Accuracy of the Yamax CW-701 Pedometer for measuring steps in controlled and free-living conditions

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Abstract

Objective: The Yamax Digi-Walker CW-701 (Yamax CW-701) is a low-cost pedometer that includes a 7-day memory, a 2-week cumulative memory, and automatically resets to zero at midnight. To date, the accuracy of the Yamax CW-701 has not been determined. The purpose of this study was to assess the accuracy of steps recorded by the Yamax CW-701 pedometer compared with actual steps and two other devices.

Methods: The study was conducted in a campus-based lab and in free-living settings with 22 students, faculty, and staff at a mid-sized university in the Southeastern US. While wearing a Yamax CW-701, Yamax Digi-Walker SW-200, and an ActiGraph GTX3 accelerometer, participants engaged in activities at variable speeds and conditions. To assess accuracy of each device, steps recorded were compared with actual step counts. Statistical tests included paired sample *t*-tests, percent accuracy, intraclass correlation coefficient, and Bland–Altman plots.

Results: The Yamax CW-701 demonstrated reliability and concurrent validity during walking at a fast pace and walking on a track, and in free-living conditions. Decreased accuracy was noted walking at a slow pace.

Conclusions: These findings are consistent with prior research. With most pedometers and accelerometers, adequate force and intensity must be present for a step to register. The Yamax CW-701 is accurate in recording steps taken while walking at a fast pace and in free-living settings.

Keywords

Accelerometer, health promotion, pedometer, physical activity, wearable device

Submission date: 14 October 2015; Acceptance date: 3 May 2016

Introduction

Inactivity is an important public health problem that has led to an increased interest in tools to measure physical activity. Pedometers and activity monitors have increased in popularity over the past decade.[1] Since they provide immediate feedback on achievement of activity goals, pedometers can be used as a motivational and educational tool. When used as a research tool, they can provide objective data on exercise,[2] which are often grossly under or over reported in self-report diaries and activity logs.[3] However, in order for pedometers and activity monitors to be used effectively, they must measure steps and physical activity validly and reliably.

The pedometers and activity meters on the market vary greatly in cost, accuracy, ease of use, and function. The Yamax Digi-Walker CW-701 (Yamax CW-701,

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Yamasa Tokei Keiki Co., Ltd., Tokyo, Japan; formerly sold as the Yamax Digi-Walker CW-600 Pedometer) is easy to use and is priced under $30. It contains a seven-day step memory and a two-week cumulative memory, and automatically resets to zero at midnight.

Pedometer accuracy studies have found that the Yamax SW-200 Digi-Walker (Yamax SW-200, Yamasa Tokei Keiki Co., Ltd., Tokyo, Japan) accurately recorded steps at various speeds and conditions.[4–6] The Yamax SW-200 pedometer has been used in research including studies of persons with Parkinson's disease,[7] community-dwelling adults,[8] track runners,[9] and persons with neurological conditions.[10] In fact, the Yamax SW-200 has been used as the criterion pedometer for evaluating other pedometers.[6] In prior studies, the Yamax SW-200 has demonstrated consistent accuracy giving step counts within 1–3% of actual steps,[9,11,12] performs well during a range of walking speeds, and the output is highly correlated to the ActiGraph GTX3 ($r = .87$).[13]

The ActiGraph GTX3 accelerometer (ActiGraph LLC., Pensacola, FL) has undergone extensive testing and has been consistently found reliable and valid.[14–16] The ActiGraph GTX3 has been used in many studies, including large cohort studies, to measure physical activity quantity and intensity.[17] In addition to number of steps taken, it can provide sleep/wake patterns, and data on heart rate and energy expenditure.[3] Though research-grade accelerometers such as the ActiGraph GTX3 are accurate and hold several weeks of data, they can cost up to $250 per unit, making them prohibitively expensive for community-based studies where funding may be limited. Also, they require computers and software to read and interpret the data, increasing cost and diminishing usefulness as a motivational tool for those who do not have the skills and equipment needed to view the data.[3]

The Yamax CW-701 has many attractive features that may make it easier to use in memory-impaired or low-literate populations. The memory and auto reset features may make this model a more useful research tool. Though pedometers may have the same manufacturer and similar mechanism, variation within pedometer models is possible.[12] To date, the reliability and validity of the Yamax CW-701 have not been established. This study was designed to determine whether it accurately counts number of steps taken at a variety of walking speeds and in free-living settings.

Methods

Accuracy, assessed in terms of inter-methods reliability and criterion validity, was determined by having participants simultaneously wear three devices: Yamax CW-701, Yamax Digi-Walker SW-200, and an ActiGraph GTX3 accelerometer. Each participant engaged in observed walking activities in a lab and on a track, and for 24 hours in free-living settings. To assess accuracy of each device, steps that were observed were tallied and compared with actual step counts. Statistical tests included paired sample t-tests, percent accuracy, intraclass correlation coefficient (ICC), and Bland–Altman plots.

We recruited 22 volunteers including 13 women and nine men for the study. Participants' ages ranged from 18 to 36 (M = 23.7, SD 4.6). The average body mass index was $23.7 \, \text{kg/m}^2$ (SD 4.6), and three participants were overweight or obese. Mean waist circumference was 82.3 cm (SD 13.2).

The study took place at a mid-sized university in the Southeastern US. Data were collected in a campus-based physical activity lab and indoor track, and in free-living settings. Participants included university students, faculty, and staff who were in good health and reported that they were able to walk quickly for 10 minutes without an assistive device. Potential participants were excluded if they were pregnant, had severe vision impairment or legal blindness, had a medical condition in which physical activity was contraindicated, or had other physical or neurological impairments that prevented walking at both a slow and fast pace. Participants were given $25 compensation for their time.

After obtaining approval to conduct the study from the university Institutional Review Board, flyers were posted throughout the university campus. Interested participants contacted a research assistant, were sent additional information, and made an appointment to visit the lab. Those who agreed to participate provided informed consent, and completed a short demographic questionnaire and health screening form. Afterwards, their height, weight, and waist circumference were taken. In addition, to eliminate health-related risks, heart rate and blood pressure were taken after participants rested for five minutes, using an Omron HEM-705CP automated blood pressure and pulse monitor (Omron Healthcare Europe, Hoofddorp, The Netherlands), before participants engaged in physical activity.

Five Yamax SW-200, five Yamax CW-701 pedometers, and four ActiGraph GTX3 accelerometers were numbered and used randomly throughout the study. Hand-tallied step count was used as the criterion measure in lab settings where steps were observed.[5,12] The Yamax SW-200 was used as the criterion measure in free-living settings where observing steps was not feasible.

While standing, a Yamax SW-200 was clipped to the participant's waistband on either the left or right hip, and a Yamax CW-701 pedometer was clipped to the opposite hip. Then, an ActiGraph GTX3 accelerometer was randomly clipped to the left or right hip. Prior research has shown that placement on the waist does not affect pedometer and accelerometer performance.[11,12]

A step test was done to assess pedometer functionality.[18,19] Participants were asked to take 10 steps on and off a six-inch riser at a self-determined pace. After the step test, each pedometer was assessed to verify step recognition. With the pedometers and activity monitor remaining in their initial position, participants were next asked to walk on a treadmill for five continuous minutes at slow pace ($54\,\mathrm{m\,min^{-1}}$) wearing an emergency stop belt. While walking, one research assistant manually counted steps using a hand-tally counter, while another research assistant video recorded the participant's steps using a digital camera. After a five-minute break, participants were asked to walk on the treadmill at a fast pace ($107\,\mathrm{m\,min^{-1}}$).

Participants were then escorted to an indoor track where they walked $400\,\mathrm{m}$ at a self-selected moderate pace; the steps they took were again counted using a hand-tally counter and video recorded. To allow participants to walk at a speed they selected, the research assistants walked behind the participant while counting and video recording. Prior to each activity, all three meters were reset to zero. At the end of each activity, the research assistant recorded the number of steps displayed on each meter. The video recordings from the camera were downloaded onto a desktop computer and viewed using a media player. A research assistant recounted the steps using a hand-held tally counter to verify accuracy. If there was a discrepancy in step count, counts were repeated until agreement was achieved.

Finally, the pedometer's ability to measure steps taken under free-living conditions was assessed. The two pedometers and ActiGraph GTX3 accelerometer were all set to zero but remained on the participant's waistband for the next 24 hours. During this time, participants were instructed to engage in their typical activities and to remove the devices only while sleeping, bathing, or engaging in contact or water sports. Participants were asked to record the start and stop time of activities such as sleeping and vigorous activity. Participants were also asked to not reset the pedometers. At the conclusion of the 24 hours, participants met with a research assistant to return the meters and the number of steps recorded by each device was recorded.

Data analysis

Statistical analysis was conducted using SPSS version 19 (IBM Corp., Armonk, NY). Mean step count and standard deviation were calculated for each device and condition. A paired sample *t*-test was used to assess whether significant differences existed between the criterion and the pedometer, using an alpha of 0.05 to denote statistical significance. To determine percent accuracy, a score was calculated using the device count and the criterion ([device count/observed step count] $\times$ 100). Percent relative error (PRE) was calculated using the following formula: (PRE = [device count − observed count)/observed count] $\times$ 100).

The SPSS reliability procedure was used to determine the ICC (two-way mixed Cronbach alpha method) and 95% confidence intervals (CI) for the CW-701 in relation to the other two devices. A value of greater than 0.80 was used to indicate practical significance.[20] For ICC in the free-living setting, the SW-200 was used as the criterion since step observation was not feasible. Finally, Bland–Altman plots with 95% prediction intervals were constructed to show the dispersion of the pedometer scores around zero for the Yamax CW-701, compared with the step count for slow walking on the treadmill, fast walking on the treadmill, and walking the track. Bland–Altman is an accepted technique used to show the accuracy of biomedical devices. The average actual step and device count is plotted on the *x*-axis. For example, the average of the actual step count and the device count (actual count + device count/2) for each person and condition is plotted on the *x*-axis. The difference between actual step and device count is plotted on the *y*-axis (actual count − device count). Individual error scores closer to zero indicated a more accurate device.[21]

Results

Means and standard deviations for each device and each condition were calculated (see Table 1). Paired *t*-tests indicated the CW-701 mean step count was significantly lower than the criterion mean count in both the slow treadmill walking (Diff = −64.23 steps; $t = -3.87$, df = 21, $p < .01$) and fast treadmill walking (Diff = −4.96 steps; $t = -4.05$, df = 21, $p < .01$), but showed no significant difference in the track walking condition (Diff = 2.91 steps; $t = -1.40$, df = 21, $p > .05$). In addition, it is valuable to consider the variability across participants. The SD, also shown in Table 1, shows that CW-701 has essentially the same amount of variability as the criterion for fast walking and track walking. This indicates that the CW-701 is accurately assessing actual individual differences in steps. However, the CW-701 shows almost twice as much variability as the criterion in the slow treadmill condition, indicating that it is less accurately assessing individual differences in that condition (i.e. there is more error).
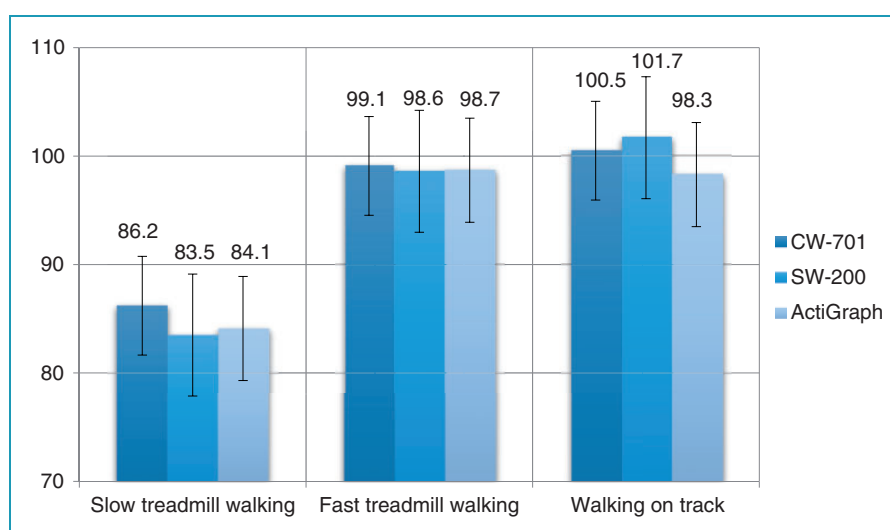
The percent accuracy of steps recorded is displayed in Figure 1. Percent greater than 100 indicated that the device over-counted the steps and less than 100 suggested an under count. Percent accuracy during slow walking on the treadmill was lower for all three devices, ranging from 83% to 86%. During fast walking on the treadmill and the track exercise, the three devices

Table 1. Means and standard deviations for each device and condition ($N = 22$).

	CW-701		SW-200		ActiGraph		Actual steps	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Slow treadmill walking	407[a]	87	393[a]	114	398[a]	101	471	35
Fast treadmill walking	584[a]	37	581	54	582[a]	38	589	39
Track walking	567	47	573	52	555	55	564	47
Free-living	9312	3980	9520	4259	9358	3649	na	na

na: Steps not observed in free-living setting.
[a]Mean significantly different from mean actual steps.

Figure 1. Percent accuracy of steps recorded on Yamax CW-701, Yamax SW-200, and ActiGraph compared with steps counted ($N = 22$).

ranged from 97% to 102%, indicating that the Yamax devices slightly over-counted steps. In addition, dependent sample correlations between the CW-701 and the criterion were computed. This test assesses the degree to which the device accurately assessing individual differences even though it may be consistently lower (or higher) than the actual criterion. The results show that the device is accurate in the fast treadmill ($r = .99$, $p < .01$) and track walking ($r = .98$, $p < .01$) conditions; its inaccuracy appears to be highly consistent across participants. The correlation in the slow treadmill condition ($r = .45$, $p < .05$) was distinctly smaller, indicating much less consistency in this condition.

Percent relative error of the three activity meters for each condition was then assessed (see Table 2). Positive scores indicated over-estimates and negative scores indicated under-estimates.[22] The Yamax CW-701 had a large margin of error during the slow walking condition. However, percent error for the fast walking, track walking, and free-living condition were within an acceptable range.

Inter-pedometer reliability was assessed using the ICC (ICC1,2) to compare the Yamax CW-701 to observed steps, steps recorded by the Yamax SW-200, and steps recorded by the ActiGraph GTX3 (see Table 3). For walking at a slow pace, the Yamax CW-701 had poor reliability when compared with observed steps (.37, 95% CI −.27 to .70), the SW-200 (.58, 95% CI −.03 to .83), and the ActiGraph GTX3 (.75, 95% CI .37 to .90). However, the CW-701 was reliable ($\geq .90$) in measuring fast treadmill walking, indoor track walking, and free-living activity when compared with observed steps and the SW-200. Reliability for the CW-701 compared with the SW-200 while walking on the treadmill (.83) and indoor track was marginal (.78). Bland–Altman plots of the CW-701 demonstrated poor accuracy for slow walking

on the treadmill (Figure 2(a)) and accuracy for fast walking on the treadmill and walking on the track (Figure 2(b),(c)). The mean error score fell near zero and most scores fell within the 95% confidence interval.

Discussion

With the growing popularity of pedometers and 10,000 steps per day recommendation,[23] there is a growing need for devices that accurately count steps across populations. The Yamax SW-200 has been compared with actual steps in multiple studies[6,9,12,13,24] and consistently performs well. Similarly, the ActiGraph GTX3 is a valid and accurate device that can be used in research.[13] There can be significant variability in accuracy of pedometers based on the model, mechanism, surface, walking speed, and user characteristics. Although the Yamax SW-200 and ActiGraph GTX3

are highly correlated devices, pedometers and accelerometers function differently and outputs should not be used interchangeably.

To date, the accuracy of the Yamax Digi-Walker CW-701 has not been established. Therefore, the primary purpose of this study was to determine the accuracy of the Yamax CW-701 pedometer during slow and fast treadmill walking, track walking, and free-living conditions. The Yamax CW-701 demonstrated accuracy at faster waking speeds, falling within ±3% of actual steps taken. The ICC suggested that the Yamax CW-701 is reliable both at faster walking speeds and in free-living situations. The Yamax CW-701 did not perform well during the slow treadmill walking activity. Consistent with prior research,[11] both Yamax spring-levered meters undercounted steps during slow walking on the treadmill (83% and 86%). During fast walking on the treadmill and the track exercise, all three meters performed well (96–102%).

To obtain a step log, researchers often rely on participant self-report to obtain a daily step log. The user must manually record the number displayed on the meter at the end of the day and the device must then be manually reset to zero. This presents a challenge for low-literate or memory-challenged individuals, and can introduce potential errors in recorded data. The memory and the reset features on the Yamax CW-701 may make this model a better choice in these populations.

In this study, all three devices undercounted steps at slower speeds. This is consistent with prior research that also reported decreased accuracy with walking at slower speeds.[5,8,11,22,25–27] With most pedometers and accelerometers, adequate force and intensity must be present for a step to register. The Yamax pedometers use spring-levered technology that detects and registers vertical movement on a lever arm, which may be affected by tilt. Yamax pedometers should be positioned vertically and adequately sensitive to step movement to accurately measure steps taken.[26] Another explanation may be the insufficient force for the lever

Table 2. Percent relative error of each meter compared with actual step count for each condition ($N = 22$).

Activity	CW-701 Mean ± SD (range)	SW-200 Mean ± SD (range)	ActiGraph Mean ± SD (range)
Treadmill, slow pace	−13.7 ± 16.6[a] (−58.2 to 1.3)	−16.4 ± 23[a] (−61.4 to 31)	−15.9 ± 19.4 (−51 to 17.7)
Treadmill, fast pace	−0.8 ± 1[a] (−3.7 to 0.8)	−1.4 ± 6.7 (−23 to 14.6)	−1.3 ± 0.9 (−2.8 to 0.6)
Walk 400 meters on track	0.5 ± 1.8 (−2.1 to 6.5)	1.8 ± 7.7 (−8.2 to 32.6)	−1.7 ± 4.5[a] (−18.7 to 0.3)
Free-living	0.7 ± 24.6 (−51.3 to 38.6)	1.2 ± 22.7 (−48.6 to 52.2)	na

na: Step count not observed in free-living condition.
[a]Significantly different compared with criterion ($p < .05$);

Table 3. Intraclass correlation coefficeint (ICC2,1) for Yamax CW-701 step count versus step count, Yamax SW-200, and ActiGraph ($N = 22$).

Activity	CW-701 vs. counted steps		CW-701 vs. SW-200		CW-701 vs. ActiGraph	
	ICC	95% CI	ICC	95% CI	ICC	95% CI
Treadmill, slow pace	.37	−.27 to .70	.58	−.03 to .83	.75	.37 to .90
Treadmill, fast pace	.99	.95 to .99	.83	.59 to .93	.99	.99 to 1.0
Walking on indoor track	.98	.93 to .99	.78	.48 to .91	.90	.74 to .96
Free-living	na		.98	.96 to .99	na	

na: Step count not observed in free-living condition.
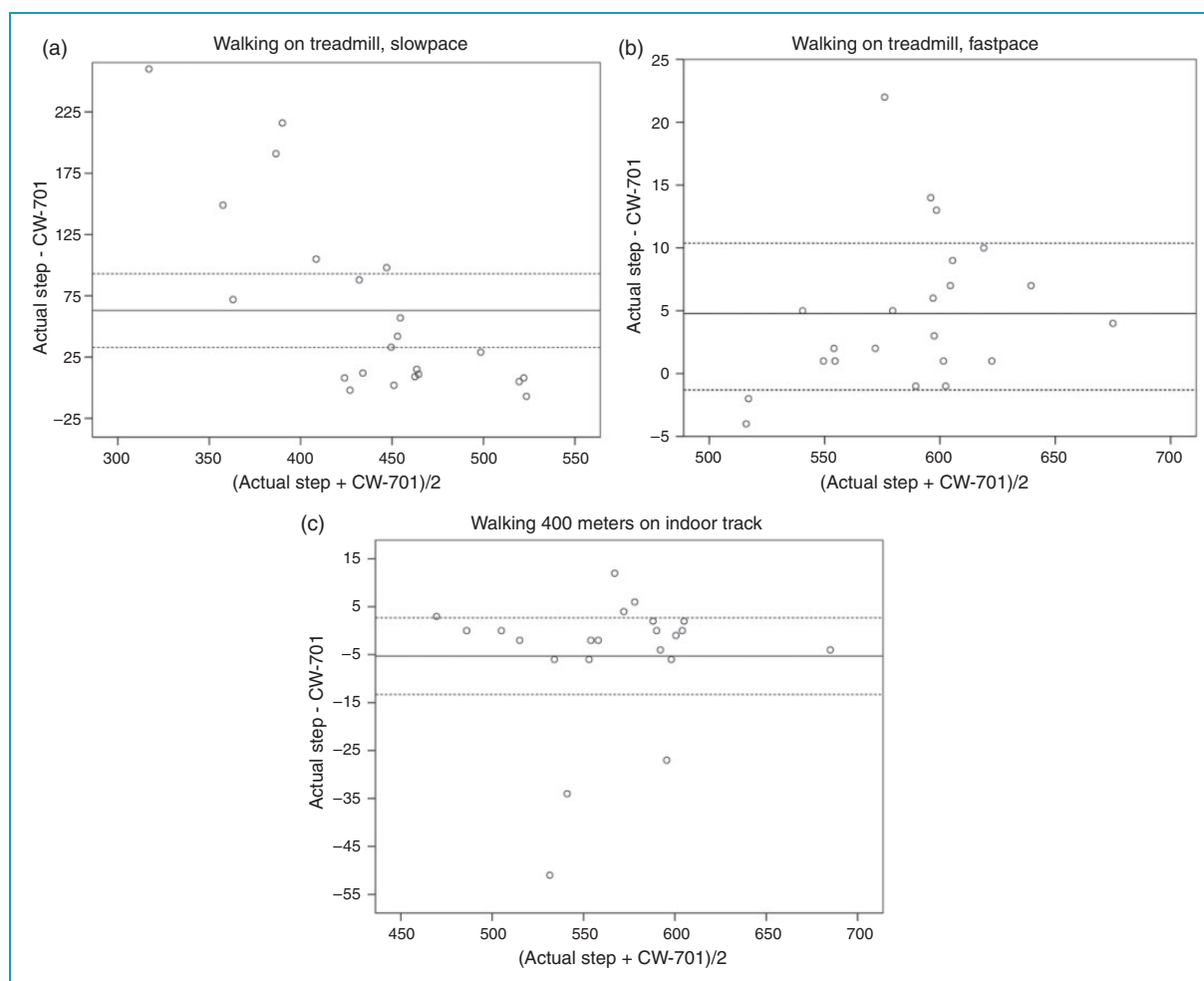
Figure 2(a)–(c). Bland–Altman plots for the Yamax CW-701 under three conditions.
Solid horizontal line = Mean error score; dotted horizontal line = 95% prediction interval.

to register movement when the pedometer is placed at the hip.[27] For overweight adults, disabled individuals, or slow walkers, accelerometer pedometers, which can tolerate more positions and recognize slower walking speeds, may be more accurate. Further research and development of devices that can be accurately used in individuals with slow walking speeds is needed.[28]

Sample size and homogeneity were limitations in this study. Though the sample size in this study was small, participants were used to test several different conditions. A review of pedometer validity studies revealed that the sample size used in this study is consistent with other pedometer accuracy studies.[4,6,12,16,18,19] Further, a meta analysis of nine walking-based pedometer studies cited one larger study with 106 participants while the remaining eight studies had a sample size that ranged from 15 to 38 with a mean of 25.[29] The age range of participants in this study was narrow; however, age alone has not been shown to be a factor in

pedometer accuracy. Another study limitation was the few participants who were overweight. Future studies should be conducted to test the accuracy of the Yamax CW-701 in overweight and obese participants.

Conclusion

In conclusion, this study demonstrates the accuracy of the Yamax CW-701 (previously sold as the Yamax CW-600). Given the accuracy demonstrated by the Yamax CW-701 compared with industry gold standards like the ActiGraph GTX3 and Yamax SW-200, it can be used in community-based settings, though may not accurately count steps at slower walking speeds. Because the Yamax CW-701 has the added benefits of a seven-day step memory, two-week cumulative memory, and automatic reset without the prohibitive cost or complexity of activity monitors, it is an ideal tool for individuals who might otherwise be unable to use such devices.

References

1. Gardner PJ and Campagna PD. Pedometers as measurement tools and motivational devices: New insights for researchers and practitioners. *Health Promot Pract* 2011; 12: 55–62.
2. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: A systematic review. *JAMA* 2007; 298: 2296–2304.
3. Bassett DR and John D. Use of pedometers and accelerometers in clinical populations: Validity and reliability issues. *Phys Ther Rev* 2010; 15: 135–142.
4. Bassett DR, Ainsworth BE, Leggett SR, et al. Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc* 1996; 28: 1071–1077.
5. Tudor-Locke C, Williams JE, Reis JP, et al. Utility of pedometers for assessing physical activity. *Sports Med* 2002; 32: 795–808.
6. Schneider PL, Crouter SE and Bassett DR. Pedometer measures of free-living physical activity: Comparison of 13 models. *Med Sci Sports Exerc* 2004; 36: 331–335.
7. Dijkstra B, Zijlstra W, Scherder E, et al. Detection of walking periods and number of steps in older adults and patients with Parkinson's disease: Accuracy of a pedometer and an accelerometry-based method. *Age Ageing* 2008; 37: 436–441.
8. Grant PM, Dall PM, Mitchell SL, et al. Activity-monitor accuracy in measuring step number and cadence in community-dwelling older adults. *J Aging Phys Act* 2008; 16: 201–214.
9. Rowlands AV, Stone MR and Eston RG. Influence of speed and step frequency during walking and running on motion sensor output. *Med Sci Sports Exerc* 2007; 94: 716–727.
10. Elsworth C, Dawes H, Winward C, et al. Pedometer step counts in individual with neurological conditions. *Clin Rehabil* 2009; 23: 171–175.
11. Crouter SE, Schneider PL, Karabulut M, et al. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc* 2003; 35: 1455–1460.
12. Schneider PL, Crouter SE, Lukajic O, et al. Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Med Sci Sports Exerc* 2003; 35: 1779–1784.
13. Barriera TV, Tudor-Locke C, Champagne CM, et al. Comparison of GTX3 Accelerometer and Yamax Pedometer steps/day in a free living sample of overweight and obese adults. *J Phys Act Health* 2013; 10: 263–270.
14. McClain JJ, Sisson SB and Tudor-Locke C. Actigraph accelerometer interinstrument reliability during free-living in adults. *Med Sci Sports Exerc* 2007; 39: 1509–1514.
15. Aadland E and Ylvisåker E. Reliability of the Actigraph GT3X+ accelerometer in adults under free-living conditions. *PloS One* 2015; 10: e0134606.
16. Lee JA, Williams SM, Brown DD, et al. Concurrent validation of the Actigraph gt3x+, Polar Active accelerometer, Omron HJ-720 and Yamax Digiwalker SW-701 pedometer step counts in lab-based and free-living settings. *J Sports Sci* 2015; 33: 991–1000.
17. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003–2004. *Am J Epidemiol* 2008; 167: 875–881.
18. Ayabe M, Aoki J, Ishii K, et al. Pedometer accuracy during stair climbing and bench stepping exercises. *J Sports Sci Med* 2008; 7: 249–254.
19. Tudor-Locke C, Sisson SB, Lee SM, et al. Evaluation of quality commercial pedometers. *Can J Public Health* 2006; 97: S10–S15.
20. Shrout PE and Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. *Psychol Bull* 1979; 86: 420–428.
21. Bland JM and Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 327: 307–310.
22. Le Masurier GC and Tudor-Locke C. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc* 2003; 35: 867–871.
23. Tudor-Locke C and Bassett Jr DR. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med* 2004; 34: 1–8.
24. Vanroy C, Vissers D, Cras P, et al. Physical activity monitoring in stroke: SenseWear Pro2 activity accelerometer versus Yamax Digi-Walker SW-200 pedometer. *Disabil Rehabil* 2014; 36: 1695–1703.
25. Martin JB, Krc KM, Mitchell EA, et al. Pedometer accuracy in slow walking older adults. *Int J Ther Rehabil* 2012; 19: 387–393.
26. Crouter SE, Schneider PL and Bassett Jr DR. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc* 2005; 37: 1673–1679.
27. Melanson EL, Knoll JR, Bell ML, et al. Commercially available pedometers: Considerations for accurate step counting. *Prev Med* 2004; 39: 361–368.
28. Cyarto EV, Myers AM and Tudor-Locke C. Pedometer accuracy in nursing home and community-dwelling older adults. *Med Sci Sports Exerc* 2004; 36: 205–209.
29. Richardson CR, Newton TL, Abraham JJ, et al. A meta-analysis of pedometer-based walking interventions and weight loss. *Ann Fam Med* 2008; 6: 69–77.