
23. Kimm SY, Glynn NW, Obarzanek E, et al. Relation between the changes in physical activity and body-mass index during adolescence: a multicentre longitudinal study. *Lancet*. 2005; 366(9482):301–7.
24. Kriska A, Delahanty L, Edelstein S, et al. Sedentary behavior and physical activity in youth with recent onset of type 2 diabetes. *Pediatrics*. 2013;131(3):e850–6.
25. Lee JA, Williams SM, Brown DD, Laurson KR. Concurrent validation of the ActiGraph gt3x+, Polar Active accelerometer, Omron HJ-720 and Yamax Digiwalker SW-701 pedometer step counts in lab-based and free-living settings. *J Sports Sci*. 2015; 33(10):991–1000.
26. McTigue KM, Cohen ED, Moore CG, Hipwell AE, Loeber R, Kuller LH. Urban neighborhood features and longitudinal weight development in girls. *Am J Prev Med*. 2015;49(6):902–11.
27. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. *JAMA*. 2012;307(5):483–90.
28. Ortega FB, Konstabel K, Pasquali E, et al. Objectively measured physical activity and sedentary time during childhood, adolescence and young adulthood: a cohort study. *PLoS One*. 2013;8(4): e60871.
29. Panter JR, Jones AP, Van Sluijs EM, Griffin SJ. Neighborhood, route, and school environments and children's active commuting. *Am J Prev Med*. 2010;38(3):268–78.
30. Peters BP, Heelan KA, Abbey B. Validation of Omron pedometer using MTI accelerometers for use with children. *Int J Exerc Sci*. 2013;6(2):106–13.
31. Powell LM, Slater S, Chaloupka FJ, Harper D. Availability of physical activity-related facilities and neighborhood demographic and socioeconomic characteristics: a national study. *Am J Public Health*. 2006;96(9):1676–80.
32. Sigmund E, Sigmundová D, Snoblová R, Gecková AM. ActiTrainer-determined segmented moderate-to-vigorous physical activity patterns among normal-weight and overweight-to-obese Czech schoolchildren. *Eur J Pediatr*. 2014;173(3): 321–9.
33. Springer AE, Hoelscher DM, Kelder SH. Prevalence of physical activity and sedentary behavior in US high school students by metropolitan setting. *J Physd Act Health*. 2006;3:365–80.
34. Tudor-Locke C, Craig CL, Beets MW, et al. How many steps/day are enough? for children and adolescents. *Int J Behav Nutr Phys Act*. 2011;8:78.
35. Tudor-Locke C, Craig CL, Thyfault JP, Spence JC. A step-defined sedentary lifestyle index: <5000 steps/day. *Appl Physiol Nutr Metab*. 2013;38(2):100–14.
36. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps per day in US children and youth. *Med Sci Sports Exerc*. 2010;42(12):2244–50.
37. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. Washington (DC): U.S. Department of Health and Human Services; 2008. p. 15.
38. U.S. Department of Health and Human Services. Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities. Washington (DC): U.S. Department of Health and Human Services; 2015.
39. Vander Ploeg KA, Wu B, McGavock J, Veugelers PJ. Physical activity among Canadian children on school days and nonschool days. *J Phys Act Health*. 2012;9:1138–45.
40. Wilson DK, Lawman HG, Segal M, Chappell S. Neighborhood and parental supports for physical activity in minority adolescents. *Am J Prev Med*. 2011;41(4):399–406.
41. World Health Organization. Physical activity and young people. *Global Strategy on Diet, Physical Activity, and Health*. World Health Organization; 2011.