Original Research

Validation of Omron™ Pedometers Using MTI Accelerometers for Use with Children

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ABSTRACT

International Journal of Exercise Science 6(2) : 106-113, 2013. The MTI accelerometer is highly regarded as a reliable means to measure physical activity in children (Trost et. al., 1998); however, it is not always a practical instrument to use. Pedometers offer an alternative method of activity measurement and are often more practical. PURPOSE: To validate Omron™ pedometer (steps/day) against MTI accelerometer (counts /day and moderate to vigorous physical activity (MVPA) min/day) for children. METHODS: 190 children (88 males, 102 females, 8.7±2.1 yrs, 76.9±27.5 BMI %tile) wore an MTI accelerometer and Omron™ pedometer attached to the same belt for 3.9±2.2 days. MVPA was defined as movement ≥4 METs (Troiano et al., 2008). A Pearson correlation coefficient was used to determine validity coefficients between Omron™ steps/day and MTI accelerometer MVPA min/day and counts/day. A stepwise regression was used to predict MVPA using Omron steps/day, sex, and age with 488 days of data. Cross-validation and paired t-tests were used to determine differences from predicted MVPA and actual MVPA. RESULTS: The correlations between Omron™ steps/day with both MTI counts/day and MTI MVPA min/day were $r=0.79$, $p<0.05$ and $r=0.74$, $p<0.05$ respectively. The model generated from the multiple regression equation accounted for 67% of the variance ($r^2 = 0.6689$, SEE = 24.5) in MVPA, MVPA = 67.99 + 0.0068(steps/day) + -7.531(age in years) + 5.559(sex). CONCLUSION: Our validation correlations between the Omron™ pedometer and MTI accelerometer were acceptable The results indicate that the Omron pedometer can be used to estimate MVPA minutes and could serve as a useful alternative to accelerometry for those with limited resources or in practical situations.

KEY WORDS: Physical activity, pediatrics, weight loss

INTRODUCTION

An increasingly high percentage of today's youth are not meeting the current physical activity (PA) guidelines that highlight the importance of maintaining a physically active lifestyle. Physical inactivity is associated with many health disparities including an increasingly high percentage of overweight and obese children (23, 21). Physical activity is recommended to improve health and to reduce the risk of several diseases including cardiovascular disease, type II diabetes, osteoporosis, obesity, and certain types of cancer (5). Studies have shown that the onset of obesity (21), cardiovascular disease (4), and various chronic disease risk factors (8) have origins early in life. Hence, there is a definite need to understand the factors that influence physical activity among children and adolescents.

Identifying an affordable, reliable, valid, and feasible tool to measure physical activity among children has become a necessity in the effort to increase physical activity among children (32). Accelerometers are one of the most commonly used methods for assessing free living physical activity (7, 36) and they have been validated as a reliable means to estimate energy expenditure during activities of daily living in children (9, 11, 19). However, the affordability of many accelerometers ($200 to $500 per unit) makes it impractical for large-scale applications and their use requires technical expertise along with additional software for processing (36). The use of pedometers has gained popularity as motivational devices for increasing physical activity levels (31, 14). These devices are often both affordable ($5 to $100 per unit) and relatively easy to use. Most electronic pedometers in today's market contain a horizontal, spring-suspended lever arm that deflects with vertical acceleration of the hips during ambulation. Each step opens and closes an electrical circuit and an accumulated step count is displayed digitally (31).

A review of adults (35) compared the validity of the Actigraph accelerometer and Omron™ pedometer in free-living conditions and found a 25.8% error when comparing steps to steps. A previous study (14) in children examined the difference between Omron steps/day and Actigraph steps/day and found a comparable measure of mean steps (M absolute delta = 431). Another study in children compared a pedometer to the Actigraph accelerometer to determine an average daily step count comparable to the 60 minutes of moderate-to-vigorous physical activity (MVPA) (9). However, no studies have attempted to formulate an equation that predicts an estimated amount of minutes in MVPA using pedometer step counts.

This study aims to test the concurrent validity of the Omron™ pedometer and Actigraph accelerometer and then determine if pedometer steps per day can be used to predict moderate to vigorous physical activity (min/day)(MVPA) for children. The study will produce a prediction equation that uses Omron pedometer steps per day to estimate MVPA from Actigraph accelerometry counts converted to MVPA.

METHODS

Participants

The data used in this study were obtained from participants in ongoing studies that were also measuring physical activity by use of the Actigraph accelerometer. These studies included a family based weight loss program, an elementary school physical education program, and a classroom physical activity intervention program. Data were collected from 190 children (age = 8.7 ± 2.1 years, BMI%tile = 76.9 ± 27.5) including 78 normal weight, 42 overweight, and 70 obese children (88 males, 102 females). BMI percentiles were determined by the method established by Center for Disease Control and Prevention (CDC, Atlanta, GA, 2012). Written consent was provided by the parents/guardians and assent was documented by the child prior to participation and the study was approved by the University of Nebraska Kearney Institutional Review Board.

Protocol

Devices: Accelerometers are electronic devices that measure accelerations produced by body movement by using piezoelectric transducers and microprocessors that convert recorded accelerations to a quantifiable digital signals referred to as “counts”. Counts can be entered into independently developed prediction equations for estimation of time spent in light, moderate, and vigorous physical activity (29). Most accelerometers have the ability to store data up to 30 days and be downloaded to a computer for processing (40).

The Actigraph accelerometer (MTI Model 7164; Actigraph, Fort Walton Beach, FL) has been used in a number of studies involving children (9, 36). It is a uniaxial accelerometer that measures acceleration in the vertical plane; it is small (5.08 X 4.06 X 1.52 cm), light (42.52 g), and unobtrusive. Its acceleration signal is filtered by an analog band-pass filter and digitized by an 8-bit A/D converter at a sampling rate of 10 samples per second (2, 16).

A review by Tudor-Locke et al (35), found that multiple studies have validated a variety of pedometers against accelerometers including the Actigraph model. Omron Healthcare (Kyoko City, Japan) developed an electronic pedometer that is marketed to be worn at different sites on and off the body. The HJ-720ITC model features dual sensors, thus offering mid-back, right pocket, and left pocket positions as well as an off-the-body backpack wearing option.

Program: Participants wore a MTI accelerometer (GT1M; Actigraph, Fort Walton Beach, FL) and Omron™ pedometer(Model HJ-720ITC, Omron Healthcare, Kyoko City, Japan) attached to the same belt for 3.9 ± 2.2 days. A wear time validation was performed using a SAS program to exclude insufficient data. For data to be included, both devices had to be worn for a minimum of 8 hours per day (minutes having zero accelerometer counts indicated non-wear time) between 7am and 9pm for at least 2 separate days over the course of one week’s time (30). The accelerometers were attached snugly to the hip at the waist line directly above the patella. This location was based on instructions given by the accelerometer’s producer Manufacturing Technology, Inc (Pensacola, FL). The pedometer was placed in a pouch to ensure that it remained securely attached to the same belt that held the accelerometer. Both the accelerometer and the pedometer were worn on the same hip at the same time.

All accelerometers were programmed to start collecting data on midnight of the day following delivery. Both devices were synced using the same computer clock. Upon return of the devices, data were downloaded and data from the MTI accelerometers were analyzed with the Actigraph software version 5.5. Data were collected in 15 second epochs based on previous research showing children tend to perform physical activity in short bursts rather than in prolonged bouts (1). The counts registered by the accelerometer were inserted into an equation developed by Trost et al. (28) that converts counts to METs specifically for children [METs = -2.23 + 0.0008 (counts per minute) + 0.08 (body mass (kg)]. MVPA was then defined as any movement ≥4 METs (26). The Omron™ pedometer data was downloaded using Omron™ software version 1.3 for total steps per day.

Statistical Analysis

Daily minutes of MVPA and counts per day from the accelerometers and steps per day from the pedometers were analyzed using by the Statistical Analysis System (SAS) program developed by SAS Institute Inc. (Cary, NC). The total number of valid days for all 190 participants with each day containing pedometer steps, accelerometer counts, and MVPA (n=732 days) were randomly divided into two groups: 66% of the days were assigned to a validation group (n=488) and 33% of the days were assigned a cross-validation group (n=244). Using the validation group data, partial Pearson correlation coefficients, adjusting for age were calculated between Omron™ steps/day and MTI accelerometer MVPA min/day and counts/day. A stepwise regression analysis was used to predict MVPA (min/day) from Omron™ steps per day, sex, and age. Sex and age were used because the currently recommended daily step counts for children are determined by sex and age (37). Sex is entered into the equation as 1 for males and 0 for females. The data from the cross-validation group was then used to cross-validate the prediction equation. Paired t-tests were used to determine differences between predicted MVPA and actual MVPA from the accelerometer for each individual day. Bland Altman plots were used to examine the individual agreement across the range of physical activity levels. In these plots, the difference between estimates (criterion-comparison) was plotted on the y-axis while the mean of the estimates ((criterion + comparison)/2) was plotted on the x-axis. Confidence intervals defining the limits of agreement were established as ± 2 standard deviations from the mean difference (6).

RESULTS

Descriptive characteristics including age, BMI ($kg \cdot m^{-2}$), BMI percentile, and activity level can be found in Table 1.

Table 1. Descriptive characteristics including physical activity measures.

Variable	Measure
N	190
Age (yrs)	8.7 ± 2.1
BMI (kg/m^2)	20.4 ± 4.9
BMI Percentile	76.9 ± 27.5
Steps/day	8701 ± 4271
MVPA min/day	62.9 ± 44.3
Counts/day	357386 ± 185627
Average wear time (days)	3.9 ± 2.2

BMI Percentile based on Centers for Disease Control child and adolescent BMI model calculated with age and gender, Steps/day from Omron™ pedometer, MVPA: Moderate to vigorous physical activity from MTI accelerometer Counts/day, MVPA and Counts/day from MTI accelerometer

Pearson correlation coefficients between Omron™ steps/day and MTI MVPA min/day and counts/day were $r = 0.76$ ($p<0.0001$) and $r = 0.79$ ($p<0.0001$) respectively.

Multiple regressions using validation groups produced a prediction equation to estimate MVPA using steps per day, age, and sex. This model accounted for 67% of variance in MVPA ($R^2 = 0.6689$, SEE = 24.5 min/day).

$$\text{MVPA min/day} = 67.99 + 0.0068(\text{steps/day}) + -7.531(\text{age in years}) + 5.559(\text{sex})$$

The data from the cross validation group was then entered into the prediction equation and results were compared to

MVPA from actual recorded MTI accelerometer data. The average MVPA from accelerometry was found to be 67.02 ± 47.54 min/day and the predicted MVPA generated from our prediction equation was calculated to be 63.69 ± 35.73 min/day with a difference of 3.32 ± 28.26 min/day. Bland-Altman plot was used to examine the distribution of error for estimation of time spent in PA (Figure 1). The patterns did not exhibit any systemic form of bias, but the relationships were tighter when the minutes of MVPA were lower. The graph also shows that as the minutes of MVPA increased there was considerable variability, in some cases as much as a 50 min differential from the mean. The overall SEE was 24.5 minutes.

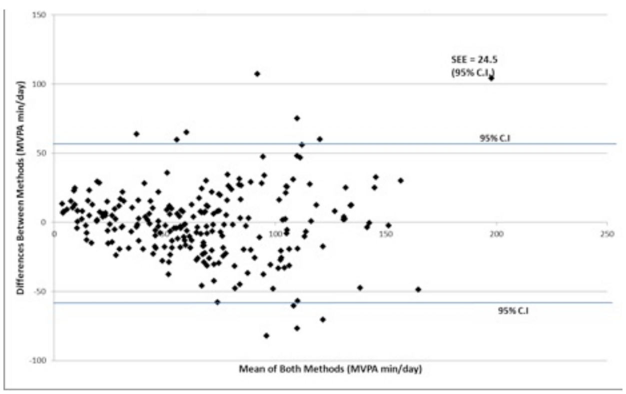

Figure 1. Bland-Altman plot comparing accuracy of prediction across the range of scores for the Omron ™ pedometer and MTI accelerometer (difference = estimated predicted).

This plot is displaying the difference between each method of calculating MVPA (MTI accelerometer and Omron pedometer) on the y axis and the mean of each method on the x axis.

DISCUSSION

One behavioral mechanism for encouraging children to be physically active is measurement of daily physical activity using a reliable and affordable method (25). Due to the limitations of self-reported physical activity, direct observation, and accelerometry, pedometer based measures appear to be a reliable and affordable technique to quantify physical activity in children. A study by Tudor-Locke et al. (35) on the convergent validity of pedometers and accelerometers (specifically uniaxial accelerometers) that included a wide array of devices found a median correlation value of r = 0.86 with the range varying from nonsignificant to r = 0.99 depending on the instruments used, epoch length, and the manner in which the outputs are expressed. Our results suggest that within limitations, Omron™ pedometers can provide a rough estimate of daily physical activity in children and predict MVPA compared to the widely validated MTI accelerometer. The large standard deviations and SEE could be related to the data being collected from a group of relatively inactive children in a weight loss intervention and a generalized mix of elementary school aged children.

Other studies found similar results when comparing pedometers and accelerometers in both adults and children. Kilanowski et al. (14) found a high correlation (r = 0.98, p < 0.001) during the recreation time of 10 children aged 7-12 yrs and a correlation of r = 0.50, p = 0.41 during their classroom time. Another study comparing the MTI counts/day and the Yamax Digiwalker 500 steps/day during free-living activities found a correlation of r = 0.84 in adults (19). Our evidence, combined with evidence from previous studies, indicates that the output of pedometers is correlated with the output of accelerometers in free-living conditions when both devices' output is expressed as raw data (i.e. steps/day, counts/day, etc.) (30). However, our study goes one step further to estimate minutes of moderate-to-vigorous physical activity based on step counts.

The findings of this study indicate that the Omron pedometer has concurrent validity with the Actigraph accelerometer when compared to studies of a similar nature (r^2 = 0.6689, SEE = 24.5). This helps to strengthen the prediction equation used to predict MVPA using steps/day. Currently the most practical and quantitative method of measuring MVPA is by use of research grade accelerometers that are often expensive and unavailable to the general public. Organizations such as ACSM and the CDC have produced physical activity recommendations for the general public based on minutes of moderate-to- vigorous physical activity. Therefore, having an equation that can predict MVPA using widely available pedometers may result in better application of step data to determine levels of physical activity.

The outliers in the data indicated that in a few cases when a particular child achieved substantially more or less estimated daily MVPA than the average daily MVPA found in this study, the equation may incorrectly predict a child's MVPA. However, the outliers were included in the Pearson correlations so therefore the equation is still noteworthy. Future studies should examine these extreme cases further. It should also be noted that the authors of this paper associated a higher daily step count to more daily MVPA, not more wear time.

This study had certain limitations. All the participants used in this study were from a rural Midwestern location (population: 30,000). The Omron™ pedometer used in this study was not cross-validated against any other acceptable means of measurement. Another limitation of the current study is the inability of either step counters or accelerometers to account for non-ambulatory movements such as swimming and cycling (18). The newest version of the Actigraph accelerometer was not used in this study, however, a previous study found no significant difference between the GT1M, GT3X, and GT3X+ when worn by children in free-living conditions (38). Each individual accelerometer and pedometer was not cross-checked to be sure each instrument was performing similarly. Future studies should analyze this pedometer against other measurements of energy expenditure including indirect calorimetry, heart rate/breathing rate, and VO2 levels to obtain a better validation. Strengths of this study included a large sample size, an average wear time of at least two full days for all participants, and the ability to sync the devices by time to ensure each is measuring the same instances.

Our data suggests that MVPA min/day can be estimated, with some variability, with the use of a cost efficient, research grade pedometer in children. With the ever changing technological advancements making better and cheaper products in today's society, the use of activity monitors (primarily pedometers) has become very popular for use in interventions and weight loss programs for children (3). The ability to estimate MVPA min/day from steps/day can lead to better physical activity assessment and expanded data collection possibilities in large populations. More importantly, our findings support widespread use of pedometry and the ability to convert the data they record (steps per day) into a more meaningful unit of measure (estimated MVPA) for those with limited resources and in practical situations.

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