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Measurement of children's physical activity using a pedometer with a built-in memory

Georgina S.A. Trapp[a,*], Billie Giles-Corti[a,1], Max Bulsara[a,2], Hayley E. Christian[a], Anna F. Timperio[b], Gavin R. McCormack[a,3], Karen Villanueva[a]

[a] Centre for the Built Environment and Health, School of Population Health, The University of Western Australia, Australia
[b] Centre for Physical Activity and Nutrition Research, Deakin University, Australia

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ABSTRACT

Objectives: We evaluated the accuracy of the Accusplit AH120 pedometer (built-in memory) for recording step counts of children during treadmill walking against (1) observer counted steps and (2) concurrently measured steps using the previously validated Yamax Digiwalker SW-700 pedometer.
Design: This was a cross-sectional validation study performed under controlled settings.
Methods: Forty five 9–12-year-olds walked on treadmills at speeds of 42, 66 and 90 m/min to simulate slow, moderate and fast walking wearing Accusplit and Yamax pedometers concurrently on their right hip. Observer counted steps were captured by video camera and manually counted. Absolute value of percent error was calculated for each comparison. Bland–Altman plots were constructed to show the distribution of the individual (criterion-comparison) scores around zero.
Results: Both pedometers under-recorded observer counted steps at all three walk speeds. Absolute value of percent error was highest at the slowest walk speed (Accusplit = 46.9%; Yamax = 44.1%) and lowest at the fastest walk speed (Accusplit = 8.6%; Yamax = 8.9%). Bland–Altman plots showed high agreement between the pedometers for all three walk speeds.
Conclusions: Using pedometers with built-in memory capabilities eliminates the need for children to manually log step counts daily, potentially improving data accuracy and completeness. Step counts from the Accusplit (built-in memory) and Yamax (widely used) pedometers were comparable across all speeds, but their level of accuracy was dependent on walking pace. Pedometers should be used with caution in children as they significantly undercount steps, and this error is greatest at slower walk speeds.

1. Introduction

Self-report and recall methods of measuring physical activity are problematic in children because of a limited ability to accurately recall their behavior.[1,2] Pedometers (i.e., small, battery-powered mechanical devices that count steps) are a feasible method of objectively measuring children's physical activity derived from bipedal locomotion (e.g., walking, running, skipping and jumping). As a result, pedometers are widely used in physical activity research and guidelines based on steps are now being published.[3–5]

Yamax SW series pedometers (Yamax Corp., Tokyo, Japan) are widely used in research and have become the criterion pedometer against which others may be compared because of their consistent performance in studies of adults.[6–8] Biomechanically, children's walk patterns are less mature than that of adults due to maturational events like changes in body proportions, increases in muscular strength and postural control.[9] Moreover, children have higher variability in their walking and running stride frequency compared with adults.[10] Thus, the performance of the Yamax SW series in children is less clear. Five pedometer validation studies measuring children's physical activity in a controlled setting, using observer counted steps as the criterion, found that the Yamax Digiwalker SW-200 performed well at moderate and fast walk speeds; but undercounted steps by from 25%[11] to 100%[12] at lower speeds.[13–15]

* Corresponding author.
E-mail addresses: georgina.trapp@uwa.edu.au (G.S.A. Trapp), b.giles-corti@unimelb.edu.au (B. Giles-Corti), max.bulsara@nd.edu.au (M. Bulsara), Hayley.Christian@uwa.edu.au (H.E. Christian), anna.timperio@deakin.edu.au (A.F. Timperio), gmccorma@ucalgary.ca (G.R. McCormack), Karen.villanueva@uwa.edu.au (K. Villanueva).
[1] Formerly[a]. Present address: McCaughey Centre, School of Population Health, Level 5, 207 Bouverie Street, University of Melbourne, Victoria 3010, Australia.
[2] Formerly[a], School of Population Health, The University of Western Australia, M707, 35 Stirling Highway, Crawley, Western Australia 6009, Australia. Present address: Institute of Health and Rehabilitation, University of Notre Dame, 19 Mouat Street, P.O. Box 1225, Fremantle, Western Australia 6959, Australia.
[3] Formerly[a]. Present address: Population Health Intervention Research Centre, University of Calgary, 3rd Floor, TRW Building, 3280 Hospital Drive, N.W. Calgary, Alberta, Canada T2N 4Z6.

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In studies of children, other factors that may impact the validity and reliability of pedometer data relate to pedometer tilt angle,[16] being overweight,[12] and pedometer placement.[15] Data from a pilot study for the TRavel, Environment and Kids (TREK) project showed that children (n = 199, 10–12-year-olds) were unable to reliably record their daily pedometer steps in a diary. Issues encountered included missing data, failure to manually reset the pedometer to zero each morning, inaccurate recording of data in the diary (i.e., too many or too few digits) and illegible handwriting. Although this could be overcome by visiting child participants at school each morning and recording pedometer data from the previous day, this method is impractical, time consuming, costly (in terms of staff time to visit each school and class) and not feasible on weekends when children are at home.[14] Alternatively, recent pedometer models incorporate an internal clock and multiday memory function (e.g., New Lifestyles NL-2000, Accusplit AH120M9, and now the Yamax CW-700). The advantage that these pedometers have over conventional pedometers (e.g., Yamax SW-200) is that the in-built memory function allows step counts on weekdays and weekends to be analyzed separately and negates the need for either researcher or child to manually record step counts each day and to reset the pedometer.

Despite this new feature, to-date only one study has validated a built-in memory pedometer in children. This study of 85 children aged 5–7 and 9–11 years, found that the New Lifetstyles NL-2000 (New Lifestyles Inc., lee's Summit, MO) MDM pedometer offered similar accuracy and better precision than the widely used Yamax SW-200 pedometer.[16] The accuracy of the NL-2000 may be related to its piezo-electric (versus spring-levered) internal mechanism that makes it less susceptible to errors due to tilt.[17] However, the considerably higher cost of the NL 2000 (approximately twice as expensive as spring-levered pedometers) may preclude its use in large-scale studies, worksite wellness programs, school physical education and other health promotion programs with limited financial resources.[15] Further research validating the use of pedometers with built-in memory in children is required.

The purpose of this study was to evaluate the accuracy of the spring-levered Accusplit AH120M9 pedometer (built-in memory) for recording step counts of children during treadmill walking against (1) observer counted steps and (2) concurrently measured steps using the previously validated spring-levered Yamax Digiwalker SW-700 pedometer (note: the Yamax SW-700 uses the same spring loaded mechanism as the previously validated Yamax SW-200).

2. Methods

One TREK study primary school was invited to take part in this sub-study. The school was selected because of its high level of co-operation to the study team. Parents and children had signed informed consent forms to participate in the main TREK study. However, parents were also asked to complete and return an 'opt out' form if they did not want their child to participate in this sub-study, and children provided verbal consent prior to participation. This method of consent was chosen because of the non-sensitive nature of the study, the low risk to participants, and because parents and children had previously provided written consent to participate in TREK. It also aimed to maximize the number of participants and reduce non-participation bias.[18] The University of Western Australia (UWA) Human Research Ethics Committee (HREC) provided ethics approval for the TREK study overall and the sub-study, including the methods of consent used (RA/4/1/1394). Age and sex was determined from a child-report questionnaire. Basset and colleagues[8] suggest that a 10% error rate in pedometers is acceptable within a field setting. Therefore to detect a 90% level of agreement, a minimum sample size of 32 children was estimated to be required (each with three ratings: Accusplit step counts, Yamax step counts and observer counted steps) with 80% power and an alpha of 5%.[19] Children were selected at random to participate (49 in total). Data were collected in May 2008 during class time.

Children's weight status was calculated using objectively measured height and weight to compute body mass index (BMI, kg/m^2). All BMI estimates were collapsed into age and sex-specific weight categories (acceptable, overweight and obese) based on internationally recognized cut-off values.[20]

Three new spring-levered Accusplit AH120 (Accusplit, Inc., Livermore, CA, USA) (herein referred to as "Accusplit") pedometers and three new spring-levered Yamax Digiwalker SW-700 (Yamax Corp., Tokyo, Japan) pedometers were used. Prior to use, all pedometers were fitted with new batteries and checked for faults using two repetitions of a 20-step short-walk test.[21] Absolute error was no more than 1 step for each of the 10 pedometers tested. A purpose-made, firm, adjustable, elastic waistband holding two pedometers (i.e., one Accusplit and one Yamax) was placed around each child's waist. These waistbands were used to improve stability and reduce any undercounting caused by large pedometer tilt angles (≥10%).[16] Pedometers were positioned at the right hip (at the anterior superior iliac spine) in line with the front of each foot. Pedometers were proximal but not touching each other, with the Accusplit medial to the Yamax.

Two identical motorized treadmills (TMR-802) placed on a flat surface were used to conduct the walk sessions. To record observer counted steps, a video camera (placed perpendicular to each treadmill approximately 1.5 m away) filmed each participant's walk session from the waist down. Numbered ID cards facing the video cameras were used to identify children and walk speeds in the footage. Without shoes, participants were encouraged to walk for several minutes on the treadmill to become familiar with it. Children were then asked to walk normally for three walk sessions of 3 min at speeds of 42, 66 and 90 m/min (in this order). These speeds were chosen as they have been used in previous pedometer validation studies to simulate slow, moderate and fast walking in children and the speed at which children walk to and from school.[16,22] Each pedometer was set to "0" immediately prior to observation. At the completion of each walk speed, children were instructed to straddle the treadmill whilst pedometer steps were recorded and reset to zero. A break of approximately 2 min was given, during which the treadmill was left running and set to the next speed. Using the video footage, steps taken in each walk session were tallied twice by the same person using a hand counter. If step counts varied by ≥1 step then the footage was reviewed and tallied a third time.

Data for a total of 45 children were included in the study (four children were excluded because the child's clothing inhibited the correct placement of the pedometer belt). Absolute value of percent error (i.e., ((pedometer steps − observer counted steps)/observer counted steps) * 100) was calculated for each comparison according to the procedures described elsewhere.[6] Descriptive statistics were obtained for all demographic and anthropometric variables. Paired samples t-tests were used to compare mean raw error scores and mean absolute value of percent error scores. A one-sample t-test was used to compare mean absolute value of percent error scores to a test value of zero. Independent samples t-tests were used to examine the difference between absolute value of percent error scores according to sex, age and weight status. Bland–Altman plots[23] were constructed to show the distribution of the individual (criterion-comparison) scores around zero. This is a standard method to compare estimates from biomedical devices.[24]