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Original research

Validation of the Fitbit One activity monitor device during treadmill walking

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ABSTRACT

Objectives: In order to quantify the effects of physical activity such as walking on chronic disease, accurate measurement of physical activity is needed. The objective of this study was to determine the validity and reliability of a new activity monitor, the Fitbit One, in a population of healthy adults.
Design: Cross-sectional study.
Methods: Thirty healthy adults ambulated at 5 different speeds (0.90, 1.12, 1.33, 1.54, 1.78 m/s) on a treadmill while wearing three Fitbit One activity monitors (two on the hips and one in the pocket). The order of each speed condition was randomized. Fitbit One step count output was compared to observer counts and distance output was compared to the calibrated treadmill output. Two-way repeated measures ANOVA, concordance correlation coefficients, and Bland and Altman plots were used to assess validity and intra-class correlation coefficients (ICC) were used to assess reliability.
Results: No significant differences were noted between Fitbit One step count outputs and observer counts, and concordance was substantial (0.97–1.00). Inter-device reliability of the step count was high for all walking speeds (ICC $\geq$ 0.95). Percent relative error was less than 1.3%. The distance output of the Fitbit One activity monitors was significantly different from the criterion values for each monitor at all speeds ($P < 0.001$) and exhibited poor concordance (0.0–0.05). Inter-device reliability was excellent for all treadmill speeds (ICC $\geq$ 0.90). Percent relative error was high (up to 39.6%).
Conclusions: The Fitbit One activity monitors are valid and reliable devices for measuring step counts in healthy young adults. The distance output of the monitors is inaccurate and should be noted with caution.

1. Introduction

Sedentary behaviour is a strong risk factor for obesity, which in turn increases the risk of chronic diseases (for example, cardiovascular disease and cancer[1,2]), disability, and death.[3] Increasing physical activity levels have been recognized as an important method of prevention and treatment for chronic disease and quality of life. Many governments recommend a minimum level of physical activity per week for healthy living, including activities such as brisk walking.[4]

In order to quantify the effects of physical activity such as walking on chronic disease, an accurate measurement of the amount of physical activity is needed. Activity monitors such as pedometers are popular tools used by clinicians and patients to measure physical activity because they provide an objective measure of step counts or distance walked, and are simple to use and inexpensive. However, many activity monitors do not accurately estimate physical activity levels,[5] particularly at low walking speeds.[6] Given that older adults and those with musculoskeletal or neurological impairment often walk at a slower pace than younger individuals, this may result in inaccurate measurement of physical activity in these at-risk populations. Inaccurate measures of physical activity levels can affect the ability to monitor health status and adherence to physical activity prescriptions during treatment. Therefore, to ensure applicability across age groups and patient populations, it is critical to assess the validity of an activity monitor at multiple speeds prior to use.

Assessment of activity monitors in multiple positions of wear is also necessary. Individuals can choose to wear the activity monitor in different placements on the body, including on the hip or in a pocket. Device placement may affect the accuracy of the activity monitor. For instance, in one study assessing pedometer validity, the percent error produced by placing the pedometer in the pants pocket was nearly five times greater than the error from wearing the pedometer on the hip (5.8% compared to 1.2%).[7] Thus, when

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assessing the validity of an activity monitor, multiple placements of the device should be used in addition to multiple speeds to increase the generalizability of the findings.

A new lightweight, portable activity monitor that contains a triaxial accelerometer has been made commercially available. The device claims to track multiple measures of physical activity – including step count and distance travelled – and to have the ability to upload activity data wirelessly to a website in order to track activity levels over time. The advantage of wireless data uploads allowing real-time data connectivity may be an attractive feature to researchers and patients alike for tracking physical activity such as walking. To date, no research on the validity or reliability of this device exists. Accordingly, validation of this new activity monitor is needed to verify its use as a measure of physical activity.

Thus, the purpose of this study was to assess the validity and reliability of the step count and distance outputs of a new activity monitor in a population of healthy adults during treadmill walking at multiple speeds and placements of wear.

2. Methods

The validity of the Fitbit One (Fitbit Inc., San Francisco, CA) step counter and distance monitor was assessed during a single session of treadmill walking, using methods similar to previous activity monitor validation studies.[8–10] Participants walked at five predetermined speeds on a treadmill with two independent observers analyzing step count using motion analysis. Observer step count was considered the criterion measure for steps and treadmill distance output was considered the criterion for distance travelled.

Interested volunteers with the ability to ambulate continuously on a treadmill unaided for 30 min were recruited from the university community. Exclusion criteria consisted of any neurological disorder, cognitive disorder, recent musculoskeletal injury or surgery that would impair motor function. Informed consent was obtained from all participants after explanation of possible risks and benefits associated with the experimental procedure. Ethics approval was obtained from the institutional Clinical Research Ethics Board. Previous studies of the correlation of activity monitor output to observed step counts range from 0.5 to 1.0.[6] Based on the most conservative findings (correlation of 0.5), $\alpha = 0.05$, and a power of 0.80, a priori sample size was calculated as 28 participants.

The Fitbit One is a small device (4.8 cm × 1.9 cm × 1.0 cm) weighing 8 g. The Fitbit One has a microelectromechanical triaxial accelerometer that converts acceleration to step counts using proprietary algorithms. The manufacturer claims the device can be worn in multiple ways without compromising the accuracy of the activity monitor, including on the hip and in the front pocket of pants or shorts. The Fitbit One can summarize step counts and distance travelled daily for the previous month. Previous data can be stored online on a password protected website via a user login. The device syncs wirelessly if it is placed within 6 m of an active USB dongle.

Participant demographic and biomechanical data were collected during a single testing session. Demographic data included age, height, mass, and dominant leg (defined as the leg the participant would kick a ball with). Twenty-two passive reflective markers were placed bilaterally on participants according to a modified Helen Hayes marker set.[11] Height, mass and gender data were entered into the Fitbit account for each participant and synced with the Fitbit One activity monitors prior to testing of each participant.

Participants were instructed in the use of the treadmill prior to the start of the protocol. Participants were first given 5 min of familiarization with treadmill walking on the calibrated treadmill. Three Fitbit One activity monitors were then placed on the participant: one on the waistband at each hip inferior to the anterior superior iliac spine (marked with reflective markers), and a third monitor in the front pocket of the dominant leg. Participants then walked at five randomly presented speeds (0.90, 1.12, 1.33, 1.54, and 1.78 m/s) for 5 min at each speed, in line with previous protocols.[6,10] Participants were given a 5 s warning before the end of each walking trial, and stopped walking after 5 min at each speed. Participants were given adequate rest between each speed condition, during which time the step count and distance on each Fitbit One were recorded. Distance was determined based on the calibrated treadmill output (displayed on the electronic output of the treadmill in miles, based on the speed of the treadmill belt and time for each revolution of the belt). Upon initiation of each trial, the distance output of the treadmill was reset and the final output after each trial recorded. This value was then converted to kilometres. Step count data were collected using an eight-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA) sampling at 120 Hz for the duration of each 5 min speed condition, with collection started prior to the start of each treadmill trial in order to accurately capture all steps. Step count data were independently analyzed by two observers, who manually counted step number offline after testing using the video motion capture data. Step count was re-analyzed if observers were not in agreement. These criterion measures were compared to the Fitbit One output, calculated as the difference between the Fitbit One display prior to and immediately after each speed condition.

Validity of the Fitbit One was assessed three different ways. First, two-factor repeated measures ANOVAs (count × speed) were used to compare the Fitbit One output with manual step count and treadmill distance data. Significant differences were explored using post hoc pairwise comparisons with Bonferroni correction at $p < 0.017$. Sphericity was evaluated using Mauchly's test, where $p < 0.05$ is indicative of violation of this principle. Second, concordance correlation coefficients were calculated to further assess criterion validity. Concordance > 0.95 was considered an acceptable level of agreement.[12] Finally, Bland and Altman plots were constructed to visually inspect the data and to assess agreement with the criterion measures. The percent relative error of the Fitbit One activity monitor step counts was also calculated, in order to facilitate comparison with previous activity monitors studied. Percent relative error was calculated by:

$$\text{Percent relative error} = \left[\frac{|\text{fitbit output} - \text{observer count}|}{\text{observer count}}\right] \times 100$$

Inter-device reliability of the Fitbit devices was calculated using intra-class correlation coefficients ($ICC_{2,k}$), using a two-way random effects model with absolute agreement. An ICC > 0.8 was considered an acceptable level of agreement.[13] All statistical analyses were conducted using SPSS v20.0.0.

3. Results

Thirty (15 males) volunteers (mean (SD) age 29.6 (5.7) years, BMI 22.7(3.0) kg/m^2) participated. All were right leg dominant. Mauchly's test indicated no violation of sphericity ($p > 0.05$) for step count. The step count function of the Fitbit One activity monitors was deemed valid, with no significant difference ($p > 0.05$) in step counts between the observed values and either of the placements at all treadmill speeds. Concordance correlation coefficients ranged from 0.97 to 1.00, suggestive of substantial agreement. Bland and Altman plots for the slowest and fastest walking speeds are provided in Fig. 1. There was no apparent systematic bias based on step count number, and most data points fell within the 95% limits of agreement. The percent relative error of each Fitbit One was less than 1.3% for all treadmill speeds (Fig. 2a). All three Fitbit One activity monitors demonstrated excellent inter-device reliability ($ICC \geq 0.95$) at all speeds (Table 1).