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Development and Evaluation of a Novel Computer-Based Tool for Assessing Physical Activity Levels in Schoolchildren

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A novel computer tool (peas@tees), designed to assess habitual physical activity levels in children aged 9 and 10 years, was evaluated. **Study 1** investigated agreement between peas@tees and accelerometry in 157 children. Bland-Altman limits of agreement (LOA) revealed peas@tees underestimated physical activity levels compared with accelerometry (bias -21 min; 95% LOA -146-105). **Study 2** investigated stability of peas@tees in a separate sample of 42 children. Intraclass correlation coefficient was 0.75 (95% CI 0.62-0.84). Computer tools are promising as a cheap, feasible, and useful method to monitor children's habitual levels of physical activity at the group level.

Across the globe, attempts to modify children's lifestyles, particularly their physical activity levels and their diets are a global public health priority. The accurate and reliable assessment of these behaviors remains a challenge (5,30). While objective methods such as accelerometry remain the most accurate option in research, simpler alternative measurement methods that are both inexpensive and easy to employ in larger community-based interventions and observational studies

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in children are required (6,9,35). Although self-report techniques, such as recall questionnaires and diary records, provide the most practical means to measure physical activity and dietary intake for population or surveillance purposes, they are time consuming, monotonous to complete and labor intensive for the researcher. Furthermore, the recall of physical activity and dietary intake in children are generally assessed independently despite the potential interactions between these behaviors (20). Recently, it has been identified that studying energy-balance related behaviors simultaneously with new technology may provide benefits and may assist future health interventions (19).

There are two main types of physical activity self-report measures; previous-day physical activity recalls and 7-day physical activity recalls. Although previous-day recalls are thought to assist memory recall in younger children, accuracy of this approach is still limited (28). Previous-day recall questionnaires do not represent usual or habitual physical activity which is particularly problematic given that younger children have shown to engage in short, intermittent bursts of activity, with varying degrees of intensity and duration (2) which also has high intraday and interday variability (37). Physical activity questionnaires which aim to collect longer term data can be used to measure 'habitual' physical activity. The newly designed questionnaire has been designed by integrating previous-day and more habitual physical activity questionnaires, to combat the limitations of both methods used separately, in accordance with previous literature (21). It was hoped that this combination of techniques might improve the low-to-moderate accuracy of recall when using both techniques independently.

Patterns of Eating and Activity at Teesside (peas@tees) is a novel computer-based tool which was designed to help combat many of the methodological problems associated with more traditional self-report methods of assessment of habitual physical activity in youth. One of the main objectives for peas@tees was to develop a convenient, global, 'typical day' method which would be accurate and reliable for assessing dietary intake and physical activity behaviors concurrently, for group or population level purposes. Essentially, the emphasis was to make the tool accessible, user-friendly, cheap, and importantly, fun for children age 9–10 years to complete.

The present study aimed to describe the development of the peas@tees computer-based tool, and assess its accuracy (Study 1) and stability (Study 2) with respect to the assessment of habitual moderate-to-vigorous intensity physical activity (MVPA).

Methods

Ethical approval for this study was received from the School of Health and Social Care, University of Teesside Ethics Committee in November 2004.

Description of peas@tees

Peas@tees was written using PHP (Version 4.0.1), MySQL (Version 3.22), and JavaScript (Version 1.3) providing adequate transfer and storage of data. The physical activity section was developed by integrating new and established methods to enhance recall in children, such as;

1. a 'typical' school day and 'typical' weekend day was assessed as children have demonstrated stable behaviors across the two day types (39);
2. delivery of the recall activity was in a segmented day format on a school day (before school, during school, break-time, lunch-time, and after school), and on a weekend day (morning, noon and evening), an approach which has been shown to enhance recall in children (4,10);
3. children were instructed to recall both physical activities and dietary intake simultaneously, to facilitate recall aided by the theory of 'behavior chaining' (3);
4. the user interface was designed by a computer gaming expert to create a novel user friendly interface to enhance recall and engagement, a method shown to be successful in previous instruments (25,26,36);
5. visual memory prompts were provided using graphics and error boxes.

The list of common physical activities ($n = 25$ within the domains of sedentary, household and play activities, structured) were selected from common children's activities selected from recommended physical activity questionnaires (21) and the Compendium of Physical Activities (1). Transport activities to- and from-school were assessed separately and categorized into: (a) walk, (b) cycle, or (c) car or bus.

Activity duration was estimated by children dragging a slider on a timeline ranging from 1 min to 60 min, which was visually segmented into 10 min intervals. If children spent more time on that activity they could nominate this activity again by inputting the information again. The landmark intervals were illustrated similar to the trichotomous format described by Ridley et al. in an attempt to prompt the memory of children (25). Previously, children have shown difficulty conceptualizing activity intensity (33) therefore, to simplify this problem children were asked to click on one of three pictures, which illustrated three progressive levels of exertion including; light, moderate and vigorous intensity (Figure 1). Children were also asked about the environmental context of the activities, for example, whether the activity was organized at school or as part of a club. To enhance the practical utility of the tool, large radio buttons and simple scrolling fields were incorporated to make all selections clear for children. The computer tool uses 'point and click' data entry and completion of data were controlled using error messages which ensured that the children could not miss out questions.

Study 1: Comparison of Methods Using peas@tees and Accelerometry. Study 1 aimed to measure the accuracy of reported absolute amount of MVPA between peas@tees and the accelerometer in children.

Participants and Recruitment

A total of 164 children took part in the method comparison study, 67 boys [mean (*SD*) age 9.7 (0.3)] and 97 girls [mean (*SD*) age 9.8 (0.4)]. Subjects were recruited from six primary schools, ranked by all three levels of socioeconomic status (SES; low, medium, and high), in the North-East of England. While the nature of the sample may be relatively unimportant in a methodological study, sampling was designed to ensure that participants were recruited from the entire SES spectrum.

Informed consent was obtained from every school, parent and child who participated in the study.

Accelerometry

The Actigraph accelerometer (Model GT 256, Fort Walton Beach, FL, USA) provided an objective measurement of physical activity behavior, which was used as a reference method for comparison against peas@tees. Accelerometry is considered

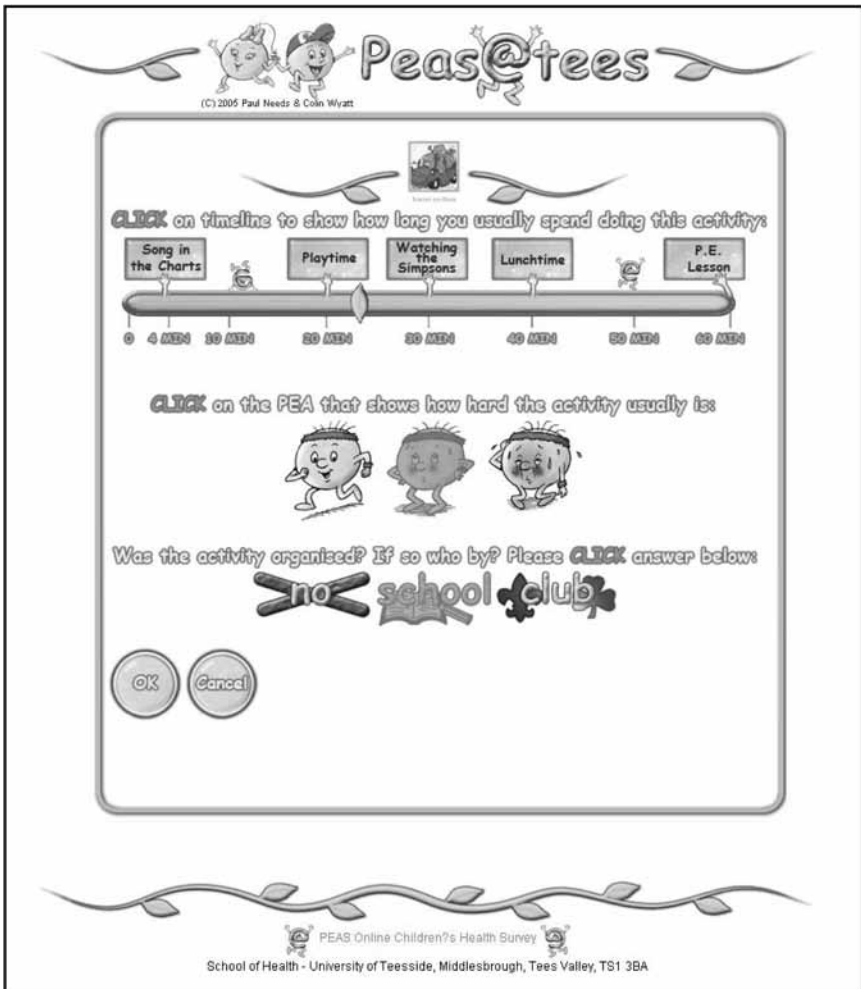


Figure 1 — An example of the graphics illustrating the volume, intensity and location of the physical activity selected using the peas@tees computer tool.

the most appropriate method to measure physical activity with respect to practical, financial and logistical considerations. The Actigraph is a small, robust, lightweight and unobtrusive monitor, worn on the right hip (secured by an elastic waistband). A recent systematic review (11) concluded that the Actigraph has high accuracy and reliability and low reactivity in children. It captures and stores instances of vertical acceleration and translates this into arbitrary “counts per epoch.”

Procedures

Participating children ($n = 164$) were fitted with an accelerometer (Actigraph, GT-256) one day before data collection to de-sensitize them wearing the monitor. Participants wore the accelerometer during waking hours, except while bathing, showering and swimming, over a period of 5 consecutive days (weekend plus 3 weekdays). Children were given detailed instructions detailing how to care for and wear their accelerometer and were also supplied with an activity diary to log the time the monitor was worn.

Within one week of the end of this recording period, children were independently assigned a computer in a classroom setting and were navigated through *peas@tees*, before independent completion. Researchers maintained the tempo at which *peas@tees* was completed and assistance was provided on an individual basis.

Data Management and Analysis

Accelerometer. Minimum wear time was defined by ≥ 3 hr and ≥ 2 days and consecutive zero counts were cross checked against the self-reported removal and replacement times of an activity log. Activity counts were analyzed in 1-min epochs and intensity thresholds were applied to the data defined by age-specific prediction equations (≥ 1100 cpm approximating thresholds for this age group; 14, 34) to assess the amount of time spent in MVPA, in minutes per day measured.

A macro, developed by Professor John Reilly and colleagues at Yorkhill Hospital in Glasgow, was applied to the data to show daily intensity proportions of time spent in, sedentary, light, and MVPA.

Peas@tees Computer-Based Tool. Activities for *peas@tees* were assigned an intensity unit based on the rate of energy expenditure, expressed as metabolic equivalent task (MET) values according to published values (1). These MET values were selected and tailored specifically for children of similar ages based on the best representative from the literature (15,38). Activities from the computer tool which exceeded 3 METs (14), were summed to represent the total time spent in moderate-to-vigorous intensity physical activity, and expressed as minutes per day in reported MVPA.

Statistical Analysis—Study 1

Analyses were conducted on an average day, given by the mean of a typical school day and a typical weekend day for each of the methods. Validity of the computer tool was determined in two ways. First, rank correlation coefficients between the accelerometer and *peas@tees* measures and estimates of daily MVPA were obtained

to assess relative validity. Second, the degree to which individual-level absolute amounts of MVPA actually agreed between the two methods was determined using the Bland and Altman technique (7). The mean difference (bias) was estimated using paired *t* tests, to determine the consistent tendency for one method to exceed the other at a group level. The size of the effect, mean difference between the methods and the 95% confidence interval of that difference were presented. Confidence limits for the correlations were calculated using Fisher's *z* transformation.

Study 2: Stability of the Computer Tool

The aim of Study 2 was to determine the stability of peas@tees, using a repeated administration of the tool to a separate sample to that recruited to study 1. Stability measured in this way includes a component of real biological variation in activity within each child, plus technical imprecision in the method.

Participants and Procedure

A separate sample of 49 children (26 boys and 23 girls) participated in the stability study [mean (*SD*) age 10.4 (0.3)]. Subjects were recruited from two elementary schools in the North-East of England. Participating children completed peas@tees on three separate occasions within a school week (Monday, Wednesday and Friday).

Data Management and Analysis

Stability analyses were conducted on an "average day," given by the mean of a typical school day and a typical weekend day. Activities reported by peas@tees were summed as 3×3 METs (14) to represent MVPA.

Statistical Analysis—Study 2

The systematic change in the mean was assessed to detect any learning effects or systematic error (relative to random error) by looking at a shift in the means over the three measurement occasions. Separate analyses on consecutive pairs of measurements (1 and 2, 2 and 3, 1 and 3,) were performed on an average day using a paired *t* test. Data were expressed using 95% confidence intervals of the mean differences. The within-subject variability provided the typical (standard) error of measurement, plus the intraclass correlation to assess the relative reliability of two or more measurement occasions. The specific intraclass correlation approach was derived from a mixed model [the ICC (3,1; 29)] presented with 95% confidence intervals (95% CI).

Results

Study 1: Assessment of Validity of the Computer Tool

A total of 157 children had complete data for comparison of methods. The mean (*SD*) duration of accelerometry was 4.4 days (0.95) and 11.4 (1.7) hours per day.

The mean (*SD*) MVPA was 118 (41) minutes/day according to the accelerometer and 96 (56) minutes/day using peas@tees for an average day.

Rank correlations (95% CI) assessing the relative validity of MVPA between the two methods on an average day were significant and positive, but only moderate, $\rho = 0.23$ ($p = .05$; Table 1).

The Bland and Altman analysis identified a systematic error in estimation of MVPA using the computer tool. Table 1 highlights that peas@tees underestimated MVPA by 21 min (95% CI: -31 to -11 min) compared with the accelerometer on an average day. At an individual level, 95% of children could lie between an underestimation of 2 hr 26 min and an overestimation of 1 hr 45 min (Table 1). The pattern of errors in relation to the physical activity level has been shown in Figure 2 and Figure 3, for boys and girls respectively.

Study 2: Assessment of Stability of the Computer Tool

A total of 42 children had complete data for all three occasions. The average time spent on MVPA reported by peas@tees over the three occasions, have been displayed in Table 2.

Shifts in the mean. The systematic change in the mean time spent in MVPA across the three occasions was calculated for the reported time in activities ≥ 3 METs by participating children (Table 3). There were no substantial systematic differences in MVPA between the three occasions as reported in the average reported times spent in physical activities (≥ 3 METs) by participating children. Although, it should be highlighted that boys showed a small shift in the mean between occasion 1 and 2 or 2 and 3. For example there was a reported increase in time spent in physical activities by boys by approximately 20 min (95% CI: 2–37) between occasions 2 and 3.

Typical Error and Relative Reliability.

The typical error (minutes) and ICC for the time spent in activities ≥ 3 METs, across the three measurement occasions were calculated in Table 3. There were no substantial differences in the random error (or “noise”) within subjects over the consecutive pairs of measurements. Consequently, the typical error and ICC were assessed using all three sets of data to enhance the precision of the analysis. The

Table 1 Correlation and Agreement Between peas@tees and the Accelerometer of the Estimated MVPA for an Average Day by Participating Children in Study 1

	Boys	Girls	Total
	0.12	0.28*	0.23*
Spearman’s Rank (ρ)	(-0.14–0.35)	(0.08–0.45)	(0.07–0.37)
Accelerometer agreement			
Bias (mins/day)	-26	-18	-21
95% CI of the difference	-44 to -7	-29 to -6	-31 to -11
LOA (95%)	-168 & 117	-130 & 95	-146 & 105

Note. LOA = Limits of Agreement

* = $p < .01$ (2-tailed test)

within-child variability at the individual level from occasion to occasion was ± 31 min (95% CI: 27–37). The corresponding ICC of the computer tool, across the three measurements, was 0.75 (0.62–0.84) for all participating children.

Discussion

Main Findings and Implications

While objective measurements are desirable for assessment of the amount of MVPA in children, subjective measurements have certain advantages and are likely to remain in use. In addition, combination of recall and typical day approaches has been noted as being promising for subjective measurement of physical activity, and use of new technology might make such an approach even more promising.

In the current study the novel peas@tees computer tool was a practical means of assessing levels of habitual MVPA in elementary school children. Completion time was relatively quick [mean 15.0 (*SD* 4.1) minutes] although reading ability

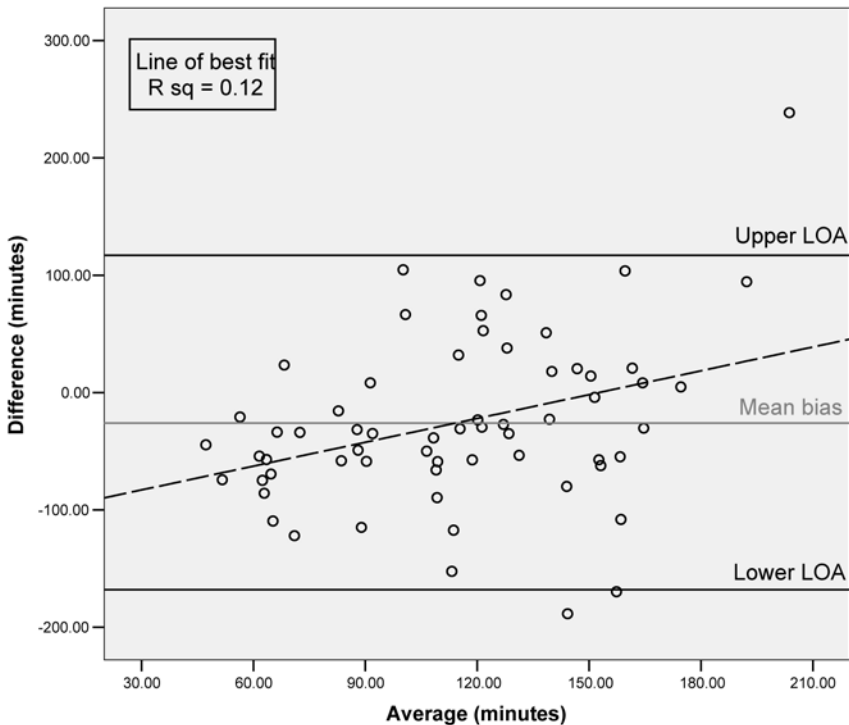


Figure 2 — Bland and Altman plot showing the difference between peas@tees and the accelerometer (MVPA defined as ≥ 1100 cpm) for boys over an average day in Study 1.

and internet connection speed may have contributed to the variation observed. Accuracy of the computer tool for assessment of daily MVPA, with significant though only modest rank correlations with accelerometry, was reasonable. The reason for the difference in relative validity between boys and girls is unclear but merits future research. For assessment of the absolute amount of daily MVPA, agreement between the computer tool and accelerometer at the level of the individual child was poor, but at the group level agreement was better with a relatively small bias given the apparently high levels of MVPA observed (and no marked gender related bias). Piloting of this project before the current study confirmed that the large majority of children enjoyed completing peas@tees and provided positive feedback. Stability of the computer tool was also reasonable, with significant and positive intraclass correlations.

Comparisons With Other Studies

Relatively few studies have compared subjective methods with accelerometry, and there is only a very limited literature on use of newer technology in subjective assessment of physical activity. However, in the current study the correlation

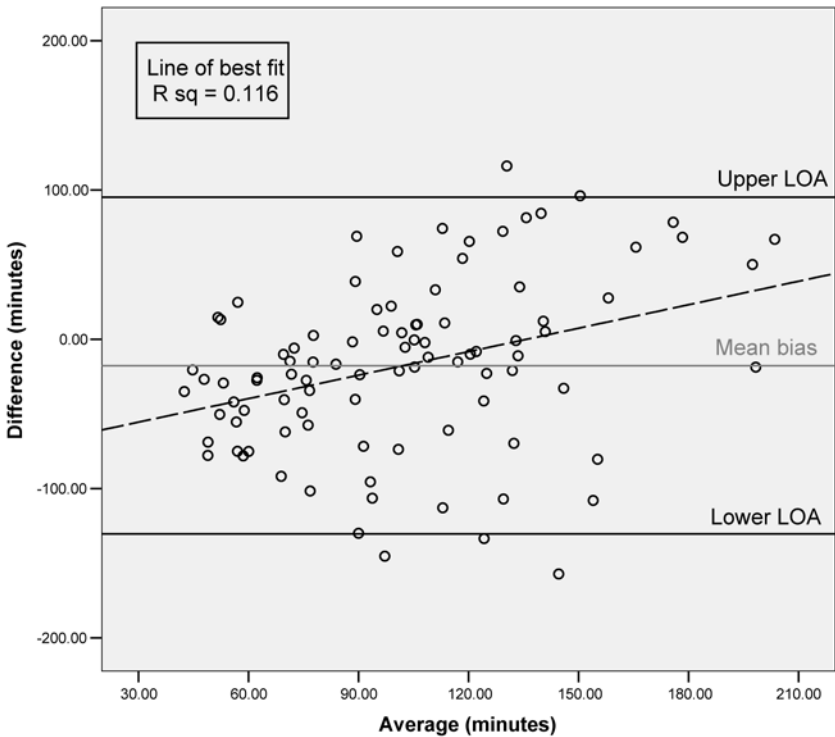


Figure 3 — Bland and Altman plot showing the difference between peas@tees and the accelerometer (MVPA defined as ≥ 1100 cpm) for girls over an average day in Study 1

between the two methods was lower than those previously reported between self report and accelerometry in some other studies (17).

The test-retest correlation observed in the current study was at the high end of the spectrum compared with other studies of global self-report tools of recall ranging from one week to one month (17). From a report of over fifty studies, test-retest reliability coefficients for recalled physical activity in children ranged from 0.20 to 0.99 (17). The present study involved recalling the same period (i.e., true instrument reliability); therefore, results of repeated measures should not differ substantially with respect to biological variability.

Limitations of Approaches to Assessing Habitual MVPA

The measurement of physical activity is challenging, particularly in children 10 years of age or younger, who are likely to have limitations in their memory and recall skills as well as difficulty understanding concepts of time and of physical activity intensity (4). Poor agreement between the two methods in the current study at the individual level was therefore not unexpected. The difference in time periods (five-days accelerometry assessment versus one-day for the computer tool) may have contributed to the differences between methods. Assessing habitual MVPA in this way oversimplifies the complexity of behavior and becomes problematic if children have difficulty defining a typical day. Previously, it has been

Table 2 Stability of Time Spent (Mins/Day) in MVPA Using peas@tees by Participating Children in Study 2

Participants		Mean minutes (SD)		
		Occasion 1	Occasion 2	Occasion 3
School day	Boys (<i>n</i> = 22)	104 (49)	128 (73)	100 (52)
	Girls (<i>n</i> = 20)	94 (46)	105 (57)	103 (65)
	Both (<i>n</i> = 42)	99 (47)	117 (66)	102 (58)
Weekend day	Boys (<i>n</i> = 22)	93 (82)	104 (85)	93 (85)
	Girls (<i>n</i> = 20)	125 (88)	101 (77)	109 (90)
	Both (<i>n</i> = 42)	108 (87)	102 (80)	101 (87)
Average day	Boys (<i>n</i> = 22)	98 (60)	116 (63)	97 (59)
	Girls (<i>n</i> = 20)	109 (61)	103 (59)	106 (71)
	Both (<i>n</i> = 42)	104 (60)	110 (60)	101 (65)

Note. Occasion 1= Monday; 2= Wednesday; 3= Friday

suggested that validity improves significantly as the recall period becomes shorter (10).

Despite the widespread use of accelerometry, there are many errors and imprecision of measurement when applying accelerometers as a “reference” or “criterion” method (13,23). There are numerous issues which are thought to be a contributor to their imprecision in children including,

1. the recordings during cycling, walking or running uphill which are not measured adequately by the uniaxial accelerometer (16,31,32),

Table 3 Shift in the Mean, Typical Error and Intraclass Correlation Coefficient (ICC) for the Reported Time in MVPA (Mins/Day) Across the Three Measurement Occasions in Study 2

Pairwise reliability		Occasion 1 & 2	2 & 3	1, 2 & 3
Boys (n = 22)	Shift in the mean	-17	19	2
	Mean	(-37-2)	(2-37)	(-15-18)
	95% CI of the difference	0.08	0.03*	0.81
	P value			
	Typical error	±32	±28	±29
	(95% CI)	(25-46)	(22-40)	(24-37)
	ICC	0.73	0.79	0.77
	(95% CI)	(0.46-0.88)	(0.56-0.90)	(0.60-0.89)
Girls (n = 20)	Shift in the mean	7	-4	3
	Mean	(-16-29)	(-17-10)	(-23 to -29)
	95% CI of the difference	0.56	0.59	0.81
	P value			
	Typical error	±34	±21	±33
	(95% CI)	(25-50)	(16-31)	(27-43)
	ICC	0.67	0.90	0.74
	(95% CI)	(0.33-0.85)	(0.77-0.96)	(0.54-0.88)
Both (n = 42)	Shift in the mean	-6	8	2
	Mean	(-21-9)	(-3-20)	(-12-17)
	95% CI of the difference	0.42	0.14	0.74
	P value			
	Typical error	±34	±26	±31
	(95% CI)	(28-43)	(21-33)	(27-37)
	ICC	0.69	0.83	0.75
	(95% CI)	(0.48-0.81)	(0.71-0.90)	(0.62-0.84)

Note. Occasion 1= Monday; 2= Wednesday; 3= Friday; CI = confidence interval of the mean; ICC = intraclass correlation coefficient

* $p < .05$

2. the underestimation of activity swimming and contact sports due to the removal of accelerometers (16,32), and
3. the particularly poor frequency response of the accelerometer due to their relatively high stride frequency (8).

In the current study, the thresholds applied to accelerometer data to estimate MVPA (14,34) are widely used and recommended in pediatric physical activity research but were derived largely from laboratory-based treadmill studies in adults, which may also contribute to the error observed in children.

Study Limitations

The extent to which a computer tool for the assessment of group level MVPA may be age-specific is unclear, but it is likely that such instruments may need to be adapted for use across different age groups, and possibly tailored to incorporate season-specific activities and different activities undertaken in other cultures. However, computer technology can be adapted readily depending on the sample group. For example, the computer tool in the current study could be updated with standard values for energy cost of children's physical activity, which have recently been published (24,27).

Future Directions

The results of the current study highlight that computer-based assessment may provide a practical, innovative, and promising tool to monitor children's physical activity behaviors at the group level in the future. It is thought that computer tools have the potential to assess the benefits of the energy balance related behavior which may provide opportunities to examine clustering effects (18) and a link to other important datasets such as body weight (12). Recently, peas@tees has informed the development of the *Synchronized Nutrition and Activity Program* (SNAP) at the University of Teesside (22). It is hoped that the results obtained from such studies will aid the design of a national surveillance tool for efficiently estimating physical activity levels in youth, and its resultant health and economic benefits.

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