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Validity of the Pedusa PE-771 pedometer

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ABSTRACT

The purpose of this study was to examine the accuracy of a new, commercially developed pedometer, Pedusa PE-771. 13 participants completed various ambulatory-based activity trials while wearing up to six pedometers, with observed steps assessed using a tally counter. The four main experiments included (1) participants wearing the pedometers during a 20 step-test, (2) an assessment of walking speed accuracy of the pedometer, (3) and an assessment of the accuracy of the pedometer over different surfaces (e.g., grass, concrete), and (4) an assessment of the pedometer's proprietary energy expenditure algorithm. During these trials, pedometers were worn on the waist, in shorts with snug pockets, and in shorts with loose pockets. For the 20 step-test, and across all conditions (i.e., pedometers worn on the belt, in snug pocket and loose pocket), each pedometer demonstrated acceptable classification accuracy, with an error rate range being 0.01-4.5%. When the pedometers were worn on the belt, the accuracy of each pedometer was exact at speeds greater than or equal to 3 mph. However, at 2 and 2.5 mph, there was some degree of under-and over-estimation. These findings were identical to when the pedometers were worn in snug or loose pockets. The Pedusa PE-771 pedometer demonstrated accuracy (i.e., 1% error rate)when placed in snug pockets during outdoor self-selected walking speed over concrete, which was not the case when the pedometer was worn in loose pockets. Lastly, the Pedusa PE-771 pedometer overestimated and underestimated energy expenditure, respectively, during walking and jogging.

KEY WORDS: Energy expenditure, pedometer, validity

INTRODUCTION

Accurate measures of physical activity help better understand the association between physical activity and health outcomes; the dose of physical activity required to elicit favorable health outcomes; determinants of physical activity; and the impact of physical activity interventions on various health-related parameters [1]. A new commercially available digital pedometer, Pedusa PE-771, was recently developed to monitor physical activity behavior. However, no published studies have evaluated this pedometer for validity. Therefore, the purpose of this brief report was to examine the validity of the Pedusa PE-771 pedometer. If demonstrating evidence of validity, then this pedometer can be used as a physical activity measure to examine, for example, the association between physical activity and health.

METHODS

Thirteen ambulatory undergraduate students were recruited to participate in this study. Among the 13 participants, the mean (standard error [SE]) age was 21.3 years (0.65); mean (SE) weight was 76.6 kg (2.6); 69.2% were male, and 100% were non-hispanic white. All study procedures were approved by the University's Institutional Review Board, and all participants provided written informed consent prior to participation. Participants completed a series of activities for 3 main studies. Unless otherwise stated, during each activity, participants wore 6 Pedusa PE-771 pedometers on their waistband; 3 monitors were worn on the right hip, with one at anterior, one at the mid, and another at the post-axillary line at the level of the iliac crest. The last 3 monitors were worn at these locations but on the left hip. Monitors were counterbalanced across participants. To validate the pedometer-determined steps across activities, one researcher counted the number of steps using a tally counter.

Study 1: 20 Step Test

The 20 step test is a short assessment to identify inaccurate pedometers. Participants completed 6 of these 20 step tests on a concrete floor inside the researcher's laboratory.

Trial 1: Participants walked at a self-selected "normal" speed with all 6 pedometers tightly secured on the elastic belt.

Trial 2: Participants walked at a normal speed with two pedometers; one positioned in each pocket, with the shorts having snug pockets. For all participants, tape was wrapped around the thigh to minimize pedometer movement within the pocket.

Trial 3: Identical to trial 2, except participants, wore the pedometer in loose-pocketed shorts (i.e., large basketball shorts). The same shorts was worn for each participant.

Study 2: Controlled Conditions

Testing for walking speed accuracy

Participants walked on a treadmill (0% incline) at various speeds, with each stage lasting 2 min. At the end of each stage, a brief interruption occurred (i.e., participants straddled the belt) to check the step count.

Trial 1:
- 2 mph with 6 pedometers positioned on waistband at same locations as 20 step test
- 2.5 mph with 6 pedometer positioned on waistband at same locations as 20 step test
- 3 mph with 6 pedometer positioned on waistband at same locations as 20 step test
- 3.5 mph with 6 pedometer positioned on waistband at same locations as 20 step test
- 4 mph with 6 pedometer positioned on waistband at same locations as 20 step test.

Trial 2:
- 2 mph with 2 pedometers in snug pockets (1 in each pocket)
- 2.5 mph with 2 pedometers in snug pockets (1 in each pocket)
- 3 mph with 2 pedometers in snug pockets (1 in each pocket)
- 3.5 mph with 2 pedometers in snug pockets (1 in each pocket)
- 4 mph with 2 pedometers in snug pockets (1 in each pocket).

Notably, all participants were the same pair of basketball shorts for the snug pocket trial. For this trial, the pedometer was placed in the pocket, and tape was wrapped around the pocket to ensure little to no movement of the pedometer occurred during ambulation.

Trial 3:
- 2 mph with 2 pedometers in loose pockets (1 in each pocket)
- 2.5 mph with 2 pedometers in loose pockets (1 in each pocket)
- 3 mph with 2 pedometers in loose pockets (1 in each pocket)
- 3.5 mph with 2 pedometers in loose pockets (1 in each pocket)
- 4 mph with 2 pedometers in loose pockets (1 in each pocket).

Notably, for the loose pocket trial, participants wore the same basketball shorts, but tape was not wrapped around the pocket/leg.

Testing for Walking Surface Accuracy (outdoors)

Trial 1 (approximately 50 m):
- Self-selected normal speed on grass with 6 pedometers positioned on waistband
- Self-selected normal speed on grass with 2 pedometers in snug pockets (1 in each pocket)
- Self-selected normal speed on grass with 2 pedometers in loose pockets (1 in each pocket).

Trial 2 (approximately 50 m):
- Self-selected normal speed on cement outdoors with 6 pedometers positioned on waistband
- Self-selected normal speed on cement with 2 pedometers in snug pockets (1 in each pocket)
- Self-selected normal speed on cement with 2 pedometers in loose pockets (1 in each pocket).

Testing for Validation of Proprietary Expenditure Algorithm

The Pedusa PE-771 provides an estimate of activity energy expenditure using a proprietary algorithm. To assess the validity of this activity energy expenditure estimate, participants completed two 5 min trials (1 walking and 1 jogging), with their activity energy expenditure concurrently measured using indirect calorimetry (parvo medics metabolic system).

Trial 1: Walking at 3 mph (0% incline) on the treadmill for 5 min with all 6 pedometers positioned on the hip, with oxygen consumption (VO_2; criterion measure of energy expenditure) concurrently measured.

Trial 2: Jogging at a self-selected speed (usually around 6-7 mph) on a treadmill for 5 min (0% incline) with all 6 pedometers positioned on the hip, with VO_2 concurrently measured.

Data Treatment and Statistical Analysis

Pedometer accuracy was computed as percent error ([steps detected-actual steps]-actual steps)*100 and expressed as absolute percent error. For study 1 (step test), an error of 1 step represents a 5% error, with greater error considered to be unacceptable [2]. For studies 2 and 3, direction of percent error was determined as underestimation ($<-1\%$), exact (within $\pm 1\%$), or overestimation ($>1\%$) [3].

RESULTS

Study 1: 20 Step Test

The results examining the validity of the 20 step test are shown in Table 1. Across all conditions (i.e., pedometers worn on the belt, in snug pocket and loose pocket), each pedometer demonstrated acceptable classification accuracy, with an error rate range being 0.01-4.5%.

Study 2: Controlled Conditions

Testing for speed accuracy

The results examining the validity of the pedometer across different walking speeds on the treadmill are shown in Table 2. When the pedometers were worn on the belt, the accuracy of each pedometer was exact at speeds ≥ 3 mph. However, at 2 and 2.5 mph, there was some degree of under-and over-estimation. These findings were identical to when the pedometers were worn in snug or loose pockets.

Table 1: Accuracy of the Pedusa PE-771 pedometer for the 20 step test

Study 1-20 step test	Pedometer-determined	Observed	Error rate (%)†	Classification†
Pedometers worn on the belt				
Pedometer 1	20.5	20.3	0.7	Acceptable
Pedometer 2	20.5	20.3	0.8	Acceptable
Pedometer 3	20.8	20.3	2.2	Acceptable
Pedometer 4	20.1	20.3	−1.1	Acceptable
Pedometer 5	20.9	20.3	2.6	Acceptable
Pedometer 6	20.6	20.3	1.5	Acceptable
Pedometer worn in snug pockets				
Left pocket	20.3	20.1	1.1	Acceptable
Right pocket	20.1	20.1	0.01	Acceptable
Pedometer worn in loose pockets				
Left pocket	21	20.1	4.5	Acceptable
Right pocket	20.7	20.1	3.4	Acceptable

†Pedometer accuracy was computed as percent error ([steps detected-actual steps]/actual steps)*100 and expressed as absolute percent error. Within±5% was considered acceptable

Table 2: Walking speed accuracy on the treadmill for the Pedusa PE-771 pedometer

Study 2: Speed accuracy	Pedometer-determined	Observed	Error rate (%)†	Classification†
Pedometers worn on the belt				
2 mph (2 min)				
Pedometer 1	187.3	186.9	0.3	Exact
Pedometer 2	186.2	186.9	−0.3	Exact
Pedometer 3	187.1	186.9	0.2	Exact
Pedometer 4	181.5	186.9	−2.8	Underestimation
Pedometer 5	186.7	186.9	−0.1	Exact
Pedometer 6	189.7	186.9	1.5	Overestimation
2.5 mph (2 min)				
Pedometer 1	211.6	209.2	1.1	Overestimation
Pedometer 2	210.4	209.2	0.6	Exact
Pedometer 3	210.9	209.2	0.8	Exact
Pedometer 4	211.1	209.2	0.9	Exact
Pedometer 5	210.3	209.2	0.5	Exact
Pedometer 6	212.3	209.2	1.5	Overestimation
3 mph (2 min)				
Pedometer 1	227.0	226.8	0.1	Exact
Pedometer 2	227.6	226.8	0.3	Exact
Pedometer 3	228.3	226.8	0.6	Exact
Pedometer 4	227.6	226.8	0.3	Exact
Pedometer 5	228.3	226.8	0.6	Exact
Pedometer 6	228.5	226.8	0.7	Exact
3.5 mph (2 min)				
Pedometer 1	241.3	240.3	0.4	Exact
Pedometer 2	241.3	240.3	0.4	Exact
Pedometer 3	241.6	240.3	0.5	Exact
Pedometer 4	241.6	240.3	0.5	Exact
Pedometer 5	241.6	240.3	0.5	Exact
Pedometer 6	241.4	240.3	0.4	Exact
4 mph (2 min)				
Pedometer 1	257.8	256.3	0.5	Exact
Pedometer 2	257.6	256.3	0.5	Exact
Pedometer 3	258.0	256.3	0.6	Exact
Pedometer 4	257.9	256.3	0.5	Exact
Pedometer 5	257.8	256.3	0.5	Exact
Pedometer 6	257.6	256.3	0.4	Exact
7 mph (5 min)				
Pedometer 1	851.5	800.6	−0.1	Exact
Pedometer 2	840.8	800.6	−0.9	Exact
Pedometer 3	855.0	800.6	0.4	Exact
Pedometer 4	851.3	800.6	0.2	Exact
Pedometer 5	855.0	800.6	0.2	Exact
Pedometer 6	859.2	800.6	0.6	Exact

Contd...

Table 2: Contd...

Study 2: Speed accuracy	Pedometer-determined	Observed	Error rate (%)†	Classification†
Pedometer worn in snug pockets				
2 mph (2 min)				
Left pocket	188.3	193.2	−2.2	Underestimation
Right pocket	190.3	193.2	−1.2	Underestimation
2.5 mph (2 min)				
Left pocket	204.3	205.9	−0.8	Exact
Right pocket	202.4	205.9	−1.6	Underestimation
3 mph (2 min)				
Left pocket	220.7	220.3	0.2	Exact
Right pocket	221.5	220.3	0.6	Exact
3.5 mph (2 min)				
Left pocket	234.5	234.6	0.01	Exact
Right pocket	233.9	234.6	-0.2	Exact
4 mph (2 min)				
Left pocket	254.0	253.6	0.2	Exact
Right pocket	252.7	253.6	−0.2	Exact
Pedometer worn in loose pockets				
2 mph (2 min)				
Left pocket	191.6	189.5	1.2	Overestimation
Right pocket	189.4	189.5	−0.01	Exact
2.5 mph (2 min)				
Left pocket	211.9	211.5	0.2	Exact
Right pocket	214.2	211.5	1.2	Overestimation
3 mph (2 min)				
Left pocket	226.0	225.3	0.3	Exact
Right pocket	226.0	225.3	0.3	Exact
3.5 mph (2 min)				
Left pocket	235.6	238	−0.9	Exact
Right pocket	236.1	238	−0.7	Exact
4 mph (2 min)				
Left pocket	250.9	253.0	−0.7	Exact
Right pocket	253.0	253.0	0.02	Exact

†Pedometer accuracy was computed as percent error ([steps detected-actual steps]/actual steps)*100 and expressed as absolute percent error. Direction of percent error was determined as underestimation (<−1%), exact (within±1%), or overestimation (>1%)

Testing for Walking Surface Accuracy (outdoors)

50 m on grass

The results examining the validity of the pedometer across different walking surfaces is shown in Table 3. When walking 50 m over grass, 5 out of the 6 pedometers worn on the belt were classified as exact accuracy, with 1 pedometer overestimating steps. When worn in snug pockets, 1 pedometer was classified as exact accuracy, with the other overestimating steps. When worn in loose pockets, both pedometers overestimated pedometer steps.

50 m on concrete

When walking 50 m on concrete, 3 out of the 6 pedometers worn on the belt were classified as exact accuracy, with 3 pedometers overestimating steps. When worn in snug pockets, both pedometers were classified as exact accuracy. When worn in loose pockets, 1 pedometer was classified as exact accuracy, with the other underestimating pedometer steps.

Study 3: Testing for Validation of Proprietary Expenditure Algorithm

The results examining the accuracy of the proprietary energy expenditure algorithm are shown in Table 4. When walking on a treadmill at 3 mph for 5 min, all 6 pedometers worn on the belt overestimated energy expenditure. When jogging on a treadmill at 7 mph for 5 min, 5 out of the 6 pedometers worn on the belt underestimated energy expenditure, with the other pedometer overestimating energy expenditure.

DISCUSSION

The purpose of this study was to examine the validity of the Pedusa PE-771 pedometer.

Results showed that the Pedusa PE-771 pedometer demonstrates acceptable classification accuracy (i.e., ≤5% error rate) over the 20-step test, which is a common rudimentary test to identify problematic pedometers. When testing for speed accuracy, the Pedusa PE-771 pedometer, regardless of where it was worn, was only accurate (i.e., 1% error rate) at ≥3 mph, which is consistent with other studies showing less accuracy at slower walking speeds [4]. The manufacturer may wish to shift the sensitivity threshold to a lower velocity to improve the ability to detect steps at slower speeds. However, this may not be absolutely necessary as the comfortable gait speed for young adults in their twenties is approximately 140 cm/s (~3.1 mph)[5].

The Pedusa PE-771 pedometer demonstrated accuracy (i.e., 1% error rate) when placed in snug pockets during outdoor self-selected

Table 3: Walking surface accuracy of the Pedusa PE-771 pedometer

Study 2: Surface accuracy	Pedometer-determined	Observed	Error rate (%)†	Classification†
50 meters on grass				
Pedometers worn on the belt				
Pedometer 1	60.6	60.1	0.8	Exact
Pedometer 2	61.1	60.1	1.7	Overestimation
Pedometer 3	60.2	60.1	0.1	Exact
Pedometer 4	60.5	60.1	0.7	Exact
Pedometer 5	60.6	60.1	0.8	Exact
Pedometer 6	60.4	60.1	0.4	Exact
Pedometer worn in snug pockets				
Left pocket	63.2	60.4	4.7	Overestimation
Right pocket	60.5	60.4	0.1	Exact
Pedometer worn in loose pockets				
Left pocket	61.6	60.1	2.5	Overestimation
Right pocket	61.1	60.1	1.6	Overestimation
50 meters on concrete				
Pedometers worn on the belt				
Pedometer 1	63.1	62.3	1.2	Overestimation
Pedometer 2	63.2	62.3	1.4	Overestimation
Pedometer 3	63.1	62.3	1.2	Overestimation
Pedometer 4	62.7	62.3	0.6	Exact
Pedometer 5	62.9	62.3	0.9	Exact
Pedometer 6	62.8	62.3	0.8	Exact
Pedometer worn in snug pockets				
Left pocket	61.7	62.3	−0.8	Exact
Right pocket	62.3	62.3	0.1	Exact
Pedometer worn in loose pockets				
Left pocket	60.2	61.1	−1.3	Underestimation
Right pocket	60.8	61.1	−0.4	Exact

†Pedometer accuracy was computed as percent error ([steps detected–actual steps]/actual steps)*100 and expressed as absolute percent error. Direction of percent error was determined as underestimation (<−1%), exact (within±1%), or overestimation (>1%)

Table 4: Accuracy of the Pedusa PE-771 pedometer proprietary energy expenditure algorithm

Study 3 conditions	Pedometer-determined kcals	Observed kcals†	Error rate (%)‡	Classification‡
3 mph (5 min)				
Pedometers worn on the belt				
Pedometer 1	26.9	20.0	35.6	Overestimation
Pedometer 2	26.5	20.0	33.3	Overestimation
Pedometer 3	27.0	20.0	36.2	Overestimation
Pedometer 4	27.5	20.0	40.0	Overestimation
Pedometer 5	26.6	20.0	34.5	Overestimation
Pedometer 6	26.6	20.0	34.3	Overestimation
Jogging - Self-selected speed (5 min)				
Pedometers worn on the belt				
Pedometer 1	40.7	45.3	−6.9	Underestimation
Pedometer 2	40.3	45.3	−8.0	Underestimation
Pedometer 3	41.4	45.3	−4.9	Underestimation
Pedometer 4	67.8	45.3	63.2	Overestimation
Pedometer 5	40.8	45.3	−6.6	Underestimation
Pedometer 6	41.0	45.3	−6.0	Underestimation

†Determined from indirect calorimetry, ‡Pedometer accuracy was computed as percent error ([steps detected-actual steps]/actual steps)*100 and expressed as absolute percent error. Direction of percent error was determined as underestimation (<−1%), exact (within±1%), or overestimation (>1%)

walking speed over concrete, which was not the case when the pedometer was worn in loose pockets. Consequently, young adult users should avoid wearing the pedometer in loose pockets, and instead, wear the monitor in snug pockets or clip it snugly to the waistband. Finally, the Pedusa PE-771 pedometer overestimated and underestimated energy expenditure, respectively, during walking and jogging. This is similar to other studies showing that objective monitors do a poor job at predicting point estimates of energy expenditure during ambulatory activities [6].

Strengths of this study include a systematic examination of the validity of the Pedusa PE-771 pedometer during various activities in a controlled setting. The main limitation, however, is not examining the validity of this pedometer in free-living conditions (e.g., over a 24-h time period).

In summary, these findings suggest that the Pedusa PE-771 pedometer is accurate when (1) walking on a treadmill at ≥3 mph, regardless of whether the pedometer is worn on

a belt/clipped over pants or worn in the pocket, and (2) when worn in snug pockets during overground concrete walking. Young adults, however, should be cautious when using the Pedusa PE-771 pedometer to measure steps when worn in loose pockets or when used to estimate energy expenditure.

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