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ORIGINAL ARTICLE

Is this Bit Fit? Measuring the Quality of the FitBit Step-Counter

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Abstract

Background: Accurate measurement of physical activity is essential for understanding the relationship between physical activity (PA) and health outcomes. Technological advances have led to a surge in commercially-available pedometers, however, limited scientific evidence exists regarding their accuracy *Purpose*: This study is the first to test the quality of the newly developed Fitbit step-counter and comparability relative to the Yamax SW-200 pedometer. *Methods*: Ten healthy young adults participated. The quality of the Fitbit was assessed through: 1) a 20 Step Test; 2) a motor vehicle test; and 3) a treadmill test at various speeds (2, 3, 4, 5, 6, 8, 9, 10, 11 $km \cdot h^{-1}$) on three locations on the body (inside pocket, waist, upper body). *Results*: The 20 Step Test revealed that none of the Fitbits had error scores greater than +/- 5% and during the motor vehicle condition, the Fitbits did not record any spurious movement. Statistical differences were found between the observed steps and detected steps for Yamax at walking speeds of 2 $km \cdot h^{-1}$ ($p < 0.001$) and 3 $km \cdot h^{-1}$ ($p < 0.05$), as well as the waist-mounted Fitbit at 2 $km \cdot h^{-1}$ ($p < 0.05$). All locations of the Fitbit and the Yamax were very accurate at normal walking speeds of 4.5 $km \cdot h^{-1}$ and 6.0 $km \cdot h^{-1}$. In terms of running speeds (8 $km \cdot h^{-1}$, 9 $km \cdot h^{-1}$, 10 $km \cdot h^{-1}$, 11 $km \cdot h^{-1}$) there were only significant differences found between observed steps and detected steps for the Fitbit in the pocket. *Conclusions*: Our quality-control testing should now enable physical activity practitioners, consumers and researchers alike to make a more informed decision on whether to purchase and utilize the FitBit. **Health & Fitness Journal of Canada 2012;5(4):30-39.**

Keywords: Physical activity, Measurement, Reliability, Validity, Pedometer, Accuracy

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Introduction

Increasing daily physical activity (PA) has been proven beneficial in preventing a wide variety of chronic diseases including diabetes, hypertension, and obesity (Warburton et al., 2010). Accurate measurement of physical activity is essential for understanding the relationship between PA and health outcomes, and also beneficial for individuals wishing to self-monitor their own physical activity levels. The information one is able to acquire may serve a motivational role and underpin goal-setting attempts to increase physical activity.

Objective measures such as pedometers and accelerometers have become standard tools in assessing PA levels (Bravata, 2007; Welk et al., 2002). Pedometers are utilized to a greater extent than accelerometers due to lower cost, reasonable accuracy and greater feasibility (Cooper, 2006). In terms of mechanics, pedometers rely on vertical movements of the body to trigger a switch (i.e., mechanical or electrical) each time a step is taken, thus registering the total number of steps. Many current commercially-available pedometers (i.e., Yamax SW-200,Sportline 345,Omron HF-100, Walk-4-Life LS-200) have been cited as having a very high degree of accuracy (>90%) in counting steps (Melanson et al., 2004; Schneider et al., 2004). Given the popular appeal of the 10,000 steps·day^{-1} target with the media and in practice (Tudor-Locke, & Bassett, 2004), it is likely that devices that calculate steps will continue to have broad appeal.

Technological advances have led to a surge in approximately 60 commercially-available pedometers (http://www.pedometersusa.com). However, a noticeable gap is that there is often little information regarding their accuracy. This is a concern because inaccurate pedometers might do harm by providing incorrect information which could misinform users (Tudor-Locke et al., 2006). Indeed, Tudor-Locke and colleagues (2006) demonstrated that pedometers widely distributed in cereals boxes as part of the Canada on the Move campaign were unacceptably inaccurate at measuring habitual daily step counts. More recently, Bergman and colleagues (2011) reported the accuracy of free pedometer application (iPedometer) for the iPhone; findings revealed poor accuracy at counting steps during controlled laboratory conditions (i.e., treadmill walking). In general, there is significant variability in the accuracy and reliability of commercially available pedometers (Schneider et al., 2004). Consequently, new devices should be examined in terms of their accuracy; potential consumers should be confident that a device performs as advertised.

A recently developed step-counter called the FitBit (www.fitbit.com; FitBit, Inc., San Francisco, CA) has become available on the market, stating enhanced features with broader commercial market appeal. Steps are measured via a 3-axis (vertical, anteroposterior, and mediolateral) analog accelerometer that differentiates the FitBit from other commercial pedometers. For example, electronic pedometers are battery operated devices that contain a spring-suspended, horizontal lever arm that moves up and down. This motion opens and closes an electrical circuit in response to vertical accelerations of the waist and provides a digital display of steps taken during running or walking (Bassett, 2002). The FitBit device uses a 3-D MEMS accelerometer implanted into its internal chip which creates a 3-way analog accelerometer (H. Hartman, personal communication, November 4, 2011). For further technological details pertaining to the FitBit device, please refer to (www.fitbit.com; FitBit, Inc., San Francisco, CA).

The FitBit marketing material suggests that due to its size and shape it can be placed at multiple locations on the body while maintaining step count accuracy. The majority of step-counters are only effective when the device is placed on the hip (i.e., belt of jeans). However, the FitBit proclaims to be reliable if placed in the pocket, attached to the waist, or on the upper body (i.e., in shirt pockets for males/strapped to bra in females; http:/www.fitbit.com/product/features). This is an important consideration as some individuals might benefit from the flexibility of FitBit placement. Those who are required to wear specific pieces of clothing for religious or cultural reasons and women who prefer wearing dresses may benefit from the ability to hook the FitBit onto the collar or bra rather than the waist. Additionally, to prevent individuals from feeling self-conscious (especially overweight individuals who may be at risk for stigmatization), placement in the pocket could provide a discrete option for physical activity monitoring that would help with issues of compliance. Thus, researchers and organizations may be attracted to utilize such a motivational and versatile device within their physical activity based studies/interventions.

The FitBit website suggests that the device is "roughly 95-97% accurate for counting steps when worn as recommended" although no further detail is provided regarding the basis for this claim (http://help.fitbit.com/customer/portal/articles/175956-how-accurate-is-the-fitbit-tracker-). However, to our knowledge, no scientific research evaluation of the quality of these devices has been conducted. Such research is critical for establishing whether manufacturer claims of high accuracy are in fact valid. Given this need for accuracy testing and the recognizable appeal of the FitBit's attractive commercial features, this study therefore aimed to investigate the quality of the FitBit step-counter. Following Tudor-Locke et al.'s (2006) developed protocol for assessing the accuracy of commercial pedometers, this study examined the quality of the FitBit step-counter while additionally comparing it to Yamax SW200. Previous research has consistently demonstrated that the Yamax SW-200 is the most accurate pedometer currently available and consequently it is considered the gold standard (Bassett et al., 2000; Crouter et al., 2003; Schneider et al., 2003). Thus, to assess the quality (i.e., reliability and validity) of the Fitbit in relation to the Yamax SW200, the following tests were conducted:

1. a 20 Step Test
2. a motor vehicle controlled condition test
3. a treadmill controlled condition test on three locations on the body (i.e., inside pocket, waist, upper body) and at various walking and running speeds.

Methods

Participants

A convenience sample of 10 (n = 5 male, n = 5 female) healthy young adults (age = 23.0 $\pm$ 1.2 yr, Body Mass Index = 21.4 $\pm$ 1.9) volunteered to take part in this study. The study was approved by the University of Toronto's Office of Research Ethics. All participants gave written informed consent prior to participating in the experiments. All participants were enrolled at the University of Toronto at the time of the study. Physical and demographic characteristics of the participants are listed in Table 1.

Instruments

This study used four FitBits (manufactured by FitBit Inc., www.fitbit.com) and four Yamax pedometers (SW-200 Digi-Walker, manufactured by Yamax Corp., http://yamaxx.com). The devices were compared across three different experiments: 1) 20 Step Test, 2) Motor Vehicle Test and 3) Treadmill Test.

Experiment 1: 20 Step Test

All devices were subjected to initial reliability testing to identify any defective instruments prior to their utilization in subsequent experiments. Both a FitBit and a Yamax pedometer were worn on the hip while 20 steps were taken at a normal walking pace. Steps were self-counted by the researchers wearing the devices, similar to the testing protocol of Tudor-Locke et al (2006). The devices were zeroed before beginning and the numbers of steps counted by each of the devices were recorded at the end of each trial. Six trials were performed for each FitBit and Yamax; three with the devices worn on the left hip and three with the right hip. One of the Yamax pedometers was found to be defective (exceeded an error of ± 5%) and was not used in any of the subsequent experiments. The 5% error threshold was established by Vincent and Sidman (2003) as a criterion for the accuracy of digital pedometers.

Experiment 2: Motor Vehicle Test

This experiment was conducted to test for any incidental step recordings produced by the FitBits while they were subject to motion without any steps being taken. This is an important test as it determines whether the devices are prone to register steps when none have been performed, which would affect the accuracy of the device. Similar to the 20 Step Test, the Motor Vehicle Test was performed on the researchers. Once seated in the car, the FitBits and Yamax pedometers were zeroed. The car was driven on paved roads and the step counts of each of the FitBits and pedometers were recorded.

Experiment 3: Treadmill Test

The purpose of the treadmill test was to test the validity of the FitBits in relation to direct videotaped observation under controlled walking conditions, at various speeds and locations on the body. Participants each wore three FitBits and one Yamax pedometer (See Table 1 for participant characteristics). The Yamax was worn at the waist while the FitBits were placed at three different locations: the waist, the pants pocket, and the shirt collar (for males) or bra (for females). The four walking speeds tested were: 2 $km \cdot h^{-1}$, 3 $km \cdot h^{-1}$, 4.5 $km \cdot h^{-1}$, and 6 $km \cdot h^{-1}$. The four running speeds tested were: 8 $km \cdot h^{-1}$, 9 $km \cdot h^{-1}$, 10 $km \cdot h^{-1}$, and 11 $km \cdot h^{-1}$. Each speed was maintained for one minute. The number of steps taken in one minute at each speed was counted by one of the investigators and the number of steps registered on the FitBits and the Yamax was recorded. Participants stood on the sides of the treadmill before starting the minute at full speed, and immediately stepped back on to the sides at the end of the minute; this eliminated a transition period of steps at a speed other than that being tested. Sessions were videotaped so that investigators could confirm accuracy of the manually counted steps.

Table 1: Physical and demographic characteristics of the participants.

	Men (n = 5)	Women (n = 5)	All
Age (yr)	22.6 ± 0.9	23.4 ± 1.5	23.0 ± 1.3
Height (cm)	183.2 ± 6.7	161.0 ± 5.9	172.1 ± 13.1
Weight (kg)	76.4 ± 9.9	52.4 ± 4.3	64.4 ± 14.6
BMI ($kg \cdot m^{-2}$)	21.7 ± 1.7	20.2 ± 1.2	21.4 ± 1.9

Statistical Analyses

Experiment 1: 20 Step Test. The percent error of each trial was computed for each of the devices to asses if any FitBit or Yamax error was greater than ± 5%.

Experiment 2: Motor Vehicle Test. The number of errors, in this case detected non-steps, were recorded and compared between the FitBit and Yamax devices.

Experiment 3: Treadmill Test. Steps were manually counted by the same researcher, and confirmed by the video recordings, for each participant for all treadmill tests.

Analyses were conducted on SPSS 19.0 for Windows. Statistical significance was set at $p < 0.05$, unless otherwise specified. One-way repeated measures ANOVAs were conducted to assess inter-device reliability and validity. Least Significant Difference post-hoc tests were conducted to determine which condition differed.

Mean error scores and percent errors were also computed in order to measure device accuracy. Percent errors were graphed at each speed to illustrate either underestimation (>-1%), exact (±1) or overestimation (>1%) of counts compared to the observed count of the Yamax and each FitBit location. Previous studies (Le Masurier et al., 2004) have demonstrated that the direction of error (over- vs. under-estimation) can vary greatly and it is important to calculate both the direction and the amount of error. The mean error scores were illustrated with a 95% confidence interval.

Results

Experiment 1: 20 Step Test. Percent error was calculated and no Yamax or FitBit had an error greater than ± 5%.

Experiment 2: Motor Vehicle Test. During the motor vehicle test, none of the FitBits recorded any steps. The Yamax detected 3 steps.

Experiment 3: Treadmill Test. Statistically significant differences between observed steps and detected steps for the Yamax at speeds 2 $km \cdot h^{-1}$ ($p < 0.001$), 3 $km \cdot h^{-1}$ ($p < 0.05$) and 4.5 $km \cdot h^{-1}$ ($p < 0.05$), as well as the waist-mounted FitBit at speed 2 $km \cdot h^{-1}$ ($p < 0.05$), were encountered. No significant differences were found between the FitBit and observed step counts for walking speeds higher than 2 $km \cdot h^{-1}$, meaning that the steps detected were valid. Table 2 illustrates the mean error scores, standard error and 95% confidence intervals between the Yamax and FitBit's location compared to observed steps for walking speeds. Statistically significant differences between observed steps and detected steps for Fitbit in the pocket occurred during running (i.e., 8 $km \cdot h^{-1}$, 9 $km \cdot h^{-1}$, 10 $km \cdot h^{-1}$, and 11 $km \cdot h^{-1}$). There were no other significant differences between observed steps and FitBit/Yamax-detected steps during running. Table 3 illustrates mean error scores, standard error and 95% confidence intervals between the Yamax and FitBit's location compared to observed steps for running speeds. Figure 1 illustrates the change in percent error as speed increases for the Yamax, and the FitBits at various locations.

Discussion

This is the first study to examine the quality of the newly designed FitBit step-counter. Commercially available step counters have been evaluated in numerous brand-to-brand comparisons, in which quality and performance are assessed relative to one another (Schneider et al., 2003; Tudor-Locke, 2006). This study aimed to examine the quality of the FitBit at various walking and running speeds on three locations on the body in comparison to direct observation, in addition to comparing it to the Yamax SW200 which is considered to be the most accurate pedometer (Bassett et al., 2000; Crouter et al., 2003; Schneider et al., 2003). Overall, the FitBit appears to be an accurate and reliable tool for measuring step counts in healthy young adults.

Table 2: Error score (Count – Steps Detected) in number of steps for walking speed conditions.

Speed (km·h^{-1})	Location	Mean Difference	SE	95% CI
2	Yamax	49**	6.49	36.27 – 61.73
	FitBit Waist	30.8*	7.69	15.73 – 45.87
	Fitbit Pocket	9.3	6.92	-4.27 – 22.87
	Fitbit Collar	12.7	5.02	2.86 – 22.54
3	Yamax	57.3**	7.09	43.39 – 71.21
	Fitbit Waist	3.5	1.86	-0.15 – 7.15
	Fitbit Pocket	2.2	1.52	-0.79 – 5.19
	Fitbit Collar	1.2	0.39	0.44 – 1.96
4.5	Yamax	17.5*	7.21	3.37 – 31.63
	Fitbit Waist	0.1	0.58	-1.05 – 1.25
	Fitbit Pocket	-0.8	0.89	-2.55 – 0.95
	Fitbit Collar	-0.5	0.91	-2.28 – 1.28
6	Yamax	5.4	2.57	0.35 – 10.44
	Fitbit Waist	0.3	0.65	-0.98 – 1.58
	Fitbit Pocket	-0.7	1.46	-3.56 – 2.16
	Fitbit Collar	0.4	0.5	0.58 – 1.38
8	Yamax	-0.90	1.55	-4.40 – 2.60
	Fitbit Waist	0.60	1.56	-2.02 – 3.22
	Fitbit Pocket	10.2*	3.69	1.85 – 18.55
	Fitbit Collar	2.40	2.69	-3.69 – 8.49
9	Yamax	-0.70	0.61	-2.09 – 0.69
	Fitbit Waist	0.10	1.91	-4.21 – 4.41
	Fitbit Pocket	19.1*	6.37	4.69 – 33.51
	Fitbit Collar	5.1	4.06	-4.08 – 14.28
10	Yamax	-1.10	0.64	-2.55 – 0.35
	Fitbit Waist	3.1	2.06	-1.55 – 7.75
	Fitbit Pocket	33.7*	10.47	10.36 – 57.04
	Fitbit Collar	4.6	3.87	-4.14 – 13.34
11	Yamax	-1.30	0.67	-2.81 – 2.10
	Fitbit Waist	4.5	2.60	-1.37 – 10.37
	Fitbit Pocket	37.9*	9.30	16.86 – 58.95
	Fitbit Collar	5.9	4.42	-4.10 – 15.90

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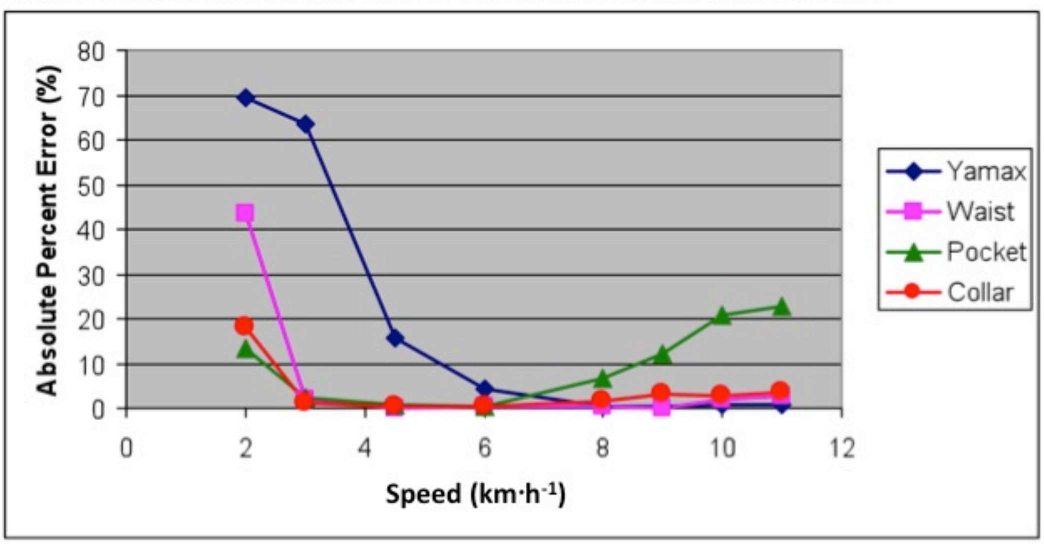
One potentially attractive feature of the FitBit is its ability to be placed at multiple locations on the body. Though pedometers are classically placed on the waist/hip region of the individual, the FitBit marketing material outlines the device's capacity to pick up an accurate step count from the pocket, the collar or bra, and the waist (http:/www.fitbit.com/product/features). This study identified that the FitBit placement in regions aside from the waist were accurate, especially the collar/bra, which was the most accurate on average at detecting steps across eight walking and running speeds. Notably, the pocket and collar were more accurate at detecting steps taken at the slowest walking speed (2.0 km·h^{-1}), where the FitBit (waist) was unable to accurately detect the steps taken. It was however anticipated that the Yamax SW200 would underestimate the steps at the slower speeds as pedometers are reliably more accurate at walking speeds between 3-5 km·h^{-1} (Schneider et al., 2003; Crouter et al., 2003). Therefore, pedometers may not be appropriate measurement devices for assessing physical activity levels in frail, institutionalized older adults with characteristically shuffling, slow gaits (Hendelman, 2000). For those individuals who walk at a slower pace, placement of the FitBit on the collar/bra might therefore be more appropriate. All four placement measures were very accurate at higher walking speeds (i.e., 4.5 km·h^{-1} and 6.0 km·h^{-1}), which illustrates the utility of both devices when walking speeds fall within a normal range. The literature suggests that inaccurate pedometer readings from slower than normal walking speeds (3.0 km·h^{-1}) are not important sources of error in studies of free-living activity in ambulatory populations (Wilcox, 2002).

The Yamax pedometer, along with two of the FitBit placements (waist and collar/bra), was very accurate at measuring steps at the higher running speeds (8 km·h^{-1}, 9 km·h^{-1}, 10 km·h^{-1} and 11 km·h^{-1}). The pocket however showed decreasing accuracy as the running speeds increased. Overall, it appears that the collar/bra FitBit placement was capable of accurate step detection across the full spectrum of walking/running speeds. The Yamax SW200 appeared to improve as speed increased, and although it was less effective at the very slow walking speeds, it remains an effective tool for measuring steps at both normal walking pace and faster running speeds.

Though the Yamax SW200 is the prevailing gold standard pedometer, the FitBit outperformed the Yamax on the treadmill test. The FitBit is essentially an accelerometer and these differences in accuracy might be explained by the different device mechanisms. Differences were modest though and should not be a

Figure 1: Speed versus absolute mean percent error for Yamax and FitBit locations.



deciding factor in device selection given the cost differential (i.e., the FitBit (approximately $100 CAN) is more expensive than the Yamax (approximately $25 CAN). However, to justify the cost of the Fitbit, it is worth noting that the device contains additional features that may serve as a physical activity motivational tool including: online components (website/mobile apps) to track physical activity progress, sleep and log caloric intake; and social networking capabilities. Researchers might find such a versatile device attractive within their physical activity based studies/interventions particularly since the Fitbit can be placed on locations other than the waist. As our findings indicated, the FitBit might be a good choice for individuals who cannot wear a pedometer on the hip due to cultural or physical challenges.

Limitations and Future Research

The study population consisted of healthy young men and women between the ages of 20 and 25 years old. Thus, these results can only be generalized to a healthy young adult population. Future research could examine various populations, including children and elderly groups, to identify the effectiveness of this device in those populations. While the sample could be considered small, there are studies reporting samples of comparable size (Buss et al., 2009; Tudor-Locke et al., 2006).

A main strength of this study was its design, which allowed for three in-depth assessment tests, highlighted by the placement and speed including a treadmill test. Future research could contrast the FitBit to a comparably priced accelerometer, which may be of use to consumers or researchers when attempting to identify the most cost-effective tool of measurement. The FitBit could also be assessed under free-living conditions and with other age groups.

Conclusions

The This study demonstrated that the FitBit device is an accurate and reliable step counting tool for young adults. Technological advances in physical activity monitoring are continuing to flood the commercial market with devices, and it is imperative that new devices be put through rigorous research evaluations of their accuracy. Our quality-control testing should now enable consumers and researchers alike to make a more informed decision on whether to purchase and utilize the FitBit to enhance their personal/professional physical activity assessment goals.

Authors' Qualifications

The authors' qualifications are: George Mammen MSc; Sarah Gardiner MSc; Arani Senthinathan BSc; Laura McClemont BSc; Dr. Michelle Stone PhD; Dr. Guy Faulkner PhD.

References

Bassett, D. R., Cureton, A. L., and Ainsworth, B. E. (2000). Measurement of daily walking distance-questionnaire versus pedometer. *Med Sci Sports Exerc,* 32, 1018-1023. URL: http://europepmc.org/abstract/MED/10795795

Bassett, D. R, and Strath, S, J. (2002). Use of pedometers to assess physical activity. In: *Physical activity assessments for health-related research*, G.J. Welk (Ed.) Champaign, IL: Human Kinetics, 166-170.

Bergman, R. J., Spellman, J. W., Hall, M. E., and Berman, S. M. (2011). Is there a valid app for that? Validity of a free pedometer iPhone application. *J Phys Act Health*, 5, 670-676. URL: http://www.ncbi.nlm.nih.gov/pubmed/21946023

Bravata, D. (2007). Using pedometers to increase physical activity and improve health. *J. Am. Med. Assoc,* 19, 2296-2308. URL: http://www.ncbi.nlm.nih.gov/pubmed/18029834

Buss, M., Van Deursen, R. W., and Wiles, C.M. (2009). Real-life step and activity measurement: reliability and validity. *J Med Eng Technol*, 33, 33-41. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Real-life%20step%20and%20activity%20measurement%3A%20reliability%20and%20validity

Canadian Society for Exercise Physiology (2011). Canadian physical activity guidelines. Retrieved November 4, 2011 from URL: http://csep.ca/guidelines.

Cooper, A. (2003). Objective measurement of physical activity. In J. McKenna & C. Riddoch (eds.), *Perspectives on health and exercise* (83-108). Basingstoke: Palgrave Macmillan.

Crouter, S., Schneider, P., Karabulut, M., and Bassett, D. R. (2003). Validity of 10 pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*, 35, 1455-1460. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Validity%20of%2010%20pedometers%20for%20measuring%20steps%2C%20distance%2C%20and%20energy%20cost

Freescale Semiconductor. Data Sheet: Technical Data. Freescale Semiconductor Literature Distribution Center. (2011, August). Retrieved November 24, 2012, from http://cache.freescale.com/files/sensors/doc/data_sheet/MMA7341LC.pdf?pspll=1

Hatano, Y. (1997). Prevalence and use of the pedometer. *Research Journal in Walking*, 1, 45-54. URL: unavailable.

Hendelman, D., Miller, K., Baggett, C., Debold, E., and Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med Sci Sports Exerc*, 32, 442-450. URL: http://www.ncbi.nlm.nih.gov/pubmed/10993413

Le Masurier, G., and Tudor-Locke, C. (2003). Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc*. 35, 867–871. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Comparison%20of%20pedometer%20and%20accelerometer%20accuracy%20under%20controlled%20conditions

Melanson, E., Knoll, J., Bell, M., Donahoo, W., T., Hill, J. O., Nysse, L. J., Lanningham-Foster, L., Peters, J. C., and James, A. (2004). Commercially available pedometers: considerations for accurate step counting. *Prev Med*, 39, 361-368. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Commercially%20available%20pedometers%3A%20considerations%20for%20accurate%20step%20counting

Oliver, M., Schofield, G., Kolt, G., and Schluter, P. (2007). Pedometer accuracy in physical activity assessment of preschool children. J Sci Med Sport , 10, 303-310. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Pedometer%20accuracy%20in%20physical%20activity%20assessment%20of%20preschool%20children

Pate, R. R, Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., Buchner, D., Ettinger, W. Heath, G. W., King, A. C, et al. (1995). Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *J Am Med Assoc*, 273, 402-407. URL: http://www.ncbi.nlm.nih.gov/pubmed/7823386

Schneider, L. P., Crouter, S. E., and Bassett, D. R. (2004). Pedometer measures of free-living physical activity: comparison of 13 models. *Medicine and Science in Exercise and Sport*, 36, 331-335. URL: http://rubytec.eu/downloads/yamax/f-2004-m.pdf

Schneider, L. P., Crouter, S. E., Lukajic, O., and Bassett, D. R. (2003). Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Med Sci Sports Exerc*, 35, 1779-1784. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Accuracy%20and%20reliability%20of%2010%20pedometers%20for%20measuring%20steps%20over%20a%20400-m%20walk

Tudor-Locke, C., Ainsworth, B. E., Thompson, R. W., and Matthews, C. E. (2002). Comparison of pedometer and accelerometer measures of free-living physical activity. *Med Sci Sports Exerc*, 34, 2045–2051. URL: http://www.ncbi.nlm.nih.gov/pubmed/12471314

Tudor-Locke, C, & Bassett, D. R. (2004). How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Med*, 34, 1-8. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Preliminary%20pedometer%20indices%20for%20public%20health

Tudor-Locke, C., Jones, R., Myers, A. M., Paterson, D. H., and Ecclestone N. A. (2002). Contribution of structured exercise class participation and informal walking for exercise to daily physical activity in community-dwelling older adults. *Res Q Exerc Sport*, 73, 350-356. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Contribution%20of%20structured%20exercise%20class%20participation%20and%20informal%20walking%20for%20exercise%20to%20daily%20physical%20activity%20in%20community-dwelling%20older%20adults

Tudor-Locke, C., Sisson, S. B., Lee, S. M., Craig, C. L., Plotnikoff, R. C., and Bauman, A. (2006). Evaluation of quality of commercial pedometers. *Can J Public Health*, 97, 10-15. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=Evaluation%20of%20quality%20of%20commercial%20pedometers

Vincent, S. D., and Sidman, C. L. (2003). Determining measurement error in digital pedometers. Measurement in Physical Education and Exercise Science, 7, 19-24. URL: http://journals1.scholarsportal.info.myaccess.library.utoronto.ca/tmp/13571210533771559919.pdf

Warburton, D. E. R., Charlesworth, S., Ivey, A., Nettlefold, L., and Bredin, S. S. D. (2010). A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults, *Int J Behav Nutr Phys Act,* 7, 39-52. URL: http://www.ncbi.nlm.nih.gov/pubmed/20459783

Welk, G., Differding, R., Thompson, S., Blair, N., Dziura, J., and Hart, P. (2002). The utility of the Digi-Walker step counter to assess daily physical activity patterns. *Med Sci Sports Exerc*, 32, 481-488. URL: http://www.ncbi.nlm.nih.gov/pubmed?term=The%20utility%20of%20the%20Digi-Walker%20step%20counter%20to%20assess%20daily%20physical%20activity%20patterns

Wilcox, S., Tudor-Locke, C., and Ainsworth, B. E. (2002). Physical activity patterns, assessment, and motivation in older adults. *In: Gender, Physical Activity and Aging*. R. J. Shephard (Ed.). Boca Raton, FL: CRC Press, 13-39.