Monitoring of Physical Activity in Young Children: How Much Is Enough?

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There is limited evidence on how much and on which days accelerometry monitoring should be performed to obtain a representative measurement of physical activity (PA) in young children. We measured 76 children (40 M and 36 F, mean age 5.6 years ([SD ± 0.4]) on 7 days using Actigraph accelerometers. Mean daily PA was expressed in counts per min (cpm). Reliability increased as the number of days and hours of monitoring increased, but only to 10 hr per day. At 7 days of monitoring for 10 hr per day, reliability was 80% (95% CI [70%, 86%]). The number of days was more important to reliability than the number of hours. The inclusion or exclusion of weekend days made relatively little difference. A monitoring period of 7 days for 10 hr per day produced the highest reliability. Surprisingly short monitoring periods may provide adequate reliability in young children.

Regular physical activity (PA) has been recognized as providing protection against many chronic diseases of adult life (4). There is substantial evidence that physical activity also provides important health benefits to children (2,30) and establishes behavior patterns that may continue into adulthood (12, 21).

The measurement of physical activity in children has its own particular difficulties. These include the sporadic nature of the children’s activity patterns and their lack of cognitive ability to accurately recall the amount and intensity of activity (16). Accelerometry has become widely used for characterizing two important dimensions of physical activity: total amount (volume) of physical activity and intensity of activity (time spent at or above a specified intensity level). The Actigraph accelerometer (formerly known as MTI Actigraph or Computer Science Applications [CSA] 7164, Fort Walton Beach, FL) is one of the most widely used accelerometers and has been shown to be a valid and reliable tool for measuring physical activity volume and intensity in young children (1,5,15,27,29).
Some outstanding methodological issues exist in the use of accelerometers to assess physical activity in children. One of the most important is how long monitoring should be to allow a representative estimate of physical activity to be determined. At present, there is limited evidence on the recommended measurement periods in free-living environments. In the literature, examples of monitoring periods range from as few as 2 days, frequently 3 or 4 days including 1 weekend day, up to 2 weeks (3, 6, 7, 9, 20). There appears to be little theoretical or empirical justification for the duration of monitoring. Trost et al. (26) investigated age-related differences in the reliability of physical activity measurements in children aged 6 to 16 years. They suggested that, depending on age, between 4 and 7 days of monitoring, including a weekend day, are required in order to obtain a reliable measurement of children’s physical activity levels. Trost and associates demonstrated that the monitoring period required to produce a representative measurement of physical activity varies with age. However, to our knowledge, there are no studies using accelerometers, which have been considered the most suitable monitoring period in children younger than 6 years.

The primary aim of this study was to investigate the number of days and hours of monitoring required to obtain representative measures of physical activity of younger children. We also wished to determine whether monitoring should include weekend days.

Methods

Participants

Accelerometry data were collected from young children, participating in the Study of Preschool Children Activity, Lifestyle, and Energetics (SPARKLE) in Glasgow, Scotland (8, 18, 19). This was a mixed longitudinal study of physical activity and sedentary behavior in a socioeconomically representative sample of children. The SPARKLE study has been described in detail elsewhere (8, 19). The Research Ethics Committee of the Royal Hospital for Sick Children at Yorkhill, Glasgow, approved the study, and written informed consent was obtained from all parents.

Initial screening identified participants with acceptable compliance with the measurement protocol as those participants with a minimum of 3 days of monitoring of at least 6 hr per day (8, 13). In practice, adherence to the measurement protocol was good and duration of monitoring was generally much longer than the minimum stipulated time. To ensure uniformity of monitoring periods in this study, those participants from the original study with missing data were excluded. This present study was a secondary analysis of data collected from a subset of 76 children (40 boys and 36 girls) participating in the SPARKLE study who had provided at least 7 consecutive days of accelerometry data (mean age 5.6 years, SD ± 0.4).

Protocol

Accelerometry

Physical activity data were collected using Actigraph activity monitors. The Actigraph is a small (51 × 38 × 15 mm) and lightweight (43 g, including the weight of
the belt) lithium-battery-powered monitoring device that measures accelerations in a vertical axis. The uniaxial accelerometer measures movements within the range 0.5 to 2 G and frequencies of 0.25 and 2.5 Hz. Movement produces a voltage signal that is proportional to acceleration. A digital count is produced by converting this signal using an 8-bit A/D converter and the counts are summed over a user-defined period of time (epoch) (28).

Participants’ Accelerometer Use

Participants’ parents were given an Actigraph and accelerometer belt. They were asked to complete a daily diary of what time the belt was attached and removed each day. The accelerometers and diaries were collected by the researchers 7 to 10 days later. Parents and children were informed that the child should wear the accelerometer on the right hip underneath clothing (5,14,25), and they were shown how to secure the accelerometer belt according to the manufacturer’s guidelines. Participants were asked to wear the device from the time they woke in the morning until bedtime in order to capture all their waking physical activity for each day. The only exception was during showering or bathing when the parents were instructed to remove the accelerometer, which is not waterproof, in order to prevent damage to the device. Parents were asked to note daily in the diary provided the time the child began wearing the device, when it was removed at the end of the day, and any time the device was removed and reattached during the day.

Data Reduction and Analyses

Data were uploaded according to the manufacturer’s guidelines for analysis. All participants’ monitoring periods included the waking hours of the day; start and finish times were determined manually in conjunction with the parental record of times from the diary. Monitoring start times for each participant on each day were identified as the beginning of the third complete minute after the appearance of counts above zero and not before the parental record indicated that the activity monitor had been attached. Finish times were identified as the end of the third last minute before the beginning of the overnight period of extended zero counts and not after the time the device was worn as recorded in the diary. The exclusion of the first and last 2 min of monitoring ensured the counts produced from movement associated with attaching and removing the accelerometer were not included in the analysis. The median start and finish times for monitoring period were 8:36 a.m. (interquartile range [IQ] 8:05 to 9:50 a.m.) and 8:13 p.m. (IQ range 7:17 p.m. to 9:08 p.m.), respectively. Mean number of hours of monitoring per day was 10.9 ($SD \pm 1.9$). Mean total number of hours of monitoring per participant was 84.5 hr ($SD \pm 16.4$).

For each participant, data were expressed in counts per minute. All accelerometer records were reviewed to identify periods of repeated zeros. These periods of repeated zeros were seen once on 1 day of monitoring in 9 participants and once on each of 2 days of monitoring in 1 out of 76 participants. Such periods were checked against parental diaries to determine whether the Actigraph was being worn. Those periods of repeated zero counts corresponding to parental records were excluded. Other, essentially identical, periods of repeated zeros where the parental
record gave no information were also excluded. Mean daily physical activity was calculated in accelerometer counts per minute (cpm) by dividing the total counts per minute by the number of minutes of monitoring per day.

Statistics

Data were summarized using standard descriptive statistics. Repeated measures analysis of variance was performed to determine whether there was a difference in activity levels between girls and boys on the weekend and weekdays.

Logarithms of the mean daily counts per minute were calculated, because of the heteroscedasticity of counts at increasing activity levels, to ensure within-participant variability remained constant. Before each analysis an assessment of data normality was determined on the logarithmically transformed data. Reliability coefficients and 95% confidence intervals (95% CI) were calculated using the Spearman Brown prophecy formula (S-B; 22,23,24). This statistical method is used to determine the internal consistency of data (26). The effect on reliability of lengthening or shortening a monitoring period can be computed using the Spearman-Brown prophecy formula. The S-B states the following:

\[
R = \frac{\sigma_B^2}{\sigma_B^2 + \left( \frac{\sigma_W^2}{\text{Number of Days of Measurements}} \right)} \times 100
\]

where: \( R = \text{reliability} \), \( \sigma_B^2 = \text{between-participant variance} \), \( \sigma_W^2 = \text{within-participant variance} \).

Results

Total Volume of Physical Activity

The mean (±SD) daily physical activity was significantly higher for males (870 ± 187 cpm) than females (771 ± 161 cpm) by 99 cpm (p = .011). Both males and females were significantly (p = .02) more active on weekends (900 ± 245 cpm and 833 ± 219 cpm, respectively) than on weekdays (858 ± 183 cpm and 747 ± 164 cpm, respectively).

Influence of Monitoring Period on Reliability

Number of Days and Hours. Reliability coefficients are shown for various combinations of days and hours per day of activity monitoring in a matrix (Table 1). As indicated by the S-B prophecy formula, the most reliable measure of physical activity was a monitoring period of 7 days and 10 hrs per day (\( R = 80\%; \ 95\% \ CI 70\%, \ 86\% \)) (Table 1). These data also showed that the reliability of the physical activity measurement clearly depended on both the number of hours and the number of days. The evidence from Table 1 suggests that the reliability of the measurement of physical activity in our sample and setting remained relatively stable from as little as 3 hr per day up to and no more than 10 hr per day of monitoring. With constant or even reduced daily periods of monitoring, higher reliabilities are possible if the number of days of monitoring is increased. Perhaps surprisingly, in the present study the reliability was lower if participants were monitored for 11 hr or
more per day (e.g., the estimated reliability for 7 consecutive days of measurement for 13 hr per day was 52% compared with 80% for 10 hr of monitoring per day; see Table 1).

**Table 1** Reliability (%) of Monitoring Period for Mean Daily Physical Activity Based on 76 Participants With Complete Data Sets of 7 Days

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<tr>
<th>Hours</th>
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Inclusion of Weekdays and Weekend Days. Table 2 shows reliability coefficients and 95% confidence intervals from Spearman-Brown analysis based on data sets with 4 days of monitoring for periods including weekdays only, and with 4 days of data including 1 weekend day. This period was chosen on the basis of the analysis as it is frequently quoted as inclusion criteria for the minimal required duration of monitoring (9,11). Reliability coefficients and 95% confidence intervals show that the inclusion of weekend days in the monitoring period either had a negligible effect on reliability or slightly decreased the reliability of the estimation of total physical activity in this sample of young children (i.e., 4-day monitoring period including 3 weekdays and 1 weekend day rather than 4 weekdays reduced the reliability slightly from 84% to 82%).

**Discussion**

In the present study, reliability of measurement of physical activity became higher as the number of days of monitoring increased up to peak reliability of 80% (95% CI 71%, 86%) for 7 days. Whether the monitoring period included a weekend day did not significantly alter the reliability.

There was a high degree of consistency between the estimated reliabilities and their confidence intervals in the present study and those reported by Trost et al. (26) for older children. In both studies, 7 days of monitoring for >8 hr per day produced the highest reliability for young children. However, there are implications to both cost and participant compliance with such a long monitoring period. In our
experience, accelerometers used in studies are sometimes returned with fewer than 7 days of monitoring and the monitoring may not always include a weekend day.

The results of the present study (Table 1) should allow researchers to determine the likely level of reliability for shorter periods of monitoring in young children. In the present study, reliability exceeded 70% (widely regarded as acceptable, e.g., Trost et al.; [26]) for even relatively short days of monitoring (e.g., 3-4 hr/day in Table 1) so long as at least 5 days were monitored. In the present study the number of days of monitoring had more marked effects on reliability than number of hours per day (Table 1).

It has been reported that participation in MVPA in 6- to 8-year-old children occurs in two distinct and independent time components (i.e., on weekdays 7:00 a.m. to 10:59 a.m. and 11:00 a.m. to 8:59 p.m.; [26]). Trost et al. proposed that participation in MVPA was consistent within each component though different between time periods; thus selecting a monitoring period with fewer than 10 hr may potentially bias the resultant physical activity estimation (26). The present study suggests that this influence is not evident in the younger children in our setting, who do not exhibit the same structure of a school day as the volunteers in Trost’s study. The results of the present study may not be generalizable across all age populations, and researchers may need empirical data for other populations with different lifestyles.

Anecdotally it is thought that the longer the monitoring period, the more representative the estimation of physical activity. However, the findings of the present study show this may be true only up to a point, in young children, since the reliability showed a marked decrease if the monitoring period extended to 11 or more hours per day of measurement, irrespective of the number of days of monitoring (Table 1).

The percentage of time spent in activity categories of sedentary, light, and moderate to vigorous, determined using published pediatric accelerometer cut points (17,18), is an important construct of physical activity. The conclusions of this current study were very similar irrespective of whether accelerometry data were expressed as counts per minute or as percentage of time in these activity categories. For instance, $R = 80\%$ (95% CI 71%, 81%) for 4 days of monitoring when activity is expressed as percentage time spent in each of the activity categories.

### Table 2  Reliability (%) and 95% Confidence Intervals of Mean Daily Physical Activity Measurements

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<th>2 days</th>
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<th>4 days</th>
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<tr>
<td>Weekdays only</td>
<td>73% (55%, 83%)</td>
<td>80% (64%, 88%)</td>
<td>84% (71%, 91%)</td>
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<tr>
<td>Including 1 weekend day</td>
<td>70% (54%, 80%)</td>
<td>78% (64%, 86%)</td>
<td>82% (70%, 89%)</td>
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</table>

*Note.* Based on data including 4 days of measurement with and without inclusion of a weekend day.
A number of studies using objective assessment methods have reported higher levels of physical activity in children during the weekend (e.g., 10,26), and for this reason it has been considered important to include a weekend day in the monitoring period (26). In the present study, both boys and girls were statistically significantly more active on weekends. However, the magnitude of the difference between weekend and weekday may not be biologically meaningful (boys were more active on weekends by just 42 cpm and girls by only 86 cpm). Further consideration of the width of published pediatric cut points delineating activity levels (e.g., light activity ranging from 801 to 3,199 cpm and moderate activity ranging from 3,200 to 8,200 cpm; [17]) would also suggest that the relatively small differences in accelerometry counts per min in the present study reflect very small differences in activity levels. With the analyses in the present study, for young children, reliability did not differ significantly with the inclusion or exclusion of weekend days.

Conclusions

The results of the present study suggest that a monitoring period of 7 days and 10 hr per day produced the highest level of reliability in measurements of physical activity in young children. However, surprisingly short monitoring periods may provide an appropriate level of reliability in this age group. These shorter monitoring durations need not include a weekend day. The evidence presented here should allow researchers to design practical research protocols at a specified level of reliability.

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References


