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Reliability and validity of the Omron HJ-720 ITC pedometer when worn at four different locations on the body

Kimberly A. Smith^{1*}, Lauren Egercic¹, Ashley Bramble¹ and Jacob Secich¹

Abstract: *Purpose:* To determine the reliability and validity of the Omron HJ-720 ITC pedometer when worn at four different locations on the body. *Methods:* Subjects wore pedometers at the hip, chest, back, and pocket. Subjects' stature, body mass, and stride length were entered in to each pedometer prior to walking one mile on a track while wearing a portable metabolic analyzer. *Results:* Intraclass correlation coefficients (ICCs) revealed that the pedometer produced high and statistically significant inter-device reliability for steps (ICC = 0.95), distance (ICC = 0.93), and kcal expenditure (ICC = 0.87), regardless of placement on the body. Measures of percent agreement and one-way ANOVAs revealed that the pedometer was valid for measures of steps and distance, but there was a statistical difference between actual and pedometer-estimated kcal expenditure ($p < 0.05$). *Conclusions:* Although the Omron pedometer produced reliable results regardless of placement on the body, it did not produce valid estimates of kcal expenditure.

Subjects: Sport and Exercise Science; Sport and Leisure Studies; Health and Social Care

Keywords: pedometer; steps; kilocalorie expenditure; reliability; validity; physical activity

1. Background

Physical activity monitors, such as pedometers and accelerometers, have become increasingly popular due to the surge in availability, cost-effectiveness, and enhanced technologies during the past



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ABOUT THE AUTHORS

Dr Kimberly A. Smith is an Associate Professor of Exercise Science in the Department of Exercise and Rehabilitative Sciences at Slippery Rock University. Dr Smith earned a BS in Exercise Science from Slippery Rock University and MS and PhD degrees in Exercise Physiology from the University of Pittsburgh. She has been teaching at Slippery Rock University for 11 years, during which she has conducted several faculty-student collaborative research projects and coordinates a campus wide pedometer-based walking program. Dr Smith's research interests include investigating physical activity interventions and physical activity monitoring devices. Dr Smith's teaching philosophy focuses on inspiring students by bringing enthusiasm and eagerness into the classroom, all while facilitating a solid and challenging education based upon theory, science, and practical application.

PUBLIC INTEREST STATEMENT

When purchasing a physical activity monitoring device, such as a pedometer, consumers are often curious to know if the manufacturer's claims are true and accurate. The purpose of this research was to investigate the claim that the Omron HJ-720 ITC pedometer is accurate when worn at various locations on the body.

several years. With an increase in available options and technologies, it is important to be able to protect the consumer by providing them with evidence of reliability and validity for each of these devices. This study will focus on examining one particular pedometer which claims to be accurate when worn on various parts of the body, a feature that is highly desirable for many consumers.

Pedometers are inexpensive, light-weight, and unobtrusive tools that measure physical activity by responding to vertical accelerations of the hip during gait cycles (Schneider, Crouter, & Bassett, 2004). Studies have shown that pedometers are most accurate at measuring steps taken (Bassett, Ainsworth, & Leggett, 1996; Bassett et al., 2000; Hendelman, Miller, Baggett, Debold, & Freedson, 2000), less accurate at estimating distance traveled (Bassett et al., 2000; Hendelman et al., 2000), and even less accurate at estimating kilocalorie (kcal) expenditure (Bassett et al., 2000). For these reasons, it has been recommended that steps taken, or steps/day, be universally adopted as a standard unit of measurement for collecting, reporting, and interpreting pedometer data (Bassett et al., 2000; Rowlands, Eston, & Ingledew, 1997).

There are two common types of pedometers: spring-levered and piezoelectric. Spring-levered pedometers typically include a horizontal, spring suspended lever arm that moves up and down with normal ambulation (i.e. walking or running). An electrical circuit closes with each movement detected and an accumulated step count is displayed digitally on a feedback screen. Spring-levered pedometers must be placed in a vertical position (with no tilt) and perpendicular to the ground. Piezoelectric pedometers typically include a mass that is attached to a cantilevered beam. When acceleration occurs, the mass presses on a crystal. This produces an electrical current which emits a signal (change in step count).

Crouter, Schneider, and Bassett (2005) reported that a piezoelectric pedometer is more accurate than a spring-levered pedometer in overweight and obese individuals, especially at slower speeds, due to the tilt of the pedometer when placed on the waistband. To address the concern of pedometer tilt, manufacturers such as Omron Healthcare marketed piezoelectric pedometers that can be worn at various locations of the body without regard for pedometer tilt. One such pedometer is the Omron HJ-720 ITC pedometer which records steps, distance, and kilocalorie expenditure. Omron manufacturers claim that their piezoelectric pedometers are accurate when worn on the waistband, in the front pocket of a shirt/pants, or in a backpack.

A previous study conducted by Holbrook Barreira, and Kang (2009), confirmed that the *Omron HJ-720 ITC* piezoelectric pedometer was accurate at measuring step counts when mounted on the right hip, left hip, mid-back, right pocket and left pocket during a 100 m walking trial. Holbrook cautioned, however, that the error reported in wearing the pedometer in a backpack was outside of the acceptable range for pedometer accuracy (3.4% Absolute Percent Error (APE) instead of the <3.0% acceptable range) (Omron, 2007).

In another study, Rider, Bassett, Thompson, Steeves, & Raynor (2014), concluded that the Omron HJ-720 ITC pedometer is a reasonably priced, wearable activity monitor that is feasible for use in clinical and research settings. As such, this pedometer has been widely used in leisure, clinical, and research settings in recent years. In fact, this device has been marketed in many popular magazines as one of the top performing pedometers on the market. Regardless of whether this pedometer is used in leisure, clinical and/or research settings, it is important to validate these claims with evidence in order to inform and protect the consumer.

In order to evaluate these claims, reliability and validity must first be examined. Reliability is the degree to which an assessment tool, in this case the Omron HJ-720 ITC pedometer, produces consistent results. After reliability is established, validity of the assessment tool can then be examined. Validity is the extent to which the assessment tool measures what it is intended to measure.

The purpose of this study was to further investigate the *Omron HJ-720 ITC's* reliability and validity in recording not only steps, but distance and kilocalorie expenditure when worn at four different locations on the body during a one-mile track walk. Several studies have examined the reliability of the pedometer during short walks (i.e. 100 m), during treadmill walks, and during 24 h free-living experiments, but there is limited evidence of reliability and validity in longer, controlled walks such as the one-mile walk conducted in this study. Furthermore, to the investigators' knowledge, no studies have examined the accuracy of the distance and kilocalorie features of this device during a walk of this distance.

2. Material and methods

Nineteen college students ranging in age from 18 to 22 years, with a mean height of 1.6 ± 0.08 m, mean weight 61.8 ± 10.3 kg, and mean stride length 73.2 ± 7.6 cm, participated in this investigation. All subjects completed the Physical Activity Readiness Questionnaire (PAR-Q) prior to participating in this study. If the subject answered YES to any of the PAR-Q questions, the subject was excluded from this study. Subjects were also excluded if they were under the age of 18 or were pregnant. Written informed consent was obtained from all subjects prior to participation in the study which was approved by the Slippery Rock University Institutional Review Board.

Each subject was required to attend two data collection sessions. One subject completed the first data collection sessions, but failed to complete the second data collection session and thus was excluded from the data analysis.

During the first session, subjects reported to the Clinger Exercise Physiology laboratory where height and body mass were measured using a Detect-Medic Stadiometer (Detecto Sales Inc., New York). Stature (i.e. height) was recorded to the nearest 0.25 cm and body mass was recorded to the nearest 0.25 kg. During this session, stride length was also determined by using the Omron manufacturer's recommended guidelines (Omron, 2007). Subjects began with their toes behind a start line. Subjects then briskly walked 10 strides, and the distance from the start line to the heel of the 10th stride was measured in centimeters. The stride length was calculated by taking the total distance traveled, divided by 10 (the number of steps taken).

During the second testing session, subjects reported to the Morrow Field House 200 m indoor track wearing athletic clothing, which included shorts or pants that had a front pocket. The participants' stature, body mass, and stride length were entered into each of the four *Omron HJ 720-ITC* pedometers prior to the start of the test. Pedometers were randomly placed in one of four locations:

- Right hip at the midline of the femur and at the level of the umbilicus
- Right front pocket
- Middle of the chest at the level of the xiphoid process
- Middle of the back at the level of the xiphoid process

Subjects were also fitted with the Cosmed K4b2 portable metabolic analyzer (Cosmed Inc, Illinois) which was used to measure total body VO_2 during each exercise minute of the session. The portable respiratory-metabolic system was calibrated prior to each data collection session. Total kcal expenditure for each walking bout was determined from VO_2 by using a non-protein respiratory exchange ratio conversion table for energy substrate utilization (Zuntz, 1901).

After donning the four pedometers and portable metabolic analyzer, subjects were instructed to step up to the start line. At the start line, all pedometers were reset to zero and the portable metabolic analyzer was set to record VO_2 . On the researcher's command, subjects walked 1,609 m (1 mile) at a self-selected brisk pace around the 200 m indoor track (8 laps plus 9 m). At the end of the trial, data from all four pedometers as well as the portable metabolic analyzer were recorded.

To assess the accuracy of the pedometers' recorded step counts, two researchers followed behind the subject with a tally counter, counting each step the subject took. At the end of the trial, the tallied step counts from each researcher were recorded. The average of the two scores was recorded as "actual step counts" and later compared to each of the four Omron pedometer's recorded step counts. Interrater reliability was found to be 0.98 between the two researchers. This measure served as the criterion for which the pedometer-recorded measures were compared.

To assess the accuracy of the pedometers' recorded distance, subjects walked exactly one mile (1,609 m) on a 200 meter indoor track. This exact distance served as the criterion for which the pedometer-recorded measures were compared. Subjects were required to begin at the start line, walk 8 laps, and end at the finish line (9 m past the start line). All subjects walked at a self-selected brisk pace in the second lane on the track. Average walking pace was 96 ± 9.3 m/min⁻¹ (3.56 mph) and ranged from 84–116 m/min⁻¹ (3.13–4.36 mph). At the end of the one mile walk, distance from each of the four pedometers was recorded.

To assess the accuracy of the pedometers' recorded kilocalorie expenditure, subjects wore the Cosmed K4b2 portable metabolic analyzer. This portable analyzer allows measurements of oxygen consumption in field settings, such as the one employed for this study. When compared to a criterion Medgraphics traditional, stationary metabolic analyzer, the Cosmed K4b2 unit produced intraclass correlation coefficients (ICCs) between 0.93–0.97. As such the Cosmed K4b2 unit served as the criterion for which the pedometer-recorded kcal were compared.

The portable metabolic analyzer was set to record VO₂ at the start of the trial. At the end of the trial, kcal expenditure from each of the four pedometers was recorded as well as the gross kcal expenditure from the metabolic analyzer. Gross kcal expenditure from the portable metabolic analyzer was later transformed into net kcal expenditure in order to match the unit of measure from the pedometers.

3. Results

Data analysis was conducted using SPSS statistical software (v. 18). The data was initially analyzed using descriptive statistics, including mean and standard deviations (See Tables 1–3). ICCs were used to determine the reliability of the pedometers. According to Atkinson and Nevill (1998), ICCs are more commonly used in reliability studies as compared to Pearson Product Moment Correlations because ICCs are univariate rather than bivariate and they can be used when more than one re-test is being compared to a test. For example, in this study there were four pedometers being compared against one another. Furthermore, the standard error of the measurement (SEM) was calculated to determine absolute reliability. To establish validity of the Omron HJ-720 ITC pedometer, percent agreements and one-way ANOVAs were used to establish concurrent validity.

3.1. Reliability

To determine the reliability of the devices worn at four different locations on the body, intraclass correlations coefficients (ICCs) were conducted. Traditionally, if a high (>0.8) and statistically significant correlation coefficient is obtained, the equipment is deemed to be sufficiently reliable (Coolican, 1994). Furthermore, standard errors of the measurement (SEM) were calculated to determine absolute reliability.

ICCs revealed that the Omron HJ-720 ITC pedometer produced high and statistically significant inter-device reliability for step counts (ICC = 0.95; 95% Confidence Interval (CI)= 0.91–0.98) ($p < 0.001$). The SEM, which calculates absolute reliability, was 33 steps with a mean of $2,069 \pm 143$ steps and a 95% CI ranging from 2,000–2,138 steps.

Likewise, ICCs indicated that the pedometer produced high and statistically significant inter-device reliability for distance traveled (ICC = 0.93; 95% CI = 0.86–0.97) ($p < 0.001$). The SEM was calculated to be <0.001 miles with a mean of 0.99 ± 0.00 miles and a 95% CI ranging from 0.99–1.01 miles.

Lastly, ICCs indicated the Omron HJ-720 ITC pedometer produced high and statistically significant inter-device reliability for kcal expenditure (ICC = 0.87; 95% CI = 0.72–0.95) ($p < 0.001$). The SEM was calculated to be 4.2 kcals with a mean of 82.4 ± 18.2 kcals and a 95% CI ranging from 73.6–91.1 kcals.

These results indicate that the Omron HJ-720 ITC pedometer is reliable, regardless of placement on the body (hip, chest, back or pocket) with regards to step counts, distance traveled, and kcal expenditure.

3.2. Validity

3.2.1. Step validity

To determine the validity of the step data, step counts recorded by the pedometer were divided by the step counts measured by the investigator in order to get a “percentage of actual steps” (Bassett et al., 1996; Crouter, Schneider, Karabulut, & Bassett, 2003; Karabulut, Crouter, & Bassett, 2005). The percentage of actual steps was calculated for each person and then the mean percent was recorded, whereas 100% would equal a perfect score. In this study, the percentage of actual steps ranged between 102–103% which indicates a slight overestimation of actual steps recorded (hip $103 \pm 0.9\%$; chest $103 \pm 0.9\%$; back $103 \pm 0.8\%$; pocket $102 \pm 0.9\%$). According to Holbrook et al. (2009), an APE of approximately 3% is deemed acceptable. Pedometers in all four positions fell within the acceptable 3% error range for steps.

To establish concurrent validity, a one-way ANOVA was used to determine if there were any differences in steps between the actual recorded measurements (criterion: tally counter) and each of the four pedometer-estimated measurements. There were no significant differences between actual steps taken ($2,016 \pm 274$) and the steps recorded by the pedometer located at the hip ($2,131 \pm 189$), chest ($2,126 \pm 190$), back ($2,120 \pm 176$), or pocket ($2,110 \pm 190$) ($p > 0.05$) (Table 1). Thus, concurrent validity was established.

3.2.2. Distance validity

The same procedure was conducted for distance and kcal expenditure. The percentage of actual distance ranged from 97–98%, which indicates a slight underestimation of distance measured (Hip $97.9 \pm 0.9\%$; chest $97.4 \pm 0.9\%$; back $97.3 \pm 0.8\%$; pocket $97.1 \pm 0.9\%$). Once again, all four pedometers fell within the acceptable 3% error range for distance.

To establish concurrent validity, a one-way ANOVA was used to determine if there were any differences in distance between the actual recorded measurements (criterion: one mile marked track) and each of the four pedometer-estimated measurements. There were no significant differences

Table 1. Actual step counts versus pedometer-recorded step counts

	Actual step counts	Hip step counts	Chest step counts	Back step counts	Pocket step counts
Step counts	$2,016 \pm 274$	$2,131 \pm 189$	$2,126 \pm 190$	$2,120 \pm 176$	$2,110 \pm 190$

Note: No significant difference between actual steps taken and steps recorded by pedometers at any location ($p > 0.05$).

Table 2. Actual distance versus pedometer-recorded distance

	Actual distance	Hip distance	Chest distance	Back distance	Pocket distance
Distance (miles)	1.0 ± 0.0	0.98 ± 0.09	0.97 ± 0.09	0.97 ± 0.08	0.97 ± 0.09

Note: No significant difference between actual steps taken and steps recorded by pedometers at any location ($p > 0.05$).

Table 3. Actual kcal expenditure versus pedometer-recorded kcal expenditure

	Actual kcal	Hip kcal	Chest kcal	Back kcal	Pocket kcal
kcal expenditure	82 ± 18	69 ± 14*	70 ± 15*	70 ± 14*	69 ± 14*

*Indicates a significant difference ($p < 0.05$) between actual kcal expenditure using indirect calorimetry and pedometer-recorded kcal expenditure.

between the actual distance traveled (1.0 ± 0.0 mile) and distance recorded by the pedometer located at the hip (0.98 ± 0.09 mile), chest (0.97 ± 0.09 mile), back (0.97 ± 0.08 mile), and pocket (0.97 ± 0.09 mile) ($p > 0.05$) (Table 2). Thus, concurrent validity was established.

3.2.3. Kilocalorie validity

The percent of actual kcal expenditure (recorded kcal/actual kcal) ranged from 80–87% (Hip $87 \pm 2\%$; chest $80 \pm 2\%$; back $87 \pm 2\%$; pocket $86 \pm 2\%$), which indicates an underestimation of kcal expenditure. Kilocalorie expenditure did not fall within the 3% acceptable error range.

To establish concurrent validity, a one-way ANOVA with Tukey Post hoc analysis was used to determine if there were any difference in kcal expenditure between the actual recorded measurement (criterion: calibrated metabolic analyzer) and pedometer-estimated kcal expenditure. The analysis revealed a significant difference between actual net kcal expenditure (82 ± 18 kcal) and kcal expenditure recorded by the pedometer at the hip (69 ± 14 kcal), chest (70 ± 15 kcal), back (70 ± 14 kcal), and pocket (69 ± 14 kcal) ($p < 0.05$) (Table 3). Thus, concurrent validity was not established.

4. Discussion and conclusions

The Omron HJ-720 ITC pedometer produces reliable and valid results in steps and distance traveled regardless of placement on the body. Knowing that this pedometer will produce accurate step counts and distance traveled regardless of body placement, users have the option of wearing the pedometer in a variety of locations based upon their clothing choices or placement preferences for any particular day. This pedometer can even be placed in multiple locations throughout the course of a single day. This may enhance the use of the pedometer, as it will reduce traditional barriers of wearing pedometers such as not having a convenient waistband (i.e. a dress) or wanting the pedometer to be more discreetly worn (i.e. formal attire).

Although the Omron HJ-720 ITC pedometer produces reliable results in steps and distance traveled, it significantly underestimates the kcal expenditure in each of the four locations. While the kcal expenditure was very reliable ($ICC = 0.87$) between pedometers, it was significantly different than measured kcal expenditure using the portable metabolic analyzer ($p < 0.05$). As such, significant advancements continue to be made in order to develop proprietary algorithms which improve pedometer accuracy. While the development of the algorithms is still a necessity, health care providers may argue that it is better to underestimate kcal expenditure, as was seen in this study, rather than overestimate kcal expenditure. For example, if a pedometer overestimates kcal expenditure, clients who are working towards a prescribed kcal expenditure goal for the purpose of weight loss may feel frustrated if they are not losing weight. On the contrary, if a pedometer underestimates kcal expenditure, clients will likely do more work than necessary in order to meet their prescribed kcal expenditure goal. Although neither situation is optimal, most healthcare providers would likely agree that an underestimation of kcal expenditure, within reason, is less detrimental than an overestimation of kcal expenditure.

This pedometer would likely be recommended for interventions that are focused on steps or distance traveled, however users and interventionists should be cautious not to use the Omron HJ-720 ITC strictly based upon kcal expenditure. Further investigations including a more heterogeneous group of participants including those of various ages, Body Mass Indexes, and gait patterns are warranted. In addition, the Omron HJ-720 ITC should also continue to be examined at various walking speeds and on various terrains (including hills).

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Competing Interests

The authors declare no competing interest.

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