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Thirty-five youth with visual impairments (13.5 ± 2.1yrs, 13 girls and 22 boys) walked four 100-meter distances while wearing two units (right and left placement) of three brands of voice-announcement (VA) pedometers (Centrios™ Talking Pedometer, TALKiNG Pedometer, and Sportline Talking Calorie Pedometer 343) and a reference pedometer (NL2000). Registered pedometer steps for each trial were recorded, compared to actual steps assessed via digital video. Inter-unit agreement between right and left VA pedometer placement was low (ICC range .37 to .76). A systematic error was observed for the VA pedometers on the left placement (error range 5.6% to 12.2%), while right placement VA pedometers were at or below ± 3% from actual steps (range 2.1% to 3.3%). The reference pedometer was unaffected by placement (ICC .98, error ~1.4%). Overall, VA pedometers demonstrated acceptable accuracy for the right placement, suggesting this position is necessary for youth with visual impairments.

Pedometers are inexpensive (prices ranging from $10 to $55), relatively easy to use, and accepted tools by which to measure the physical activity of individuals of all ages (Tudor-Locke, Williams, Reis, & Pluto, 2002, 2004). Given these strengths, not all pedometers are created equal. The accuracy of pedometers (i.e.,

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actual steps taken versus the number of steps registered) varies considerably across brands (Beets, Patton, & Edwards, 2005; Crouter, Schneider, & Bassett, 2005; Crouter, Schneider, Karabulut, & Bassett, 2003; Schneider, Crouter, & Bassett, 2004; Schneider, Crouter, Lukajic, & Bassett, 2003). Variations in accuracy have been attributed to walking speed (Beets et al., 2005; Crouter et al., 2003; Schneider et al., 2003), manufacturing quality (Bassett et al., 1996; Beets et al., 2005), and pedometer tilt (Crouter et al., 2005). For these reasons, when new pedometer models come to market, there is a need to systematically test their accuracy. The outcomes from such testing can then be used to guide recommendations for which pedometer(s) to use in both research and health-promotion settings.

Advances in technology have allowed for manufacturers to introduce new features in pedometers. One of these is voice announcement or "talking." This feature provides an audible voice announcement of the number of steps the pedometer registered. These pedometers can be set to automatically announce steps according to preset intervals (e.g., every 1,000 steps) or can be triggered via a button by the wearer. Such features can be useful in certain populations where reading of the display is not feasible. This includes youth with visual impairments.

Pedometers that "talk" can prove to be a useful means by which to not only track the daily activity levels of youth with visual impairments, but more importantly, may serve as a motivational tool by providing feedback to the wearer about the number of steps they accumulated over the course of a given time frame (e.g., hour, day, week; Lieberman, Stuart, Hand, & Robinson, in press). Pedometer step counts do not lead to increased physical activity (Glazener, DeVoe, Nelson, & Gotshall, 2004; Matevey, Rogers, Dawson, & Tudor-Locke, 2006; Rooney, Smalley, Larson, & Havens, 2003), but in conjunction with goal setting or informational materials (e.g., flyers), pedometers can be useful in promoting higher levels of activity (Glazener et al., 2004; Rooney et al., 2003). For these reasons, a pedometer that can announce steps may assist practitioners in developing pedometer-based programs for individuals with visual impairments. However, prior to conducting descriptive or intervention studies, the accuracy of voice-announcement pedometers needs to be systematically evaluated. Therefore, the purpose of this study was to examine the accuracy of voice-announcement pedometers in a sample of youth with visual impairments.

Methods

Thirty-five youth with visual impairments (22 boys, 13 girls) 9 to 19 years old were recruited from a youth activity camp for children and adolescents with visual impairments. Parents of camp attendees were contacted prior to the camp start date to obtain written consent for their child's participation in the study. During the camp, children provided verbal assent prior to participating in the walking trails. The university's Institutional Review Board and the camp directors approved all study procedures. Participants' visual statuses were categorized as blind (B1, n = 10), travel vision (B2, n = 2; travel vision is the ability to see at 5-10 feet what the normal eye can see at 200 feet, visual acuity of 5/200-10/200), or legal blindness (B3, n = 23) according to the U.S. Association for Blind Athletes (1982/1998/2004) sports classifications. See Table 1 for descriptive characteristics of the participants.

Table 1 Descriptive Characteristics of Participants (*N* = 35)

	Girls (*n* = 13)		Boys (*n* = 22)	
Variable	**M**	**SD**	**M**	**SD**
Age (yrs)	12.9	1.4	13.9	2.3
Body Mass Index	21.1	3.2	21.6	4.9
BMI age-gender percentile	72.1%	28.4%	65.0%	31.7%

All data presented herein were collected for the sole purpose of assessing the accuracy of VA pedometers.

Pedometers

Three voice-announcement pedometers were evaluated. These were the Centrios™ Talking Pedometer (Orbyx Electronics, LLC, Walnut, CA), Spartan Sports TALKiNG Pedometer (Spartan Sports, Melbourne, FL), and Sportline Talking Calorie Pedometer 343 (Sportline Inc., Hazelton, PA). A fourth non-talking pedometer, the New Lifestyles NL2000 (Lee's Summit, MO) was also evaluated and used as the reference pedometer. This pedometer was selected based on prior studies demonstrating its high degree of accuracy during laboratory (i.e., treadmill) and semi-controlled (i.e., outdoor athletic track) assessment (Crouter et al., 2005; Crouter et al., 2003; Schneider et al., 2003). Two units of each pedometer, labeled right and left, were used throughout the entire test. The shake test (Vincent & Sidman, 2003) was performed for all pedometers prior to use in the study, with no pedometer deviating more than ± 1% (i.e., 1 step out of 100).

Walking Trails

Each youth walked four 100-meter distances (one for each pedometer model) marked by cones on an outdoor athletic track. One 100-meter distance comprised one walking trial with right and left pedometers (e.g., Centrios right and Centrios left). Participants were instructed to walk at their normal walking pace. Based on their level of visual impairment, participants could choose to either walk unassisted (i.e., without the use of a guide or assistive device, $n = 24$) or walk with a camp counselor (i.e., assisted, $n = 11$) by holding their arm. The counselor then walked on the right or left depending upon the participant's preference. For assisted walks, the counselors were informed to walk at the speed dictated by the participant. At the beginning of each trial, the participants were instructed to remain standing completely still (i.e., "stand like a statue"). At this time the right and left pedometers of the same model were affixed to the participants' waist using an adjustable belt. The pedometers were reset to zero and the participants were instructed to walk to the other end of the 100-meter distance. Immediately upon reaching the opposite end, the registered step counts were recorded. This procedure was performed until each participant had worn all four pedometer models. The order of the pedometer models was randomly assigned for each participant.

Criterion Steps

The actual steps for each walking trial were determined via videotape. One research staff member held a video camera (Panasonic Model PV-DV851D) while walking approximately 10 feet behind each participant during each of his/her walking trials. The camera was positioned in order to record the entire body from head to foot throughout the 100-meter distances. Trained research staff viewed the videos and recorded the actual steps walked using hand-tally counters. A step was defined as the elevation of the foot from the ground.

Statistical Analysis

Single measure intraclass correlation coefficients (ICC) and 95% confidence intervals (95CI) were calculated to determine the inter-unit agreement of steps registered between right and left placed units for each pedometer brand. Based on prior standards for evaluating ICCs (Baumgartner, Jackson, Mahar, & Rowe, 2003), the following guidelines were used to determine the inter-unit agreement of the ICC calculated for each pair of pedometers: (a) ≤ 0.79 is low agreement; (b) 0.80 to 0.89 is moderate agreement; and (c) ≥ 0.90 is high agreement. A high ICC would indicate the difference between the steps registered on the left and right placed units is minimal; that is, the two units, regardless of placement, register steps similarly. Conversely, a low ICC can be interpreted as the two placements differ in the steps registered on each unit.

Percent error scores (PES) were calculated (mean and standard deviation) for the right and left units for each pedometer brand, using the following equation: (registered steps minus actual steps) × 100. The absolute percent error scores (APE) were calculated using the PES formula disregarding the sign (i.e., positive and negative) of the error score. The PES were used to verify the direction of the error (over- or underestimation); the APE were used to determine the overall average error expected for each pedometer brand. In addition, the PES were graphically illustrated to visually interpret the direction of error for each participant. Preliminary analyses were conducted to determine if differences existed between the APE observed for boys and girls. No differences were observed across the four pedometer brands; therefore, all analyses were conducted for the complete sample.

In accordance to manufacturing standards of quality (Hanato, 1993), the minimum threshold for APE was set at 3%, which would translate into an error of ± 3 registered steps out of 100. Where APE scores exceeded the 3% threshold, exploratory ordinary least squared (OLS) regressions were modeled with the APE score, serving as the dependant variable and a predictor variable (dummy coded as 1/0), assisted vs. unassisted walking, entered into the model.

Results

No VA pedometer met the minimum ICC inter-unit agreement, with only the Centrios (ICC = .76, 95CI = .57, .87) approaching this requirement. The other two VA pedometers, TALKiNG and Sportline, ICCs (95CI) were .37 (.05, .63) and .59 (.32, .77), respectively. Thus, the agreement between units by placement was minimal, indicating that the registered steps were considerably different between right and left placement. The NL2000 demonstrated considerable inter-unit accuracy with an ICC of .98 (.97, .99). The PES and APE scores are presented in Table 2. As indicated by the difference between right and left APE scores, a systematic error was observed for all the left placed VA pedometers. The PES scores indicated the left placed TALKiNG underestimated step counts by approximately -11.7%, whereas the Sportline and Centrios overestimated step counts by 5.0% and 2.0%, respectively. The PES scores for right and left placement are illustrated in Figure 1 and the APE scores illustrated in Figure 2. Each right placed VA pedometer APE scores met the ±3% error minimum for accuracy, with the TALKiNG and Sportline averaging 2.3% and 2.1% error, while the Centrios minimally exceeded the minimum with an average APE of 3.3%. Both right and left placed NL2000 units were under the ± 3% minimum error with average APE scores of 1.4% and 1.3%, respectively.

To explain the systematic errors, the predictor variable, assisted and unassisted, for left placed pedometers were regressed on the left APE scores. The results were nonsignificant ($p > .05$) across the three VA pedometer brands. Although nonsignificant for assisted vs. unassisted in the OLS regressions, descriptive (mean and standard deviations) are presented in Table 3. Through this division of the sample, it is indicative that the APE for the assisted vs. unassisted walking trials were greater for the left side for both the Centrios (6.8% vs. 1.9% for the right, 8.5% vs. 4.5% for the left) and Sportline (4.3% vs. 1.1% for the right, 11.5% vs. 7.3% for the left), whereas the left APE scores for the TALKiNG were greater for the unassisted vs. assisted walking trials (9.6% vs. 13.5%). The NL2000 did not suffer from the systematic error.

Discussion

Establishing the accuracy of a measurement device, in this case voice-announcement pedometers, is essential prior to utilizing the devices in descriptive and intervention-based studies. Within certain populations, some measurement devices are more attractive than others due to specialized features that lend their use more readily given characteristics unique to the target population. For physical activity interventions with youth with visual impairments, the ability to voice-announce

Table 2 Absolute Percent Error (APE) and Percent Error Scores (PES) for Each Pedometer Brand by Right and Left Placement

	Absolute Percent Error				Percent Error Score			
	Right		Left		Right		Left	
Pedometer	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Talking	2.3%	2.2%	12.2%	14.9%	-0.5%	3.2%	-11.7%	15.4%
Sportline	2.1%	2.9%	8.6%	11.2%	1.3%	3.4%	5.0%	13.3%
Centrios	3.3%	4.4%	5.6%	8.3%	1.5%	5.3%	2.0%	9.9%
NL2000	1.4%	1.1%	1.3%	1.4%	0.7%	1.7%	0.2%	1.9%

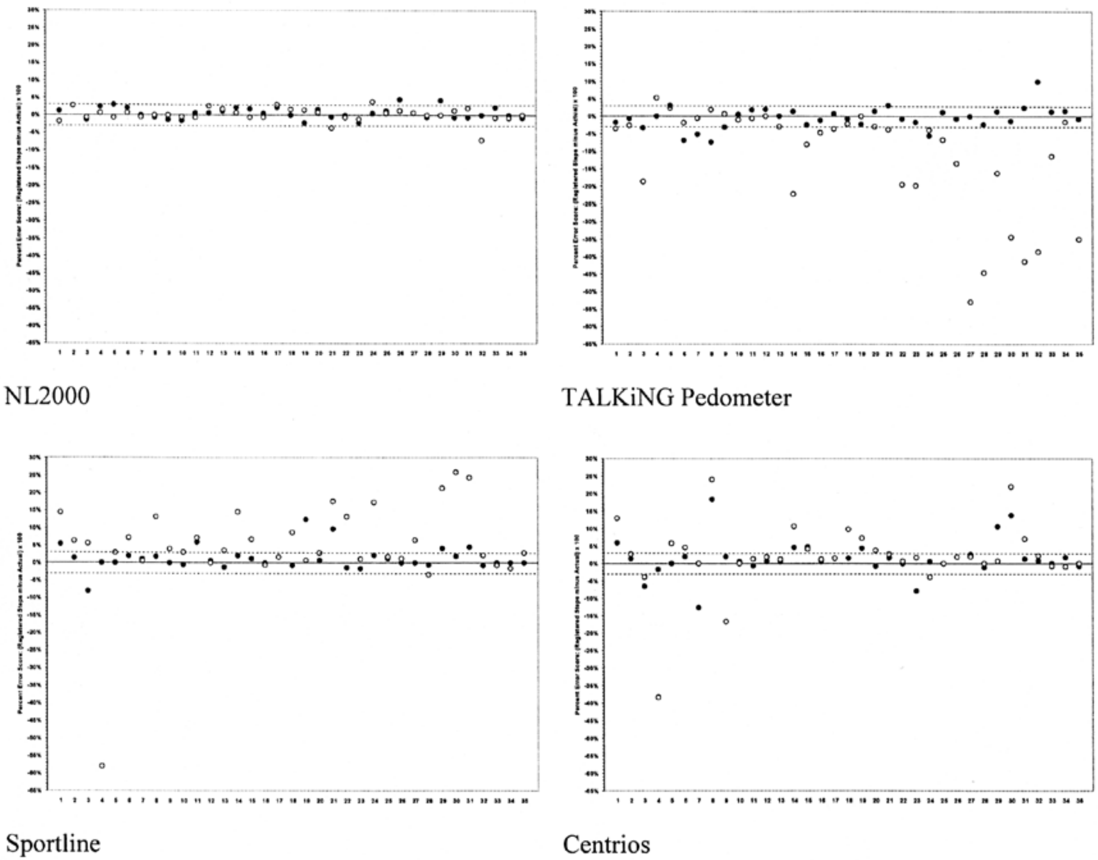

Figure 1 — Percent error scores for right and left placement for four brands of pedometers. Black circles (●) represent right placed units and white circles (○) represent left placed units.

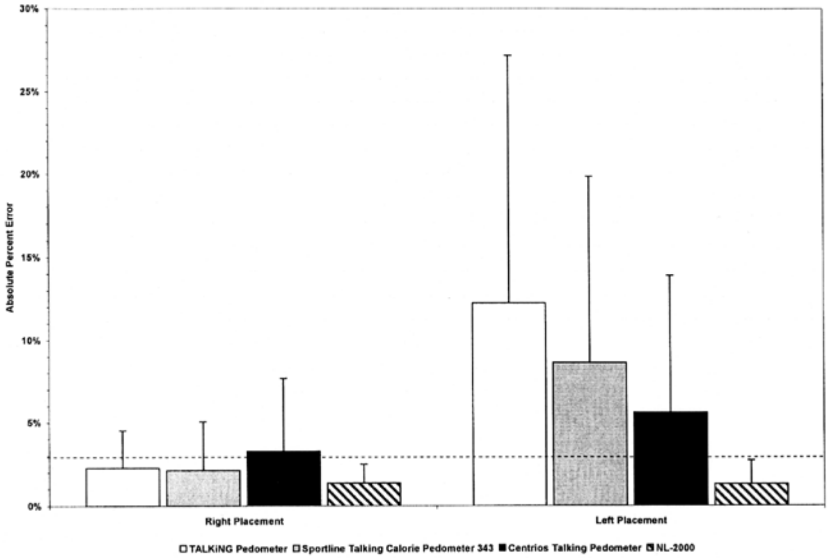

Figure 2 — Absolute percent error scores for right and left placed units. Error bars represent one standard deviation. Dashed line indicates the 3% error minimum threshold.

Table 3 Absolute Percent Error Scores (APE) and Walking Speed for Each Pedometer Brand for the Assisted (n = 11) and Unassisted (n = 24) Walking Participants

	Assisted		Unassisted	
Pedometer	***M***	***SD***	***M***	***SD***
Talking				
Right	2.7%	2.3%	2.1%	2.2%
Left	9.6%	11.6%	13.5%	16.3%
Walking speed (mph)	3.9	0.4	4.3	0.5
Centrios				
Right	6.8%	5.9%	1.9%	2.7%
Left	8.5%	8.8%	4.5%	8.0%
Walking speed (mph)	4.0	0.4	4.2	0.6
Sportline				
Right	4.3%	3.8%	1.1%	1.8%
Left	11.5%	8.4%	7.3%	12.3%
Walking speed (mph)	3.8	0.4	4.4	0.6
NL2000				
Right	1.7%	1.1%	1.2%	1.1%
Left	0.8%	0.6%	1.5%	1.6%
Walking speed (mph)	3.9	0.4	4.4	0.7

steps in conjunction with other motivational strategies (e.g., goal setting) may prove fruitful in promoting more active lifestyles. Therefore, the purpose of this study was to examine the accuracy of three voice-announcement pedometers in a sample of youth with visual impairments.

Overall, the three voice-announcement pedometers demonstrated acceptable absolute percent error scores for the right placed units (APE range 2.1% to 3.3%; see Table 2). The left placed units were systematically prone to either over- or underestimating steps (APE range 5.6% to 12.2%, see Table 2). This systematic error was likely the cause for the low inter-unit agreement between right and left placed units (ICC range .37 to .76). In order to understand the source of this error, the group was divided into those participants that required assistance (i.e., were led via the arm by a camp counselor) or were able to walk unassisted. Interestingly, for two of the models, Sportline and Centrios, the assisted condition inflated both the right and left units' APE scores. While it is apparent by examining the means of the APE scores between assisted and unassisted participants that there are greater error scores for the Sportline and Centrios for the assisted participants, the systematic error on the left side is still evident for the unassisted participants (see Table 3). Such findings counteract the notion that being led was the sole cause for the inflated left error, indicating other unmeasured variables are responsible for the systematic error observed. Interestingly, the difference between assisted and unassisted participants in APE scores for the left placed TALKiNG was the opposite, with greater APE for the unassisted participants in comparison to those who were assisted (13.5% vs. 9.6%). Of interest is the lack of error observed for the NL2000 across placement and assisted or unassisted walking. This indicates the triggering mechanism used in this pedometer—piezo-electric sensor—versus the spring-lever device in the voice-announcement pedometers is unaffected by the unknown source of error. Unfortunately, pedometers that utilize the piezo-electric sensor have yet to include a voice-announcement feature, limiting their use in an intervention setting with youth with visual impairments. Further, the cost associated with this brand (~$55) may present barriers to utilize this pedometer with large numbers of youth.

There are multiple reasons why the registered step counts of pedometers of the same brand worn simultaneously do not coincide. Several studies suggest that the lack of stringent manufacturing quality can produce units of the same brand that do not register steps with similar accuracy (Bassett et al., 1996; Beets et al., 2005). Discrepancies of this type are likely to produce error scores that are higher in one unit versus another. In the current study, it is unlikely the unit of lower quality (i.e., least accurate) would have been selected for left placement across all three voice-announcement pedometers, thereby ruling out this as a source of error. Other possible error sources are pedometer tilt (Crouter et al., 2005) and walking speed (Beets et al., 2005; Crouter et al., 2003). Pedometer tilt is affected by adiposity that pushes the pedometer away from the waist, which causes the pedometer to deviate from its required vertical positioning. Given the pedometers were positioned in similar places over the right and left hip, it is unlikely the left placement would experience more tilt than the right. Slower walking speeds on the treadmill also affect pedometer accuracy. Yet, as with tilt, there is little reason to believe the participants walked faster on the right side than on the left. It is, therefore, unclear from the current study what may be contributing to the systematic error observed on the left placed voice-announcement pedometers. Placement of the pedometer, either right or left hip or middle back, has minimal influence on step count accuracy, eliminating this as a potential source of error (Beets et al., 2007; Beets et al., 2005; Ramirez-Marrero, Smith, Kirby, Leenders, & Sherman, 2002). Thus, the cause for the systematic error observed is open for speculation. Future studies may consider evaluating gait patterns and biomechanical movements of the lower body and trunk to determine whether these are causes for pedometer error.

In conclusion, although low inter-unit agreement was observed, the APE scores for the right placed voice-announcement pedometers met the minimum criteria of ± 3% for accuracy. Based on these findings, it is recommended that when using any of the three brands of voice-announcement pedometers tested, the units should be placed on the right hip of youth with visual impairments.

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