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Stability of Habitual Physical Activity and Sedentary Behavior Monitoring by Accelerometry in 6- to 8-Year-Olds

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Background: Accelerometry is rapidly becoming the instrument of choice for measuring physical activity in children. However, as limited data exist on the minimum number of days accelerometry required to provide a reliable estimate of habitual physical activity, we aimed to quantify the number of days of recording required to estimate both habitual physical activity and habitual sedentary behavior in primary school children. **Methods:** We measured physical activity and sedentary behavior over 7 days in 291 6- to 8-year-olds using Actigraph accelerometers. Between-day intraclass reliability coefficients were calculated and averaged across all combinations of days. **Results:** Although reliability increased with time, 3 days of recording provided reliabilities for volume of activity, moderate-vigorous intensity activity, and sedentary behavior of 68%, 71%, and 73%, respectively. **Conclusions:** For our sample and setting, 3 days accelerometry provided reliable estimates of the main constructs of physical activity and sedentary behavior.

Keywords: sedentary behavior, children, accelerometry

Regular physical activity in childhood is advocated for maintenance of good health, including prevention of diabetes, cancer, and obesity.¹ The increase in childhood obesity, coupled with a series of reports of low levels of habitual physical activity in children in recent studies which have used accelerometry²⁻⁶ reinforces the requirement for reliable monitoring of physical activity. There are problems inherent with any physical activity measurement system⁷ but the Actigraph accelerometer is used most often, has been shown to be valid, and is supported by a recent systematic review and many individual studies.^{8,9} However, although there are now many studies using the Actigraph accelerometer, few have assessed stability of accelerometry output in their target population.

One fundamental question that must be considered when monitoring physical activity in children is that of length of the monitoring period—the minimum number of days required to obtain a stable estimate of habitual physical activity or sedentary behavior.¹⁰ However, the number of empirical investigations of the stability of Actigraph accelerometry remains very limited¹¹⁻¹⁴ and the range indicated by these 4 previous studies (suggesting that 3 to 7 days,¹² 5 to 7 days of 3 to 12 hours,¹³ 4 days,¹¹ or 3 days¹⁴ of recording are sufficient) suggests that reliability of monitoring may vary between populations and in particular may vary with age.¹²

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More evidence on the stability of Actigraph accelerometry is therefore required and for the time being, the minimum monitoring period for specified stability should be assessed in each population being studied.

Three of the four previous reliability studies concentrated on reliability of the overall volume of activity (mean accelerometer “counts” per minute [cpm])¹²⁻¹⁴ while one assessed the amount of time spent in moderate-to-vigorous physical activity (MVPA),¹¹ although this was not the primary purpose of the study.¹¹ There is therefore a lack of information on reliability estimates for MVPA, currently regarded as the most important construct of physical activity, in children.¹ In addition, engagement in habitual sedentary behavior is also an important construct—distinct from habitual physical activity—which is also readily and accurately measured using Actigraph accelerometry in children.⁷ However, to date, we are not aware of any empirical investigations of the reliability of estimates of habitual sedentary behavior in children using Actigraph accelerometry. Reliability in field measurements is a composite of an element of intrainstrument reliability (technical reliability), usually very small,⁹ plus biological variability, between day differences within study subjects. The current study concerns this composite measure.

The aim of the current study was therefore to investigate the number of days recording that were required to obtain stable estimates of children’s total volume of habitual physical activity, habitual MVPA, and habitual sedentary behavior using data from the Gateshead Millennium Study (GMS).

Methods

Study Participants

The GMS recruited 1029 subjects shortly after birth between June 1999 and May 2000 in Gateshead, an urban district in North East England. All infants born to mothers resident in Gateshead in 34 prespecified weeks were eligible for recruitment.¹⁵ All GMS families who had not previously opted-out were invited to take part in the current study. Parents provided informed written consent before participation and children provided assent. The study was approved by the Gateshead and South Tyneside Local Research Ethics Committee.

Accelerometry

During data collection (October 2006 to December 2007) for the current study Actigraph GT1M accelerometers on an elastic waist belt were given out (Actigraph LLC, Pensacola, FL, USA) to 597 children (58% of the original sample, mean age 7.4 years) who were requested to wear them on the right hip during waking hours for 7 days, removing them only for water-based activities. Parents were asked to keep a written log of the times that the accelerometer was put on and taken off. Data were downloaded from the accelerometer and compared with diary times to identify and edit periods when the accelerometer was not being worn. Manual data reduction involving comparison of diary and accelerometry records (and contact with parents where necessary) was used as described previously.^{16,17} Automatic removal of 'zeros' from the accelerometry records was not used—periods of consecutive zeros were rare and only removed if they corresponded to entries of belt removal in the parental log.

A total of 512 (86% of those given out) accelerometers were returned with data, of which 291 had been worn for 7 days with at least 6 hours recording per day and these accelerometry records formed the basis of the current study.

Data were expressed as mean cpm, an index of the total volume of habitual physical activity, calculated by dividing the total cpm by the number of minutes

of monitoring per day. Physical activity output was also stratified by intensity to assess time spent in light-intensity activity, MVPA, and sedentary behavior using published cut-points from pediatric calibration and validation studies: sedentary behavior < 1100 cpm,¹⁸ light-intensity activity 1100 to 3200 cpm,¹⁷ moderate and vigorous activity > 3200 cpm.¹⁹

Statistical Analyses

Sample size for the current study was fixed by the size of the GMS cohort, the extent to which families participated in the current study and by the number of children who provided complete (7 days) data. Previous studies of reliability have successfully used smaller cohorts (eg, $n = 92$ for the comparable age group in Trost et al¹² and $n = 76$ in the slightly younger age group of Penpraze et al¹³). Thus the sample size of 291 was deemed adequate to carry out the analyses.

All data were first checked for normality with Anderson-Darling tests. As data were skewed, differences between boys and girls were examined using Kruskal-Wallis nonparametric analysis with median and interquartile range presented unless otherwise stated. Mann-Whitney tests were used to examine differences between weekend and weekdays. Between-day intraclass reliability coefficients were calculated following the method of Nader et al,¹¹ which is based on analysis of variance methods. Reliability coefficients were averaged across all combinations of days for each number of days from 2 to 7. Analysis was done using the statistical software packages Minitab release 15.1 and Stata, version 10.

Results

Characteristics of Study Participants

Seven day accelerometry data from 291 children were used in the current study, 156 boys and 135 girls. Physical characteristics of participants are summarized in Table 1. The boys and girls studies were not significantly different in terms of age or BMI.

Table 1 Participant Characteristics (Median and IQR)

	Combined (n = 291)	Boys (n = 156)	Girls (n = 135)	P-value for sex difference
Age	7.4 (7.1–7.8)	7.4 (7.1–7.8)	7.5 (7.2–7.8)	0.146
BMI*	16.2 (15.2–17.8)	16.7 (15.2–17.7)	16.7 (15.1–17.9)	0.626
Mean cpm	737 (614–881)	745 (617–913)	734 (610–859)	0.416
MVPA (min·day ⁻¹)	28 (19–41)	30 (18–48)	26 (19–36)	0.061
Light intensity activity (as % total wear time)	18.3 (15.1–21.3)	18.7 (15.6–22.2)	17.9 (14.6–20.9)	0.047
% time in MVPA	4.1 (2.7–6.0)	4.2 (2.7–6.9)	4.0 (2.6–5.4)	0.083
% time sedentary	77.3 (73.0–81.5)	76.6 (71.8–81.0)	78.0 (74.4–82.1)	0.025

* $n = 285$.

There was no difference in physical activity between Saturday and Sunday ($P > .9$), so the mean value was used for the “weekend.” The median total volume of physical activity was similar for boys and girls, 745 v. 734 cpm respectively, $P = .416$, with no significant differences between the sexes for either weekends ($P = .692$) or weekdays ($P = .209$), and no difference in physical activity at the weekend compared with weekdays (median cpm 736 v. 724, $P = .488$).

Boys took part in more MVPA than girls (30 v. 26 min·d⁻¹, Table 1), and spent a greater proportion of their time in MVPA (4.2 v. 4.0%) although neither difference reached statistical significance ($P = .061$ and 0.083 respectively). Girls spent a significantly greater proportion of time sedentary (78.0 v. 76.7%, $P = .025$) and significantly less time in light intensity physical activity ($P = .047$, Table 1).

Stability of Measures of Different Constructs of Physical Activity and Sedentary Behavior

Reliability coefficients for total volume of habitual physical activity (accelerometry cpm), percentage of time spent in MVPA, and percentage of time spent sedentary are shown in Table 2. As shown in Table 2, reliability increased as more days were included for all 3 constructs. However, overall there were only relatively small increases in reliability as the number of days monitored increased above 3 days.

Relatively small differences in reliability between the 3 constructs were observed, with percentage of time sedentary the most stable, 73% reliability demonstrated for 3 days, up to a maximum of 85% after 7 days.

Discussion

In the current study to determine the minimum number of days of monitoring required to estimate children’s habitual physical activity and sedentary behavior with acceptable stability, we found that reliability increased with number of days of recording, as expected.^{12,13} We estimated that 7 days of monitoring, widely regarded as the ‘gold standard’ in accelerometry, provided reliabilities

of 83% for volume of activity (cpm), 83% for habitual MVPA, and 85% for habitual sedentary behavior. These reliabilities would generally be considered to be high and probably acceptable for most purposes.¹²

However, 7 days of accelerometry is usually difficult to achieve and a lower reliability—around 70%—is usually deemed to provide adequate reliability in practice^{12,13}. In the current study of 6- to 8-year-olds measured in a community setting, 3 days of monitoring provided around the minimum 70% reliability for estimates of habitual total volume of physical activity, MVPA, and sedentary behavior.

Published work using the Actigraph with 92 UK children of a similar age¹² suggested that 2 to 3 days and 4 to 5 days of monitoring are required to achieve reliabilities of 70% and 80%, respectively for habitual volume of physical activity. The results of the current study are consistent with this, and also show that reliability increases relatively little above 3 days of monitoring—the gain in reliability for additional numbers of days appears to be smaller than might have been expected.

The inclusion of at least 1 weekend day is also often required in published studies of accelerometry in children. Only a limited number of studies of UK children have considered the question of whether total volume of physical activity and/or MVPA differ significantly between weekend days and weekdays. These UK studies have generally found either very small but significant differences,¹⁴ or no evidence of such systematic differences.⁶ In the recent study by McClure et al (2009) of English 10 year olds, with physical activity measured using the same methods as in the current study, no significant differences were found either for total volume of physical activity or MVPA.⁶ In other samples and settings weekend-weekday differences may be more marked.¹² We did not observe a difference in volume of activity between weekends and weekdays in the current study, and there were no benefits to including a weekend day in terms of reliability in the current study (reliability, for example, of 70% for Saturday, Monday, Tuesday; 69% for Sunday, Monday, Tuesday; and 71% for Monday, Tuesday, Wednesday). This finding may be important for future studies, as children do not always comply with a complete 7 days of monitoring, or forget to wear the accelerometer at weekends, so these findings may enable inclusion of greater

Table 2 Average Reliability Coefficients (%) and 95% Confidence Intervals for Each Construct of Physical Activity/Sedentary Behavior for Varying Numbers of Days

No. of days	Total volume of physical activity (cpm)	% time in MVPA	% time sedentary
7	83 (0.80–0.85)	83 (0.80–0.85)	85 (0.83–0.87)
6	81 (0.78–0.84)	81 (0.78–0.84)	83 (0.80–0.86)
5	78 (0.75–0.81)	78 (0.75–0.81)	80 (0.77–0.83)
4	74 (0.70–0.78)	73 (0.69–0.77)	76 (0.72–0.80)
3	68 (0.63–0.73)	71 (0.66–0.75)	73 (0.68–0.77)
2	59 (0.51–0.66)	58 (0.50–0.65)	62 (0.54–0.69)

numbers of children in future research with the Actigraph. Mattocks et al¹⁴ also reported no noticeable improvement in reliability when including a weekend day in activity measurements on a large cohort of English 11 year olds.

Sedentary behavior is thought to exert an independent effect on childhood overweight²⁰ and is considered to be a separate construct from physical activity.⁷ A recent review concluded that sedentary behavior in younger children is generally associated with overweight,²¹ with TV viewing the component of sedentary behavior currently considered the most 'obesogenic.' Validity of sedentary behavior measurement in children using Actigraph accelerometry has already been established,^{18,22} but reliability was unclear. The current study appears to be the first investigation of the reliability of habitual sedentary behavior measurement using the Actigraph and it suggests that reliability of sedentary behavior measurement might be at least as high as reliability of physical activity measurement. It also suggests that the reliability of measurement of the 3 constructs studied may be very similar.

In summary, the current study has provided estimates of the minimum monitoring period for acceptable stability of measurements of habitual physical activity, MVPA, and sedentary behavior in English 6- to 8-year-olds. Stability may differ between samples and settings and, ideally, should be assessed for each population and/or setting of interest, in conjunction with the question of the degree of stability required to answer the question of interest.^{10,12}

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