Tracking of Pedometer-Determined Physical Activity: A 5-Year Follow-Up Study of Adolescents in Sweden

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Tracking refers to the tendency for individuals to maintain their rank in a group over time. The authors explored tracking of pedometer-determined physical activity. In October of 2000, 2003, and 2005, data of physical activity as steps per day were collected with sealed Yamax SW-200 pedometers (Tokyo, Japan) for 4 consecutive schooldays in 97 (46 boys and 51 girls) Swedish adolescents (mean age 12.7 in 2000). In general, tracking of pedometer-determined physical activity was low to moderate during adolescence. A sex difference, with boys expressing higher tracking, was seen. Moderate tracking was seen in the individuals who, according to recommendations, were insufficiently active.

Physical activity is important in order to reach and maintain good health and well-being in adulthood (28). Moderate, daily physical activity provides substantial health benefits (2, 28), and, together with diet, physical activity is considered a key component of weight control in adults (33). Health benefits of physical activity are reported for children and adolescents (23), although studies are limited for ethical and methodological reasons (28). A change in body-mass index (BMI) of Swedish children and adolescents has occurred during the last decades, resulting in an increase in overweight and obese children and adolescents (7, 22). The World Health Organization (34) urgently calls for action to monitor data and key influences on physical activity, including methods for evaluating intervention programs.

Tracking refers to the tendency for an individual to maintain his or her rank or position in a group over time (i.e., to what extent physical activity is a stable aspect of our behavior), an important factor in intervention (12). Longitudinal data for at least two points in time are necessary, and interage correlations between the measurements can estimate tracking. It has been reported that activity patterns established at an early age have a tendency to continue into adulthood; however, this depends on the time span and the way the physical activity is monitored (13).

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (3). Physical activity can be seen as an umbrella term for human behavior with multiple dimensions and subcategories such as exercise, sports, leisure activities, dance, and transportation (5). The emphasis on lifestyle physical activity for health promotion has increased the interest in

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monitoring activity. Several techniques have been proposed for measuring activity levels, some of them subjective (direct observation, self-report) and some objective (heart-rate monitoring and motion sensors) (31).

The reliability and validity of self-reports have been questioned because of subject bias and individuals’ difficulty in recalling activities accurately (21). Motion sensors such as accelerometers and pedometers are common in field research because they are unobtrusive and unbiased, can store information, and measure a whole day without much inconvenience (9). Pedometers are a cost-effective, valid, and reliable alternative that provides summary outputs of ambulatory activity throughout the day (26,32). Pedometers do not give any information about intensity, however, so when providing standards for daily pedometer-determined steps per day, it would be preferable, if possible, to relate to a health criterion (i.e., BMI). So far no standards related to health criteria are available in adolescents. The preliminary health-related criterion reference standard for children ages 6–12 recommends 12,000 daily steps for girls and 15,000 daily steps for boys to optimize their chances of maintaining normal weight (27).

Using a physical activity index based on questionnaire data from Finnish adolescents, Raitakari et al. (14) found an overall moderate correlation, higher in boys than in girls. Furthermore, they found a higher correlation for 3-year intervals and a decline as intervals increased. Malina (13), who reviewed European and U.S. studies, indicated a low to moderate interage correlation for indicators of physical activity, such as observational teacher ratings, questionnaires, and energy expenditure based on heart-rate monitoring.

Many factors are important for the individual level of daily physical activity, such as personal, cultural, and social factors (e.g., training in sport clubs). Again in Finnish adolescents, the highest interage correlations are for frequency of sport-club training (24). Sport-club training is, in Scandinavia, organized outside the school curriculum and carried out during evenings and weekends. With increasing age, the participation in sport-club activities in Sweden decreases. At 12 years of age, 70% of the boys and 62% of the girls train in sport clubs at least once a week. At 15 years of age, 58% of the boys and 47% of the girls are involved in sport-club training (8).

The few longitudinal studies that have been done (10,11) indicated that physical activity levels decline as children move into adolescence. These studies demonstrate that physical inactivity tracks over time (i.e., children who are inactive tend to remain inactive as they grow older).

Janz et al. (11) report that prepubescent boys who were inactive at baseline were 2.2 times more likely than their peers to be inactive at a 5-year follow-up. Identifying inactive youths early and encouraging activity in these youths ought to be a priority for health-care systems, teachers, researchers, and policy makers. Long-term studies that use objective measures facilitate the ability to accurately determine changes in patterns over time and accurately determine whether or not youth meet activity guidelines on a regular basis. To our knowledge, no other longitudinal studies using pedometers for this length of time have been published.

The main purpose of this study was to explore tracking of pedometer-determined physical activity, and the subpurposes were tracking according to physical activity level, BMI, and sport-club training.
Methods

Participants
In autumn 2000, as part of an international study on schoolchildren, data on daily mean steps and BMI were collected for 326 boys and girls 12–14 years of age in Kalmar, Oskarshamn, and Mörbylånga, all middle-class Swedish communities (16,17). The schools in these communities were categorized as countryside schools, suburban schools, or city schools. Written informed parental, child, and school consent was obtained for all participants. In every age group at least two of the three categories were represented except for age group 13, in which data were collected in city schools only.

In autumn 2003, school adolescents in the same geographical area were asked to participate. There were 295 adolescents ages 15–17 included in the study, and they were measured for the same variables with the same methodology as in the 2000 data collection (15). There were 109 adolescents who were identified as students measured for daily steps, height, and weight in 2000 and in 2003, and they were asked to participate for measures a third time. In October 2005, 97 of the adolescents, 46 boys and 51 girls (30% of the original 326), were measured for the same variables with the same methodology for the third time. Reasons for not participating a third time were lack of interest or inability to locate the individual. Participants in the study were those for whom we had data for all three time points.

The study was approved by the research ethics committee at Linköping University (Dnr. M109-05).

Assessments

Collection of Physical Activity Data. On all three occasions (2000, 2003, and 2005) daily step counts were measured by sealed Yamax pedometers (Digiwalker SW-200, Tokyo, Japan) during four consecutive October weekdays. The pedometers were attached to the waistband and placed in line with the midpoint of the right knee. Physical education teachers were trained to collect data. The researcher collected the pedometers every 24 hr, documented the number of steps, resealed the devices, and returned them to the participants. A questionnaire was completed by all participants to ensure that the pedometers were carried according to given instructions during the entire day. In 2005 self-reported 4-weekday data were collected from mailed pedometers of 18 individuals, age 19, who had graduated from school. Participants were also asked to report the types of physical activity they had performed during the days of measurement, including training in sport clubs. Sport-club training was defined as participating in training at least once a week, organized by a sport club. The participants were categorized into four groups: i = no sport-club training, ii = training at baseline, iii = training at baseline and in 2003, and iii = all-time sport-club training.

Collection of Body-Mass-Index Data. Height and mass were measured for all participants to determine their BMI. Height was measured on a tape attached to a wall (Friedrich Richter; Kirchenlaibach, Germany) and rounded down to the nearest centimeter. Mass was measured on step-up scales (EKS International,
Wittesheim, France; HEFA Digital AB Halmstad, Sweden) and rounded up to the nearest kilogram. In 2005, 18 students (age 19) who had graduated from school self-reported height and mass.

Obesity is defined as an excess of body-fat mass (1). In adults, it is defined as a BMI greater than 30 kg/m\(^2\). Overweight in adults is defined as a BMI of 25–30 kg/m\(^2\). In youth, overweight and obesity are defined as cutoff points that will pass through 25 and 30, respectively, at the age of 18, according to Cole et al. (4). These cutoff points were used to define the prevalence of overweight and obesity in the present study.

Statistical Analysis

Data were analyzed using SPSS 13.0 for Windows. Means and standard deviations were calculated for age, height, mass, BMI, and daily step counts. Independent \(t\) tests were used to analyze the daily mean step differences between boys and girls. To calculate the differences between 2000, 2003, and 2005 in the follow-up group, repeated-measures ANOVA for daily steps was conducted. When significant differences were found, we conducted a post hoc paired \(t\) test to identify the difference. In order not to violate alpha, \(p\) was then set at \(\leq .001\).

A paired \(t\) test was used to analyze the difference in daily mean steps between baseline and the 5-year follow-up in the different groups of sport-club training.

Tracking was assessed using Pearson’s product–moment correlation (\(r\)) to investigate interage correlation between the 0–3, 0–5, and 3–5 year measures. Spearman’s rank correlation test (\(r_s\)) was conducted to explore the correlation when categories such as activity tertiles and groups of sport-club training were used.

To evaluate the strength of the Pearson and Spearman correlations, the following interpretations were used: <.30 is low, .30–.59 is moderate, and \(\leq .60\) is moderately high, as suggested by Malina (12). Significance was set at \(p \leq .05\).

Results

Description of the Sample

At baseline the mean age for boys and girls was 12.7 years (± 0.8). Baseline height was 1.59 ± 0.09 m and 1.58 ± 0.07 m, and the 5-year follow-up height was 1.80 ± 0.07 m and 1.65 ± 0.06 m for boys and girls, respectively. Baseline mass was 47.0 ± 10.3 kg and 51.4 ± 12.5 kg, and the 5-year follow-up mass was 70.7 ± 10.5 kg and 61.7 ± 12.6 kg for boys and girls, respectively. The percentage considered overweight or obese at baseline was 15.2% of the boys and 25.5% of the girls, and at the 5-year follow-up 17.4% of the boys and 27.5% of the girls were overweight or obese.

Follow-Up Group Data From 2000, 2003, 2005

At baseline boys had significantly higher levels of physical activity than girls (\(p = .001\)). At the 3-year follow-up, girls’ physical activity level was significantly higher than the boys’ (\(p = .025\)); however, no significant difference was seen at the 5-year follow-up.
There was a significant effect for time in boys, Wilks’s $\Lambda = .33$, $F(2, 44) = 43.84$, $p < .005$, multivariate $\eta^2 = .66$. A decrease of mean steps per day occurred between baseline and the 3-year follow-up ($p < .001$), as well as between baseline and the 5-year follow-up ($p < .001$). No significant differences were found at any time span in girls. Age of participants, level of physical activity as mean steps per day, and standard deviation for boys and girls are presented in Table 1.

**Tracking of Pedometer-Determined Steps per Day**

Pearson’s product–moment correlation coefficients representing the tracking of activity measures over time was moderate in boys for the 0- to 3-year measures ($r = .55, p < .001$) and 0- to 5-year measures ($r = .35, p = .019$). For the 3- to 5-year measures, a low correlation ($r = .23, p = .121$) was found. In girls, the correlation was not significant and low, $r = .22, p = .117$; $r = -.06, p = .673$; and $r = .22, p = .673$, for the respective year measures.

**Tracking According to Activity Level**

Dividing individuals into activity tertiles at baseline (i.e., as least, more, and most steps per day) and exploring to what extent they kept their tertile over the 0- to 3-, 0- to 5-, 3- to 5-year spans revealed no significant correlations. The lack of significant correlations might be a result of the small number of participants. Doing the same tertile division at the end of the study, we found one significant moderately high correlation—the most active girls in time span 3–5 years ($r = .64, p = .004$). The proportions of boys and girls who remained in the same tertile, moved up in tertiles, or moved down in tertiles are presented in Table 2.

**Tracking According to Pedometer Recommendations**

We divided the individuals into two groups of activity—those who met the BMI-referenced standards for 12-year-olds ($n = 56$) and those who did not ($n = 41$), which revealed a significant moderate correlation ($r = .45, p = .003$) over the 3- to 5-year span in those not meeting the standards. In those classified as active, low correlations were found.

**Table 1**  Steps per Day in the Follow-Up Group in 2000, 2003, and 2005 for Boys and Girls

<table>
<thead>
<tr>
<th>Year</th>
<th>$n$</th>
<th>Age</th>
<th>$SD$</th>
<th>steps/day, $M$</th>
<th>$SD$</th>
<th>$n$</th>
<th>Age</th>
<th>$SD$</th>
<th>steps/day, $M$</th>
<th>$SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>46</td>
<td>12.5</td>
<td>0.8</td>
<td>15,633</td>
<td>3,683</td>
<td>51</td>
<td>12.9</td>
<td>0.8</td>
<td>13,276</td>
<td>2,818</td>
</tr>
<tr>
<td>2003</td>
<td>46</td>
<td>15.5</td>
<td>0.8</td>
<td>11,499</td>
<td>2,954</td>
<td>51</td>
<td>15.9</td>
<td>0.8</td>
<td>12,787</td>
<td>2,614</td>
</tr>
<tr>
<td>2005</td>
<td>46</td>
<td>17.5</td>
<td>0.8</td>
<td>11,398</td>
<td>3,783</td>
<td>51</td>
<td>17.9</td>
<td>0.8</td>
<td>12,286</td>
<td>3,523</td>
</tr>
</tbody>
</table>

*Note.* There was a significant effect for time in boys, but not in girls. Boys: Wilks’s $\Lambda = .33$, $F(2, 44) = 43$, $84$, $p < .005$, multivariate $\eta^2 = .66$. Girls: Wilks’s $\Lambda = .95$, $F(2, 49) = 1$, $16$, $p = .32$, multivariate $\eta^2 = .04$. 


Tracking of Pedometer-Determined Physical Activity

Tracking According to BMI Level

Adolescents \( (n = 20) \) classified as overweight or obese at baseline tracked nonsignificantly moderately at Years 0–3 \( (r_s = .30, p = .197) \) and at Years 3–5 \( (r_s = .35, p = .132) \).

Tracking According to Sport-Club Training

We divided individuals into four groups of sport-club training in order to explore to what extent the different groups’ physical activity was correlated over the different time spans.

At baseline, 80% of the adolescents were training in sport clubs. Thirty-nine percent of the adolescents reported sport-club training through all adolescent years, and 20% never participated in sport-club training. A decrease in activity level from baseline to the 5-year follow-up was seen in all groups except in the adolescents who were still training in sport clubs at the end of the study. During the later adolescent years (15.7–17.7) there was an increase in activity among the adolescents still training in sport clubs. In general, there were low to moderate correlations of mean steps per day over the time spans of 0–3 years, 0–5 years, and 3–5 years.

Descriptive data on the number of adolescents in each group of sport-club training, physical activity as steps per day, standard deviations, and differences in steps per day between baseline and the 5-year follow-up in boys and girls are shown in Table 3.

### Table 2 Tertile Movement for Boys and Girls

<table>
<thead>
<tr>
<th>Activity level at baseline</th>
<th>Remained in Same Tertile (all time points, first and last time point)</th>
<th>Moved Up a Tertile</th>
<th>Moved Down a Tertile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Total</td>
</tr>
<tr>
<td>Least ( (n = 32, 17 \text{ girls}) )</td>
<td>6, 3</td>
<td>3, 1</td>
<td>9, 4</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>More ( (n = 33, 17 \text{ girls}) )</td>
<td>2, 4</td>
<td>2, 3</td>
<td>4, 7</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Most ( (n = 32, 17 \text{ girls}) )</td>
<td>4, 3</td>
<td>4, 2</td>
<td>8, 5</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

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Adolescents \( (n = 20) \) classified as overweight or obese at baseline tracked nonsignificantly moderately at Years 0–3 \( (r_s = .30, p = .197) \) and at Years 3–5 \( (r_s = .35, p = .132) \).
The main findings of the present study were that pedometer-determined physical activity seems to track lowly to moderately during adolescence, and the highly significant decrease seen in boys during early adolescence seemed to level out in later adolescence, whereas girls’ level of physical activity was somewhat level over the adolescent years. Furthermore, youth training in sport clubs maintained a higher level of pedometer-determined physical activity throughout the adolescent years.

Some limitations of this study might be that the samples were gathered in overall midsocioeconomic communities, and, from a national point of view, the study was geographically narrow. Furthermore, several factors are reported to influence interage correlations, such as age at first observation, biological variation, major environmental changes, and measurement variability. The 18 participants who graduated spent their weekdays outside of school, a major environmental change from the other participants, which resulted in lower mean steps per day. We started our investigation with 12-year-old participants, with a range of 12 to 14, and concentrated on only one sociocultural factor, sport-club training. Using interage correlations to explore tracking might have limitations because important covariates are not controlled for.

The strength of the study is the longitudinal design using objective measures of physical activity. The follow-up sample did not significantly differ regarding mean steps per day or body size compared with the remainder of the baseline sample. The results might be useful as reference data because we use the same protocol and device (Yamax SW-200 pedometer) used in previous international studies (27,30).

The emphasis on accumulating total amounts of daily activity makes pedometers a reasonable choice of method, although they are unable to measure biking, swimming, and non-weight-bearing activities. Pedometers’ usefulness in goal setting makes them appropriate in surveillance and in intervention. Because our expression of physical activity is in mean steps per day, it is reasonable to question whether or not the increasing height as a result of growth during adolescence and thereby increased leg length and stride length result in a decline in accumulated steps. No significant correlation between height and mean steps per day was seen, however, at any time point in any group. Furthermore, we calculated the difference

### Table 3 Difference Between Baseline and 5-Year Follow-Up in Boys and Girls

<table>
<thead>
<tr>
<th>Year</th>
<th>No Training</th>
<th>Training Until 2000</th>
<th>Training Until 2003</th>
<th>Training Until 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Steps/ day, M</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>2000</td>
<td>19</td>
<td>14,302</td>
<td>3,201</td>
<td>21</td>
</tr>
<tr>
<td>2005</td>
<td>19</td>
<td>9,778</td>
<td>2,542</td>
<td>21</td>
</tr>
<tr>
<td>difference</td>
<td></td>
<td>−4,524</td>
<td></td>
<td>−2,782</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td>&lt; .001</td>
<td></td>
<td>.030</td>
</tr>
</tbody>
</table>

### Discussion

The main findings of the present study were that pedometer-determined physical activity seems to track lowly to moderately during adolescence, and the highly significant decrease seen in boys during early adolescence seemed to level out in later adolescence, whereas girls’ level of physical activity was somewhat level over the adolescent years. Furthermore, youth training in sport clubs maintained a higher level of pedometer-determined physical activity throughout the adolescent years.

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in height between the measures of 2000 and 2003, as well as the difference in mean steps per day between the two points of measures for each boy. A closer examination revealed no significant correlation between height difference and step difference. In addition, the energy cost of a step is reported as being economically equal, whether taken by a small or large individual (6). Taken at the same speed, the number of steps taken can be viewed as equivalent.

Pedometers do not provide information about the intensity of activity. Some individuals involved in high-intensity and low-duration activities might collect few steps per day and be judged inactive by the pedometer (19). Data were gathered in October with 12 hr of daylight to control for the season-related difference in daylight hours in Sweden. The weather conditions over the weeks differed, and this might have influenced the results.

Identifying the ages of greatest decline in physical activity might be useful in targeting interventions to critical periods in life. Comparing the follow-up groups of 2000 with 2003, we found a significant drop in daily mean steps in boys. An average of 15,600 steps in boys in 2000 had decreased to 11,500 three years later. This finding of the greatest decline in boys between the ages of 12.5 and 15.5 corresponds to Finnish (25) and Dutch (29) longitudinal recall studies. We did not find any significant differences between levels of steps per day in girls, and their level of physical activity drops to a more modest extent. A drop in physical activity has been reported in adolescent girls when measuring energy expenditure (18). The decline, however, is generally greater for male than female youth and varies by type of intensity; vigorous activity is reported to decline more (20). It is interesting that girls’ physical activity as steps per day was higher than boys at age 17.7. The pedometers’ inability to register intensity might be one difference that can explain this result.

Consistent with other studies (13,14), we found, in general, low to moderate tracking. Boys showed higher correlation of pedometer-determined physical activity than girls did. The fact that the tracking was higher at shorter time spans was seen in this study, and this is also in line with other findings (13).

To better identify and monitor the participants we also explored tracking according to activity level. In a group, individuals differ in physical activity, and tracking gives us information as to what extent individuals maintain their rank or position in a group (i.e., to what extent the least active stay least active and the most active stay most active). In our study, 28% remained in the low-active tertile at all three time points, and 25% stayed in the most active tertile. From a health perspective, low tracking is preferable, for instance when a low-active individual moves up in activity, but high tracking is preferable when an active individual maintains active.

As an approach to tracking according to activity levels, we divided individuals as either meeting the BMI-referenced standards of pedometer-determined steps per day or not meeting these standards (27). The preliminary cut points (12,000 steps/day for girls and 15,000 steps/day for boys) are established for ages 6–12. Because the adolescents were, on average, 12.7 at baseline (close to 12 years), these standards were used to identify two groups. The significant moderate tracking of insufficiently active participants in the 3- to 5-year measures and the low tracking in the participants who met the standards are in line with previous reports of higher tracking of inactivity (12).
A significant decrease in activity level from baseline to the 5-year follow-up was seen in all groups of sport-club training, except for those training in sport clubs at all times of measurement. During the later adolescent years (15.7–17.7), there was an increase in activity among the adolescents still training in sport clubs. Sport-club training for older adolescents is normally longer in duration and more frequent (two or three times per week) than at younger ages.

The strongest correlation for physical activity to continue into adulthood is from 18 to 24 years of age, reported by Raitakari et al. (14). Thus, keeping individuals physically active on a regular basis is important for the health benefits not only during these years but also for the future. Participating in sport-club training during adolescence counteracted the decrease of physical activity. Therefore, interventions directed toward those who drop out of sport-club training are important, especially in boys. Physical education lessons, with their possibility of reaching all adolescents, might contribute substantially to the physical activity of those most inactive. It has been reported in unpublished Swedish data that physical education lessons add 3,000–5,000 steps in sixth grade and 2,000–4,500 steps in ninth grade, depending on content and lesson time; physical education is relatively more important for individuals identified as inactive. Regrettably, during the last decade there has been a cutback in these lessons for those in the important adolescent years.

Further Research

Continuing this longitudinal study and following the individuals into adulthood would provide useful information on the impact of adolescent physical activity on adult activity. In addition to increasing the body of knowledge with longitudinal data, including the intensity of physical activity might be helpful. Furthermore, adding more determinants of physical activity such as level of physical self-esteem, parental support, and fitness level, is desirable.

Conclusions

In summary, the tracking of pedometer-determined physical activity was, in general, low to moderate during adolescence. A sex difference, with boys expressing higher tracking, was seen. The significant decrease of physical activity, as steps per day, in boys in early adolescence seems to level out during late adolescence. Girls’ level of steps per day remained somewhat level over these years. Sport-club training during adolescence counteracted the decrease in physical activity.

Acknowledgment

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