Pedometer-Determined Physical Activity Levels of Youth

Guy C. Le Masurier, Aaron Beighle, Charles B. Corbin, Paul W. Darst, Charles Morgan, Robert P. Pangrazi, Bridgette Wilde, and Susan D. Vincent

Background: The purpose of this study was to describe the pedometer-determined physical activity levels of American youth. Methods: A secondary analysis of six existing data sets including 1839 (1046 females, 793 males; ages 6 to 18) school-aged, predominantly white subjects from the southwest US. Grade clusters for elementary (grades 1 to 3), upper elementary (grades 4 to 6), middle school (grades 7 to 9), and high school (grades 10 to 12) were created for statistical analysis. Results: Males in grades 1 to 3 and 4 to 6 accumulated significantly more steps/d (13,110 ± 2870 and 13,631 ± 3463, respectively; \( P < 0.001 \)) than males in grades 7 to 9 and 10 to 12 (11,082 ± 3437 and 10,828 ± 3241). Females in grades 1 to 3 and 4 to 6 accumulated significantly more steps/d (11,120 ± 2553 and 11,125 ± 2923; \( P < 0.001 \)) than females in grades 7 to 9 and 10 to 12 (10,080 ± 2990 and 9706 ± 3051). Conclusions: Results are consistent with those reported for other objective assessments of youth activity indicating that males are typically more active than females and physical activity is less prevalent among secondary school youth than those in elementary school. Pedometer-determined physical activity levels of youth, including secondary school youth, are higher than reported for adult populations.

Key Words: pedometers, children, adolescents, motion sensors

Pedometers have the potential to become effective youth physical activity surveillance tools because they are inexpensive, easy to use, accurate, and objective measures of accumulated physical activity.\(^1,2\) Moreover, researchers have identified and addressed a number of important issues central to conducting pedometer research with youth including the number of monitoring days needed to determine habitual physical activity,\(^3\) reactivity,\(^3,4\) and protecting pedometer data.\(^4\) Yet, large-scale

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studies describing the pedometer-determined physical activity levels of youth are nonexistent.

The purpose of this study was to combine six data sets and describe the pedometer-determined physical activity levels of youth. The six data sets met inclusion criteria related to empirically established methods of pedometer data collection. A secondary purpose was to compare the physical activity profile of youth generated from pedometer data with an existing youth physical activity profile based on accelerometer data.

**Methods**

This is a secondary analysis of six existing data sets of 1839 youth (1046 females, 793 males; ages 6 to 18) from the southwest United States. The statistical analysis undertaken here has not been performed previously on these data sets.

**Subjects**

Data were collected in the greater Phoenix metropolitan area during the 2000, 2001, 2002, and 2003 school years (August to May), when the weather was conducive to outdoor activities. Convenience samples of student subjects were recruited from local school districts where researchers had access to large numbers of student subjects from urban communities. The 1839 student subjects consisted of 71% white, 19% Hispanic and African American, 2% Native American, 1% Pacific Island/Asian, and 5% other (mixed ethnicities). Ethical approval for the individual studies was granted by Arizona State University’s Institutional Review Board (IRB). All youth involved submitted a written assent form along with an informed consent form signed by their parents. In addition, IRB approval was granted from the university to perform this secondary analysis.

**Inclusion Criteria**

Inclusion criteria were based on four methodological issues related to pedometer data collection including (1) the brand of pedometer used, (2) the number of days of pedometer monitoring, and (3) whether the pedometers were sealed during data collection, and (4) similar data collection procedures. In order for a data set to be included in the study, pedometer data had to have been collected using a brand that has demonstrated acceptable accuracy at a range of walking speeds and distances. The six data sets included in this study used either the Yamax SW 200 (Yamax Corp., Tokyo, Japan) or the Walk4Life LS 2525 (Walk for Life, Plainfield, IL). Research has consistently demonstrated the accuracy of both the Yamax SW 200 and the LS 2525 for measuring steps taken. In each of the individual studies that contributed to this secondary analysis, either a shake test or a walking test was conducted on a random sample of pedometers used to determine the accuracy of each of the devices. Pedometers exhibiting \( \pm 5\% \) error on a walking test (19, 20, or 21 steps out of 20) and pedometers within \( \pm 1\% \) error during a shake test were included in the studies.

The minimum pedometer monitoring frame required for a data set to be included was 4 d. Previous research has established that 4 weekdays of pedometer monitoring provide reliable estimates of habitual physical activity levels among children. The number of weekdays required for reliable estimates of adolescent
physical activity using pedometers has not been determined, but reliable weekday estimates have been attained with middle school students using 4d of monitoring. Gathering baseline physical activity levels of youth also demands that researchers account for reactivity. Reactivity is defined as a change in normal activity patterns when subjects’ know that their activity levels are being monitored. Pedometers are novel “gadgets” with digital displays that provide immediate feedback to subjects. It is not uncommon for children, adolescents, and adults to try and “make the pedometers work” when they first receive them. Reactivity is indicated when subjects’ accumulate significantly more steps/d in the early days of the study compared to the latter. For researchers seeking to establish baseline physical activity levels, reactivity causes an overestimation of baseline physical activity levels. Previous research has demonstrated that reactivity does not exist when pedometers are sealed (i.e., mechanically closed). In addition, research has demonstrated that sealed pedometers prevent data losses that occur when youth have access to the pedometer’s digital display and reset buttons. In order for a data set to be included in this secondary analysis, sealed pedometers were required for data collection.

**Procedures**

On the first day of monitoring (Monday), students were instructed on pedometer attachment (at the waist, on the right side), pedometer removal (during showering, bathing, swimming, and sleeping), and reattachment each morning before going to school. Subjects were instructed to wear the pedometer from the time they woke up until the time they went to bed, excluding bathing and swimming. Students were also instructed to maintain their normal daily activities and refrain from tampering with the cable ties for the duration of monitoring. At school each morning, research staff collected the pedometers, cut the cable ties, recorded steps taken, reset the pedometers to zero, resealed the pedometers, and returned them to the students (within 15 min for PE classes, within 30 min for classroom periods). Depending on the data set, students were either asked whether they had removed the pedometer during the day for more than 1 h or given a brief survey to determine whether they removed the pedometer for more than 1 h. The data acquired from students who reported removing their pedometers for more than 1 h/d were removed from the data set. This protocol is similar to previous research.

**Data Treatment and Statistical Analysis**

The pedometer data accumulated on the first 4 weekdays of monitoring were averaged to provide a steps/d variable for each student. Intraclass correlation coefficients (ICC; Cronbach’s alpha) were calculated for 2 d (1 and 2), 3 d (1, 2, and 3), and 4 d (1 to 4) of adolescent (grades 7 to 12) step data to ensure that reliable estimates (alpha ≥ 0.80) of weekday physical activity. The children’s pedometer-determined physical activity data used in this study demonstrated acceptable reliability in a previous study. In addition to presenting mean steps/d by grade level, the data were statistically analyzed using grade clustering commonly used in the school system and used in previous research examining the differences in the physical activity levels of school-age children using accelerometers. The grade clusters created were elementary (grades 1 to 3), upper elementary (grades 4 to 6), middle school (grades 7 to 9), and high school (grade 10 to 12). A 2 × 4 ANOVA (sex ×
grade cluster) was performed to determine whether differences in mean steps/d between sex and the grade clusters existed, and if there was a sex \( \times \) grade cluster interaction. Significance was established \textit{a priori} at the 0.05 level. SPSS version 12.0 (SPSS, Inc., Chicago, IL) was used to perform the analyses.

## Results

Means ± standard deviation steps/d for each sex and grade group are presented in Table 1. Mean steps/d by sex and grade are presented in Figure 1. The ICCs (95% CI) for 2, 3, and 4 d of adolescent pedometer data were 0.91 (0.90 to 0.93), 0.94 (0.93 to 0.95), and 0.90 (0.88 to 0.91). Statistical analyses indicated significant main effects for sex \( F(3, 1831) = 49.4, P < 0.001 \) and grade cluster \( F(1, 1831) = 117.4, P < 0.001 \). There was a significant sex \( \times \) grade cluster interaction \( F(3, 1831) = 5.8, P = 0.001 \). Post hoc analyses indicated that males in grade clusters 1 to 3 \( (n = 172) \) and 4 to 6 \( (n = 188) \) accumulated significantly more steps/d \( (P < 0.001) \) than males in grades 7 to 9 \( (n = 298) \) and 10 to 12 \( (n = 135) \). Females in grade clusters 1 to 3 \( (n = 167) \) and 4 to 6 \( (n = 293) \) accumulated significantly more steps/d \( (P < 0.001) \) than females in grades 7 to 9 \( (n = 443) \) and 10 to 12 \( (n = 143) \). Mean steps/d by grade cluster are illustrated in Figure 2.

### Table 1 Steps/Day for Female and Male Students in Grades 1 to 12

<table>
<thead>
<tr>
<th>Grade</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12,891 ± 2711 (( N = 54 ))</td>
<td>11,237 ± 2491 (( N = 45 ))</td>
</tr>
<tr>
<td>2</td>
<td>13,466 ± 2924 (( N = 68 ))</td>
<td>11,143 ± 2156 (( N = 55 ))</td>
</tr>
<tr>
<td>3</td>
<td>12,863 ± 2971 (( N = 50 ))</td>
<td>11,022 ± 2911 (( N = 67 ))</td>
</tr>
<tr>
<td>4</td>
<td>12,788 ± 2969 (( N = 43 ))</td>
<td>10,389 ± 2987 (( N = 71 ))</td>
</tr>
<tr>
<td>5</td>
<td>13,521 ± 3029 (( N = 65 ))</td>
<td>11,311 ± 2820 (( N = 126 ))</td>
</tr>
<tr>
<td>6</td>
<td>14,174 ± 3946 (( N = 80 ))</td>
<td>11,427 ± 3088 (( N = 96 ))</td>
</tr>
<tr>
<td>7</td>
<td>11,560 ± 3415 (( N = 124 ))</td>
<td>9,880 ± 2959 (( N = 217 ))</td>
</tr>
<tr>
<td>8</td>
<td>10,962 ± 3323 (( N = 133 ))</td>
<td>10,105 ± 3051 (( N = 181 ))</td>
</tr>
<tr>
<td>9</td>
<td>10,505 ± 3051 (( N = 41 ))</td>
<td>10,570 ± 3488 (( N = 45 ))</td>
</tr>
<tr>
<td>10</td>
<td>11,480 ± 3543 (( N = 47 ))</td>
<td>10,419 ± 3304 (( N = 41 ))</td>
</tr>
<tr>
<td>11</td>
<td>10,652 ± 2563 (( N = 41 ))</td>
<td>9,846 ± 3245 (( N = 46 ))</td>
</tr>
<tr>
<td>12</td>
<td>10,329 ± 3409 (( N = 47 ))</td>
<td>9,067 ± 2583 (( N = 56 ))</td>
</tr>
</tbody>
</table>

\textit{Note:} Values are means ± standard deviation.

## Discussion

This secondary analysis describes the pedometer-determined physical activity levels of youth. These data provide an initial steps/d curve for youth (Figure 1) and are strengthened by the consistent use of empirically established data collection methods. While research on a variety of youth populations (i.e., urban vs. urban settings).
Figure 1 — Mean steps/day for female and male students in grades 1 to 12.

Figure 2 — Mean steps/day for female and male students by grade cluster. †Significant sex × grade interaction (P < 0.001).

rural, high vs. low socioeconomic levels, and multiple ethnicities) are needed to produce a more representative curve, these data establish a point of reference for researchers and professionals to evaluate baseline weekday steps/d data gathered on American youth.
Based on the ICCs generated from 2, 3, and 4 d of adolescent data it appears that reliable estimates of adolescent physical activity were obtained. Previous research using accelerometers\(^8\) has indicated that when weekend data is collected in addition to weekday data more days are needed to obtain reliable estimates of physical activity among children and youth. Specifically, children accumulate more moderate-to-vigorous physical activity (MVPA) on the weekend compared to the weekdays, and adolescents accumulate more MVPA during the weekday compared to the weekend. Presently it is unknown whether differences exist between weekend and weekday pedometer data of youth because it is very difficult to gather weekend pedometer data on youth. Also, researchers can expect pedometer data to differ from the results of existing accelerometer data\(^8\) because light activity was eliminated from the accelerometer study referenced above, whereas the pedometer does not discriminate between physical activities of differing intensities.

Figures 1 and 2 illustrate the decline in accumulated steps/d from elementary to high school. Large differences in steps/d (>1500 steps/d) were evident between males and females in elementary school (Table 1 and Figure 2). Smaller differences were found between middle and high school females and males. The grade cluster by sex interaction resulted from the increased physical activity levels of the upper elementary males (Figure 2). It is possible that extracurricular activities available to upper elementary students that are preferentially selected by boys contributed to this increase in physical activity (e.g., soccer, football, baseball, etc.). Elementary students in this study had physical education 2 d/wk. All students in 7th and 8th grade participated in daily physical education. Despite having daily physical education, female and male middle school students accumulated fewer steps/d than elementary students. Seventy-six percent of the grade 9 students were enrolled in daily PE. In the high schools, 11% of 10th graders, 9% of 11th graders, and 4% of 12th graders were enrolled in daily PE. The decreasing prevalence of students enrolled in physical education at the senior grade levels reflects what has been reported in the Youth Risk Behavior Surveillance System.\(^{18-20}\)

The statistical analysis of grade clusters indicated that elementary students accumulated significantly more steps/d than middle and high school students (Figure 2). The lack of difference in steps/d among the elementary grade levels supports the findings of previous research.\(^{14}\) At every grade cluster males accumulated significantly more steps/d than females. Studies examining energy expenditure via heart rate monitoring\(^{21}\) and physical activity using accelerometers\(^{17}\) have demonstrated more dramatic declines as children move into adolescence (Figures 3 and 4). Using grade clusters, accelerometer research with youth\(^{17}\) indicated three main differences from these data. First, Trost et al.\(^{17}\) did not find a difference in accumulated minutes of moderate-to-vigorous physical activity (MVPA) between females and males for the elementary grade cluster (grades 1 to 3). Second, Trost et al.\(^{17}\) found that the elementary grade cluster accumulated significantly more minutes of MVPA than the upper elementary grade cluster (grades 4 to 6). Finally, there were significant differences in accumulated minutes of MVPA between every grade cluster (see Figure 4). These differences could be the result of differences in the populations (i.e., amount of recess, physical education requirements, sports participation, socioeconomic status, etc.), but are most likely the result of the differences in the way pedometers and accelerometers capture physical activity.
Figure 3 — Total daily energy expenditure for females and males ages 6 to 18. Adapted from Rowland, 1990, see reference 21.

Figure 4 — Mean minutes of moderate-to-vigorous physical activity (MVPA) of youth. †Significantly different from previous grade group. *Significant ($P < 0.05$) gender difference within grade group. Based on data from Trost et al., 2002, see reference 11.
Accelerometers have the ability to estimate the intensity of physical activity, whereas pedometers only detect steps and do not discern between light, moderate, and vigorous steps. Therefore, the observed differences between the pedometer and accelerometer grade cluster curves are likely the result of differences in data resolution. For example, if accelerometers and pedometers were worn concurrently by students in the middle and high school clusters and the middle school grade cluster accumulated significantly more minutes of MVPA compared to the high school grade cluster, it is possible that significant differences in accumulated steps/d would not be found between grade clusters if high school students took the majority of their steps in light activity versus MVPA. In fact, the significant differences in accumulated minutes of MVPA between the grade clusters reported by Trost et al.\textsuperscript{17} could not be accounted for solely by a decrease in the vigorous physical activity (VPA) because MVPA included vigorous physical activity and the decreases in MVPA are larger than the declines in VPA. Therefore, the differences between the grade clusters were the result of decreases in both moderate and vigorous activity. Nevertheless, both motion sensors indicate a significant decline in physical activity levels as children move into adolescence.

The number of steps/d accumulated by youth is higher than reported in the literature for adults, as male youth accumulate 11,000 to 13,000 steps/d and female youth accumulate 10,000 to 11,000 steps/d while sedentary adults accumulate between 5000 to 8000 steps/d and more active adults accumulate between 7000 to 10,000.\textsuperscript{2} Based on the current available evidence preliminary step/d indices have been established for adults and suggest that < 5000 steps/d might be used as a sedentary lifestyle index, 5000 to 7499 steps/d for low active, 7500 to 9999 steps/d for somewhat active, and \( \geq 10,000 \) steps/d for an active adult index.\textsuperscript{22} Interestingly, a recent pedometer study of Old Order Amish women and men found that they accumulated an average of 14,000 and 18,000 steps/d, respectively.\textsuperscript{23} Not surprisingly, there was a very low prevalence of obesity in this population.

Although these youth accumulated enough steps/d to be considered active adults using the criteria established by Tudor-Locke and Bassett,\textsuperscript{22} the trend indicates that high school students are on their way to becoming sedentary adults. As adolescents move into adulthood, three significant sources of physical activity can be lost: physical education, discretionary playtime, and organized sports participation. Quality physical education can add 1500 to 2000 steps/d\textsuperscript{24,25} and discretionary time such as recess and lunch can add an equal amount to males’ physical activity levels.\textsuperscript{25} Studies have also demonstrated that students who participate in organized sports programs\textsuperscript{13,26,27} and after-school activity programs\textsuperscript{24} accumulate significantly more physical activity than those who do not. As adolescents move into adulthood opportunities to be active are diminished and, unfortunately for the majority of adults, insufficient daily physical activity is accumulated.\textsuperscript{28}

These data provide an initial description of the pedometer-determined physical activity levels of youth from the southwest United States. A decrease in accumulated physical activity is evident as children move into adolescence. Compared to previous large-scale descriptive studies, the physical activity declines indicated using pedometers are not as dramatic. The declines in physical activity parallel the circumstances facing children as they transition from childhood to adolescence (e.g., loss of physical education), and the transition from adolescence into adulthood (i.e., no physical education, reduced discretionary time). More
research using pedometers and the empirically established methods of data collection are needed to create a more representative pedometer-determined physical activity curve.

Authors’ note: The data for this secondary analysis were purposefully combined based on devices and methods used to collect them. Each data set was gathered after receiving approval from Arizona State University’s Institutional Review Board. The analyses of the secondary data were approved by the board as well.

References