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Accuracy of the Omron HJ-720ITC in Free-Living Individuals

Nathan Andrew Silcott
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Nathan Andrew Silcott entitled "Accuracy of the Omron HJ-720ITC in Free-Living Individuals." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Exercise Science.

David R. Bassett, Jr., Major Professor

We have read this thesis and recommend its acceptance:

Dixie L. Thompson, Eugene C. Fitzhugh

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accuracy Of the Omron HJ-720ITC Pedometer In Free-Living Individuals

A Thesis Presented for
the Master of Science
Degree
The University of Tennessee, Knoxville

Nathan Andrew Silcott
December 2009

DEDICTATION

This master thesis is dedicated to the memory of Shawn Craig Stewart.

June 13, 1976 – April 27, 2009

To live in the hearts we live behind, is not to die. –Thomas Campbell

ACKNOWLEDGEMENTS

I would like to thank Dr. David Bassett for serving as my major professor throughout my graduate studies and to Dr. Dixie Thompson and Dr. Eugene Fitzhugh for serving on my committee. I would also like to thank the many participants who took time out of their schedule to participate in this study. Without their desire to help, this would not have been possible to complete. To doctoral candidates Brian Tyo, Dinesh John, and Yuri Feito: thank you for patiently answering my questions. Special thanks also goes to Kristi Sykes and Jenifer Ohriner for all of their guidance and advice throughout my time spent at the University of Tennessee. Lastly, I would like to thank my family and friends who supported me in my decision to return to school. You have been unparalleled by anyone else and I appreciate everything you have done for me. Thank you to all of those who saw potential in me.

Abstract

The primary purpose of this investigation was to examine the accuracy of the Omron HJ-720ITC piezo-electric pedometer in a free-living environment over a 24-hr period across 3 different BMI categories. A secondary purpose was to compare the accuracy the Omron HJ-720ITC to that of a spring-levered pedometer (Yamax SW-200). 62 adult volunteers were placed in 3 BMI categories: Normal weight (N=19), Overweight (N=23), or Obese (N=23). Subjects wore five devices over a 24-hr period except when bathing or sleeping. The criterion pedometer (StepWatch-3) was worn on the lateral side of the right ankle. The Omron HJ-720ITC was worn in the mid-line of the right thigh, in the right pants pocket and on a lanyard around the neck. A comparison pedometer (Yamax SW-200) was worn on the belt, in mid-line of the left thigh. The Omron HJ-720ITC significantly underestimated steps taken per day in all three BMI categories compared to the criterion measure ($P < 0.001$). The pocket position demonstrated mean percent errors in normal, overweight and obese BMI categories of -31.7%, -29.8%, and -35.1% respectively, and was the most accurate in obese individuals. However, in normal and overweight individuals, the Omron in each position was less accurate than the Yamax pedometer. (MPE = -19% and -21%). The Omron HJ-720ITC pedometer is a valid instrument for step counting during continuous walking bouts. However, the Omron significantly underestimates the number of steps taken in free-living individuals. A 4-second step filter that determines walking pattern may contribute to an underestimation of steps accumulated through light, intermittent activity.

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Chapter 1:

Introduction And General Information

The accurate measurement of physical activity has become important to researchers in order to quantify dose-response relationships between physical activity and its outcomes, to solve research questions concerning the merits of vigorous, moderate and light physical activity, and to accurately record the physical activity performed in intervention studies (2). One objective measure in physical activity is the number of steps an individual takes, which can be measured through the use of pedometers. A wide variety of new, piezo-electric pedometers have been developed, which makes it necessary to examine the accuracy and reliability of these devices (16,17). The Omron HJ-720ITC is a new pedometer that can be worn in the pocket, on the belt, or around the neck (16,17). This pedometer model is inexpensive ($30), and has the capability to store data in one-hour epochs over 42 days. However, the Omron HJ-729ITC has not been tested under free-living conditions.

Pedometer accuracy can be determined by counting steps in controlled laboratory settings (2,3,7), but it is not feasible to assess pedometer accuracy in this manner over a 24-hr period (31). Pedometer accuracy over a 24-hour period can be assessed against criterion measurements of physical activity (13,21,24,31,37). The Stepwatch-3 (Cymatech, Inc., Seattle WA) is an extremely accurate device in laboratory environments at measuring steps taken (4,14,21,32,34). The StepWatch-3, however, is an expensive device ($500 + $1500 for docking station and software) which is a limitation for large studies that seek to measure walking behaviors.

Purpose

Studies that have validated the Omron HJ-720ITC have only used the laboratory environment (19, 20). These studies have also shown that the Omron HJ720-ITC is accurate for all placement sites (19,20), and in normal and overweight individuals (19). To date, the Omron HJ-720ITC has not been validated over 24 hours, in a free-living environment. Thus, the primary purpose of this study was to test the accuracy of the Omron HJ-720ITC against a criterion pedometer (StepWatch-3) in free-living individuals over a 24-hr period in 3 BMI categories. A secondary purpose was to compare the accuracy of the Omron HJ-720ITC to that of a spring-levered electronic pedometer (Yamax SW-200). The Yamax pedometer is widely used in research studies.

CHAPTER 2:

REVIEW OF THE LITERATURE

The Role of Physical Activity Assessment

Accurate measurement of physical activity has become a priority in research (1). In recent years it is has become evident that there is a need for valid and reliable instruments by which physical activity can be assessed (2,12,21). Physical activity can be measured subjectively through questionnaires, logs, diaries and interviews. It can also be measured through objective measures such as activity monitors, pedometers, heart rate monitors, doubly labeled water and indirect calorimetry (2,12,36). The purpose of this literature review will be to focus on the objective measurement of physical activity, in particular, the use of motion sensors in assessing physical activity.

Objective Monitoring

Objective monitoring of physical activity can be performed in several different ways, each with its own advantages and disadvantages. Physical activity has been linked to reduced risk for several chronic diseases such as coronary artery disease, hypertension, diabetes mellitus and obesity. Thus, it is imperative that there be more accurate methods of measuring physical activity. Objective monitoring quantifies physical activity without relying on subjective paper-and-pencil questionnaires (12).

As stated previously, there are several different methods by which physical activity can be objectively assessed. In 2000, Bassett (2) examined validity and reliability issues with regards to several different objective monitoring devices. These devices were heart rate monitors, pedometers, and accelerometers. According to Bassett, although all measurement techniques have certain limitations, each varying in degree, the pedometer is the best choice in free-living epidemiological research (2). Also, in 2000, Freedson (12) discussed objective monitoring using accelerometers, pedometers and heart rate monitors. According to Freedson, it is imperative to use motion sensors to quantify physical activity (12) noting that, ideally, the instrument should be easily administered to large populations, relatively low cost, non-intrusive, valid and reliable (12).

Motion Sensors

Motion sensors are instruments that record bodily movements. Their purpose is to measure acceleration of the trunk or a specific limb. A wide range of motion sensors are available that vary in price with mechanical pedometers being the most simplistic, and triaxial accelerometers being the most complex (12). The motion sensors that will be discussed in this review are pedometers.

Pedometers

The pedometer can be traced back to Leonardo DaVinci roughly 500 years ago (1,12,14,15,26), and it was commonly used as a land surveying tool (1). Today, pedometers are used mostly as physical activity assessment tools (2,9,12), however, some researchers have also used them in intervention and observational studies (6,7,13,23,33). Pedometers contain three different types of mechanisms for step counting. These mechanisms are mechanical, spring-lever design and piezo-electric.

Mechanical Pedometers

Old style, mechanical pedometers operated on ratchet and gear mechanisms that required hand calibration of the spring's tension (14,21,26,35). The mechanical pedometer responds to vertical accelerations of the trunk, thus displacing a lever-arm that is balanced by a coil spring with each step. The spring then turned a series of gears that were attached to a display on the front of the pedometer (35). Due to the variations within the gear mechanisms, these early mechanical pedometers were deemed un-acceptable for research. For example, Gayle and Montoye (14) examined the accuracy of mechanical pedometers in 8 male subjects using six commercial brands of pedometers. Each individual was asked to walk at 3 mph on a treadmill for approximately 1 mile at 0% elevation. The results showed that the distance recorded by each of the pedometers ranged from 0.7 to 1.4 miles. This study showed the inaccuracies of the mechanical pedometer and the authors concluded that in order for these devices to be more accurate, they must be calibrated for each individual's gait characteristics, in particular stride length (14).

A study of mechanical pedometer validity and reliability by Kemper and Verscher (21) revealed similar inaccuracies. 58 school-aged boys (ages 12-18) were selected from Amsterdam and were fitted with two different types of mechanical pedometers. Each subject walked on a treadmill at speeds of 2, 4, and 6 $km \cdot hr^{-1}$ for 5, 4 and 4 minutes, respectively. The subjects were also asked to run at 6, 8, 10, and 14 $km \cdot hr^{-1}$ for approximately 3 minutes per trial. The only exception was 14 $km \cdot hr^{-1}$, which the boys maintained for only 2 minutes. The author(s) concluded that both pedometers overestimated the actual steps taken by the subjects at running speeds with pedometer 1 overestimating by 3.4% ± 9.8%, 0.6% ± 9.5%, and 8.6% ± 8.1% and pedometer 2 overestimating by 3.9% ± 6.4%, 3.7% ± 3.4%, and 9.0% ± 8.6%. The walking speeds showed even greater inaccuracies with pedometer 1 underestimating the number of actual steps by 66% ± 35.6% at the slowest speed and overestimating by 7.1% ±33.3% and 6.9% ± 11.4% at the faster speeds. Clearly, these early mechanical pedometers demonstrated several problems with validity and reliability, however, advancements have been made and newer electronic pedometers have been introduced.

Electronic Spring-Lever Arm Pedometers

An electronic pedometer is battery-powered and works by using a spring-suspended, horizontal lever arm that is able to freely move up and down (1,3,9,16,29,36). The motion of the lever arm is determined by vertical accelerations of the hip that occur during walking and running (1). The lever arm opens or closes a circuit that is connected to a display in which each step is registered. Electronic pedometers have a variety of features with some requiring input of step length and body mass in an attempt to estimate energy expenditure and distance. Several electronic pedometers have been tested for accuracy and reliability. Several of these pedometers have been proven accurate in laboratory settings (3,9,25,29). For example, in 1996 Bassett et al. (3) analyzed the accuracy of 5 electronic spring-lever pedometers available at the time. The main purpose of the study was to test several electronic pedometers under varying situations. 20 subjects were selected to walk under the settings of an outdoor course, a laboratory treadmill, and a rubberized outdoor track. The sidewalk portion consisted of a 4.88km course in which the subjects wore the same pedometer on the left and right hip for a total of 5 trials. The results indicated a significant difference ($P < 0.05$) between each of the 5 pedometers in measuring the distance each subject walked, with the Yamax Digiwalker DW-500 demonstrating the closest estimate. Similar results were also shown for the outdoor track experiment. Next, 10 participants engaged in a treadmill walk at 54, 67, 80,94 and 107 $m \cdot min^{-1}$ for 5 minutes respectively. The Yamax was the most accurate at slow and moderate speeds ($P < 0.05$) vs. other pedometers used, however, there were no significant differences found at the fastest speed of 107 $m \cdot min^{-1}$.

In 2003, Crouter et al. (9) examined the validity of 10 electronic pedometer models. All of the pedometer models used spring lever-arm mechanisms (except the NL-2000). 10 subjects (33 ± 12 yr) walked in a controlled treadmill setting under the same protocol used in Bassett's study with regards to speed (3). Two of the same brands of pedometer were worn on the left and right belt. Results indicated that at all speeds, except the slowest, the Yamax Digiwalker DW-

701 demonstrated mean values that were within ± 1% of the actual steps taken. The other spring-lever design, the Sportline 345 did not show equivalent accuracy demonstrating a 0.57 (95% CI) correlation coefficient between the left and right hip and demonstrating a significant underestimation ($P < 0.05$) at 54 $m \cdot min^{-1}$ and 67 $m \cdot min^{-1}$, respectively. The Digiwalker actually demonstrated one of the highest correlation coefficients between the right and left hip (0.98, 95% CI).

Piezo-electric Pedometers

Another type of technology that has been developed in the pedometer industry has been the insertion of a piezo-electric accelerometer (16). This mechanism counts steps by measuring the instantaneous upward acceleration and the number of zero-crossings versus a time curve (16). Zero-crossings are defined as the peak in acceleration where a sine wave goes from positive to negative. Several piezo-electric pedometers have been examined for validity and reliability in laboratory settings. Melanson et al. (25) compared the validity of the Omron HF-100 (Omron Corp., Kyoto, Japan) against several commercially available spring-lever designed pedometers in a two-part study in 2004. The Omron pedometer was chosen because it was one of the first pedometers to use the piezo-electric mechanism (16,25). Part two of the study examined 32 healthy adults (M=16, F=16) of two different BMI categories: Overweight or Obese (BMI < 29kg/m^2) and normal (BMI < 25 kg/m^2). 3 different instruments (Omron HF-100, Walk-4-Life LS2500, Step Keeper HSB-SKM) were placed on the subjects in positions recommended by the manufacturers. Subjects walked at 1.0, 1.8, and 2.6 MPH for 12 minutes at each speed. The researchers reported that the piezo-electric pedometer was significantly more accurate at 1.0 MPH (56.4 ± 33.8%) and 1.8 MPH (97.8 ± 9.6%) than the Step Keeper (20.5 ± 28.4%, 73.4 ± 36.7%) and the Walk-4-Life (7.5 ±16.3%, 52.1 ± 38.7%). At 2.6 MPH, the piezo-electric pedometer (101 ± 4.3%) was also significantly better than the Walk-4-Life (81.8% ±12.3%). The authors concluded that for slower walking speeds, the piezo-electric pedometer may be more appropriate.

Hasson et al. (16) examined a more advanced piezo-electric pedometer (Omron HJ-112) during treadmill walking. The Omron HJ-112 features two piezo-electric sensors positioned perpendicular to each other and is able to sense movement in multiple orientations when worn in the pocket, around the neck or in a purse (16). 92 subjects (M = 44, F = 48) were placed into 2 different BMI categories: BMI < 30 $kg \cdot m^{-2}$ and BMI ≥ 30 $kg \cdot m^{-2}$ and were asked to walk at speeds of 1.12, 1.34 and 1.56 $m \cdot s^{-1}$ for 12 min. Validity of the HJ-112 pedometer was assessed from 4 different locations on the body during the three, 12 min bouts of walking. A spring-lever designed pedometer (Yamax Digiwalker SW-701) was also used to compare against the piezo-electric model and each were tested against manual hand counting of steps. Results indicated that the Omron HJ-112 pedometer's random error was 3.7% during the variable speed tests for BMI < 30$kg \cdot m^{2}$ compared to the Yamax which demonstrated 20% random error. What is unique about this study is the researchers found no statistically significant bias between the different placement positions ($P < 0.001$). It was determined that the Omron HJ-112 pedometer accurately assesses steps in laboratory settings across all BMI categories and placement positions.

Ankle-Mounted Pedometers

Recent advancements have enabled pedometers to be worn on other parts of the body (4,11,16,17,20,30), including lower limbs. In particular, ankle-mounted pedometers have set the precedent in validity when measuring steps taken by an individual. One ankle-mounted pedometer, The Step Activity Monitor (OrthoCare Innovations, Seattle, WA) features a two-dimensional accelerometer and has been proven accurate (30). The SAM was designed specifically to target lower limb movements and can be calibrated to each individual through computer software and a docking port. Calibration includes cadence differences and adjustable refractory periods that prevent the instrument from counting multiple steps at the same time (30). Shepherd et al. (30) examined the accuracy of the SAM in 29 subjects using a 400-M walk, stair descent, 10-M walk, and a stair ascent. The steps from the SAM were compared to a common electronic pedometer (Sportline-345, Campbell, CA). Results indicated that the SAM had a mean absolute error of 0.54% for all trials whereas the electronic pedometer was 2.82%. The interesting findings of the study were that the Sportline-345 pedometer positively correlated ($r = 0.792$, $p < 0.0001$) with BMI and the subjects weight ($r = 0.753$, $p < 0.0001$). The SAM was not significantly correlated to either body mass or weight.

The StepWatch-3 (OrthoCare Innovations, Seattle, WA), which is the latest version of the SAM (Step Activity Monitor), has been shown to be extremely accurate during slow walking speeds (< 67 $m \cdot min^{-1}$) and during walking speeds ranging from 26.8 $m \cdot min^{-1}$ to 107 $m \cdot min^{-1}$ (20). Karabulut et al. (20) recruited 20 individuals to examine the accuracy of the StepWatch-3 during several different situations including heel tapping, leg swinging, car driving, cycle ergometry and treadmill walking. The StepWatch-3 was also compared to the Yamax SW-701 and the New Lifestyles NL-2000, which are waist mounted pedometers and another ankle-mounted pedometer, the AMP-331. During treadmill walking, the StepWatch-3 estimated step counts within 1% of the actual steps at all speeds (27 $m \cdot min^{-1}$, 40 $m \cdot min^{-1}$, 54 $m \cdot min^{-1}$, 67 $m \cdot min^{-1}$, 80 $m \cdot min^{-1}$, and 107 $m \cdot min^{-1}$). The StepWatch-3 did record some erroneous steps during leg swinging and heel tapping (118 and 29, respectively), however, it did not record steps during car driving trials. The author(s) concluded that the StepWatch-3 would be an instrument that might prove useful as a criterion vs. waist-mounted pedometers over a wide range of research situations.

The StepWatch-3 has been examined and validated in numerous "slow walking" populations as well (4,11,31). Populations such as obese individuals, chronic heart failure patients and community-dwelling older adults are individuals in which objective monitoring is needed. In 2008, Bergman (4) examined the Stepwatch-3 in older adults in assisted living facilities. Twenty-one older men and women wore the StepWatch-3 and the Yamax SW-200 over 161 m. The SW-200 only recorded 51.9% ($r^2 = -0.8$, $P = 0.75$) of steps taken. The Stepwatch-3 recorded 102.6% ($r^2 = .99$, $P < 0.001$) of actual steps taken. The author(s) concluded that the StepWatch-3 is a valid device when measuring individuals with slow walking speeds.

Free-Living Physical Activity

With advances in motion sensor technology, it is now feasible to assess an individual's actual physical activity in free-living environments. Self-report instruments have been deemed valid for recalling structured physical activity, but have less validity when trying to capture ubiquitous, light activity (22,28). It is these limitations that have led to the development of more accurate objective monitoring devices for research. Several researchers have attempted to validate pedometers during free-living physical activity with the use of motion sensing devices. Several of today's pedometers are conducive to free-living studies due to their data storage capabilities. Tudor-Locke (34) examined the accuracy of two motion sensors in a free-living environment over a 2-wk period. 52 participants were selected and instructed to wear the instruments for all waking hours for seven consecutive days. The International Physical Activity questionnaire was also administered to compare with the objective monitoring devices. The CSA accelerometer (model 7164 Version 2.2) and the Yamax SW-200 were worn in accordance with the manufacturer's specifications. A high correlation was discovered between the two instruments ($r = 0.80$), with regards to steps per day, however, a Bland-Altman plot detected a mean difference of approximately 2000 steps$\cdot d^{-1}$.

Le Masurier (22) compared three different pedometer models (Yamax SW-200, Omron HJ-105, Sportline 330), to the CSA (dual mode accelerometer) in a free-living environment. This was one of the first studies to use the CSA as the criterion in a 24-hr period (22). 12 subjects wore the 3 different pedometers and the CSA at all waking hours of the day, except when bathing or sleeping. Le Masurier and colleagues found that only the Sportline pedometer significantly underestimated steps taken ($P < 0.05$) compared to the CSA and that the absolute value of percent error was the lowest for the SW-200. In conclusion, both the Yamax SW-200 and the Sportline-330 undercounted steps per day, with the Omron HJ-105 over counting steps.

Omron HJ-720ITC Pedometer

Piezo-electric pedometers are more accurate in laboratory settings vs. electronic spring lever design models (16,17,29), particularly at slower speeds of walking. Omron Healthcare Corp. has designed several piezo-electric models of pedometers that feature dual accelerometers that enable the device to be worn on multiple positions of the body (16,17) as well as horizontally and vertically. The Omron HJ-720ITC, commonly known as the "pocket pedometer" features this technology and was tested for accuracy by Holbrook et al. (17). 47 healthy individuals (24 males, 23 females) were selected to test the Omron pedometer using multiple positions on the body under controlled and self-paced conditions. The positions were selected based on the manufacturer's recommendations and included the backpack, right and left hip pockets, and the mid-back. Under the prescribed walking condition, subjects were asked to walk on an outdoor track at 3 different speeds (2.0, 3.0 and 4.0). With regards to positioning, the Omron HJ-720ITC demonstrated absolute percent error of only 2.3% ± 2.8% across all walking speeds, with the mid-back demonstrating the least absolute percent error (1.1% ± 1.1%). What is interesting is that there were no significant differences (P = 0.381) discovered among walking speeds (2.0, 3.0, 4.0 mph).

CHAPTER 3:

MANUSCRIPT

Abstract

SILCOTT, N.A., D. R. BASSETT, JR., D.L. THOMPSON, E.C. FITZHUGH. Accuracy of the Omron HJ-720ITC Pedometer in Free-Living Individuals **Purpose:** The primary purpose of this study was to examine the accuracy of the Omron HJ-720ITC piezo-electric pedometer in a free-living environment over a 24-hr period across 3 BMI categories. A secondary purpose was to compare the accuracy the Omron HJ-720ITC to that of a spring-levered pedometer (Yamax SW-200). **Methods:** 62 adult volunteers were placed in 3 BMI categories: Normal (N = 19), Overweight (N= 23), Obese = 20 (N=20).Subjects wore five devices over a 24-hr period except when bathing or sleeping. The criterion pedometer, StepWatch-3, was worn on the lateral side of the right ankle. The Omron HJ-720ITC was worn in the mid-line of the right thigh, in the right pants pocket and on a lanyard around the neck. A comparison pedometer (Yamax SW-200) was worn on the belt, in mid-line of the left thigh. **Results:** The Omron HJ-720ITC significantly underestimated steps taken per day in all three BMI categories compared to the criterion measure ($P < 0.05$). The pocket position demonstrated absolute percent errors in normal, overweight and obese BMI categories of -32%, -30%, and -35% respectively, and was the most accurate in obese individuals. However, in normal and overweight individuals, the Omron in each position was less accurate than the Yamax pedometer (MPE = -19% and –21%). **Conclusion:** Based on previous laboratory studies, the Omron HJ-720ITC pedometer is a valid instrument for step counting during continuous walking bouts. However, results from our study show that the Omron significantly underestimates the

number of steps taken in free-living individuals. A 4-second step filter that determines walking pattern may contribute to an underestimation of steps accumulated through light, intermittent activity.

Key Words: PHYSICAL ACTIVITY, PEDOMETER, STEPWATCH, STEPS, WALKING, YAMAX

Introduction

The accurate measurement of physical activity is important to researchers seeking to quantify dose-response relationships between physical activity and its outcomes, to determine the merits of light, moderate and vigorous physical activity, and to record the physical activity performed in intervention studies (2). One objective measure of physical activity is the number of steps an individual accumulates per day, which can be measured through the use of pedometers. Recently, pedometers have been introduced that utilize multiple piezoelectric accelerometer sensors which makes it necessary to examine the accuracy and reliability of these devices (16,17).

The Omron HJ-720ITC is a new pedometer that can be worn in a pocket, on a belt or around the neck (16,17). This particular pedometer is inexpensive ($30), and has the capability to store data in one-hour epochs over 42 days. It has been validated for treadmill and over-ground walking at various speeds, however, the Omron HJ-720ITC has not been tested under free-living conditions.

Pedometer accuracy can be determined by counting steps in controlled laboratory settings (3,8,9,11,14,16,17,20,21,32,35), however, it is not feasible to assess pedometer accuracy in this manner over a 24-hr period (28). However, pedometer accuracy over a 24-hour period can be assessed against a criterion device. (10,20,22,34). The Stepwatch-3 (Cymatech, Inc., Seattle WA) is an extremely accurate device in laboratory environments at measuring steps taken (4,11,30,31). Its accuracy is also unaffected by speed of locomotion and BMI (30). The StepWatch-3, however, is an expensive device ($500 + $1500 for docking station and software) which is a limitation for large studies that seek to measure walking behaviors.

Methods

Participants

62 volunteers (31 males, 31 females), 18-69 years of age, were recruited from the University of Tennessee and the surrounding community. Each participant was asked a series of questions to screen abnormal gate patterns (APPENDIX C). Participants were also asked questions about their physical activity habits and they were excluded if they could not refrain from performing non-ambulatory activities (elliptical and rowing machines, lifting weights and running). Individuals who had an internal defibrillator or a pacemaker were also excluded from the study. Participants were asked to read and sign an informed consent form before participating.

Anthropometric measures

The protocol used for this study was approved by the University of Tennessee Institutional Review Board (IRB #7909B). After each participant was screened, an initial visit was scheduled in the Applied Physiology Laboratory. Participants removed their shoes and socks before height was measured to the nearest 0.1 cm using a stadiometer (Seca Corporation, Columbia, MD.). Weight was assessed in light clothing on a physician's scale (Health-O-Meter, Inc., Bridgeview, IL) to the nearest 0.25 lb. Waist and hip circumference measurements were taken using a Gulick fiberglass measuring tape with a tension handle. Waist circumference was measured at the narrowest portion of the torso between the iliac crest and inferior rib. Hip measurements were taken at the maximal circumference of the buttocks, above the gluteal fold (24). Waist-to-hip ratio was determined by dividing the waist circumference (cm) by the hip circumference (cm). Body fat percentage was assessed using the Tanita body fat analyzer (Model #BC-418; Tanita Corp., Tokyo, Japan). Body fatness was recorded to the nearest 0.10 percent.

Stride Length

Each participant's stride length was determined by having the participant walk exactly 20 steps down an indoor hallway. The total distance was measured in feet and divided by 20. Stride length was computed from the average of two measurements.

Pedometers

Participants were shown the proper placement of the pedometers. An instruction sheet with a labeled picture was also given to the participants to ensure the correct placement (APPENDIX B). Omron HJ-720ITC pedometers were placed on the waist in mid-line of the right thigh, the right pants pocket and around the neck in the center of the chest. Time of day, stride length, and body weight were entered into to the Omron pedometer. The Yamax SW-200 was placed on the waist, in mid-line of the left thigh. The Stepwatch-3 was set to each participant's height and the default settings for "walking speed", "range of speeds", and "leg motion" were used. Participants were asked to wear the pedometers for the remainder of the first day, until they retired for the evening, so that they would become accustomed to the devices.

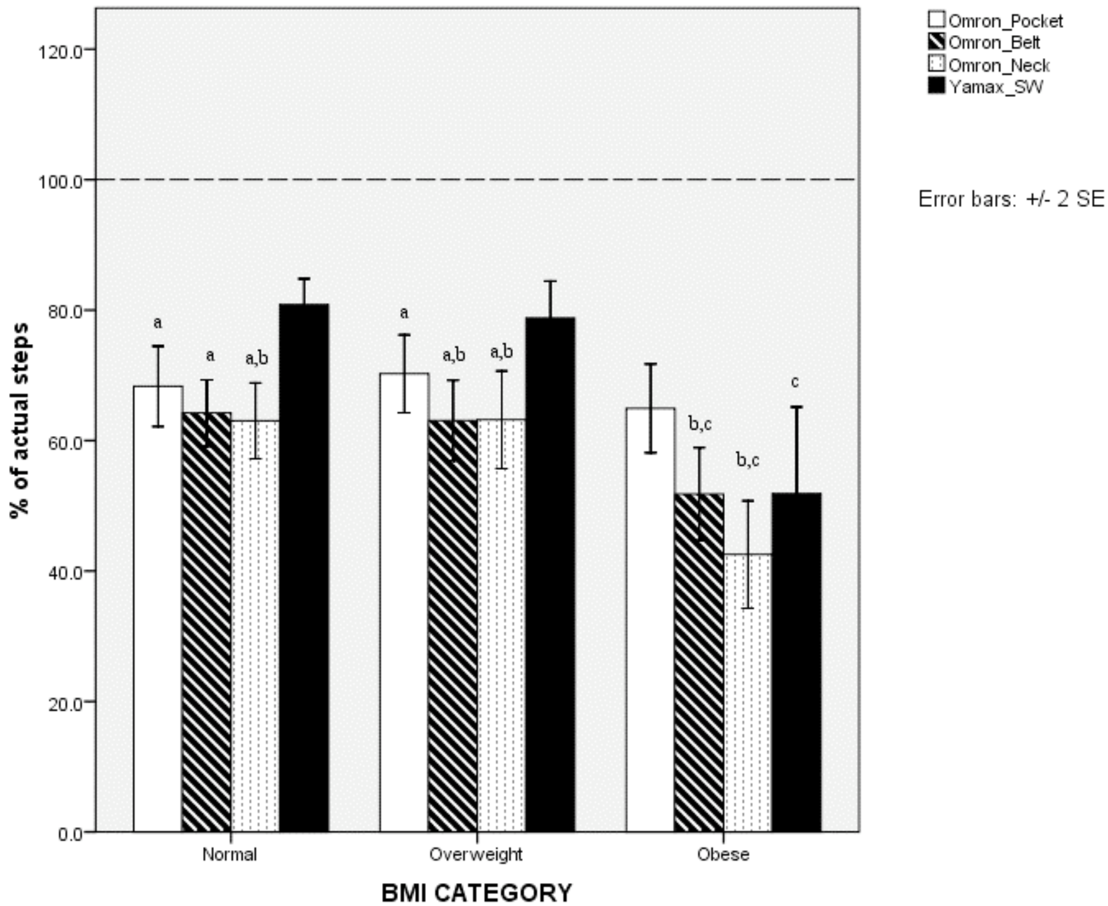
24-h study

Following the first day, the participants were instructed to wear the pedometers from the time they woke up until they went to bed at night. They were encouraged to participate in normal daily activities, but to avoid non-ambulatory activities during the testing period such as using an elliptical machine, lifting weights or using a rowing machine. The Omron HJ-720ITC and

Stepwatch-3 automatically stored the number of steps in the instrument's memory and reset to zero at midnight. Since the Yamax SW-200 has no internal memory, participants were asked to record the amount of steps taken on a log sheet when they removed the instruments before they retired.

Statistical Analysis

SPSS version 17.0.0 for Windows (SPSS Inc., Chicago, Illinois) was used for statistical analysis. An alpha level of 0.05 was used to show significant differences and all values are shown as mean ± standard deviation. A repeated measures ANOVA (3 x 4) was used to determine if there was an interaction between BMI categories and pedometer placements. In the case of significant main effects, pairwise comparisons using Bonferroni adjustments were used to locate specific differences between the devices within each BMI category. One-way ANOVA was used to determine if there were differences between the BMI categories, within each device. Where appropriate, Tukey post hoc analysis was performed to determine which BMI categories were different within each device. Bland-Altman plots were constructed to show pedometer accuracy (5) and are shown in Figures 2 – 5.



a. significant difference from Yamax in same BMI category (P<0.05)
b. significant difference from Omron_Pocket, in the same BMI category (P<0.05)
c. significant difference from normal and overweight categories, within the same device (P<0.05)

Figure 1. Percent of actual steps recorded by the Omron HJ-720ITC (worn in the pocket, on the belt, & around the neck) and the Yamax SW-200 (worn on the belt). N=62

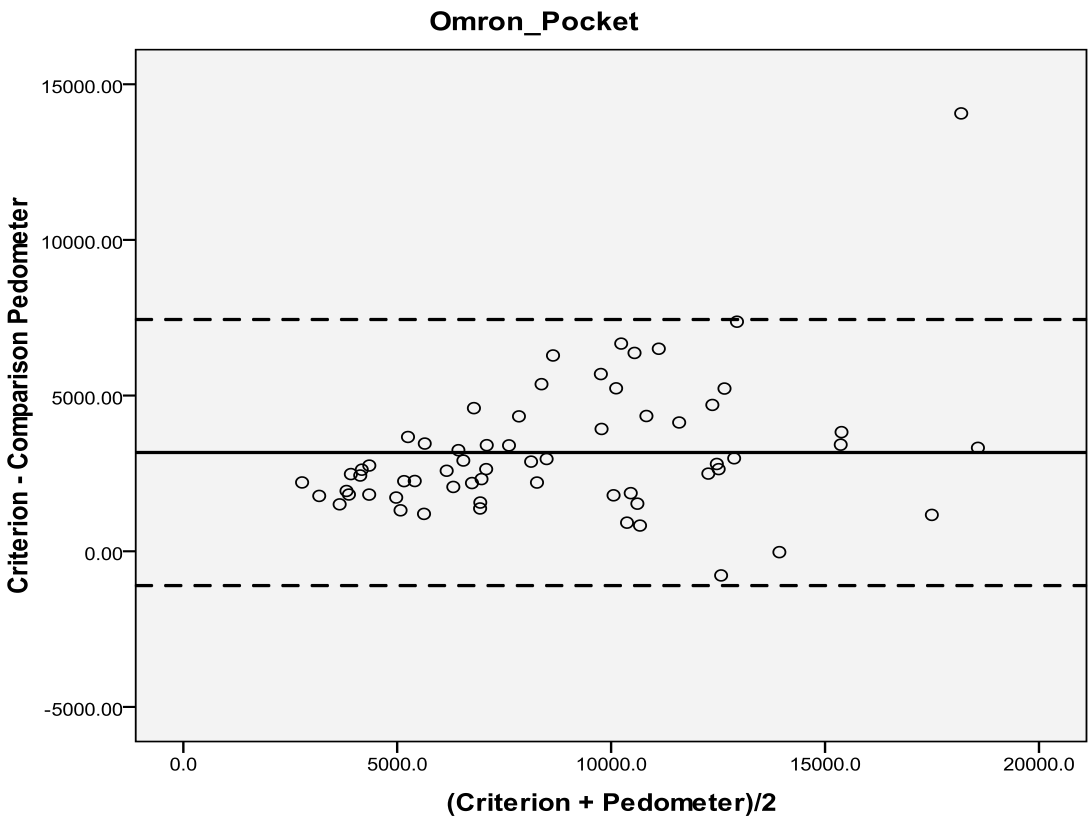


Figure 2. Bland-Altman plot showing accuracy of the Omron HJ-720ITC, when worn in the pants pocket.

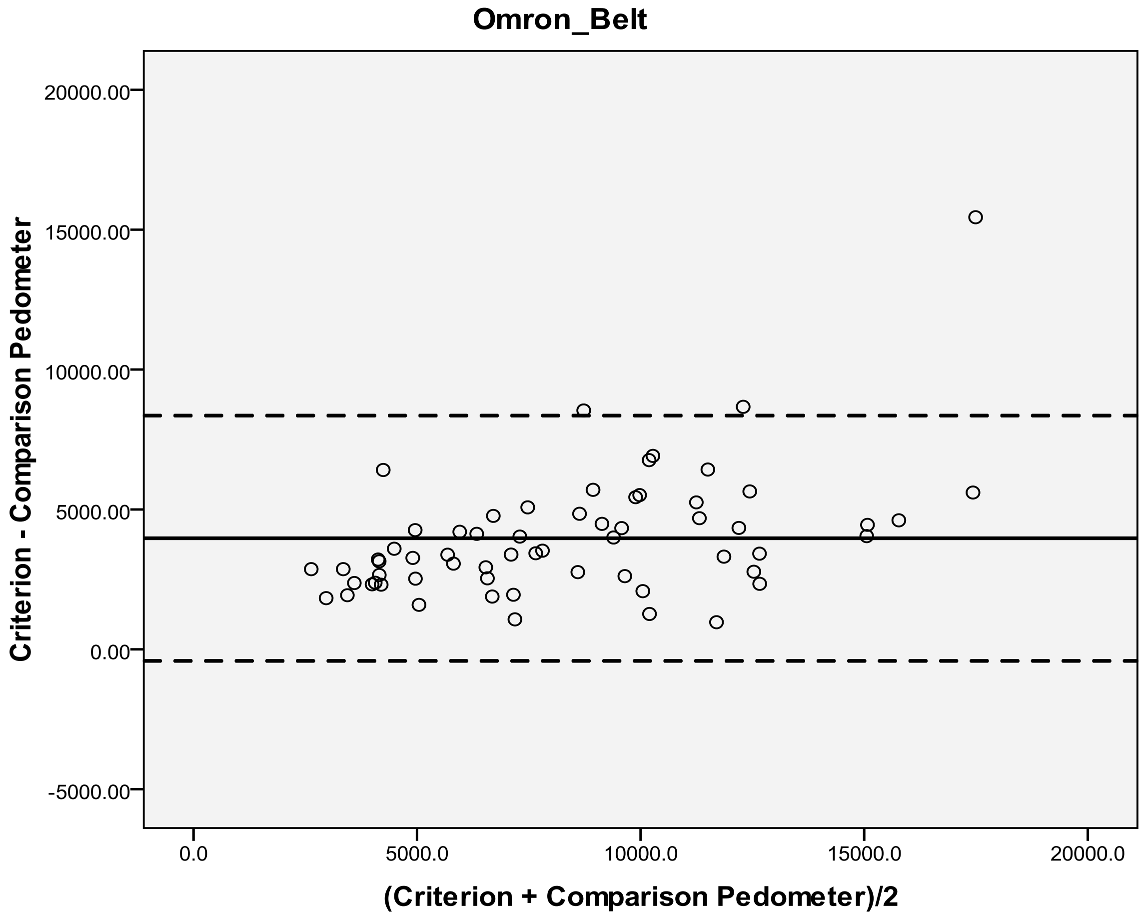


Figure 3. Bland-Altman plot showing the accuracy of the Omron HJ-720ITC, when worn on the belt.

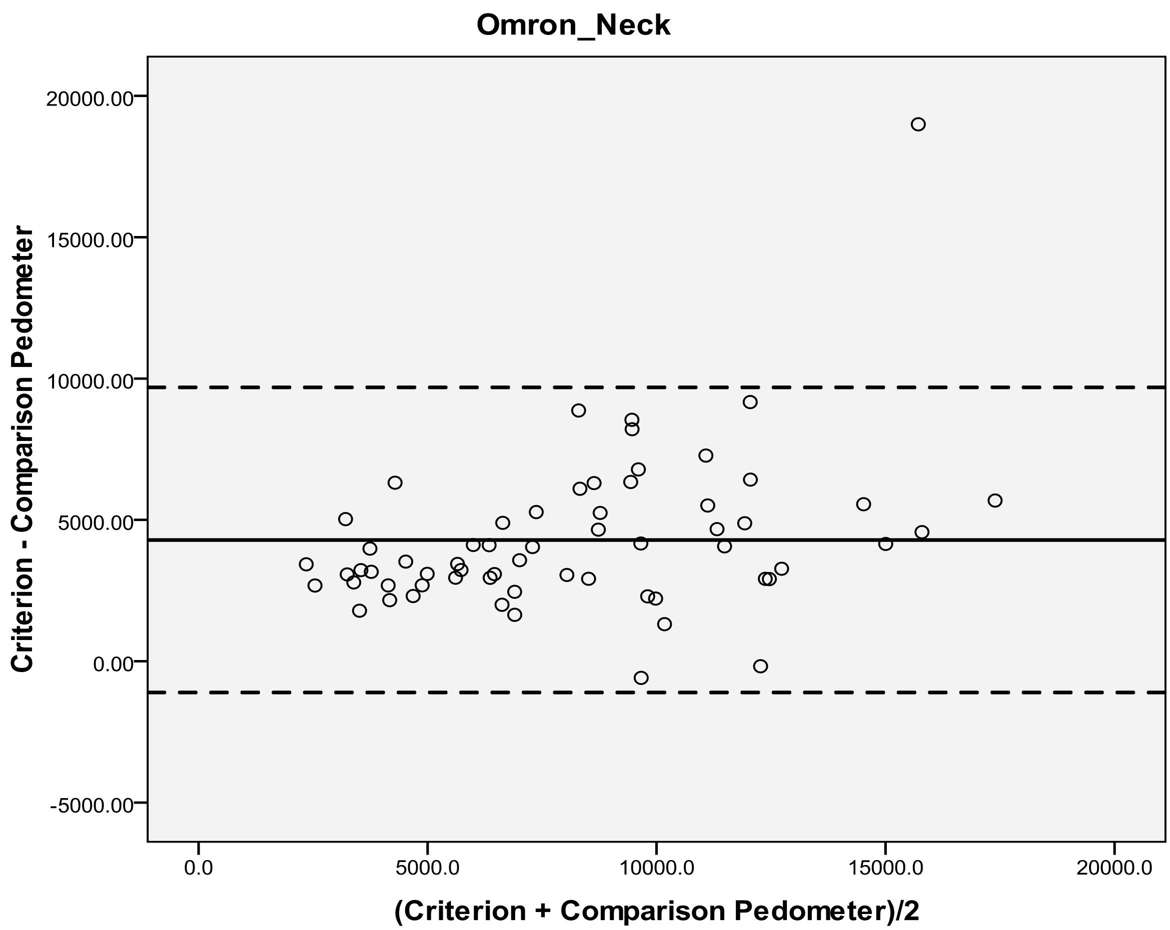


Figure 4. Bland-Altman plot showing the accuracy of the Omron HJ-720ITC, when worn around the neck.

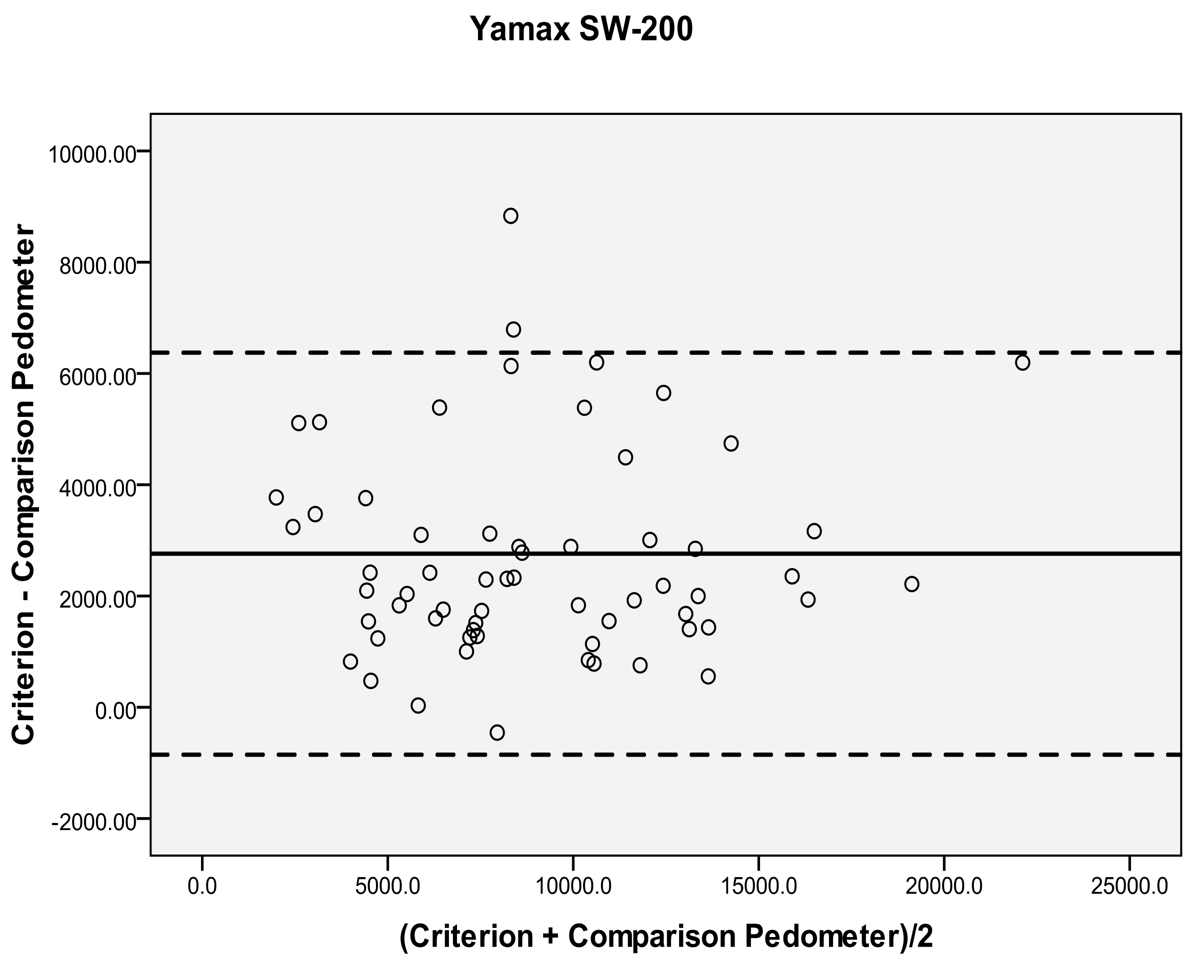


Figure 5. Bland-Altman plot showing the accuracy of the Yamax SW-200.

Results

Descriptive characteristics are shown in Table 1. Mean values for BMI were 22.2 $kg \cdot m^{-2}$, 27.0 $kg \cdot m^{-2}$, and 36.5 $kg \cdot m^{-2}$ for normal, overweight and obese participants. The Omron HJ-720ITC significantly underestimated steps in all three locations, for all three BMI categories ($P < 0.001$). Mean steps for each BMI category are listed in Table 2. The Yamax pedometer demonstrated significantly higher accuracy than the Omron pedometer among normal and overweight individuals ($P < 0.05$) regardless of the position. In the obese category, however, the pocket position demonstrated significantly greater accuracy than the other two positions. (Omron_Belt, Omron_Neck). Mean percent error for each device was calculated and is shown in Table 3.

TABLE 1. Descriptive characteristics.

Variable	**Normal (N=19)**	**Overweight (N=23)**	**Obese (N=20)**
Age (yrs)	31.3 ± 8.6	35.8 ± 11.0	46.2 ± 12.7*
Height (cm)	169. 7 ± 7.8	174.4 ± 10.1	169.0 ± 10.4
Weight (kg)	63.9 ± 8.0	82.5 ± 10.4*	104.1 ± 19.4*
Waist (cm)	71.0 ± 6.7	85.8 ± 5.4*	106.5 ± 12.1*
Hip (cm)	93.0 ± 4.6	103.0 ± 6.7*	117.3 ± 13.3*
WHR	0.77 ± 0.07	0.83 ± 0.06*	0.91 ± 0.77*
BMI ($kg \cdot m^{-2}$)	22.2 ± 1.7	27.0 ± 1.5*	36.5 ± 5.8*
BF (%)	17.6 ± 7.3	25.8 ± 9.1*	36.8 ± 8.9*

Values are Mean ± standard deviation; WHR, waist to hip ratio; BMI, body mass index; BF, body fat percentage.
* Significantly different than normal category ($P < 0.05$).

TABLE 2. Mean steps per day

Device	**Normal (N=19)**	**Overweight (N=23)**	**Obese (N=20)**
Omron_Pocket	8000 *	7145*	6391*
Omron_Belt	7541*	6452*	5149*
Omron_Neck	7362*	6426*	4357*
Yamax	9367*	7859*	5822*
Stepwatch	11453	10009	9648

Values are the mean steps accumulated over a 24-hr period. OM_Pocket, Omron Pocket; OM_Belt, Omron Belt; OM_Neck, Omron Neck; Yamax, Yamax SW-200; SW, Stepwatch-3
* Significantly different than StepWatch-3 ($P < 0.05$).

TABLE 3. Mean percent error (MPE) for the Omron HJ-720ITC pedometer and the Yamax SW-200 during 24 hours of free-living activity. (N = 62)

Device	Normal (N=19)	Overweight (N=23)	Obese (N=20)
Omron_Pocket	-31.7 ± 13.4	-29.8 ± 14.3	-35.1 ± 15.2
Omron_Belt	-35.7 ± 11.0	-36.9 ± 14.8	-48.2 ± 15.9*†
Omron_Neck	-36.9 ± 12.7	-36.8 ± 17.9	-57.5 ± 18.4*†
Yamax	-19.2 ± 8.7	-21.2 ± 13.6	-48.1 ± 29.8*†

Values are Mean ± standard deviation; Omron_Pocket, Omron Pocket; Omron_Belt, Omron Belt; Omron_Neck, Omron Neck; Yamax; Yamax SW-200.
* Significantly different than normal category. ($P < 0.05$)
† Significantly different than overweight category. ($P < 0.05$)

Discussion

To our knowledge, this is the first study to examine the Omron HJ-720ITC under free-living conditions over a 24-hr period. Previous research has shown that the Omron HJ-720ITC is an accurate pedometer for speeds ranging from 2.0 to 4.0 mph., across multiple positions and among lean, overweight and obese individuals (16,17). It has even been suggested that the Omron device is suitable for epidemiological studies in which ambulatory activity is of interest, due to its multiple mounting positions (17). Even though the Omron has demonstrated mean APE scores of < 3.2% for all positions in laboratory settings, it did not demonstrate the same accuracy in free-living individuals. When the Omron was worn on the belt, it underestimated steps per day by 35.7% in normal individuals, 36.9% in overweight individuals and 48.2% in the obese category. When the Omron was worn in the pocket, it underestimated steps by 31.7% in normal individuals, 29.8% in the overweight category and 35.1% in the obese category. The neck position was the least accurate of the three positions, underestimating by 36.9% in normal, 36.8% in overweight and 57.5% in obese individuals. Inaccuracies in the Omron HJ-720ITC were also found by Jehn et al. (19) when it was used at slow walking speeds (≤ 50 m/min.) in chronic heart failure patients. The Omron device was worn on the right hip and was found to have an overall correlation of ($r = 0.92$, $P < 0.001$) and yielded significant underestimation at 40 m/min ($P < 0.001$) when compared to a digital hand counter.

In the present study, the Omron was worn in three different locations and compared to the Stepwatch-3 and Yamax SW-200, which has not been done previously. This is also the first study to compare the Omron HJ-720ITC between three different BMI categories. Holbrook et al. (17) examined the effects of walking speed, mounting position, but they did not examine the impact of BMI. Our current findings from the free-living environment contrast with findings from laboratory studies using a similar pedometer (16). Hasson et al. validated the Omron HJ-112, which utilizes the same dual-sensor technology as the Omron HJ-720ITC, and they report that accuracy was not influenced by BMI (16). However, in obese individuals, in a free-living environment, position of the device clearly affects device step counting. The belt and neck positions in obese individuals resulted in decreased accuracy, compared to the pocket position. When worn in the pocket, the Omron was unaffected by BMI category. This finding may prove useful for researchers needing an alternative mounting position for individuals who are obese or in individuals whom central adiposity causes an undesirable tilt angle of the belt-mounted Omron pedometer.

With regard to the Omron belt and neck positions, underestimation in step counting in obese individuals may be attributed to several factors. A slow, shuffling gait or tilt angle of the instrument could cause error in step counting with the Omron device, however these traits are also associated with spring-levered pedometers such as the Yamax SW-200 (8,25). Omron manufacturers recommend that the front or back of the device should not be worn past a 30 degree angle. In obese individuals, it may be possible that the tilt angle exceeded 30 degrees when the Omron was worn on the belt. Our findings regarding the decreased accuracy of the

Omron device in obese individuals contradicts those of Hasson et al. (16) who reported that pedometer accuracy in obese individuals (BMI ≥ 30) was maintained even though the vertical axis of the sensor was not aligned properly (16).

The Omron pedometer's underestimation of steps for all BMI categories is partially due to a 4-second filter that is incorporated into the device. The filter was designed to determine the walking pattern in each individual before recording steps. If a participant walks less than four seconds and stops, the pedometer will not record any steps (27). The filter in the Omron HJ-720ITC results in a very accurate device for step counting during continuous walking bouts, however, the device may miss a significant percentage of steps taken during intermittent lifestyle activities.

Researchers have shown that piezo-electric pedometers are generally more accurate than spring- lever arm electronic pedometers in laboratory settings (3,9,25,29). (In particular, the Yamax SW-200 pedometer consistently underestimates step counts at slow walking speeds.) In contrast, in the free-living environment the spring-levered, Yamax SW-200 demonstrated better accuracy in normal weight (MPE = -19.2%) and overweight (MPE = -21.2%) individuals than the Omron. However, the Yamax SW-200 greatly underestimated steps per day in obese individuals (MPE = - 48.1) to a greater extent than in normal and overweight individuals, ($P < 0.05$) which is consistent with previous research (8,25,30).

Even though the Stepwatch-3 is considered to be a good criterion because of its accuracy in step counting (20), there is still the potential for a minimal amount of error. The StepWatch requires less acceleration (< 0.30 g) than most accelerometers and pedometers to trigger a step, thus making it a very sensitive device. In 2005, Karabulut (20) demonstrated that driving a car, heel tapping, leg swinging and cycle ergometry will produce errors with the

Stepwatch-3. However, the author(s) concluded that error from these types of activities would be unlikely to have a significant effect the total daily number of steps recorded per day.

Previous studies have shown that the Omron HJ-720ITC pedometer is an accurate device when measuring continuous bouts of walking at 2.0 – 4.0 mph (16,17). However, this particular device may not be suitable for detecting activities that are intermittent. It also may not be suitable for individuals who walk with a slow, shuffling gait. The Omron pedometer is an excellent device for clinical interventions in which continuous walking is prescribed as the mode of exercise, however, it is not a good choice for research studies that attempt to measure each step taken throughout the day. For obese individuals, the Omron's accuracy is highest when it is worn in the pants pocket.

REFERENCES

1. **Bassett DR J.** Use of pedometers to assess physical activity. . In: *Physical Activity assessments for health-related research* edited by GJ W. Champaign, IL: human kinetics 2002, p. 163-177.
2. **Bassett DR, Jr.** Validity and reliability issues in objective monitoring of physical activity. *Res Q Exerc Sport* 71: S30-36, 2000.
3. **Bassett DR, Jr., Ainsworth BE, Leggett SR, Mathien CA, Main JA, Hunter DC, and Duncan GE.** Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc* 28: 1071-1077, 1996.
4. **Bergman RJ, Bassett DR, Jr., Muthukrishnan S, and Klein DA.** Validity of 2 devices for measuring steps taken by older adults in assisted-living facilities. *J Phys Act Health* 5 Suppl 1: S166-175, 2008.
5. **Bland JM and Altman DG.** Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1: 307-310, 1986.
6. **Butler L, Furber S, Phongsavan P, Mark A, and Bauman A.** Effects of a pedometer-based intervention on physical activity levels after cardiac rehabilitation: a randomized controlled trial. *J Cardiopulm Rehabil Prev* 29: 105-114, 2009.
7. **Clemes SA, O'Connell S, Rogan LM, and Griffiths PL.** Evaluation of a commercially available pedometer used to promote physical activity as part of a national programme. *Br J Sports Med*, 2009.
8. **Crouter SE, Schneider PL, and Bassett DR, Jr.** Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc* 37: 1673-1679, 2005.
9. **Crouter SE, Schneider PL, Karabulut M, and Bassett DR, Jr.** Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc* 35: 1455-1460, 2003.
10. **Felton GM, Tudor-Locke C, and Burkett L.** Reliability of pedometer-determined free-living physical activity data in college women. *Res Q Exerc Sport* 77: 304-308, 2006.
11. **Foster RC, Lanningham-Foster LM, Manohar C, McCrady SK, Nysse LJ, Kaufman KR, Padgett DJ, and Levine JA.** Precision and accuracy of an ankle-worn accelerometer-based pedometer in step counting and energy expenditure. *Prev Med* 41: 778-783, 2005.
12. **Freedson PS and Miller K.** Objective monitoring of physical activity using motion sensors and heart rate. *Res Q Exerc Sport* 71: S21-29, 2000.
13. **Gardner PJ and Campagna PD.** Pedometers as Measurement Tools and Motivational Devices: New Insights for Researchers and Practitioners. *Health Promot Pract*, 2009.
14. **Gayle R, Montoye HJ, and Philpot J.** Accuracy of pedometers for measuring distance walked. *Res Q* 48: 632-636, 1977.
15. **Gibbs-Smith C.** *The inventions of Leonardo da Vinci* New York Charles Scribner Son's 1978.
16. **Hasson RE, Haller J, Pober DM, Staudenmayer J, and Freedson PS.** Validity of the Omron HJ-112 pedometer during treadmill walking. *Med Sci Sports Exerc* 41: 805-809, 2009.
17. **Holbrook EA, Barreira TV, and Kang M.** Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc* 41: 670-674, 2009.

18. **Jehn M.** Validity and Reliability of Omron Pedometers at Slow Walking Speeds. *Med Sci Sports Exerc* 41: 142, 2009.

19. **Jehn M, Schmidt-Trucksaess A, Schuster T, Hanssen H, Weis M, Halle M, and Koehler F.** Accelerometer-based quantification of 6-minute walk test performance in patients with chronic heart failure: applicability in telemedicine. *J Card Fail* 15: 334-340, 2009.

20. **Karabulut M, Crouter SE, and Bassett DR, Jr.** Comparison of two waist-mounted and two ankle-mounted electronic pedometers. *Eur J Appl Physiol* 95: 335-343, 2005.

21. **Kemper HC and Verschuur R.** Validity and reliability of pedometers in habitual activity research. *Eur J Appl Physiol Occup Physiol* 37: 71-82, 1977.

22. **Le Masurier GC, Lee SM, and Tudor-Locke C.** Motion sensor accuracy under controlled and free-living conditions. *Med Sci Sports Exerc* 36: 905-910, 2004.

23. **Lindberg R.** Active living: on the road with the 10,000 Steps program. *J Am Diet Assoc* 100: 878-879, 2000.

24. **Lohman TG, A.F. Roche, and R. Martorell.** *Anthropometric standardization reference manual* Champaign, IL: Human Kinetics, 1988.

25. **Melanson EL, Knoll JR, Bell ML, Donahoo WT, Hill JO, Nysse LJ, Lanningham-Foster L, Peters JC, and Levine JA.** Commercially available pedometers: considerations for accurate step counting. *Prev Med* 39: 361-368, 2004.

26. **Montoye HJ.** Use of Movement Senors in Measuring physical activity *Medicine and Science in Sports and Exercise* 3: 223-236, 1988.

27. **Nakae S, Oshima Y, and Ishii K.** Accuracy of spring-levered and piezo-electric pedometers in primary school Japanese children. *J Physiol Anthropol* 27: 233-239, 2008.

28. **Schneider PL, Crouter SE, and Bassett DR.** Pedometer measures of free-living physical activity: comparison of 13 models. *Med Sci Sports Exerc* 36: 331-335, 2004.

29. **Schneider PL, Crouter SE, Lukajic O, and Bassett DR, Jr.** Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Med Sci Sports Exerc* 35: 1779-1784, 2003.

30. **Shepherd EF, Toloza E, McClung CD, and Schmalzried TP.** Step activity monitor: increased accuracy in quantifying ambulatory activity. *J Orthop Res* 17: 703-708, 1999.

31. **Storti KL, Pettee KK, Brach JS, Talkowski JB, Richardson CR, and Kriska AM.** Gait speed and step-count monitor accuracy in community-dwelling older adults. *Med Sci Sports Exerc* 40: 59-64, 2008.

32. **Swartz AM, Bassett DR, Jr., Moore JB, Thompson DL, and Strath SJ.** Effects of body mass index on the accuracy of an electronic pedometer. *Int J Sports Med* 24: 588-592, 2003.

33. **Tudor-Locke C.** Taking steps toward increased physical activity: using pedometers to measure and motivate. . *President's Council Phys Fitness Sports Res Digest* 3: 1-8, 2002.

34. **Tudor-Locke C, Ainsworth BE, Thompson RW, and Matthews CE.** Comparison of pedometer and accelerometer measures of free-living physical activity. *Med Sci Sports Exerc* 34: 2045-2051, 2002.

35. **Washburn R, Chin MK, and Montoye HJ.** Accuracy of pedometer in walking and running. *Res Q Exerc Sport* 51: 695-702, 1980.

36. **Welk G.** Introduction to physical activity research. In: *Physical activity assessments for health-related research*, edited by GJ W. Champaign, IL, 2002, p. 6.

APPENDICES

APPENDIX A: INFORMED CONSENT

INFORMED CONSENT

Accuracy of the Omron Model HJ-720ITC Pedometer in Free-Living Individuals

Investigators: Nate Silcott, B.S.
Dr. David Bassett, Ph.D.

Address: The University of Tennessee
Department of Exercise, Sport and Leisure Studies
1914 Andy Holt Ave.
Knoxville, TN 37996
Telephone: 865-974-5091

PURPOSE:
You are invited to participate in a research study that examines the accuracy of several commonly available pedometers.

EXCLUSION CRITERIA:
If you have an internal defibrillator, pacemaker, or joint replacement, use any type of assistive walking device, or are pregnant, you will be excluded from participating in this study.

PROCEDURES:
You will be asked to come to the Applied Physiology lab on two separate occasions. You will be asked not to eat or exercise for approximately 4 hours prior to testing on the first day. You will need to bring light-weight clothing such as shorts and a t-shirt. Measurements will be taken of you're height and weight and your Body Mass Index (BMI) will be determined. Your percentage of body fat will also be collected using a device that looks like a typical bathroom scale. You will be asked to remove your shoes and socks and stand barefoot on the device for 1 minute.

You will then be asked to walk approximately 20 steps down a hallway and the total distance will be measured. This will be used to determine your stride length that will be entered into the pedometer. The first two pedometers will be placed on your belt or pants over the left and right hips. A third pedometer will be strapped to your right ankle. A fourth pedometer will be worn in your pants pocket and the last pedometer will be worn around your neck with a lanyard. You will be asked to wear the devices as soon as you wake up and during all hours of the day except for bathing, sleeping or swimming. A picture will be provided to show you the correct locations. The second appointment will be scheduled with Nate Silcott and it will consist of returning the pedometers to the lab and returning your instruction sheet with Yamax steps.

RISK AND BENEFITS:
The risks involved in this study are no greater than those you are experience in your normal daily life. You should not change anything about your daily activities. Please follow the instructions given to you by the researcher.

CONFIDENTIALITY

The information obtained from these tests will be treated as privileged and confidential and will not be released to any person without your consent. The information may be used in research reports or presentations, but your name and other information will not be disclosed.

CONTACT INFORMATION

If you have any questions at any time about the study or the procedures, requirements (or you experience adverse effects as a result of participating in this study), contact the investigator Nate Silcott, nsilcott@utk.edu at (865)-974-5091. If you have any questions about your rights as a participant, contact Brenda Lawson of the Research Compliance Services of the Office of Research at (865)-974-3466.

RIGHT TO ASK QUESTIONS AND WITHDRAW

You are free to decide if you want to participate in this study or withdraw from it at any time.

Before you sign this form, please ask questions about any aspects of the study that are unclear to you.

Consent

By signing this form, I am indicating that I understand what I will be asked to do in this study and agree to participate in this research study.

______________________________ ______

Your Signature Date

______________________________ ______

Researcher's Signature Date

Appendix B: Instruction Sheet

Name____________________ Date ____________________ ID # ________ (STAFF USE)

INSTRUCTIONS

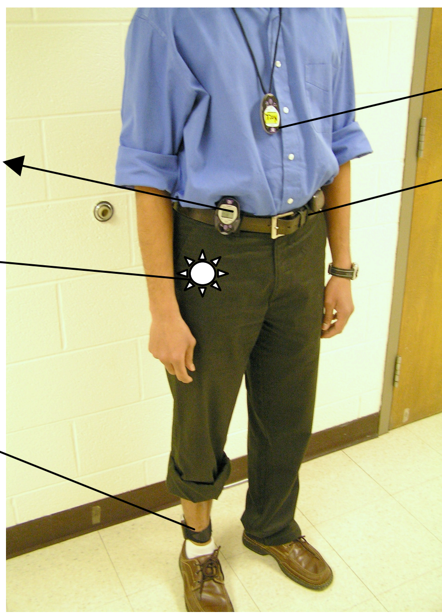
TESTING DAY

1. The Pedometers should be worn at ALL times except for bathing or in bed.

2. As soon as you wake up, press the yellow reset button on the YAMAX pedometer to register "0".

3. Place the pedometers in or on your clothing as indicated below.

(The waist-mounted pedometers are worn on the belt or waistband, in the midline of the thigh.)



4. Just before you go to bed at night, remove all the pedometers. Open the Yamax pedometer by holding onto the belt clip and pulling it open from the top. Record the number of steps here:

YAMAX PEDOMETER ________________STEPS

5. Place all of the pedometers and this form into the plastic zip-lock bag you've been given and return to Nate Silcott on your second scheduled visit to the lab.

Appendix C: Screening Questions

Thank you for calling and expressing interest in our pedometer study. In order for us to begin, I will need to ask you a few questions that will determine whether we will be able to move forward.

Are you between the ages of 18 and 69?

Do you use an assistive walking device? i.e. cane, walker, crutches.

Are you currently pregnant?

Do you have a pacemaker or an internal defibrillator?

Do you participate in a lot of non-ambulatory physical activities on a daily basis?

Examples: Biking, running, elliptical machine, rowing machine etc. If so, are you able to postpone those activities for 24 hrs?

When are you able to schedule a visit for these measurements?

As a participant in this study you will be asked to come into the lab and have measurements taken. Examples would be height and weight, and body fat percentage.

The body fat percentage requires no eating or drinking within 4 hours of measurements and also to avoid any type of exercising within 12 hrs of testing.

We also ask that you not drink alcoholic beverages within 48 hrs of testing.

Thank you for calling and we look forward to your participation in our study.

APPENDIX D: FLYER

SUBJECTS NEEDED ! !

Currently seeking volunteers to participate in a research study to examine the accuracy of a new pocket pedometer. No change in activity or exercise will be required. A FREE body composition test using the Tanita Body Composition Analyzer will be provided.

REQUIREMENTS

* 18-69 years of age
* Willing to wear activity monitors for 24hrs.
* No internal defibrillator, pacemaker, or joint replacement surgery.
* Must not be pregnant
* Must not use assistive walking devices

  Canes, walkers etc.

If you would like to participate in this research study please contact Nate Silcott at 865-974-5091 or e-mail nsilcott@utk.edu

VITA

Nathan Andrew Silcott was born on December 21st, 1981 in Weston, West Virginia and currently resides in Knoxville, Tennessee. He is the son of Larry Kennely Silcott and Rosanna Marie Corathers, both of Weston, West Virginia. He attended Weston Central Elementary School, Robert L. Bland Middle School and Lewis County High School and excelled in numerous sports. He earned varsity letters at Lewis County his freshman through senior years in basketball and golf (1996-2000). He played baseball only 2 years, earning varsity letters both years (1998-2000). He is the only individual from the class of 2000 to earn varsity letters in 3 different sports. In 2000, he earned all-conference honors in basketball in the North Central Athletic Conference (WV) and competed in the West Virginia state golf tournament finishing 5th in 1997 and 3rd in 1999.

Nathan graduated from West Virginia University with a Bachelor of Science in Physical Education-Teaching Education and was also awarded a minor in Community Health in 2005. He was accepted into the University of Tennessee in 2006 and obtained his Master's of Science degree in Exercise Physiology. During his master's program, Nathan served as an assistant strength and conditioning coach for the University of Tennessee men's track team in which he directed the strength program for Men's Cross Country and Middle Distance track.