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Original article

Effect of walking speed and placement position interactions in determining the accuracy of various newer pedometers

Wonil Park, Victor J. Lee, Byungmo Ku, Hirofumi Tanaka*

Department of Kinesiology and Health Education, University of Texas at Austin, Austin, TX 78712, USA

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Abstract

Older types of pedometers had varied levels of accuracy, which ranged from 0% to 45%. In addition, to obtain accurate results, it was also necessary to position them in a certain way. By contrast, newer models can be placed anywhere on the body; however, their accuracy is unknown when they are placed at different body sites. We determined the accuracy of various newer pedometers under controlled laboratory and free walking conditions. A total of 40 participants, who varied widely in age and body mass index, were recruited for the study. The numbers of steps recorded using five different pedometers placed at the waist, the chest, in a pocket, and on an armband were compared against those counted with a hand tally counter. With the exception of one, all the pedometers were accurate at moderate walking speeds, irrespective of their placement on the body. However, the accuracy tended to decrease at slower and faster walking speeds, especially when the pedometers were worn in the pockets or kept in the purse ($p < 0.05$). In conclusion, most pedometers examined were accurate when they were placed at the waist, chest, and armband irrespective of the walking speed or terrain. However, some pedometers had reduced accuracy when they were kept in a pocket or placed in a purse, especially at a slower and faster walking speeds.

Keywords: Aerobic exercise; Energy expenditure; Physical activity; Walking steps

Introduction

Regular physical activity (PA) is critical in maintaining and enhancing physical fitness and cardiovascular and metabolic health.[1] Despite this fact, more than half of US adults do not accumulate enough PA.[2] Pedometers are increasingly used as a convenient way to quantify PA levels because they provide an accurate and objective method of monitoring and recording walking and other ambulatory activities.[3–5] Some pedometers also provide comprehensive feedback that can estimate distance traveled and calorie expenditure.[6] Interestingly, wearing a pedometer and setting a step goal motivates individuals to increase their PA,[4] and indeed pedometers have been shown to be effective in increasing PA in previously sedentary adults.[2] The Japanese Industrial Standards recommend that adults should walk at least 10,000 steps a day for maintaining optimal health.[7] However, the goal of achieving and sustaining 10,000 steps/day may not be possible for some groups including the elderly people and patients with chronic diseases.[8] Accordingly, some alternatives such as <5000 steps/day as a sedentary lifestyle index and >10,000 steps/day to classify individuals as active have been proposed.[8]

There are a number of different types of pedometers with regard to internal mechanism. Spring-suspended horizontal lever-arm pedometers move the lever up and down in response to trunk vertical displacement. A glass-enclosed magnetic reed proximity switch uses a spring lever arm, but uses a magnetic field to count a step. Pedometers with a piezoelectric crystal use mechanical force from body movement to generate electrical charge for counting steps.[6,9] A previous study[10] reported that a piezoelectric pedometer counts steps more accurately

* Corresponding author. Department of Kinesiology and Health Education, University of Texas at Austin, Austin, TX 78712, USA.
E-mail address: htanaka@austin.utexas.edu (H. Tanaka).

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than a spring-levered pedometer for overweight and obese individuals, particularly at slower walking speeds. Since then, a wide variety of newer pedometers have been emerging in the market and a number of options, including three-dimensional accelerometers and smart phone interfaces, have been incorporated. However, the accuracy of these newer pedometers is not clear. In addition, technological advances allowed users to place the pedometers in many convenient locations (e.g., in a pocket, on a lanyard), but it is not known whether the placement of pedometers in various locations would cause any differences in their accuracy.

Accordingly, the primary aim of this study was to determine the accuracy of various newer pedometers in the market worn at different locations of the body and at different walking speeds. We hypothesized that step rates recorded on the pedometers would deviate from those recorded manually on the hand tally counter at some locations as well as at slower and faster walking speeds. To address this issue as comprehensively as possible, the accuracy of pedometers was assessed at a variety of walking speeds in controlled laboratory conditions and in self-selected free walking conditions on paved ground. In addition, to make the study findings more applicable to a wider population, participants widely varying in age and body mass index were recruited and studied.

Methods

Participants

A total of 40 volunteers (20 males and 20 females) varying widely in age (18–61 years) were recruited from the city of Austin, Texas, USA and the surrounding community using online advertisements. Participants with cardiovascular and other chronic degenerative diseases were excluded from the study. In addition, we recruited only those who were able to walk without any difficulty. Before participation in the study, the nature of the study was explained to the participants, and they were asked to read and sign an informed consent form that was previously reviewed and approved by the Institutional Review Board of the University of Texas at Austin. Body mass was measured to the nearest 0.1 kg with a physician's balance scale (SECA, Hamburg, Germany). Percent body fat was estimated using the skinfold thickness method. Body mass index was calculated according to the following formula: body mass (kg) divided by height squared (m^2). Selected physical characteristics of the participants are presented in Table 1.

Table 1
Selected characteristics of the participants.

Characteristics	Men	Women
N	20	20
Age (y)	38.1 ± 13.4	39.1 ± 14.0
Height (cm)	175 ± 7	162 ± 7
Body mass (kg)	83.4 ± 14.9	70.4 ± 14.8
BMI (kg/m^2)	27.4 ± 4.8	26.9 ± 5.5
Body fat (%)	23 ± 8	35 ± 8

Data are presented as mean ± standard error of the mean.
BMI = body mass index.

Protocol

Five models of commercially available electronic pedometers were evaluated (Fig. 1): Fitbit Ultra Activity Plus Sleep Tracker (FB), Lifesource XI-25ant Ehealth Wireless Activity monitor (XI), Omron HJ-320 (OB), Omron HJ-324U (OU), and Virgin HealthMiles GoZone pedometer (VG). The selection of these pedometers was based on midlevel pedometers that had been used in corporate fitness settings. Five pedometers were worn, at three different locations, namely, in the front pants' pocket, on the waist (belts or upper elastic part of the pants), or on a lanyard in front of the chest. Four pedometers (FB, XI, OB, and OU) were also worn on an armband placed on the upper arm at the insertion of deltoid. Only a limited number of VG pedometers were available for the study because subscription to the Virgin health and fitness plan was required for the acquisition of VG pedometers and was cost prohibitive. Two of the pedometers (OB and OU) were also positioned in a handbag (purse) that was carried by the participants in their hand. The pedometers were randomly assigned to a specific location (e.g., medial to lateral locations on the waist) for every test by an investigator. Before the first trial, the participants received instructions for the test and walked or jogged on a motor-driven treadmill (Full Vision, Newton, KS, USA) at speeds of 54, 80, 107, 134, and 161 m/minute for 6 minutes at each speed. These walking speeds correspond to 2, 3, 4, 5, and 6 miles/hour. During the test, an investigator counted actual steps using a hand tally counter. There were 5–10-minute rests between the treadmill trials to record the step counts from each pedometer and to reset the pedometers. In addition to the laboratory testing session, the participants performed self-selected speed walking tests outside on paved ground for approximately 10 minutes (around the football stadium of the University of Texas at Austin). One investigator guided the participants, and another investigator followed behind them to count the steps taken using a hand tally counter.

Statistical analyses

Absolute values of step counts obtained with each pedometer were compared with those recorded with hand counts (criterion) using *t* tests. A percent difference score [(comparison − criterion)/criterion × 100] was calculated and used as an outcome measure. The smaller the percent difference score, the better the accuracy. Three-way (pedometers × locations × walking speed) analysis of variance was used to evaluate mean difference in step counts obtained with various pedometers against the hand tally counter. If a significant difference was shown, a follow-up Bonferroni adjustment was performed to locate the significant difference. For all analyses, $p < 0.05$ was used to denote statistical significance. The data were processed using SPSS version 18 (SPSS Inc., Chicago, IL, USA).