Age and gender differences in objectively measured physical activity in youth

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ABSTRACT

TROST, S. G., R. R. PATE, J. F. SALLIS, P. S. FREEDSON, W. C. TAYLOR, M. DOWDA, and J. SIRARD. Age and gender differences in objectively measured physical activity in youth. *Med. Sci. Sports Exerc.*, Vol. 34, No. 2, pp. 350–355, 2002. **Purpose:** The purpose of this study was to evaluate age and gender differences in objectively measured physical activity (PA) in a population-based sample of students in grades 1–12. **Methods:** Participants (185 male, 190 female) wore a CSA 7164 accelerometer for 7 consecutive days. To examine age-related trends, students were grouped as follows: grades 1–3 ($N = 90$), grades 4–6 ($N = 91$), grades 7–9 ($N = 96$), and grades 10–12 ($N = 92$). Bouts of PA and minutes spent in moderate-to-vigorous PA (MVPA) and vigorous PA (VPA) were examined. **Results:** Daily MVPA and VPA exhibited a significant inverse relationship with grade level, with the largest differences occurring between grades 1–3 and 4–6. Boys were more active than girls; however, for overall PA, the magnitudes of the gender differences were modest. Participation in continuous 20-min bouts of PA was low to nonexistent. **Conclusion:** Our results support the notion that PA declines rapidly during childhood and adolescence and that accelerometers are feasible alternatives to self-report methods in moderately sized population-level surveillance studies. **Key Words:** CHILDREN, EXERCISE, ACCELEROMETER, ASSESSMENT

Descriptive epidemiological studies of youth physical activity have consistently reported that male subjects are more active than female subjects and that physical activity declines with age (18,24). There is, however, considerable disagreement as to the timing and magnitude of these trends (19). This discrepancy may be attributable, in part, to the difficulty associated with measuring physical activity in children and adolescents. Indeed, recent evidence indicates that self-report methods may greatly underestimate group differences in youth physical activity (20).

Identifying group disparities in health enhancing behaviors such as physical activity remains an important goal of public health surveillance systems (13). Unfortunately, current youth surveillance systems may be ill-equipped to provide precise estimates because they rely on self-report methods that have limited validity among young children and do not provide adequate description of the intensity and duration of physical activity (6,12,14). Moreover, self-report methods do not provide an opportunity to assess patterns of physical activity (i.e., bouts of activity) within a given day or over several days. A potential solution to these problems is to utilize objective measures of physical activity such as accelerometers or heart rate monitors in population-based samples of children and adolescents. Objective measures of physical activity have been used in previous studies of children and adolescents (6,23), but few of those studies have had sufficient numbers of subjects and age diversity to effectively examine age and gender differences in physical activity. Hence, the purpose of this study was to evaluate age and gender differences in objectively measured physical activity in a population-based sample of public school students in grades 1 through 12.

METHODS

Sample

Subjects were recruited from seven elementary schools, one junior high, and one senior high school in the public school system of Amherst, MA. All 3648 students enrolled in physical education were provided with a packet containing study information, an informed consent document, and a parental questionnaire. Of this number, 1379, or approximately 38%, returned a signed informed consent and a questionnaire completed by their parent or guardian. To ensure that only one parental questionnaire was completed per household, surveys completed for additional siblings were excluded from the analyses ($N = 269$). The final sample consisted of 1110 students (51.4% female, 75.1% white). Before participation in the study, written informed consent was obtained from each student and his or her primary guardian. The study was approved by the University of Massachusetts Institutional Review Board.

TABLE 1. Demographic characteristics of the questionnaire sample and the monitoring subsample.

Grade Group	Variable	Total Sample (N = 1110)	Monitoring Sample (N = 375)
Grades 1–3	N	261	90
	% Female	49.8	53.3
	% White	70.2	66.0
	Mean age	7.1 ± 0.9	7.2 ± 1.4
	Median MET·min	4135	4050
	% Sports participation	20.0	23.3
	% PA classes/lessons	17.7	18.9
Grades 4–6	N	291	91
	% Female	47.6	50.5
	% White	73.9	73.5
	Mean age	10.1 ± 0.9	10.4 ± 1.0
	Median MET·min	4650	5157
	% Sports participation	43.1	41.5
	% PA classes/lessons	16.7	16.0
Grades 7–9	N	332	96
	% Female	50.9	50.0
	% White	81.5	85.4
	Mean age	12.9 ± 0.9	12.9 ± 0.9
	Median MET·min	6231	6567
	% Sports participation	42.6	41.5
	% PA classes/lessons	14.5	11.7
Grades 10–12	N	226	92
	% Female	59.1	52.2
	% White	73.0	75.3
	Mean age	15.6 ± 0.9	15.8 ± 1.1
	Median PA score (MET · min)	6965	7040
	% Sports participation	30.3	34.1
	% PA classes/lessons	14.7	14.8

To examine age-related differences in the physical activity variables, participants in the survey sample were categorized into four grade groups: grades 1–3 (N = 261), grades 4–6 (N = 291), grades 7–9 (N = 332), and grades 10–12 (N = 226). Participants for the activity monitoring portion of the study were identified by randomly selecting 100 students (50 male and 50 female) from each of the grade groups (N = 400). For each student selected, a telephone call was made to his or her primary guardian to obtain consent to participate in the monitoring study. If consent was not given, an additional student was randomly selected from the appropriate age group category as a replacement. After deletions for monitor failure (N = 14), monitor loss (N = 1), or incomplete monitoring data (N = 10), the final sample consisted of 375 students. The demographic characteristics and physical activity profile of the questionnaire and activity monitoring samples are shown in Table 1. Within each grade group, parent-reported participation in sports and physical activity were similar for both samples.

Physical Activity Measure

Objective assessments of physical activity over seven consecutive days were obtained using the Computer Science and Applications Inc. (CSA) 7164 activity monitor (Shalimar, FL). The CSA 7164 is a uniaxial accelerometer designed to detect vertical acceleration ranging in magnitude from 0.05 to 2.00 Gs with frequency response of 0.25–2.50 Hz. These parameters allow for the detection of normal human motion and will reject high-frequency vibrations encountered in activities such as riding in a car and operation of a lawn mower. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified time interval. At the end of each interval, the summed value or activity "count" is stored in memory, and the integrator is reset (4). For the current study, a 1-min time interval was used. Previous studies have demonstrated the CSA accelerometer to be a valid and reliable measure of physical activity in children and adolescents (5,26).

Procedure

Timeline. The activity-monitoring portion of the study was performed in two waves. The first wave of monitoring took place during the fall of 1996, beginning in late October and ending in mid-December. The second wave took place during the spring of 1997 (April). Within each measurement wave, activity monitors were distributed evenly across age and gender groups. To control for seasonal variations in physical activity level, measurement wave (1 or 2) was included as a covariate in the statistical analyses.

Protocol. Before monitoring, families were contacted by phone to confirm the date and time that the activity monitor would be distributed at school. For students attending elementary school, activity monitors were attached either at the beginning of the school day or during lunch. Middle and high school students received their monitors at the beginning of their physical education class. Students were instructed to wear the CSA during the waking hours for 7 consecutive days. Consistent with previous studies, monitors were attached to adjustable elastic belts and worn over the right hip. At the time of distribution, students were given a 7-d log sheet to record the time the monitor was worn and to provide information about any physical activity performed while the monitor was not worn (e.g., swimming). Students in grades 1–7 completed the log with the assistance of a parent or guardian. One to two days before monitor collection, the participants' families were contacted by phone to remind them of the date and time that the monitor would be collected. After collection, stored activity counts were downloaded and saved to a desktop computer for subsequent data reduction and analysis.

Data Reduction

Minute-by-minute activity counts were uploaded to a QBASIC data reduction program (available on request) for determination of time spent in moderate (3–5.9 METs) and vigorous (≥6 METs) activity, during each 60-min segment of the 7-d monitoring period. The age-specific count ranges corresponding to the above intensity levels were derived from the energy expenditure prediction equation developed by Freedson and coworkers (7).

$$\text{METs} = 2.757 + (0.0015 \cdot \text{counts·min}^{-1}) - (0.08957 \cdot \text{age [yr]})$$
$$- (0.000038 \cdot \text{counts·min}^{-1} \cdot \text{age [yr]})$$

In an independent sample of 80 children and adolescents aged 6–18 yr, this equation accounted for 90% of the variance in observed MET levels and predicted energy expenditure during treadmill running and walking within

± 1.1 METs. The correlation between predicted MET level and observed MET level was 0.86.

Daily totals for participation in moderate-to-vigorous (MVPA; ≥3 METs) and vigorous physical activity (VPA; ≥6 METs) were calculated by summing the appropriate values from the 24, 60-min time blocks comprising each day. Students with less than 7 d of complete monitoring data were excluded from the analyses. We have previously shown that 7 d of monitoring provides reliable estimates of daily participation in MVPA in children and adolescents (25). To evaluate the potential contribution of "nonmonitored" activities to overall activity level, physical activity scores were calculated with and without the inclusion of self-reported participation in swimming, cycling, and weight training. Inclusion of these data resulted in no significant changes to the mean MVPA and VPA scores and were not included in the analyses.

To examine patterns of physical activity behavior (i.e., continuous bouts), data were uploaded to a second data reduction program that calculated the weekly number of 5-, 10-, and 20-min bouts with physical activity greater than or equal to 3 and 6 METs, respectively. The number of 10- and 20-min bouts was calculated in two ways. The first method required that all counts in the bout be above the cut-off value for the intensity in question. The second, more lenient method specified that 90% or more of the counts in the bout be above the cut-off value. Thus, if a bout lasted exactly 20 min, then 18 or more of those minutes were above the count cutoff for the specified intensity. In all cases, a 5-min bout required that all counts be above the cut-off value for the specified intensity.

Statistical Analyses

Gender and grade group differences in the physical activity variables were tested using a two-way (grade group × gender) ANCOVA. Included in each linear model were the main effects for grade group, gender, the interaction of gender and grade group, and the covariate measurement wave. Where appropriate, the least square means procedure was used to detect significant subgroup differences. Because of positive skewness, scores for daily MVPA, VPA, and weekly 5-min bouts of VPA were log transformed for the analyses. All statistical analyses were conducted using SAS (Version 6.12). Statistical significance was set at $P < 0.05$.

RESULTS

Non-transformed means and standard deviations for daily MVPA and VPA are displayed in Figures 1 and 2, respectively. With the exception of MVPA in grades 1–3, boys exhibited significantly greater participation in MVPA and VPA than girls. For MVPA, the gender difference ranged from 8.4% in grades 10–12 to 18.9% in grades 1–3. The average gender difference for MVPA was 11%. For VPA, the gender difference ranged from 31.8% in grades 1–3 to 57.1% in grades 4–6. The average gender difference for VPA was 44.7%.
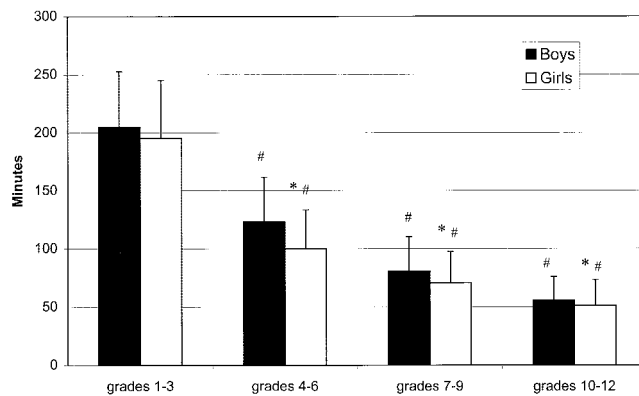

FIGURE 1—Nontransformed means ± SD for daily MVPA by gender and grade level; * significant gender difference within grade group, $P < 0.05$; # significantly different from previous grade group within gender, $P < 0.05$.

For both genders, daily MVPA and VPA exhibited a significant inverse relationship with grade level. Among male subjects, the average grade group difference (relative to the previous grade level) for MVPA was 35.1%, with the largest difference (40%) occurring between grades 1–3 and 4–6. For VPA, the average grade group difference was 31%, with the largest difference (45%) occurring between grades 4–6 and 7–9. Among female subjects, the average grade group difference (relative to the previous grade level) for MVPA was 35.3%, with the largest difference (48.8%) occurring between grades 1–3 and 4–6. For VPA, the average grade group difference was 37.9%, with the largest difference (55.6%) occurring between grades 1–3 and 4–6.

Means and standard deviations for the weekly number of 5-, 10-, and 20-min bouts of MVPA are shown in Table 2. Across all grade groups, boys exhibited more sustained bouts of MVPA than girls; however, only the differences observed among students from grades 1–3 and 4–6 reached statistical significance. For both genders, weekly 5-, 10-, and 20-min bouts of MVPA exhibited a significant inverse relationship with grade level, with the largest differences occurring between grades 1–3 and 4–6. For boys, significant differences (relative to the previous grade group) were
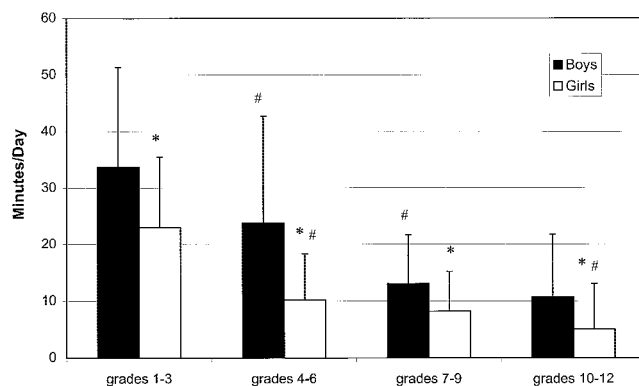

FIGURE 2—Nontransformed means ± SD for daily VPA by gender and grade level; * significant gender difference within grade group, $P < 0.05$; # denotes significantly different from previous grade group within gender, $P < 0.05$.

TABLE 2. Weekly 5-, 10-, and 20-min bouts of MVPA (≥ 3 METs).

	5-min Bouts		10-min Bouts		20-min Bouts	
Group	Boys	Girls	Boys	Girls	Boys	Girls
Grades 1–3	85.0 (28.7)	76.4 (28.5)*	27.0 (12.0)	22.2 (11.1)*	7.9 (4.4)	5.1 (3.6)*
Grades 4–6	47.9 (22.5)†	29.4 (15.7)*†	17.4 (10.7)†	7.6 (5.9)*†	4.9 (4.7)†	1.3 (2.0)*†
Grades 7–9	27.2 (13.7)†	21.2 (13.9)†	8.6 (5.7)†	6.1 (5.1)	2.4 (2.9)†	1.2 (1.8)
Grades 10–12	21.8 (12.6)	15.3 (11.3)	6.5 (5.2)	4.7 (4.8)	1.8 (2.5)	0.9 (1.7)

* Significant gender difference ($P < 0.05$).
† Significantly different from previous grade group ($P < 0.05$).

noted in grades 4–6 and 7–9. For girls, significant differences in weekly 10- and 20-min bouts of MVPA were noted in grades 4–6, whereas the number of 5-min bouts differed significantly in girls from grades 4–6 and 7–9.

Means and standard deviations for weekly 5-, 10-, and 20-min bouts of VPA are shown in Table 3. On average, boys and girls from all grade levels exhibited few bouts of VPA over the 7-d monitoring period. Across all grade groups, boys tended to perform more bouts of VPA than girls; however, only the differences observed among students from grades 1–3 and 4–6 for vigorous 5- and 10-min bouts reached statistical significance. Weekly bouts of VPA tended to be higher in elementary school students than middle school and high school students, but only the difference observed in boys from grades 4–6 and 7–9 and girls from grades 4–6 for vigorous 5-min bouts reached statistical significance. When bouts were defined in a more lenient manner (≥90% of the time in activity), the average number of 10- and 20-min bouts of MVPA increased by approximately 75%; however, the trends with respect to gender and grade group were almost identical to those observed for continuous 10- and 20-min bouts. Inclusion of the interruption interval had little to no effect on the number of vigorous bouts.

DISCUSSION

No previous study has employed a state-of-the-art accelerometer to evaluate age and gender physical activity differences in a population-based sample of children and adolescents. Our results strongly support the concept that physical activity declines rapidly during childhood and adolescence. However, contrary to previous reports (3,11,18,19,22,24,27), we observed the greatest age-related differences to occur during elementary school, rather than during the teen years. This discrepancy is perhaps due to the small number of studies and/or the small samples that have been studied at younger ages. Across all grade groups, boys were more active than girls; however, for overall physical activity, the magnitude of the gender differences was noticeably smaller than that reported by studies using self-report methods to assess physical activity.

The results of this study highlight the utility of objective monitoring devices in field-based studies involving children and adolescents. The CSA accelerometer, which can detect and store movement on a real-time basis, is a particularly effective assessment tool because it provides reliable information about physical activity patterns within a given day or over several days. Moreover, the availability of age-specific count cutoffs that take into consideration age-related differences in economy and resting metabolism (16,17) allows for the estimation of daily participation in moderate and vigorous physical activity.

Traditionally, objective measures of physical activity have been used in smaller descriptive studies (9,10,21,24). However, our success in collecting 7-d of complete monitoring data from approximately 400 youth ranging in age from 6 to 18 yr indicates that accelerometers are feasible alternatives to self-report methods in moderately sized population-level surveillance studies.

Across the four grade groups, boys were consistently more active than girls. However, it is informative to examine the gender differences in physical activity in the context of exercise intensity. For daily VPA, the average gender gap was substantial at around 45%. In contrast, the average gender difference for MVPA was quite modest, at around 11%. This indicates that the boys and girls within our sample did not differ markedly with respect to daily participation in moderate physical activity and that the majority of the gender gap in overall physical activity was accounted for by the girl's low participation in vigorous-intensity activities. Other studies have reported similar findings. van Mechelen et al. (27) evaluated physical activity behavior in a cohort of Dutch youth over a 15-yr period, beginning at age 13 and ending at age 27. During adolescence (age 13–16), girls reported significantly greater participation in moderate-intensity physical activity than boys; yet, by virtue of their low participation in vigorous physical activity, girls

TABLE 3. Weekly 5-, 10-, and 20-min bouts of VPA (≥ 6 METs).

	5-min Bouts[I]		10-min Bouts		20-min Bouts	
Group	Boys	Girls	Boys	Girls	Boys	Girls
Grades 1–3	7.9 (6.1)	4.3 (4.9)*	1.5 (1.8)	0.8 (2.0)*	0.19 (0.4)	0.04 (0.2)
Grades 4–6	6.0 (8.4)†	1.6 (2.7)*†	1.3 (3.1)	0.2 (0.6)*	0.11 (0.5)	—
Grades 7–9	2.8 (3.1)†	2.0 (2.6)	0.6 (1.2)	0.4 (1.0)	0.08 (0.3)	0.06 (0.4)
Grades 10–12	3.1 (4.8)	1.5 (3.9)	0.7 (1.4)	0.3 (0.9)	0.16 (0.6)	0.06 (0.03)

I, Variable log transformed before analysis.
* Significant gender difference ($P < 0.05$).
† Significantly different from previous grade group ($P < 0.05$).

were found to have significantly lower levels of total physical activity. Fuchs et al. (8) longitudinally examined physical activity behavior in a population-based sample of German children in grades 6 and 7. Boys reported significantly greater participation in total physical activity, despite the fact that participation in moderate physical activity was similar for boys and girls. The consistent observation that boys participate in substantially greater amounts of vigorous physical activity than girls underscores the need of physical activity intervention programs for girls of all ages.

In agreement with previous studies, we observed elementary school students to be significantly more active than their middle and high school counterparts (19,20,24). However, the magnitudes of the grade level differences were not consistent, with the largest differences occurring between grades 1–3 and 4–6. For students in North America, this time interval corresponds roughly to late elementary school. Previous descriptive studies have reported the greatest declines to occur during middle adolescence, or more specifically, during the transition form middle school to high school (3,11,22,27). However, it is important to note that none of these studies included children under the age of 9 and none used objective measures of physical activity. One longitudinal study that employed an objective measure of physical activity was the 10-yr NHBLI Growth and Health Study (11). In that study, participants wore a Caltrac accelerometer for 3 consecutive days during years 3, 4, and 5 of the study. During this period, which corresponded to the ages of 11–14, physical activity, as measured by the Caltrac, activity declined by 21%. Interestingly, this figure compares favorably with the observed 27% difference in MVPA between girls in grades 7–9 and 10–12 in the present study.

Over the course of a week, the children and adolescents in this study performed very few sustained bouts of physical activity. Indeed, for vigorous physical activity, the mean number of weekly 20-min bouts approached zero for all grade levels. Participation in sustained bouts of MVPA was also relatively low, with girls in grades 10–12 averaging less than a single 20-min bout of MVPA a week. There was, however, a clear trend for greater participation in the shorter 5- and 10-min bouts of MVPA. Previous descriptive studies have reported similar findings. Armstrong et al. (1) utilized continuous heart rate monitoring to assess the physical activity patterns of British school children aged 11–16. On weekdays, 77% of boys and 88% of girls demonstrated no 20-min bouts of MVPA, with these percentages increasing to 88% and 96.7%, respectively, on Saturday. In contrast, 72.9% of boys and 87% of girls exhibited three or more 5-min bouts of MVPA during weekdays. In similar fashion, Baranowski and colleagues (2) observed no 20-min bouts of MVPA in 24 third- to sixth-grade children during 48 d of direct observation. The consistency of this finding across studies and modes of activity assessment highlights the need to consider the unique activity patterns of children and adolescents when devising physical activity recommendations or guidelines for this population (15).

The present study had several limitations that warrant mention. First, our recruitment rate was relatively low (36.6–40.3%). Consequently, we are unable to completely rule out the possibility of selection bias. However, there is little reason to believe that children with markedly different physical activity profiles would have chosen to (or not to) participate in the study. Second, our use of grade levels rather than specific age groups may have lead to some loss of sensitivity, particularly for the younger groups. Third, it is important to note that accelerometers do not accurately assess exercise intensity during nonweight-bearing activities such as cycling and may not be sensitive to many of the complex movement patterns exhibited by youth. Therefore, our estimates of MVPA and VPA probably underestimate the true level of physical activity.

In summary, objective monitoring of physical activity in population-based samples of children and adolescents appears to be a feasible alternative to traditional self-report methods. Future studies should employ objective physical activity measures in larger, more diverse representative samples of youth, taking care to include subjects from minority groups and children from younger age groups. Furthermore, studies examining the mediators of age- and gender-related differences in objectively measured physical activity (e.g., differences in the quality and quantity of physical education) are warranted. Clearly, the cross-sectional design of this study precludes our ability to make definitive conclusions regarding age-related trends in objectively measured physical activity behavior. Consequently, longitudinal objective monitoring studies with long-term follow-up are warranted.

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