Measures of reliability and validity of school-based pedometer step counts in Singaporean children

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Abstract

The purpose of the study was to examine the reliability and validity of school-based pedometer step counts in Singaporean children. Participants were 10 boys and 10 girls aged 10-11 years old. School-based physical activity was monitored over a five-hour period using an electronic pedometer (PCB 147PDO) and a tri-axial accelerometer (RT3), fastened securely at the waist. Test-retest measurements of physical activity revealed no significant differences in step count (21.86.1 vs. 22.16.3 steps/min, $p>0.05$) and vector magnitude (580.470.9 vs. 581.189.4 vm/min, $p>0.05$). The girls' physical activity measurements were 77.5 % and 87.4 % that of boys'for pedometer and accelerometer readings. Typical error (TE) expressed as a coefficient of variation (CV) for repeated measurements were 9.6% for pedometry compared to 4% for accelerometry. Intra-class correlations (ICC) were 0.90 for step count and 0.92 for vector magnitude, while Bland and Altman plots showed a similar spread of activity readings for the pedometer and accelerometer. Significant correlations were established between accelerometer readings and pedometer readings ($r>0.75$, $p<0.05$). Data from the study showed that the electronic pedometer was a reliable and valid motion sensor for assessing the school-based physical activity of Singaporean children, using a variety of reliability indicators. With the reliability and validity of pedometers established, future research should focus on the efficacy of intervention programs to curtail sedentary behaviours and heighten the attractiveness of active behaviours in the context of school.

Key words : Step count, vector magnitude, children

Introduction

Considerable attention has been paid to the physical activity of children and adolescents in recent years (e.g. Armstrong, 1998; McManus, 2000). Physical activity is behaviour that involves any bodily movement, which results in energy expenditure above resting levels (Bouten, Westerterp, Verudin et al., 1994). Appropriate amounts of physical activity are linked to a reduced risk of premature death, heart disease, certain cancer forms, type 2 diabetes, hypertension and osteoporosis in adulthood (Haskell, 1994). Although the reduction of these disease risks in young people isless definitive, present pronouncements for the age- and developmentally-appropriate physical activity exposure among children and adolescents [i.e. accumulating 30-60 minutes of moderate-to-vigorous intensity physical activity daily; (Biddle, Sallis & Cavill, 1998) or accumulating 11 000-13 000 steps daily (Vincent & Pangrazi, 2002)] have come to the fore.

In order to quantify physical activity exposure among young people, objective methods are preferred to subjective ones (Armstrong, 1998). Ideally, theobjective device for assessing physical activity should have acceptable levels of reliability and validity, be feasible for measuring large groups of children, must be easy to administer and is low in cost. Motion detectors such as the uni-axial electronic pedometer and the tri-axial accelerometer provide objective quantification of physical activity exposure and are easily administered in a school setting.

Tri-axial accelerometers measure acceleration in the vertical, horizontal and medio-lateral planes (Freedson & Miller, 2000). Motion is stored as counts over a user specified time interval (i.e. per second or per minute) for each individual plane (i.e. x, y and z) and all planes combined (i.e. vector magnitude). Tri-axial accelerometers correlate highlywith oxygen uptake (Bouten et al., 1994), doubly labeled water (Bouten, Verboeket-Van de Venne, Westerterp et al., 1996) and heart rate methods (Rowlands, Eston & Ingledew, 1997) for measuring

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physical activity. The validity of the RT3 accelerometer (Stayhealthy Inc. Monrovia, CA) has been recently established for the assessment of children's physical activity (Rowlands & Philip, 2003). The researchers cited examined the validity of the RT3 accelerometer by making comparisons with measurements of physical activity taken by Tritrac tri-axial accelerometer, heart rate measurements and oxygen uptake during the last minute of seven different activities in 19 boys aged 9.5 years. The seven activities were: walking at 4- and 6 km/hr, running at 8- and 10 km/hr, playing hopscotch, playing a computer game and kicking a football to and fro.

Validity data for all activities combined for vector magnitude garnered by the Tritrac and RT3 accelerometers were r=0.86 and r=0.87 (both $p<0.01$), respectively, with measured oxygen uptake (VO_2). In the same study, vector magnitude derived from the RT3 accelerometer, combined with heart rate, was the best overall predictor of VO_2 consumed ($R^2=0.82$, $p<0.01$) during seven types of physical activities. The RT3 accelerometer is however relatively expensive costing about US$550 per unit compared to uni-axial electronic pedometers which cost about US$20 per piece. Bassett, Ainsworth, Leffett et al., 1996 reported that the Yamax Digiwalker was accurate for counting steps on concrete surfaces with 100.6±1.0 % and 100.7±1.5 % of actual steps recorded. However, the cited brand of pedometer is no longer in production.

A pedometer that is available in Singapore is the PCB 147PDO step counter. The reliability and validity of the electronic pedometer (PCB 147PDO) for use on Singaporean children within the school context is in need of investigation. This can be done by comparing the results of repeated physical activity measurements over two school days using the PCB 147PDO pedometer and the RT3 accelerometer simultaneously in the same group of participants. Previous data on activity measurements using an electronic pedometer (Yamax Digiwalker SW-200) and a tri-axial accelerometer (Tritrac-R3D T303) demonstrated correlations of r=0.98 for recreational physical activities (e.g. soccer, basketball, dodge ball and dancing) and r=0.50 for sedentary classroom activities (e.g. desk work, computer work and art work) (Kilanowski, Consalvi & Epstein, 1999). However, the study involved only seven boys and three girls aged between 7 and 10 years, who were involved in a summer day school program.

There is a need to establish population-specific reliability and validity for the electronic pedometer since the device is an unobtrusive, economical and objective measurement of physical activity among young people. Moreover, a greater number of boys and girls, than those in the cited literature (e.g. Kilanowski et al., 1999) should be involved in studies on the reliability and validity of the electronic pedometer. Additional research on the reliability and validity of using pedometry and accelerometry are also needed using longer measurement periods in children's natural environment (e.g. school life activities), rather than during brief and structured laboratory tasks.

In the exercise science literature, the appropriateness of using inter-class correlations for establishing the validity has been called to question, mainly because the outcome is influenced by the heterogeneity of the sample of participants (Bland & Altman, 1986), but results using the method continue to be reported. Statisticians have recommended alternative approaches to establishing validity of two measurement protocols such as the 95 % limits of agreement (Bland & Altman, 1986) or regression techniques (Hopkins, 2000). Nonetheless, because validity correlation coefficients using the inter-class technique continues to be reported (e.g. Kilanowski et al., 1999; McManus, 2000), it may be prudent to report inter-class correlation coefficients together withother recommended methods for assessing the validity of measuring tools. This will help to facilitate inter-study comparisons but will also help to advance appropriate statistical information about the reliability and validity of the electronic pedometer.

A variety of reliability indicators such as the change in the mean (cM), typical error (TE), the coefficient of variation (CV) and the intra-class correlation coefficients (ICC) (Hopkins, 20000) are proposed to provide more appropriate information about the reliability or reproducibility of measurements taken by an instrument. However, these indicators are scarcely reported for pedometer and accelerometer measurements. Hence the main purpose of the present study was to examine the reliability and validity of the electronic uni-axial pedometer in relation to that of the tri-axial accelerometer in a group of Singaporean children.

Materials and Methods

Participants

Participants were 10 boys and 10 girls who were randomly selected by the class teacher to be involved in the present study. These participants were drawn from a larger group of participants who were involved in a physical activity intervention study. A university human ethics board approved of all the data collection procedures and all participants gave informed assent for the study.

Data collection procedures

A university trained researcher was present in school during the data collection period (Tuesday and Wednesday; 1330-1730 hrs) and was responsible for the data collection. The five-hour periodof monitoring included a 30-minute recess period on both days and academic lessons in blocks of 30 minutes. Neither of the days monitored included physical education lessons.

Participants were issued with a pedometer and an accelerometer each and were given a 30-minute briefing on the functions of the instruments, familiarization and a hands-on session. Both pedometer and accelerometer were calibrated in the factory. During this period, participants where given the opportunity to satisfy their curiosity and find out how the pedometer and accelerometer worked. This was necessary to overcome any participant reactivity to the pedometer and accelerometer. Reactivity is explained as a change in normal physical activity patterns when participants are aware that their physical activity is being monitored (Kilanowski et al., 1999). In their study on 48 children, aged between seven and 12 years old, where pedometers were used to collect physical activity data over four days, the authors reported no reactivity to the use of pedometers. The pedometer and accelerometer were securely attached to the waistbands of the participants and were kept in line with the right and left knees, respectively. It was previously established among 16 children aged 7-8 years old that there was no significant difference in accelerometer readings in counts/min between the placements of the accelerometer at the hip or lower back (Nilsson Ekelund, Yngve et al., 2002).

Fairweather, Reily, Grant et al (1999) also reported little difference in accelerometer output between left and right hip placements in 11 four-year old pre-school children during a 45-minute class lesson. Encouraging results were also reported by Bassett et al (1996) where 20 adult participants, aged 18-65 years, wore two pedometers of the same brand on the right and left sides of the body during a 4.88 km walk. Results showed that no significant difference in step count accumulated between a pedometer of the same brand worn on the right or left side of the body.

Data collection commenced at 1330 hrs and ended at 1730 hrs, with the university trained researcher recording the step count and the vector magnitude achieved, respectively. Throughout the data collection period, participants adhered to the day's schedule for academic lessons. These involved mainly desk work activities. The school-based monitoring included a 30-minute recess period where participants were free to engage in play within the school premises. The same data collection procedure was repeated the following day. The total number of steps achieved at the end of the data collection was recorded and the vector magnitude, averaged over a minute was accessed and recorded by the university researcher. Data download and processing were carried in accordance to manufacturer's instructions for the accelerometer.

Statistical analyses

Data were stored and analysed using SPSS for Windows (SPSS Inc., Chicago, USA Version 11.5). Descriptive statistics (means SD) were computed by sex for age, body mass, stature, pedometer and accelerometer readings (i.e. steps/min and vector magnitude/min). Normality of distributions and homogeneity of variance for step count and vector magnitude readings were examined using the Shapiro-Wilks and Levene test statistic respectively. Sex differences were examined using one-way analysis of variance (ANOVA) and a 2X2 repeated measures analyses of variance (RM-ANOVA) were used to detect differences between two measurement periods for physical activity indicators (i.e. step count/min and vector magnitude/min)

Indicators of reliability computed were the change in the mean, typical error (TE) and coefficient of variation (CV) and intra-class correlation coefficient (ICC) for the pedometer and RT3 accelerometer. These statistical methods were conducted in accordance to the methods that were described by Hopkins (2000). Preliminary analyses of the data revealed that pedometer and accelerometer readings for Day 1 and Day 2 were not significantly different (paired sample t-tests statistics, -1.748; -0.096, respectively and both $p>0.05$), hence the Day 1 and Day 2 data were pooled for subsequent statistical analyses of reliability and validity.

The TE was computed by taking the difference in pedometer or accelerometer measurements in Day 1 and Day 2 for each participant, and dividing the standard deviations for the difference ($SD_{difference}$) by the square root of 2 (Hopkins, 2000). The TE was also expressed as a coefficient of variation (CV) in percentage terms. The validity of pedometer step counts was assessed by inter-class correlations (Pearson Product Moment and

Spearman's Rho) (Vincent & Pangrazi, 2002), and also by examining the relationship between pedometer output and accelerometer output. Statistical significance was accepted at $p<0.05$.

Results

Physical characteristics of the boys and girls

The physical characteristics of the participants are presented in Table 1. Boys and girls were not significantly different in age, body mass, stature or body mass index.

Table 1. Physical characteristics of the participants

Variable	Boys (N=10)	Girls (N=10)
Age (yrs)	10.8±0.4	10.7±0.5
Stature (m)	1.45±0.57	1.44±0.87
Body mass (kg)	35.6±7.1	39.5±11.5
Body mass index (BMI) (kg/m^2)	16.8±2.7	18.5±3.5

No significant differences ($p>0.05$) in male and female characteristics were detected

Step count (pedometer) and vector magnitude (accelerometer)

Complete data sets were obtained for pedometer and accelerometer readings for all participants. Step counts and vector magnitude achieved were divided by the total time of monitoring (i.e. five hours) and were expressed as steps/min and vector magnitude/min. Shapiro-Wilks test (statistic=0.23-0.33, $p>0.05$) and Levene test statistic (F= 0.12-0.26, $p>0.05$), showed that there was normality of distribution and homogeneity of variance in the pedometer and accelerometer data sets (pooled data of male and female subjects). Distribution characteristics of the same data sets for Skewness and Kurtosis statistics were 1.2±0.2 and 3.5±1.0 (mean±SE) for pedometer data and 0.59±0.14 and 0.96±0.09 for accelerometer data, respectively. The step counts and vector magnitude, garnered over two consecutive weekdays, are summarized in Figure 1 and Figure 2, respectively.

Day 1 and Day 2 pedometer readings (step count/min, SC) were not significantly different for boys and girls (SC, Pillai's Trace F=0.11, $p>0.05$; SCSex, Pillai's Trace F=0.12. $p>0.05$; partial eta squared=0.11), hence the data were pooled for subsequent statistical analyses. However, the step count/min of boys over the two days was significantly higher than that of girls (F=5.74, $p<0.05$; ES= 1.5)

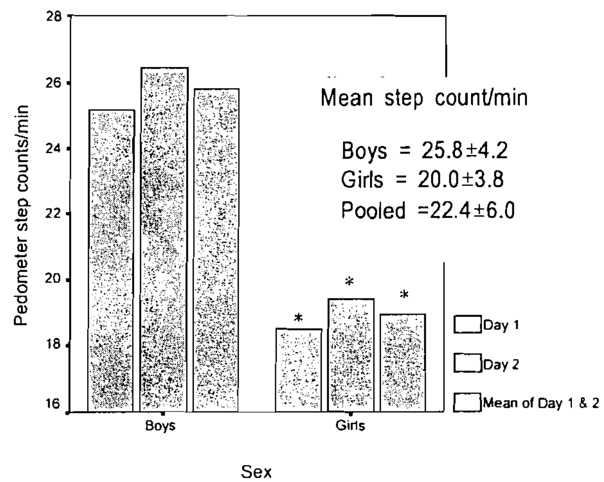

Figure 1. Pedometer step counts/min in boys and girls (N=40) over two days of monitoring in school. *Step count/min significantly greater ($p<0.05$) in boys than in girls.

Day 1 and Day 2 accelerometer readings (vector magnitude/min, VM) were not significantly different for boys and girls (VM, Pillai's Trace F=1.78, $p>0.05$; partial eta squared=0.11) hence the data were pooled for subsequent statistical analyses. However, the vector magnitude/min of boys over the two days was significantly higher than that of girls (F=4.72, $p<0.05$; ES=1.1)

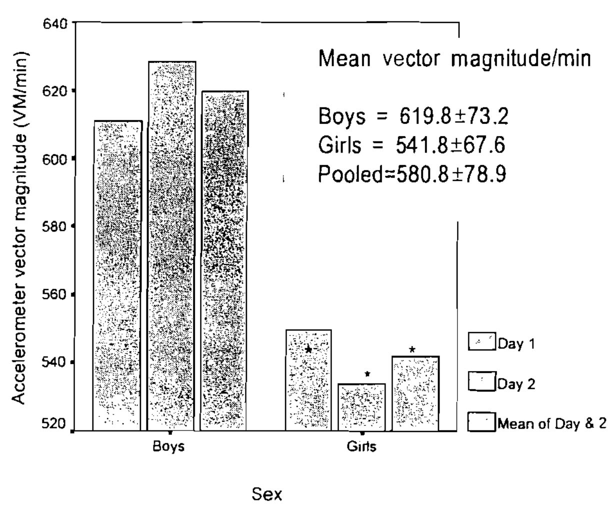

Figure 2. Accelerometer vector magnitude/min in boys and girls (N=40) over two days of monitoring in school. Vector magnitude/min was significantly greater ($p<0.05$) in boys than in girls.

Reliability indicators for pedometer and accelerometer measurements

Reliability was assessed using the change in the mean (cM), typical error (TE), coefficient of variation (CV) and

Table 2. Indicators of reliability for pedometer (PCB147PDO) and accelerometer (RT3)

Indicator of reliability	Pedometer reading (step count/min)	Accelerometer reading (vector magnitude/min)
Change in the mean (cM)	1.09 (0.01 to 2.16)	0.71 (-12.09-13.51)
Typical error (TE)	1.97 (1.56-2.70)	23.42 (18.59-32.09)
TE as coefficient of variation (CV)	9.6% (7.9-14.0%)	4% (3.2-5.7%)
Intra-class correlation coefficient (ICC)	0.90 (0.82-0.96)	0.92* (0.82-0.96)

Numerals in brackets are the 95% confidence limits. *Data are significantly different at $p<0.05$.

intra-class correlation coefficient (ICC), in accordance to the methods described by Hopkins (2000). Pooled data of boys and girls over the two days of school-based monitoring were used to derive the reliability indicators. The results are summarized in Table 2.

The typical error (TE) expressed as a coefficient of variation (CV) for the uni-axial electronic pedometer was higher than thatof the tri-axial accelerometer, but the intra-class correlation (ICC) coefficient was similarly high for the pedometer and the accelerometer.

Figure 3 shows the 95 % limits of agreement (i.e. Bland and Altman, 1986) for Day 1 and Day 2 pedometer and accelerometer readings. The plots showed that participants demonstrated considerable but equivalent variability in both pedometer and accelerometer readings over the two days of monitoring.

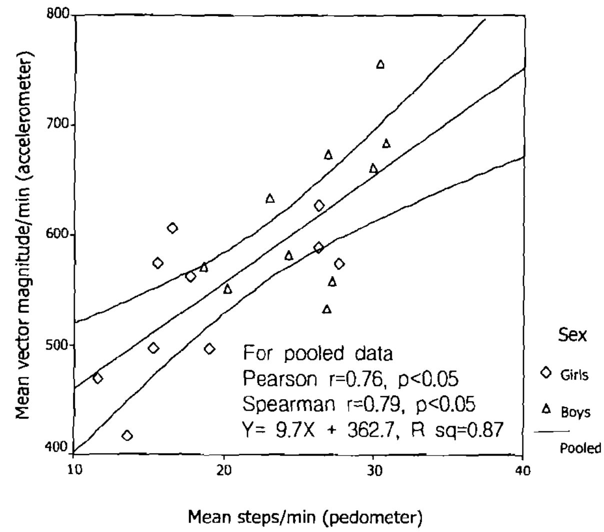

Figure 4. Relationship between accelerometer and pedometer readings in Singaporean children. The regression equation is given by Y (accelerometer reading in vector magnitude/min) = 9.7 X (pedometer reading in steps/min) + 362.7. The standard error of the estimate (SEE) is ± 54.2 vector magnitude/min.

Validity assessment of the pedometer

Figure 4 shows the validity of the pedometer by examining the relationship between step counts/minute (pedometer reading) and vector magnitude/min (accelerometer reading).

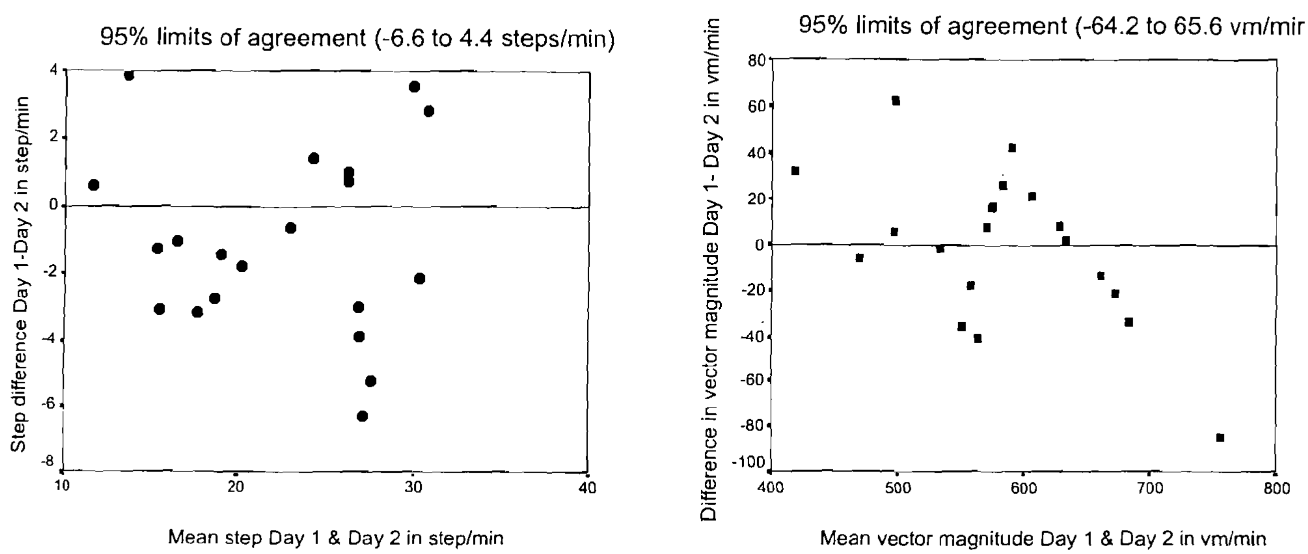

Figure 3. Bland and Altman plots for pedometer and accelerometer readings

Discussion

Data from the present study are apparently the first that have been conducted on Singaporean children using two objective simultaneous measurements of physical activity (i.e. uni-axial electronic pedometer and tri-axial accelerometer) albeit, there are some physical activity data of 110 children and adolescents, aged 9-14 years that were based on heart rate monitoring (e.g. Chia, Quek, Wang et al., 2003; Gilbey & Gilbey, 1995). In essence, the juxtaposed data showed that the physical activity of young people in Singapore did not meet international recommendations for adequate amounts of daily physical activity. These data mirror those reported on 50 Hong Kong children aged 7-12 years. (Rowlands, 1997), but it is noteworthy that different methodologies for assessing physical activity were employed across the studies.

The present study examined the reliability and validity of an electronic pedometer (model PCB 147PDO) in a sample of male and female children during school hours in Singapore. These data sets were unique in that reliability and validity studies are often focused on laboratory based activities such as walking or running at various treadmill speeds (e.g. Freedson & Miller, 2000), while the present study focused on reliability and validity of the activity monitors to assess school-based activities over two five-hour data collection periods over two consecutive days.

Indicators of reliability, specifically, change in the mean (cM), typical error (TE), co-efficient of variation (CV) and intra-class correlations (ICC) were computed and compared to that of a tri-axialaccelerometer (RT3). Importantly, the reliability measures were measured in the context of normal school-based activities, (i.e. academic lessons and recess time activity), thereby heightening the ecological validity of the study. These reliability measurements, according to Hopkins (2000), and Bland and Altman (1986) provide useful information to researchers about the reproducibility of using different measuring instruments.

A key result of the study was that the TE expressed as a CV was 9.6 % for pedometer measurement but was 4 % for accelerometer measurement in a test-retest situation. However, Bland and Altman plots for test-retest measurements of steps/min and vector magnitude/min revealed relative spread of readings that were similar for both activity monitors. Moreover, the ICC for the pedometer was 0.90, which compared favourably, with the ICC of 0.92 for the accelerometer.

Tudor-Locke and Myers (2001) reported that large day-to-day fluctuations in pedometer data may exist. They contended that suchspread of readings across two measurement periods are actually good since they reflect on the extreme sensitivity of pedometers to detect even small changes in ambulatory activity. Our present reliability data (i.e. ICC) for the pedometer compared favourably with those reported by Schonhofer, Ardes, Geibel et al. (1997) and Sieminski, Cowell, Montgomery et al. (1997). Both team of researchers examined the reliability of the pedometer in sedentary groups of participants (i.e. patients with pulmonary diseaseand patients with vascular disease) in a test-retest measurement period that was separated by one week. Data were reported as steps achieved on a daily basis, and they concluded that the step count device was reliable.

Juxtaposing the results of the two studies, the ICC ranged from 0.86 to 0.94. Since data in the present study were collected over five hours in the school day, barring a 30-minute recess time period, the rest of the time, participants were engaged in classroom activities which were mostly sedentary since pupils were sat behind desks, it appeared that the electronic pedometer and accelerometer had reasonable levels of reliability when measuring physical activity among sedentary groups.

This result contrasted with researchers who reported thatpedometers (Louie, Eston, Rowlands, et al., 1999) and accelerometers (Bouten et al., 1996) were less sensitive to low intensity sedentary activities. In the present study, a 30-minute recess period where children were free to engage in play activities (i.e. physical exertions higher than that for class-room based activities) could have contributed to the higher correlations obtained. These contrasting observations between studies could also be due to the different brands of pedometers and accelerometers used.

Correlations between pedometer and accelerometer measurements were significant and were in excess of 0.75. These were higher than the 0.5 r value reported for classroom-based activity but lower than the 0.98 r value reported for recreational activities(i.e. games and dancing) by Kilanowski et al. (1999). It should be noted that the results of inter-class correlation coefficients could be affected by the heterogeneity of sample response to physical activity (Bland & Altman, 1986) and that expressing the relationship between accelerometer measurement and pedometer measurement (i.e. in different units) is more appropriate (Hopkins, 2000).

Equivalent data in the extant literature are apparently non-existent and this precluded comparisons across studies. Future validation studies should include this information, together with the standard error of estimate of the regression equation so that researchers can make informed decisions about the acceptable levels of prediction errors (Vincent, 1995). In the present study, the authors found the SEE of ±54.2 vm/min of predicting accelerometer output from pedometer output to be acceptable for school-based research among Singaporean children.

Both pedometer and accelerometer data showed that boys achieved significantlyhigher readings than girls. Girls attained 77.5 % and 87.4 % of the physical activity readings attained by boys. These data are interesting in that the sex difference in physical activity was exacerbated when using pedometer data compared to accelerometerdata, despite having the two motion sensors attached securely to participants at the same time. One possible explanation is that the uni-axial pedometer is designed to register activity in the vertical plane while the tri-axial accelerometer registers movement activity from three planes. Precision may therefore be compromised when using the electronic pedometer. However this trade-off in precision is compensated by the economical cost of the pedometer compared to the tri-axial accelerometer. In the present study, the cost of the accelerometer was 60 times that of the pedometer.

There is ample evidence that boys are physically more active than girls during school-hours and outside of school hours in Singapore (e.g. Chia et al., 2003; Gilbey & Gilbey, 1995) and in many other developed countries in Asia and in the West (McManus, 2000). The present data affirmed the findings of earlier studies, albeit different methodologies to collecting physical activity data were used. Using pedometers and accelerometers, the effect sizes for the sex difference in physical activity were considerably small (ES=1.5 for pedometer and ES=1.1 for accelerometer). Notwithstanding that, more should be done in schools to encourage girls to be more physically active. One approach worthy of consideration is to make sedentary behaviours less attractive than engaging in physical activity. Further research is warranted to examine this form of 'intervention' in the context of schools in Singapore.

Conclusion

Data from the present study showed that the electronic uni-axial pedometer (PCB 147PDO) showed acceptable levels of reliability and validity in comparison to a previously validated tri-axial accelerometer (RT3) for school-based research among Singaporean children. With the reliability and validity of pedometer step counts established, future school-based research involving the electronic pedometer could include the efficacy of intervention programmes to curtail long periods of sedentary behaviour among children and at the same time heighten the attractiveness of physically active behaviours.

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References

Armstrong, N (1998). Young people's physical activity as assessed by heart rate monitoring. Journal of Sport Science, 16: S9-S16.

Bassett, DR, Ainsworth, BE, Leggett, SR et al (1996). Accuracy of five electronic pedometers for measuring distance walked. Medicine and Science in Sport and Exercise, 28: 1071-1077.

Biddle, S, Sallis, JF & Cavill, NA (1998). Young and Active? Young people and health enhancing physical activity: Evidence and implications. Health Education Authority. London.

Bland, JM & Altman, DG (1986). Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, 1: 307-310.

Bouten, CV, Verboeket-Van de Venne, WPHG, Westerterp, KR, et al (1996). Daily physical activity assessment: comparison between movement registration and doubly labelled water. Journal of Applied Physiology, 81: 1019-1026.

Bouten, CV, Westerterp, KR & Verduin, M et al (1994). Assessment of energy expenditure for physical activity using tri-axial accelerometer. Medicine and Science in Sport and Exercise, 26: 1516-1523.

Caspersen, CJ (1989). Physical activity epidemiology: concepts, methods, and applications to exercise science. Exercise and Sports Science Reviews, 17: 423-473.

Chia, M, Quek, JJ, Wang, J, et al (2003). The nexus of hours of computer use, physical activity and physical fitness of pupils in Singapore. National Institute of Education, Nanyang Technological University, Singapore. Pp.1-28.

Fairweather, SC, Reilly, JJ, Grant, S, Whittaker, A, et al

(1999). Using the computer science and applications (CSA) activity monitor in pre-school children. Pediatric Exercise Science, 11: 413-420.

Freedson, PS & Miller, K (2000). Objective monitoring of Physical activity using motion sensors and heart rate. Research Quarterly for Exercise and Sport, 71: 21-29.

Gilbey, H & Gilbey, M (1995). The physical activity of Singapore primary school children as estimated by heart rate monitoring. Pediatric Exercise Science, 7: 26-35.

Haskell, WL (1994). Health consequences of physical activity: understanding and challenges regarding dose-response. Medicine and Science in Sport and Exercise, 26: 649-660.

Hopkins, WG (2000). Measures of reliability in sports medicine and science. Sports Medicine, 30: 1-15.

Kilanowski, CK, Consalvi, AR & Epstein, LH (1999). Validation of an electronic pedometer for measurement of physical activity in children. Pediatric Exercise Science, 11: 63-68.

Louie, L, Eston, RG, Rowlands, AV, et al (1999). Validity of heart rate, pedometry and accelerometry for estimating energy cost of activity in Hong Kong Chinese boys. Pediatric Exercise Science, 11: 229-239.

McManus, a (2000). Physical activity in children: measurement and meaning. European Journal of Physical Education, 5: 133-146.

Nilsson, A, Ekelund, U, Yngve, A & Sjostrom, M (2002). Assessing physical activity among children with accelerometers using different time sampling intervals and placements. Pediatric Exercise Science, 14: 87-96.

Rowlands, AV & Philip, VM (2003). Comparison of the validity of the Tritrac and RT3 triaxial accelerometers for assessment of children's physical activity. Review Portuguese De Cinch Do Des, 3: 155.

Rowlands, AV, Eston, RG & Ingledew, DK (1997). Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. Sports Medicine, 24: 258-272.

Rowlands, AV, Eston, RG, Louie, L, et al (2002). Physical activity levels of Hong Kong Chinese children: relationship with body fat. Pediatric Exercise Science, 14: 286-296.

Schonhofer, B, Ardes, P, Geibel, M, et al (1997). Evaluation of a movement detector to measure daily activity in patients with chronic lung disease. European Respiration Journal, 10: 2814-2819.

Sieminski, DJ, Cowell, LL, Montgomery, PS, et al (1997). Physical activity monitoring in patients with peripheral arterial occlusive disease. Journal of Cardiopulmonary Rehabilitation, 17: 43-47.

Tudor-Locke, CE & Myers, IS (2001). Challenges and opportunities for measuring physical activity in sedentary adults. Sports Medicine, 31: 91-100.

Vincent, SD & Pangrazi, RP (2002). Does reactivity exist in children when measuring activity levels with pedometers? Pediatric Exercise Science, 14: 56-63.

Vincent, WJ (1995). Statistics in Kinesiology. Human Kinetics. Champaign, IL.

Welk, G (2002). Physical activity assessments for health-related research. Human Kinetics.