Comparison of Pedometer and Accelerometer Measures of Physical Activity in Preschool Children

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In this study, daily step counts were recorded for 4 consecutive days in 129 four- and five-year-old children. To compare daily Yamax Digiwalker step counts with minutes of engagement in moderate to vigorous physical activity (MVPA), concurrent accelerometer data were collected in a random subsample (n = 76). The average daily step count was 9,980 (± 2,605). Step counts and MVPA minutes were strongly correlated (r = .73, p < .001). The daily step count of 13,874, equating to 1-hr MVPA engagement, was reached by 8% of the children. Daily step counts in preschool children give valid information on physical activity levels—daily step counts in preschoolers are low.

Because low levels of physical activity can predispose children to obesity in later life (6), it is important to begin promoting physical activity as early as preschool age (27). Moreover, recent findings have shown that preschoolers spend little time engaged in moderate to vigorous physical activity (MVPA) and that most of their time is devoted to sedentary activity (11,12,15,18,21). Hence, further study and physical-activity-promotion efforts in this young age group were recently advocated in the literature (9,12,18,21,28). As a result of the short intermittent bursts of activity characteristic of young children (1) and their cognitive-ability and recall limitations, only direct observation or objective measures such as accelerometers should be used to evaluate physical activity levels in this age group. Despite the many advantages, accelerometer use has some disadvantages such as being expensive and requiring technical expertise and additional hard- and software to analyze data. Therefore, the use of accelerometers might be less feasible in population studies or certain applications.

Compared with accelerometers, pedometers have become a popular choice for monitoring physical activity because of their low cost and feasibility, and they have been shown to be reliable and valid in elementary-school children and adolescents (7,13,22). To the authors’ knowledge, however, only one study has evaluated the validity of pedometer registrations for measuring physical activity in preschool children. McKee et al. (14) reported a strong relationship between children’s activity-rating scale and step counts/3 min in 30 three- to four-year-olds during normal school activities in a 1-hr period in a nursery setting. The validity of daily

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step counts to measure daily physical activity in the home setting, as well as activity in a more structured setting such as preschool, has not been evaluated.

It has been shown that pedometer readings tend to register less than the actual number of steps during slow walking (24). Consequently, smaller or younger children who might walk at such speeds would have total step counts that are underestimated (7). Eisenmann and Wickel (7) compared the cost of locomotion between a 6-year-old and a 12-year-old and concluded that the number of steps taken is equivalent among humans of varying body size, if taken at the same speed. The optimal speed of locomotion, or the speed at which the minimum mechanical work occurs, however, increases from 3 to 12 years of age, and it has been observed that a younger child runs at speeds that an older child walks.

Consequently, it is still unclear how daily step counts and daily activity minutes relate and how many daily steps equate to the recommended 1 hr of MVPA per day. This recommendation is evidence based and widely accepted in school-age youth (5,27). Although the link between physical activity engagement and health outcomes in preschool children needs further study, the recommendation of a minimum of 60 min of MVPA per day has also been used in young children (5). Moreover, the National Association for Sport and Physical Education (16) recently suggested that children attending preschool accumulate at least 120 min of physical activity per day—one half of that time is spent in structured physical activity and the remaining in unstructured free-play settings.

Only one study could be located that used pedometers to evaluate physical activity levels. Boldemann et al. (3) described step counts per minute in 197 four- to six-year-olds; however, overall daily step counts were not reported. Standards for daily step counts could be used by researchers and could offer health educators and parents an easy method for monitoring activity levels.

There are three fundamental questions about the use of pedometers for preschool children: How many steps do preschool children take in a day? How do daily step counts and daily activity minutes relate? How many steps equate to 1-hr MVPA engagement in preschool children?

Therefore, the current study aimed to describe daily step counts in preschool boys and girls in Flanders, Belgium. In addition, step counts on preschool-attending days were compared with step counts on weekend days, and possible differences between children attending different preschools were evaluated for step-count levels during weekdays.

Other aims of the study were to compare daily pedometer step counts with accelerometer-based MVPA engagement minutes and to explore what daily-step-count value indicates that children have engaged in MVPA for at least 1 hr.

**Methods**

Participants for the present study were recruited through preschools in Flanders, the Dutch-speaking part of Belgium. In Flanders, almost all elementary schools have a preschool program (2,213 schools with a preschool program; 95%), which allows children to participate from the age of 2.5 years. Virtually all children in Flanders attend preschool, and all preschool programs have a similar curriculum led by college-educated teachers. Five randomly selected preschools located in dif-
ferent municipalities were asked to participate in the study. All five schools agreed to participate. All 301 parents of the 4- and 5-year-old children at the participating schools were invited by an informational letter to enroll their children in the study. One hundred twenty-nine parents (43%) provided informed consent. After omitting 7 participants with incomplete data, the present study sample consisted of 122 children (59 boys and 63 girls, mean age 4.99 years, range 4–5.9 years, mean weight 19.1 ± 2.8 kg, mean height 111 ± 7.1 cm). Because of limited availability of accelerometers, a random subsample of 89 children was selected to wear an accelerometer and a Yamax pedometer concurrently as a strategy to compare step counts with activity minutes. Pedometer data were considered satisfactory when missing data, reported by a parent, did not exceed more than 1 hr on 1 or more days. For the accelerometer registrations, a minimum duration of monitoring of 8.6 hr per day was considered satisfactory. Satisfactory measurements were obtained in 76 of the 89 children. The subsample consisted of 37 boys and 39 girls (mean age 4.97 years, range 4–5.9 years, mean weight 19.4 ± 2.7 kg, mean height 111 ± 6.1 cm).

Classification of the occupations of the parents who filled out questionnaires revealed that 67 children (55%) were from a higher socioeconomic status (white collar), and 55 (45%) were from a lower socioeconomic status (blue collar). Measurements were performed in December 2005 and January 2006, which is wintertime in Belgium. The average day temperature during data collection was 5 °C. The study was approved by the ethical committee of Ghent University.

Measures and Procedure

Pedometers. Step counts were assessed using the Yamax Digiwalker pedometer, model SW-200 (Yamax Corp., Japan), which is an unobtrusive instrument measuring 19 × 39 × 52 mm that uses a horizontal spring-suspended mechanical lever to measure vertical movement. In the present study, step counts were registered in absolute counts per day. Mean daily step counts were calculated for the entire registration period—weekdays and weekend days. In the subsample concurrently wearing an accelerometer, steps per minute scaled by wear time were calculated, making use of the daily starting and ending times of accelerometer activity registrations.

Accelerometers. To evaluate activity minutes, the MTI Actigraph, model 7164 uniaxial accelerometer (Fort Walton Beach, FL; formerly manufactured by CSA, Inc.) was used. The MTI Actigraph is small (5 × 4 × 1.6 cm), lightweight (37.5 g), and unobtrusive to wear. Accelerometry has been shown to provide valid assessments of physical activity and sedentary behavior among preschool-aged children (8,20,26).

Because the typical 1-min sampling interval can mask the short, intermittent bursts of activity typical of young children, a 15-s sampling interval was used (17). In the present study, minutes of engagement in MVPA were reported. Detailed information on engagement in activities of the different intensity levels will be explored in a separate study.

Diaries. The parent of each child was asked to register the daily step counts in a diary and record any time frame and reason for not wearing the instruments. In addition, the receptivity to wearing the instruments (from very pleasant to very
unpleasant on a 5-point scale) was questioned in the diary, and parents were asked to report their sex and occupation and the sex, height, and weight of their child.

**Procedure**

All participants received a pedometer, a diary, and an informational letter for their parents at school on the first morning of the study. Before the pedometers were handed out, they were all reset to zero and checked for proper fit and function. A pedometer was fastened to the waistband of each pupil’s pants or skirt. Children were instructed to wear the pedometer on the left hip, in line with the midpoint of the left knee. The pedometers were not sealed, but children were instructed to only open the pedometers for daily step registration and reset at nighttime by their parents. In the subsample in which pedometer counts were compared with accelerometer data, an accelerometer was fixed securely to an adjustable elastic belt on the right hip, also. The children in the subsample were instructed to wear the accelerometer and the pedometer concurrently. Children were familiarized with the pedometers and the accelerometers at school, and a sticker of a cartoon figure was attached to each pedometer and accelerometer to make them more attractive to the children and to avoid upside-down wearing.

All children were instructed to wear the instruments the whole day and to take them off only for sleeping, swimming, and bathing. All preschool teachers were informed of the procedure and proper instrument use. The parents’ informational letter included instructions for proper instrument use. Parents were asked to have their children wear the instruments for as long as possible during all waking hours, removing them only for water-based activities and sleeping.

Instruments were worn during waking hours for 5 consecutive days. Data of the first day were omitted to minimize the influence of possible behavior change. As a result, data were collected on 2 weekdays and 2 weekend days. Pedometers, accelerometers, and diaries were collected at school 1 day after the last registration day. Measurements were considered satisfactory when missing data did not exceed more than 1 hr on 1 or more days. The pedometer registrations of 7 pupils were excluded before analysis as a result of not wearing the pedometer more than 1 hr on one or more days. From these 7 cases, one pedometer was lost and one was damaged by falling into water. The missing step counts from periods of less than 1 hr/day were not taken into account. On average, the pedometers were worn 12.2 hr/day. For the accelerometer registrations, satisfactory measurements were obtained from 76 children. A mean duration of monitoring of 11.8 hr/day was achieved, with a minimum duration of monitoring of 8.6 hr/day. To interpret the accelerometer data, activity counts for each 15-s interval were uploaded to a customized data-reduction program. To analyze the amount of time children spent in activity of moderate to vigorous intensity, the separate count cutoffs for 4- and 5-year-olds developed by Sirard et al. (26) were used. These cut points are based on empirically derived relationships between CSA accelerometry output and directly observed behavior during 3-min structured activities in 3-, 4-, and 5-year-olds. Fast walking was categorized as moderate-intensity activity, and jogging, as vigorous-intensity activity (26). The cut points are specific for the use of 15-s epochs. According to these cutoffs, a distinction was made between 15-s epochs of 812 to 1,234 (4-year-olds) and 891 to 1,254 counts (5-year-olds) and 1,235 or more
(4-year-olds) and 1,255 counts or more (5-year-olds), corresponding to moderate and vigorous activity, respectively (26).

**Statistical Analyses**

Data were analyzed using SPSS for Windows (11.0). Independent *t* tests were used to test differences in steps per day between sexes and between 4- and 5-year-olds and to compare instrument receptivity in children wearing only the pedometer with that of children wearing the pedometer and the accelerometer concurrently. To determine if step counts during the weekend differed from step counts during weekdays, paired-sample *t* tests were used. Mean step counts on weekdays at the different preschools were compared, making use of factorial ANOVA. Pearson *r* correlation coefficients were generated to compare minutes of MVPA engagement and the concurrently measured steps per day. To predict how many daily steps equate to the recommendations of 1 hr of MVPA per day, a regression equation was calculated with minutes of MVPA as the independent variable and step counts as the dependent variable. The alpha level was set at .05 for all analyses.

**Results**

In the present study sample, the average daily step count was 9,980 ± 2,605 (range 5,412–18,535). Sex differences were not significant (*t* = .53; see Table 1). Step counts during the week (mean 10,729 ± 2,833) were significantly higher than weekend step counts (mean 9,224 ± 3,754; *t* = 4.2, *p* < .001). Mean step counts on weekdays did not significantly differ between the different preschools (*F* = 0.383, *p* = .82). Daily step counts of 4-year-olds (9,842 ± 2,724) did not significantly differ from step counts of 5-year-olds (10,092 ± 2,550; *t* = .5). In the subsample of children concurrently wearing an accelerometer, children took 18.68 ± 5.3 (range 7.5–32.2) steps/min, with no significant difference between sexes (see Table 1). Figure 1 shows individual data points for mean daily step counts (10,192 ± 2,798) plotted against the mean daily minutes of MVPA engagement (34 ± 27 min). A positive significant correlation was found between mean step counts and minutes of MVPA engagement (*r* = .73, *p* < .001). The regression equation predicting step counts by minutes of MVPA was *y* = 6,134 + 129*x*. As a result, 60 min of MVPA = 13,874 step counts. The explained variance in daily step counts was 53%. In the present sample, 8% (10 children) reached the standard of 13,874 daily step counts.

According to the parents’ reports, 83% of the children found it very pleasant (59 children, 46%) or pleasant (50 children, 38%) to wear the accelerometer or the accelerometer and the pedometer, 8% (11 children) found it not pleasant or not unpleasant, and 2% found it unpleasant (2 children). None of the parents reported

| Table 1  Daily Step Counts and Steps Per Minute, *M, SD*, and *t* Values |
|---------------------------------|-------|-------|-------|--------|
|                                 | Total | Boys  | Girls |        |
| Daily step counts (*n* = 122)   | 9,980 ± 2,605 | 10,121 ± 2,836 | 9,867 ± 2,422 | .53 (ns) |
| Steps per minute (*n* = 76)     | 18.7 ± 5.3    | 18.3 ± 5.0    | 19.0 ± 5.6    | .60 (ns) |
that their child found wearing the instruments very unpleasant. Receptivity of wearing the instruments was higher in children concurrently wearing the accelerometer and the pedometer (1.7 ± 0.8) than in children wearing only the pedometer (1.4 ± 0.5; \( t = 2.6, p = .01 \)).

**Discussion**

The present study aimed to describe daily step counts in preschool children and to examine how step counts relate to accelerometer-based MVPA engagement minutes at this young age.

The preschool children of the present sample averaged 9,980 steps/day. In the literature, we could find no study describing daily step counts in this young age group. Therefore, step counts could only be compared with samples of older children. In the study of Tudor Locke et al. (30), normal-weight 6-year-old girls took 13,246 steps/day and overweight or obese 6-year-old girls took 10,388 steps/day. In boys of the same age, 17,548 and 12,886 steps/day were recorded, respectively.
Each group, however, included only 8 children. In the literature, step-count averages in elementary-school-age children range from 12,000 in the United States (31) to 15,038 in Belgium (4). The daily step counts found in the present sample of preschoolers are lower than those reported in elementary-school children. The low step counts in the present sample of preschool children are in line with the literature, which report high levels of sedentary behavior and low levels of physical activity engagement in preschoolers based on accelerometer data (12,18,21). Moreover, the value of 19 steps/min found in a subsample in the present study is comparable to the steps per minute for 4- to 6-year-olds (girls = 18 steps/min, boys = 21 steps/min) reported by Boldemann et al. (3) and the step counts of 67 steps/3 min for boys and 47 for girls reported by McKee et al. (14).

It is reported that the Yamax pedometer underestimates the number of steps taken at slower walking speeds (<60 m/min) (2). Consequently, the low daily step counts could be a result of an underestimation of step counts because preschoolers have a smaller stride length, resulting in slower walking speeds. In the present study, however, a high correlation was found between pedometer outputs and accelerometer-based minutes of engagement in MVPA ($r = .73$). The high correlation and the scatterplot suggest a strong linear relationship between the registrations of the two instruments and is comparable to correlations between accelerometer outputs and pedometer outputs found in 8- to 10-year-olds (23) and in adults (29). Moreover, the relationship is in line with the correlation between pedometer registrations and behavioral observation in 3- to 5-year-olds reported by McKee et al. (14). Hence, it can be concluded that daily step counts in preschool children give valid information on daily physical activity levels, which, in preschoolers, are low.

In contrast to the findings in the literature (3,14), daily step counts in the present sample of preschool children did not differ between sexes. In addition, age differences were not significant, probably as a result of the small age range. On the other hand, step counts during weekdays were higher than step counts during weekend days. On weekdays, all children attended preschool. Moreover, step counts on weekdays did not differ between children of the five participating schools. Because preschools in Flanders have spaces to trigger physical activity, the higher daily step counts during weekdays might therefore be attributed to preschool attendance. Step counts during preschool-attending hours, however, were not evaluated separately. Furthermore, the standard deviations of the week and weekend step counts were sizable, showing that preschool children’s habitual activity levels vary considerably between participants. The lower step counts on weekends emphasize the need to increase parents’ capacity to provide instrumental and motivational support for their children’s physical activity.

Further study is needed to set evidence-based guidelines for physical activity engagement in preschool children. In the meantime, the recommended daily participation of 60 min or more in MVPA, generally used in school-age youth, is also used in preschoolers (5). According to the regression equation used to predict step counts by MVPA minutes in the present study, 60 min of MVPA equals 13,874 step counts. This step-count standard is higher than the Presidential Active Lifestyle Award (19) norm-based standard recommending that children acquire 11,000 steps/day for at least 5 days per week. The standard of 13,874 step counts, however, is comparable to the body-mass-referenced standards for recommended pedometer-determined steps per day in 6- to 12-year-old children by Tudor-Locke.
et al. (30), namely, 12,000 for girls and 15,000 for boys. Given the difference in body size, further study is necessary to evaluate if these body-mass-referenced standards are applicable to preschool children.

In the present sample, only 8% of participants reached the standard of 13,874 daily step counts or 1 hr of MVPA per day. Therefore, it can be concluded that, in line with the literature, physical activity levels in this sample of preschool children were far lower than recommended for good health. Because Sallis et al. (25) detected some tracking of physical activity over 2 years in 4-year-olds, the level of physical activity as a part of lifestyle might be established as early as preschool age.

A positive finding of the present study was that almost all children found it pleasant or very pleasant to wear a pedometer; moreover, the compliance with the data registration was high. As a result, the use of pedometers for monitoring and health promotion in this age group holds promise.

In the present study, the children were not contacted daily because we wanted to minimize reactivity. A disadvantage of this method is that pedometers could not be sealed, which increases the risk of resets and result bias because of possible access to recorded feedback. Children, parents, and teachers, however, were told that pedometers should only be opened for registration, and, according to our diaries, pupils were very compliant with registrations and pedometer wearing. Moreover, while familiarizing the children with the instruments, we observed that preschool children had difficulty opening the pedometer without assistance.

A limitation of the present study is that all data were collected during winter. Therefore, physical activity levels possibly suffered from seasonal influence. Belgium has a mild climate, however, and according to the recent findings of Fisher et al. (10), seasonality plays a limited role in physical activity and sedentary behavior in young children. Another limitation is the possible selection bias, because only 43% of the eligible parents gave informed consent. Higher and lower socioeconomic-status families were equally presented, however, and children from 5 schools of different regions were included. A strength of the present study is that a relatively large sample was recruited, and 4 overall days of activity in a field setting were taken into account.

It can be concluded that the present study’s findings provide insights into pedometer step counts of a sample of preschool children in Flanders, Belgium. Our opinion is that the daily-step-count values of the present study are of comparative interest. Moreover, given the strong correlation with accelerometer-based activity minutes and the high receptivity of pedometer wearing, further study using pedometry in preschoolers is warranted.

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References


