Validity of 2 Devices for Measuring Steps Taken by Older Adults in Assisted-Living Facilities

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Background: This 2-part study examined validity of selected motion sensors for assessing physical activity in older adults residing in assisted-living communities. Methods: Twenty-one older adults (mean age = 78.6 ± 13.1 years) wore the StepWatch 3 Step Activity Monitor (SW3) and the Yamax Digi-Walker SW-200 pedometer (DW). Part I compared accuracy of these devices for measuring steps taken over 161 m. Part II compared devices over a 1-day (24-hour) period. Results: In part I, the DW recorded 51.9% (r² = −.08, P = .75) and the SW3 recorded 102.6% (r² = .99, P < .001) of steps. In part II, the DW measured significantly fewer steps (1587 ± 1057 steps) than did the SW3 (6420 ± 3180 steps). Conclusions: The SW3 pedometer was more accurate in counting steps and recorded higher 24-hour step counts than the DW pedometer. Thus, the SW3 is a valid research instrument for monitoring activity in the assisted-living population.

Keywords: StepWatch, pedometer, physical activity, walking, geriatric

The percentage of older adults in the United States population is rapidly increasing. Currently, 12% of the population is 65 years of age or older. By 2050, that percentage will increase to 21%, and 5% will be 85 years of age and older. As individuals grow older, there is a tendency to lose physical function, and daily physical activity levels decline. Approximately 900,000 (3%) of the 30.8 million older adults in the United States today live in assisted-living facilities.

Although the benefits of physical activity are widely known, many people are insufficiently active to achieve health benefits. Among all age categories, older adults are the least-active group, with more than 60% being inactive. Healthy People 2010 has identified a need to increase the amount of physical activity performed by all American adults, including older individuals.

With the current emphasis on increasing physical activity comes the need to accurately assess the amount of activity a person gets each day. Physical activity questionnaires have limitations because of problems with cognitive function and memory recall in many older adults. Objective monitoring is, therefore, gaining...
favor among researchers. Pedometers and accelerometers have become standard tools for measuring physical activity, as well as for motivating individuals in exercise-intervention studies. Pedometers might have great potential for research on aging, because walking is the most common leisure-time physical activity performed by older adults 75 years of age and above, and it is the mode of choice for older adults in many ethnic groups. Furthermore, walking is common even among seniors who perform no leisure-time physical activity because many routine daily activities require ambulation.

Waist-mounted pedometers detect vertical accelerations of the trunk that occur during ambulatory activity, and they use this to measure steps taken or distance walked. A spring-suspended lever arm moves up and down during walking, opening and closing an electrical circuit. Studies have reported the accuracy of pedometers in assessing physical activity at different walking speeds in adults. In general, these studies have shown that waist-mounted pedometer accuracy increases with walking speed, and the Yamax Digi-Walker pedometer is one of the most accurate. Few studies, however, have assessed the accuracy of waist-mounted pedometers in older adults (65 years of age and older). In nursing-home residents, Yamax pedometers significantly underestimated steps, particularly for those who have significant ambulatory impairment or a slow shuffling gait. The accuracy of these devices, however, has not been tested in assisted-care residents.

Ankle-borne instruments might provide a potential solution to the undercounting of the waist-mounted pedometers in older adults with ambulatory challenges. The StepWatch (SAM; Cyma Corporation, Mountlake Terrace, WA) is a unique pedometer with an accelerometer built in and is worn on the ankle. In a study of gait-impaired stroke patients performing 6-minute walking trials, it recorded 98% of actual steps. Other studies support the notion that the ankle-borne SAM is a valid and reliable tool for assessing ambulatory activity in clinical populations. Currently there is a need to further examine the use of these devices in older adults. This will advance our ability to assess levels of physical activity and provide a measurement tool for physical activity interventions.

The purposes of this 2-part study were (1) to investigate the accuracy of the StepWatch 3 Step Activity Monitor (SW3; Cyma Incorporated, Seattle, WA) and the Yamax Digi-Walker SW-200 (DW; Yamax Corporation, Tokyo, Japan) in measuring step counts in older adults residing in assisted-living facilities and (2) to compare the step counts for these 2 devices over the course of 1 day. It is hypothesized that the SW3 is more accurate in measuring the steps taken by older adults than the DW and that the SW3 gives higher 1-day total step counts than the DW. The SW3 is the newest generation of the SAM, produced by Cyma.

**Methods**

**Participants.** Twenty-one older adults (age range, 65–91, mean age = 78.6 ± 13.1 years; 5 men, 16 women) were recruited from 2 assisted-living facilities to participate in this study (Table 1). Criteria for exclusion from the study included a recent cardiovascular event (>6 months), severe visual impairment, mental illness, severe dementia (as reported by a registered nurse), and individuals who
were nonambulatory. Registered nurses and activity directors identified and helped recruit prospective participants.

**Procedures.** Administrators from each site provided a letter of cooperation permitting the research in the facility. Recruitment meetings were organized to discuss the purpose and procedures of the study. At the recruitment event, a cover letter and informed consent were provided to each prospective participant. Forms were read aloud, and the participants asked questions about matters that were unclear. Participants were asked to review the cover letter and sign written informed consent with appropriate power of attorney signature(s) before testing. The University of Tennessee Institutional Review Board approved the study protocol.

Data collection occurred over a 7-day period. Information on age, height, weight, and walking-assistive devices was collected before pedometry recording.

**Instruments.** The waist-mounted DW and the ankle-mounted SW3 pedometers were used in this study. DW pedometers are housed in a plastic case with a hinged cover that protects the display and buttons from accidental contact. The entire unit is small (51 × 38 × 19 mm) and lightweight (21.35 g). To prevent loss of and damage to the DW pedometer, a security strap loops into the pedometer clip and is attached to the user’s waistband when in use.

The SW3 is a completely sealed microprocessor-controlled step counter that measures 75 × 50 × 20 mm, weighs approximately 37.01 g, and is made of high-impact plastic that is contoured to fit comfortably against the leg. An elastic attachment securely attaches the device to the ankle without irritating the skin. The device consists of a sensor, surface-mount electronics, and a battery. Programming and downloading are controlled with the StepWatch Analysis Software. This software programs the SW3 monitor before deployment and downloads it to the computer via a USB-compatible docking station for viewing at the end of the recording session. Sensitivity of the instrument is optimized for each subject’s gait characteristics.

| Table 1 Characteristics of the Participants in the One-Tenth-Mile Trial (Part I) |
|--------------------------------|--------------------------------|--------------------------------|
| Men, mean ± SD (N = 5)         | Women, mean ± SD (N = 16)     | All participants, mean ± SD (N = 21) |
| Age (y)                        | 77.8 ± 23.5                   | 78.8 ± 9.1                     | 78.6 ± 13.1       |
| Height (cm)                    | 179.8 ± 8.7                   | 160.8 ± 7.3                   | 165.3 ± 11.2      |
| Gait aid (walker, cane)        | 2 (40%)                       | 7 (43.75%)                    | 9 (42.86%)        |
| Walking speed (m/s)            | 0.68 ± 0.28                   | 0.70 ± 0.24                   | 0.70 ± 0.24       |
| Observed steps                 | 467 ± 231                     | 423 ± 162                     | 433 ± 175abc      |
| SW3 steps                      | 476 ± 237                     | 435 ± 170                     | 444 ± 182         |
| DW steps                       | 200 ± 146                     | 232 ± 136                     | 225 ± 135         |

Abbreviations: SW3, StepWatch 3 Step Activity Monitor; DW, Yamax Digi-Walker SW-200 pedometer.

a Observed, SW3, and DW, P < .001.
b Observed and SW3, P < .001.
c Observed and DW, P < .001.
by programming in the subject’s height and answering questions that describe the subject’s gait. Answers to 4 of the 5 questions in the SW3 software were standardized for the purpose of these studies. (The fifth question asks about height.) These questions and answers are identified as follows:

1. Q: Does the client regularly participate in activities that involve short quick steps? A: No.
2. Q: Relative to people of similar height, the client’s normal walking speed is? A: Slow.
3. Q: What is the client’s range of walking speed? A: Rarely varies pace.
4. Q: How would you describe the appearance of the client’s leg motion? A: Gentle and/or geriatric.

Data were collected in 1-minute time intervals.

**Protocol.** A one-tenth-mile distance (161 m) was measured in the hallways of each facility. All participants performed 1 walking trial on a carpeted course at a self-selected walking pace. The DW was attached on the belt or waistband in the midline of the right thigh and the SW3 was attached above the lateral malleolus of the right leg per manufacturer’s instructions. During the trial, actual steps were recorded with a hand-tally counter, and the time to complete the course was documented. The number of steps registered by each device was recorded at the end of each trial, and the devices were reset or reprogrammed to zero before the next trial. Walking speed (m/s) was calculated by dividing distance (161 m) by time in seconds. Participants completed only 1 trial because they tired easily.

**Statistical Analysis.** All analyses were conducted using SPSS 12.0 for Windows (SPSS Inc, Chicago, IL). Statistical significance was set at $P < .05$ unless otherwise noted. Because the DW counts steps for both legs and the SW3 only counts steps for 1 leg, SW3 steps were doubled to enable comparison.

Correlations between pedometers and observed step counts were examined. Data were analyzed using Pearson product-moment correlations for the DW and SW3 with the observed step count, and repeated measures ANOVA were used to assess differences between pedometers and observed step counts for the one-tenth-mile walk. In the case of a significant main effect, Bonferroni post-hoc analysis was used to determine between which methods of measurement differences occurred.

**Part II**

**Participants.** Thirteen Caucasian, older adults (age range, 65–91, mean age $\pm$ SD, 75.5 $\pm$ 26.5) were recruited from 1 assisted-living facility to participate in this 12-hour pilot study (Table 2). These participants represented a subset of the participants in part I of the study, and, hence, the criteria for exclusion were the same as in part I. Identical procedures were followed for recruitment of participants and obtaining written, informed consent.

Data collection occurred over a 7-day period. Reminders about the testing days and instructions were provided to the participants and staff on how to attach and remove the DW and SW3 the day before.
Participants and their aides were instructed on how to properly attach the 2 pedometers. If an individual needed assistance in securing the pedometer, an aide was called. Instructions were given for the assisted-care facility residents to wear the pedometers from the time they awoke until the time they went to bed and to remove the devices only when bathing. The time when the devices were put on in the morning and the time when they were taken off at night were recorded on a log sheet. During this 7-day period, the researcher visited the facility each morning to verify that the pedometers were correctly attached.

**Statistical Analysis.** All analyses were conducted using SPSS 12.0 for Windows (SPSS Inc, Chicago, IL). An alpha of .05 was used to denote statistical significance for all analyses. Because DW counts steps for both legs and the SW3 only counts steps for 1 leg, SW3 steps were doubled to enable comparison. Paired *t* tests were conducted on the 12-hour data to evaluate differences between pedometers.

## Results

### Part I

Self-selected walking speed averaged 0.7 m/s and ranged from 0.29 m/s to 1.07 m/s. Of the 21 participants, 9 were aided by a walking device (43%). Data analysis indicates statistically significant differences between observed, SW3, and DW step counts (*F* = 12.24, *P* < .001). Error scores were computed (observed steps minus pedometer steps) to determine accuracy according to the method of Bland and Altman. Table 3 illustrates the mean error scores between the observed steps and the pedometer-measured steps. Positive scores indicated underestimates, negative scores represented overestimates, and values close to zero reflected more-accurate pedometer results. The SW3 overestimated the observed number of steps taken (*P* < .001), whereas the DW underestimated the observed number of steps taken (*P* < .001). Bland–Altman plots were constructed for each pedometer to illustrate the distribution of the individual error scores around zero (Figure 1). Error scores with a closer prediction interval around zero indicate a more-accurate device. The waist-mounted DW pedometers appear to underestimate steps taken by residents of assisted-living communities, but the ankle-mounted SW3 more accurately measures steps.
Table 3  Error Scores (Actual Pedometer) in Number of Steps During One-Tenth-Mile Walk at Self-Selected Pace

<table>
<thead>
<tr>
<th>Pedometer</th>
<th>Mean(^a)</th>
<th>SE</th>
<th>95% Prediction interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW3</td>
<td>−11.33(^b)</td>
<td>2.56</td>
<td>−18.01 to −4.65</td>
</tr>
<tr>
<td>DW</td>
<td>208.43(^b)</td>
<td>50.07</td>
<td>77.62 to 339.24</td>
</tr>
</tbody>
</table>

Abbreviations: SW3, StepWatch 3 Step Activity Monitor; DW, Yamax Digi-Walker SW-200 pedometer.

\(^a\) Negative scores indicate overestimations, and positive scores correspond with underestimations of observed steps taken.

\(^b\) \(P < .05\).

Figure 1 — Representative Bland–Altman plots for pedometers. Note. Solid horizontal line indicates mean error score; dashed lines indicate 95% prediction intervals.
Pearson product-moment correlation ($r$) indicated that observed steps and SW3 are highly correlated ($r^2 = .99, P < .001$), thus confirming the initial hypothesis. Observed steps and DW, however, are not significantly correlated ($r^2 = -.08, P = .75$; Figure 2).

**Figure 2** — Scatter plot of number of steps observed versus pedometers during one-tenth-mile walk. *Note.* StepWatch correlated ($r^2 = .99, P < .001$); Digi-Walker not correlated ($r^2 = -.08, P = .75$).

**Part II**

The SW3 and DW devices were worn an average of 11.63 ± 2.15 hours (mean ± SD) during the 12-hour study, and wear time ranged from 8.0 hours to 15.0 hours. The DW measured significantly fewer steps (1587 ± 1057 steps) than the SW3 (6420 ± 3180 steps). Data analysis indicates statistically significant differences between the SW3 and DW step counts ($t_{12} = 6.62, P < .001$).

**Discussion**

Part I of this study confirmed the hypothesis that the ankle-mounted SW3 is more accurate than the waist-mounted DW in assisted-living older adults. The findings supported previous research\textsuperscript{13} suggesting that the Yamax pedometer underestimates steps taken at walking speeds slower than 0.9 m/s. Cyarto et al\textsuperscript{15} previously exam-
ined DW accuracy in nursing-home residents and found that it underestimated steps taken at slow (0.42 m/s), normal (0.64 m/s), and fast paces (0.8 m/s) by 74%, 55%, and 46%, respectively. Mean walking speed of the current sample (0.7 m/s) was comparable to the normal pace from nursing-home residents and stroke patients but less than self-selected pace and controlled pace in younger samples.

The spring-levered mechanism in the Yamax model requires vertical accelerations greater than 0.35 g to close the circuit and record a step. Any movements resulting in acceleration below this threshold are not recorded. For slower-walking older adults (<0.9 m/s), the Yamax pedometer is not accurate for measuring the number of steps taken. In this sample of older adults, the Yamax mechanism only recorded about one-half of all steps being recorded, possibly because of gait impairments, decreased hip flexion, and smaller ground-reaction forces.

Although the SW3 had a statistically significant overestimation of steps (444 SW3 steps versus 433 observed steps), the magnitude of the error is small (<2.5%). This supports previous research that a step activity monitor is a valid step counter. The SW3 and the first-generation StepWatch (SAM) contain a custom accelerometer and electronic filter that minimizes extraneous signals. Threshold, cadence, and motion parameters of the sensor are adjusted each time the SW3 is initialized. Researchers previously changed sensitivity settings of the SAM when it was <90% accurate. For this study, these parameters were set at the most-sensitive settings. All questions concerning the sensitivity of the SW3 were answered exactly the same, with the exception of each participant’s height. The advantage to standardizing the SW3 settings in this study is that it provides a consistent methodology for future research.

Coleman et al observed adults with diabetic peripheral neuropathy, with or without amputation, over a walking course using the SAM and observed step counts. On 2 different trials 2 weeks apart, the SAM recorded 99.7% of steps taken. Walking speeds for these 45 participants, however, were not reported. It is possible that the slight overestimation in steps recorded by the SW3 in the current study was the result of extraneous movements being recorded as steps. Nevertheless, this overestimation in steps is a small error for research applications of the device.

The main finding from part II is that the SW3 recorded higher 24-hour step counts than did the DW in assisted-living older adults. Coleman et al reported 3 case studies examining the use of the SAM for long-term continuous recording of different gait activities before and after medical interventions or health changes. The authors concluded that the SAM is an accurate device that can be used to perform long-term step monitoring outside the laboratory.

Haeuber et al used the SAM to record the ambulatory activity of 17 individuals with chronic hemiparetic gait after suffering a stroke. Two 48-hour recordings revealed a high test–retest reliability ($r = .96$), leading the authors to conclude that the SAM was a reliable device for quantifying steps taken by stroke patients with gait impairment. In a study that used a SAM for long-term activity monitoring, the researchers randomly assigned 2 participants to wear the device for 6 hours, 1 for 8 hours, and 1 for 48 hours. Along with wearing the SAM, the participants were asked to keep an activity log. It was reported that in all 4 cases, the SAM closely matched the recorded activity in the diaries. Taken together, these studies suggest that the SW3 and its predecessor, the SAM, demonstrate adequate accuracy and reliability.
The current study has both strengths and limitations. It is the first study to report on the accuracy of the SW3 and DW in assisted-care facility residents, and it points out that only 1 of these (SW3) is a valid instrument for step counting in this population. Limitations of the study include the small sample size, limited age range, and exclusion of nonambulatory or cognitively impaired assisted-living residents. Although this study included only those who were ambulatory and cognitively functional, further research needs to be conducted using the SW3 to measure activity in the excluded population. For instance, Algase et al.\(^\text{24}\) successfully monitored the wandering activity of dementia patients using a LSI activity meter. Future studies are needed to examine the use of the SW3 to monitor activity on older adults with dementia. Another limitation was the selection of the study population, which was not representative of the broader population of residents in assisted-living facilities. Excluded from the study were nonambulatory individuals and those with severe dementia, mental illness, severe visual impairments, and recent cardiovascular events. Thus, the daily step counts obtained in this study are likely higher than those that would be obtained with a more-representative sample.

Expense of the SW3 is a factor to consider, because they cost $525 each with an additional cost for the docking station and software ($945). Because of the high cost and the need to download results into a computer, the SW3 is primarily useful as a research tool. Future studies should explore whether any existing waist-borne or shoe-borne pedometers or accelerometers can offer accuracy similar to the SW3 at a lower cost.

In conclusion, the current study found that the SW3 is a valid and feasible research instrument for monitoring ambulatory activity in the assisted-living population. Further research with the SW3 in the older adult population is needed. It would be useful to assess steps at varying paces, in individuals with and without gait disorders, and during different daily activities. There is a growing interest in monitoring steps per day because of the important role of physical activity in maintaining physical functioning in older adults. Objective monitoring devices currently are considered among the most valid and reliable techniques available to measure physical activity of assisted-living residents.

References

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