Validation of a Talking Pedometer for Adults with Visual Impairment

ELIZABETH ACKLEY HOLBROOK[1], SANDY L. STEVENS[2], MINSOO KANG[2], and DON W. MORGAN[2]

[1]*Department of Health and Human Performance, Roanoke College, Salem, VA; and* [2]*Department of Health and Human Performance, Middle Tennessee State University, Murfreesboro, TN*

ABSTRACT

HOLBROOK, E. A., S. L. STEVENS, M. KANG, and D. W. MORGAN. Validation of a Talking Pedometer for Adults with Visual Impairment. *Med. Sci. Sports Exerc.*, Vol. 43, No. 6, pp. 1094–1099, 2011. Alterations in gait mechanics and mobility aid (MA) use have been observed in persons with visual impairment (VI) in response to environmental changes, yet the influence of these modifications on the accuracy of an adaptive pedometer has not been documented. **Purpose**: The purpose of this study was to establish validity evidence for the Centrios talking pedometer relative to environmental familiarity and MA use in adults with VI. **Methods**: Thirteen adults with VI (age = 38 ± 14 yr) completed two walking trials over an unfamiliar, quarter-mile course while wearing a Centrios talking pedometer at the right and left sides of the hip. Walking speed, pedometer-determined steps, and actual steps were recorded during the first session, reflecting walking in an "unfamiliar environment." After a series of additional walks over the same course, outcome measures were reassessed during a second trial, reflecting walking in a "familiar environment." Absolute percent error (APE) scores were calculated between actual and pedometer-determined steps. Paired *t*-tests were used to assess differences in APE relative to mounting position across environmental settings. **Results**: During unfamiliar trials, the pedometer accurately reported steps when mounted at the hip opposite the user's MA (APE = 2.1%) but was significantly less accurate when mounted at the hip on the user's MA side (APE = 11.1%). In the familiar setting, the pedometer accurately reported steps when mounted at the left hip and the hip opposite the user's MA (APE <3%). APE values did not differ across environmental conditions ($P > 0.05$). **Conclusions**: In unfamiliar and familiar walking conditions, the Centrios pedometer accurately monitors step-based activity in adults with VI when mounted at the hip opposite the user's MA. **Key Words:** PHYSICAL ACTIVITY, MOBILITY AID, ENVIRONMENTAL FAMILIARITY

Although vision-related disability affects 21 million Americans and ranks as the fourth-leading class of disability in the United States (33), the relatively low prevalence of severe visual impairment belies the significant health-related needs of persons with vision loss. Despite a higher incidence of functional limitations (35), comorbid conditions (6–8), obesity (15,27,34), depression (22), and mortality (6), public health efforts aimed at promoting the health status of persons with visual impairment are generally nonexistent. Given the efficacy of pedometer-based walking interventions in promoting physical activity and improving health among large groups of clinical subpopulations (1,4,12,30–32), previous investigators have considered establishing validity evidence for talking pedometers as a preliminary step toward promoting ambulatory activity in persons with vision loss (3,21). Before physical activity interventions can be conducted, however, unique characteristics that are inherent to persons with visual impairment, but have not been addressed in previous validation studies, should be considered.

Several factors have been identified in the measurement literature as having the potential to affect pedometer accuracy, including walking speed (2,14,20), mounting position (2,14), and the morphological and ambulatory characteristics of the individual wearing the pedometer (9,14,23). The validity of a pedometer can also be influenced by the internal counting mechanism within the device. Piezoelectric pedometers, for instance, tend to be more accurate than spring-levered models at slow walking speeds (2,20,23) and when worn by overweight individuals (9,23). It is possible, however, that in addition to the factors that are known to influence pedometer accuracy in the general population, other characteristics may need to be considered when validating a pedometer for use in special populations.

The locomotor patterns of individuals with visual impairment have previously been described as being mechanically inefficient (5,16,17). Even among blind athletes, Ferro et al. (11) observed higher stride rates, shorter stride lengths, and longer contact times (e.g., shorter flight phases) when compared with individuals without vision loss. Moreover, alterations in gait and long-cane mechanics have been observed in persons with visual impairment in response to changes in the environment, leading to a decrease in hip flexion velocity

Address for correspondence: Elizabeth Ackley Holbrook, Ph.D., Department of Health and Human Performance, Roanoke College, 221 College Lane, Salem, VA 24153; E-mail: holbrook@roanoke.edu.
Submitted for publication August 2010.
Accepted for publication November 2010.

0195-9131/11/4306-1094/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e318205e2d6

and stride length (26). Consequently, for a pedometer to provide valid activity-related feedback to an individual with vision loss, it must be adaptive in nature (e.g., feature "voice announcement" technology) and sensitive enough to function in response to unique kinematic changes. Because commercially available pedometers with adaptive features incorporate a spring-levered internal counting mechanism, kinematic alterations produced in response to environmental changes may affect the accuracy of these pedometers. With respect to this point, Beets et al. (3) recently examined validity evidence for three models of adaptive pedometers. During validation trials, youth with visual impairment were led by a sighted guide through a series of 100-m walking trials, but factors such as walking with a sighted guide in lieu of a mobility aid, challenges associated with the built environment, and course familiarity were not taken into account. Reflecting these limitations, an unexplainable systematic error (overestimation or underestimation, depending on the model of pedometer) was observed in pedometers mounted on the left side of the body (3).

In an attempt to identify the source of the systematic error observed by Beets et al. (3) and to provide an acceptable level of external validity evidence for adaptive pedometers, it would seem appropriate to incorporate different environmental settings within the context of validation trials involving persons with vision loss. Moreover, mobility aid use should be encouraged during validation studies so that potential interactions between pedometer mounting position and the type of mobility aid used can be discerned. The inclusion of specific environmental and mobility aid factors in walking validation trials featuring persons with visual impairment would also help ensure that a more generalizable account of validity evidence is obtained. Against this backdrop, the purpose of the current study was to document the accuracy of a talking pedometer relative to mounting position and environmental familiarity in adults with visual impairment.

METHODS

Participants. On receiving approval from the institutional review board at a university in the southeastern United States, volunteers were solicited for participation using snowball sampling. Initial solicitations were made through presentations at various advocacy organizations for persons with visual impairment across a large metropolitan area and secondary solicitations occurred within the community of persons with vision loss via personal conversations. Inclusion in this study was limited to ambulatory adults (aged ≥18 yr) with a visual acuity of 20/200 or less (e.g., legal blindness). Of the 61 individuals who were contacted, 14 adults (10 females and 4 males; age = 38 ± 14 yr) consented to participate. In general, participants were overweight (body mass index = 26.5 ± 4.2 $kg \cdot m^{-2}$) and were self-reported "skilled travelers" (mean = 4.14, SD = 0.93) as rated on a five-point Likert scale evaluating proficiency with orientation and mobility. The severity of visual impairment among participants, which was classified using the *International Statistical Classification of Diseases* (*ICD*) schematic (36), ranged from peripheral or travel vision (n = 8; *ICD* classification 1–3), to light perception (n = 3; *ICD* classification 4), and no light perception (n = 3; *ICD* classification 5). Two participants did not use a mobility aid, four participants used a dog guide, and eight participants used a long cane. Eight participants also reported having a congenital visual impairment.

Instrumentation. The Centrios talking pedometer (model 6310620; Orbyx Electronics, Concord, ON) features a spring-levered counting mechanism and provides estimates of the number of steps taken, total active time, distance walked, and caloric expenditure. This pedometer also features a personal alarm that can be activated by releasing an external pulley. The Centrios pedometer is commercially available through wholesale retailers of adaptive technology and ranges in price from $20 to $40. Although the voice-announcement technology contained within the device makes the Centrios pedometer larger than typical spring-levered monitors, automated feedback can be announced periodically at the touch of a button or throughout the day (e.g., after every 1000 steps or 10 min of accumulated activity time). The Centrios pedometer is reportedly accurate during locomotor activity when mounted vertically toward the midline of the waistband at the right or left hip (25).

Validation trials. Before conducting pedometer validation trials, a closed-course walking route was established. The route was quarter mile in length and consisted of a flat, meandering sidewalk on a college campus with a single street crossing and three bisecting sidewalks with curb cuts. To verify that the chosen route was safe and reflective of an environment typical of everyday living, a state-certified orientation and mobility specialist assisted the primary investigator in developing the walking course.

Validation trials were conducted in a single session, during which participants completed multiple walking trials while wearing two Centrios talking pedometers positioned at the right and left hip along the waistband and in line with the knee. Before each trial, pedometers were randomly selected from a pool of eight devices that had been previously calibrated using a shake test. The first walking trial simulated walking in an unfamiliar environment, as the established walking route was novel for all participants. During this trial, participants were instructed to walk at a self-selected pace and to use their mobility aid as they normally would in an unfamiliar environment. An investigator walking behind each participant tallied actual step counts using a hand counter. Pedometer-determined steps were recorded relative to mounting position at the right hip (RH) or left hip (LH) and as a function of the user's mobility aid (e.g., mobility aid side = MA; nonmobility aid side = NMA). The actual number of steps taken and the time to complete the quarter-mile course were also recorded. Walking speed was calculated from measures of walking distance and time.

After completing the first walking trial, participants were accompanied by the primary investigator as they completed a series of additional walking trials (over the same overground course) until a sense of familiarity with the course was established. During these exploratory walks, measures of actual- and pedometer-determined step counts and walking speed were not recorded. The number of additional walks needed to establish course familiarity varied among participants, reflecting an array of mobility skills and visual capabilities. Once participants were comfortable with the route, a final validation trial was conducted, reflecting walking in a "familiar environment." After completing this final walking trial, measurements of pedometer-determined step counts (across RH, LH, MA, and NMA mounting positions), actual step counts, and the time required to traverse the course were recorded, and walking speed was calculated from distance and time values.

Data analysis. Data screening and analyses were performed using SPSS (version 17.0) and Microsoft Excel for Windows. Because of a pedometer malfunction during a validation trial involving a dog guide user, data from 13 participants were included in the final analysis. Absolute percent error (APE) scores were calculated between actual steps and pedometer-determined steps (APE = [(pedometer steps − actual steps)/actual steps] × 100) across mounting positions and environmental conditions and used as an accuracy index, wherein a smaller APE represented better accuracy. Previous investigators have regarded an APE of <3% as an acceptable level of variance (10,13,14). Paired *t*-tests were conducted to assess differences in APE relative to mounting position (RH vs LH; MA vs NMA) and environmental condition (unfamiliar and familiar walking trials). Cohen *d* effect sizes were also calculated to evaluate the magnitude of the effect of mounting position and environmental familiarity on pedometer accuracy. Statistical significance was established *a priori* at $P < 0.05$.

RESULTS

The influence of mounting position and environmental familiarity on the accuracy of the Centrios talking pedometer is shown in Table 1. During unfamiliar walking trials, walking speed and APE scores ranged from 0.74 to 2.22 $m{\cdot}s^{-1}$ (mean = 1.43 $m{\cdot}s^{-1}$) and from 0.00% to 26.05%, respectively. Within this condition, the least amount of mean error was observed among pedometers mounted at the NMA position (mean = 2.14%, SD = 1.98%) and the largest mean APE was found in the MA position (mean = 11.12%, SD = 11.29%). The accuracy of the Centrios pedometer during unfamiliar walking trials did not differ between the LH (mean = 3.35%, SD = 2.74%) and RH mounting positions (mean = 8.63%, SD = 11.39%, $t_{12} = 1.66$, $P = 0.123$, $d = 0.64$). However, the pedometer was significantly more accurate when mounted at the NMA position (mean = 2.14%, SD = 1.98%) compared to the MA position (mean = 11.12%, SD = 11.29%, $t_{10} = 2.89$, $P = 0.016$, $d = 1.11$).

TABLE 1. APE of the Centrios pedometer: influence of mounting position and environmental familiarity.

Condition	Position			
	RH (n = 13)	LH (n = 13)	MA (n = 11)	NMA (n = 11)
Unfamiliar	8.63 ± 11.39	3.35 ± 2.74	11.12 ± 11.29[a]	2.14 ± 1.98[ab]
Familiar	5.18 ± 5.18	2.14 ± 3.32[b]	5.29 ± 4.98	2.68 ± 4.52[b]

Values expressed as percentages and mean ± SD.
[a] $P < 0.05$.
[b] Conditions that meet or exceed the accepted threshold for validity (APE <3%).
LH, left hip; MA, mobility aid side; NMA, nonmobility aid side; RH, right hip.

Reflecting the heterogeneity of vision loss experienced by participants, the number of trials required to establish a sense of familiarity with the walking course varied from zero to three. Under familiar walking conditions, walking speed ranged from 0.84 to 2.23 $m{\cdot}s^{-1}$ (mean = 1.59 $m{\cdot}s^{-1}$) and APE ranged from 0.00% to 25.63%. Unlike the unfamiliar walking trials, the smallest mean APE score in the familiar setting occurred when pedometers were mounted at the LH position (mean = 2.14%, SD = 3.32%), whereas the largest mean APE score was observed in RH-mounted pedometers (mean = 5.18%, SD = 5.18%). No significant differences in APE were observed between the RH and LH positions ($t_{12} = 1.64$, $P = 0.127$, $d = 0.70$) or between the MA and NMA positions ($t_{10} = 1.13$, $P = 0.284$, $d = 0.55$) during the familiar walking trial. Similar to the results of the unfamiliar walking trials, however, larger APE values were observed in RH (mean = 5.18%, SD = 5.18%) and MA positions (mean = 5.29%, SD = 4.98%) compared with LH (mean = 2.14%, SD = 3.32%) and NMA positions (mean = 2.68%, SD = 4.52%).

When comparing unfamiliar and familiar environmental conditions relative to pedometer mounting position, no significant differences in APE were observed among pedometers mounted at the RH, $t_{12} = 1.04$, $P = 0.321$, $d = 0.39$, LH, $t_{12} = 1.23$, $P = 0.244$, $d = 0.40$, MA, $t_{10} = 1.65$, $P = 0.129$, $d = 0.67$, and NMA positions, $t_{10} = -0.32$, $P = 0.755$, $d = -0.16$.

DISCUSSION

It is well documented that pedometer-based walking interventions are an effective means of improving physical activity participation and health status in many clinical subpopulations (1,4,12,30–32). On the basis of these data, it is reasonable to infer that comparable health benefits could be achieved by persons with visual impairment participating in similar walking programs if adaptive pedometers with voice announcement technology were used. Previous investigations documenting the accuracy of talking pedometers in youth with visual impairment have featured highly controlled walking trials and reported unexplainable systematic errors (3). Acknowledgement of the context-specific nature of validity evidence has led to the suggestion that investigators should actively seek to simulate "real-life" experiences during validation trials to generate validity evidence that is more ecologically appropriate (1,18,28,29). By documenting the effects of mobility aid use and environmental familiarity on the validity of the Centrios pedometer, results from the current study collectively illustrate that this device can serve as an accurate means of monitoring physical activity among adults with vision loss in both unfamiliar and familiar settings.

Validity evidence. On the basis of the recommended threshold for pedometer validity (APE ≤3%) (10,13), validity evidence was established for the Centrios pedometer across a range of walking speeds and environmental conditions. In the unfamiliar setting, validity evidence was obtained when the pedometer was mounted in the NMA mounting position. Similarly, in the familiar environmental setting, validity evidence for the Centrios pedometer was established at the NMA- and LH-mounted positions. Within the context of both environmental conditions, APE was consistently higher in pedometers worn at the RH compared with the LH and when mounted on the MA side compared with the NMA side. Interestingly, these findings contradict the observations of Beets et al. (3), who reported a systematic error among LH-mounted pedometers. In the current study, allowing participants to use their mobility aid during validation trials enabled the source of the systematic error observed among pedometers mounted at the RH to be linked to the use of the mobility aid. Specifically, the majority of participants in the current study were long-cane users (n = 8) displaying a large degree of movement in the right arm while walking, which allowed feedback from the environment to be gained from the long cane. Although speculative, the movement of the right arm across the body in long-cane users may have interfered with the spring-levered counting mechanism of the pedometer, resulting in a consistent overestimation of steps in the RH- and MA-mounted pedometers. It would also be expected that this level of interference would be greater when walking in an unfamiliar environment owing to a need to increase the range of motion of the long cane (and thus, the right arm) to acquire a greater level of feedback from the environment. Our data support this notion, as pedometer error was highest in the RH and MA positions when participants walked in an unfamiliar setting.

Influence of environmental familiarity. It is well documented that a generally linear relationship exists between walking speed and pedometer accuracy (2,9,10,19). In particular, the dynamic gait pattern associated with moderate-to-brisk walking speeds, while eliciting a heightened degree of accuracy in many pedometers, is particularly detrimental to the accuracy of spring-levered pedometers (23). In the current investigation, slower walking speeds, a more "shuffling" gait pattern, and a greater reliance on mobility aid use were observed during unfamiliar walking trials compared with walking in a familiar setting. This triad of responses was anticipated, as previous investigators have reported similar findings in adults with visual impairment during attention-demanding tasks (26).

Despite observable kinematic differences between unfamiliar and familiar settings, no statistically significant differences in APE were apparent between walking environments relative to pedometer mounting positions. However, a large effect for environmental familiarity was detected for MA-mounted devices, insofar as MA pedometers were more accurate during familiar compared with unfamiliar trials. In addition, the Centrios pedometer met the criterion for acceptable accuracy (APE <3%) when it was worn in the NMA position during walking trials in the unfamiliar setting and in the LH and NMA positions while walking in the familiar setting. It is possible that the level of orientation and mobility skill of the participants may partially explain these findings. As self-reported "skilled travelers," only five of our participants exhibited noncongenital vision loss, whereas the remaining participants reported a congenital visual condition. It has been documented that persons with congenital blindness display more developed compensatory strategies when performing novel tasks (24). Hence, given the brisk walking speeds recorded during both unfamiliar and familiar walking conditions (1.43 and 1.59 $m \cdot s^{-1}$, respectively), the Centrios pedometer may have yielded less accurate step count readings had persons with inferior mobility skill been tested. Consequently, the findings of this investigation are probably most applicable to visually impaired individuals with a modest-to-high degree of travel skill.

Influence of mobility aid use. The heightened reliance on mobility aid use while orienting in an unfamiliar environment and the consistent use of mobility aids when walking in a familiar setting may have contributed to the more favorable degree of accuracy displayed by NMA-mounted pedometers (APE <2.70%) in both walking environments. Specifically, an increased range of motion among long-cane users and a more pronounced level of arm rigidity among dog guide users may have interfered with pedometer function in the MA position. When locating a sidewalk, for instance, long-cane users typically use a sweeping motion of the cane from side-to-side to explore the surrounding area. Although beneficial, this motion may result in an overestimation or underestimation of step activity in spring-levered pedometers, as the increased range of motion of the arm across the body may impede or increase pedometer oscillations (e.g., in the current study, an overestimation of steps was observed).

Because a long cane is typically held in the right hand and a dog guide is usually held in the left hand, we thought that additional trends might be detected by evaluating our findings in relation to the use of specific types of mobility aids. Therefore, an exploratory *post hoc* analysis was conducted to compare the influence of long-cane and dog guide use on pedometer accuracy. Results of this secondary analysis, presented in Table 2, demonstrated that in the unfamiliar setting, the effect of mobility aid use was particularly noticeable, as a higher degree of pedometer accuracy was registered among dog guide users (APE <2%) at the RH/NMA position and among long-cane users (APE <3%) at the LH/NMA position. In addition, among participants who did not use a mobility aid, an acceptable level of accuracy was achieved when the pedometer was mounted at both the RH and LH positions. Because the dog guide and long-cane

TABLE 2. APE of the Centrios pedometer: influence of mounting position and environmental familiarity as a function of mobility aid type.

	Position			
Condition	RH	LH	MA	NMA
Unfamiliar environment				
Dog guide (n = 3)	1.53 ± 2.04[a]	5.57 ± 3.56	5.57 ± 3.56	1.53 ± 2.04[a]
Long cane (n = 8)	12.82 ± 12.98	2.76 ± 2.29[a]	13.21 ± 12.66	2.37 ± 2.05[a]
None (n = 2)	2.56 ± 2.11[a]	2.39 ± 2.88[a]		
Familiar environment				
Dog guide (n = 3)	7.34 ± 7.35	1.42 ± 0.91[a]	1.42 ± 0.91[a]	7.34 ± 7.35
Long cane (n = 8)	5.15 ± 5.00	2.53 ± 4.22[a]	6.74 ± 5.14	0.94 ± 1.01[a]
None (n = 2)	2.04 ± 2.36[a]	1.65 ± 1.81[a]		

Values expressed as percentages and mean ± SD.
[a] Conditions that meet or exceed accepted threshold for validity (APE <3%).
LH, left hip; MA, mobility aid side; NMA, nonmobility aid side; RH, right hip.

are held in opposite hands, these trends were anticipated. Moreover, the observation that nonmobility aid users experienced similar APE scores at both RH and LH positions further supports the notion of mobility aid interference on pedometer accuracy.

In the current study, mean APE scores across pedometer mounting positions were lower in the familiar setting among long-cane users and nonmobility aid users. This was not a particularly surprising result, as it can be hypothesized that greater familiarity with one's walking environment would result in a faster walking speed and more normalized gait pattern, thus leading to improved pedometer accuracy. Whereas the influence of mobility aid use on pedometer accuracy remained consistent among long-cane users in the familiar setting (such that higher levels of accuracy were recorded in the LH/NMA position compared with the RH/MA position), this trend was not observed among dog guide users. Whereas pedometers mounted at the RH/NMA position met the criteria for acceptable accuracy in the unfamiliar setting (APE <3%), LH/MA–mounted pedometers were tied to lower APE values in the familiar setting. With only three dog guide users, it is difficult to explain this finding. However, two dog guide users continued to exhibit lower APE scores at the RH/NMA position in the familiar setting, whereas one participant experienced a 15% overestimation of steps in RH/NMA–mounted pedometers. Given these findings, continued efforts to distinguish the influence of specific types of mobility aids on pedometer accuracy are needed.

CONCLUSIONS

In conclusion, results from the current study indicate that the Centrios talking pedometer provides an accurate account of step-based activity in persons with visual impairment in both familiar and unfamiliar settings when mounted at the hip opposite the user's mobility aid. This finding highlights the importance of altering data collection strategies when working with special populations to ensure that valid assessments of physical activity can be obtained. From a health-related standpoint, the Centrios pedometer may be an appropriate tool for future interventions aimed at promoting physical activity participation among individuals with visual impairment.

No financial support was provided for this study.

Funding was not received from any of the following organizations: the National Institutes of Health, Wellcome Trust, Howard Hughes Medical Institute, or others.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

APPLIED SCIENCES

REFERENCES

1. Araiza P, Hewes H, Gashetewa C, Vella CA, Burge MR. Efficacy of a pedometer-based physical activity program on parameters or diabetes control in type-2 diabetes mellitus. *Metabolism*. 2006;55:1382–7.
2. Bassett DR, Ainsworth BE, Leggett SR. Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc*. 1996;28(8):1071–7.
3. Beets MW, Foley JT, Tindall DWS, Lieberman LJ. Accuracy of voice-announcement pedometers for youth with visual impairment. *Adapt Phys Activ Q*. 2007;24(3):218–27.
4. Chan CB, Ryan DAJ, Tudor-Locke C. Health benefits of a pedometer-based physical activity intervention in sedentary workers. *Prev Med*. 2004;39(6):1215–22.
5. Chen S, Wang Y, Mok MCM. Impact of safe environment on the gait and posture pattern of individuals with visual impairment. *Res Q Exerc Sport*. 2009;81(suppl 1):A101.
6. Christ SL, Lee DJ, Lam BL, Zheng DD, Arheart KL. Assessment of the effect of visual impairment on mortality through multiple health pathways: structural equation modeling. *Invest Ophthalmol Vis Sci*. 2008;49:3318–23.
7. Crews JE, Campbell VA. Health conditions, activity limitations, and participation restrictions among older people with visual impairments. *J Vis Impair Blind*. 2001;95:453–67.
8. Crews JE, Jones GC, Kim JH. Double jeopardy: the effects of comorbid conditions among older people with vision loss. *J Vis Impair Blind*. 2006;100:824–48.
9. Crouter SE, Schneider PL, Bassett DR. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc*. 2005;37(10);1673–9.
10. Crouter SE, Schneider PL, Karabulut M, Bassett DR. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35(8):1455–60.
11. Ferro A, Graupera L, Vera P. Kinematic and kinetic study of running technique at different high speeds in blind paralympic athletes. *Caceres Extremadura*. 2002;523–6.
12. Gray SR, Baker G, Wright A, Fitsimons CF, Mutrie N, Nimmo MA.

The effect of a 12 week walking intervention on markers of insulin resistance and systemic inflammation. *Prev Med*. 2008;48(1):39–44.
13. Hatano Y. Prevalence and use of pedometer. *Res J Walking*. 1997; 1:45–54.
14. Holbrook EA, Barriera TV, Kang M. Validity and reliability of Omron pedometers for prescribed and self-paced walking. *Med Sci Sports Exerc*. 2009;41(3):669–73.
15. Holbrook EA, Caputo JL, Perry TL, Fuller DK, Morgan D. Physical activity, body composition, and perceived quality of life of adults with visual impairment. *J Vis Impair Blind*. 2009;103(1):17–29.
16. Huang Y, Huang W, Tsai F, Liu Y. The regulation of leg stiffness and EMG activities on person with visual impaired during step-down walking. *Int Sympos Biomech Sports Arch*. 2005;22:493–5.
17. Jankowski LW, Evans JK. The exercise capacity of blind children. *J Vis Impair Blind*. 1981;75:248–51.
18. Kang M, Holbrook EA, Barriera TV. Response: validity and reliability of Omron pedometers at slow walking speeds. *Med Sci Sports Exerc*. 2009;41(9):1827.
19. Karabulut M, Crouter SE. Comparison of two waist-mounted and two ankle-mounted electronic pedometers. *Eur J Appl Physiol*. 2005;95(4):335–43.
20. Le Masurier GC, Tudor-Locke C. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc*. 2003;35(5):867–71.
21. Lieberman LJ, Stuart ME, Hand K, Robinson B. An investigation of the motivational effects of talking pedometers among children with visual impairments and deaf–blindness. *J Vis Impair Blind*. 2006;100(12):726–36.
22. Margolis MK, Coyne K, Kennedy-Martin T, Baker T, Schein O, Revicki DA. Vision-specific instruments for the assessment of health-related quality of life and visual functioning: a literature review. *Parmacoeconomics*. 2002;20(12):791–812.
23. Melanson EL, Knoll JR, Bell ML, Donahoo WT, Hill JO, Nysse LJ. Commercially available pedometers: considerations for accurate step counting. *Prev Med*. 2004;39(2):361–8.
24. Monegato M, Cattaneo Z, Pece A, Vecchi T. Comparing the effects of congenital and late visual impairments on visuospatial mental abilities. *J Vis Impair Blind*. 2007;101(5):278–95.
25. Orbyx Electronics (2003). *Talking Pedometer with Panic Alarm: Owners Manual*. Concord (ON Canada): Orbyx Electronics; 2003. pp. 1–3.
26. Ramsey VK, Blasch BB, Kita A, Johnson BF. A biomechanical evaluation of visually impaired persons' gait and long-cane mechanics. *J Rehabil Res Dev*. 1999;36(4):323–32.
27. Ray CT, Horvat M, Williams M, Blasch BB. Clinical assessment of functional movement in adults with visual impairments. *J Vis Impair Blind*. 2007;101:108–13.
28. Rowe DA, Mahar MT. Validity. In: Wood TM, Zhu W, editors. *Measurement Theory and Practice in Kinesiology*. Champaign (IL): Human Kinetics; 2006. pp. 9–26.
29. Shepard LA. Evaluating test validity. In: Darling-Hammon L, editor. *Review of Research Education. Vol. 1*. Washington (DC): AERA; 1993. pp. 405–50.
30. Swartz AM, Strath SJ, Bassett DR, et al. Increasing daily walking improves glucose tolerance in overweight women. *Prev Med*. 2003; 37:356–62.
31. Talbot LA, Gaines JM, Huynh TN, Metter EJ. A home-based pedometer-driven walking program to increase physical activity in older adults with osteoarthritis of the knee: a preliminary study. *J Am Geriatr Soc*. 2003;51(3):387–92.
32. Tudor-Locke C, Bell RC, Myers AM, et al. Controlled outcome evaluation of the First Step Program: a daily physical activity intervention for individuals with Type II diabetes. *Int J Obes Relat Metab Disord*. 2004;28(1):113–9.
33. US Department of Health and Human Services [Internet]. *Progress Review: Vision and Hearing*; [cited 2009 June 24]. Available from: http://www.healthypeople.gov/data/2010prog/focus28/default.htm.
34. Weil E, Wachterman M, McCarthy EP, et al. Obesity among adults with disabling conditions. *JAMA*. 2002;288(10):1265–8.
35. West SK, Rubin GS, Broman AT, Munoz B, Roche KB, Turano K. How does visual impairment affect performance on tasks of everyday life? The SEE Project. *Arch Ophthalmol*. 2002;120: 774–80.
36. World Health Organization Web site [Internet]. *ICD-10*: Diseases of the Eye and Adnexa; [cited 2010 August 1]. Available from: http://apps.who.int/classifications/apps/icd/icd10online/.