Validity and Reliability of Omron Pedometers for Prescribed and Self-Paced Walking

ELIZABETH A. HOLBROOK, TIAGO V. BARREIRA, and MINSOO KANG

Department of Health and Human Performance, Middle Tennessee State University, Murfreesboro, TN

ABSTRACT

HOLBROOK, E. A., T. V. BARREIRA, and M. KANG. Validity and Reliability of Omron Pedometers for Prescribed and Self-Paced Walking. *Med. Sci. Sports Exerc.*, Vol. 41, No. 3, pp. 669–673, 2009. **Purpose**: The purpose of this study was to examine the validity and reliability evidence for the Omron Healthcare HJ-151 and HJ-720ITC pedometers for prescribed and self-paced walking. **Methods**: A total of 47 adults (24 males, 23 females; age = 24 ± 4.4 yr.; body mass index = 25.7 ± 4.2 $kg \cdot m^{-2}$) participated in this study. Under prescribed walking conditions, 34 participants completed three randomized 100-m walking trials through a range of scripted walking speeds (slow, moderate, and very brisk) for each pedometer model. Under self-paced walking conditions, 31 participants completed one 1-mile walk on a standardized course for each model. HJ-151 pedometers were chosen at random from a pool of 54 devices and were worn along the waistband at the right hip, the left hip, and the midback, whereas HJ-720ITC pedometers were chosen from a pool of 24 devices and incorporated right pocket, left pocket, and backpack positions in addition to the three waist-mounted sites. Absolute percent error (APE) scores were calculated to examine pedometer accuracy between actual steps (a criterion measure) and pedometer-determined steps. Coefficient of variation (CoV) was computed to describe interdevice reliability. **Results**: With the exception of the HJ-720ITC at the backpack position in the prescribed walking setting (mean APE = 3.4%), the HJ-151 and the HJ-720ITC accurately reported step counts under prescribed and self-paced conditions (all APE values <3.0%). Moreover, interdevice reliability evidence was established for the HJ-151 and the HJ-720ITC under prescribed and self-paced conditions (all CoV values <2.1%). **Conclusions**: The Omron HJ-151 and HJ-720ITC pedometers demonstrated validity and reliability at various mounting positions under prescribed and self-paced walking conditions with both healthy and overweight adults. **Key Words:** PHYSICAL ACTIVITY, SPEED, WEARING POSITION, STEP COUNTS

Pedometers are simple body-worn motion sensors that can be used effectively as motivational tools to increase daily levels of ambulatory physical activity (4,10,18,19). Increasing daily step counts through pedometer-based interventions has been associated with disease prevention and improvements in overall health and quality of life (5,9,15,20). As an increasing number of pedometers become commercially available for walking promotion and evaluation, it is necessary to determine the accuracy with which new models are measuring step counts.

Several recent articles have illustrated considerable variation in pedometer accuracy between models (3,6,16). Common sources of error associated with pedometer monitoring include slow walking speeds (3,13,14) and obesity (6,14). To address these issues, researchers have examined a handful of mediating factors that may alleviate the burden of choosing an appropriate tool for monitoring physical activity among slow-walking or overweight populations. Specifically, Crouter et al. (6) recently examined the appropriateness of spring-levered versus piezoelectric pedometers in a group of overweight and obese adults. The authors reported higher levels of pedometer accuracy using the piezoelectric pedometer compared with the spring-levered model. Moreover, Melanson et al. (14) determined that a piezoelectric pedometer was more accurate than a spring-levered pedometer for counting steps taken at slow walking speeds. Using a different approach, Swartz et al. (17) considered altering the mounting position of a spring-levered pedometer along the waistband for obese individuals yet determined that at slow to moderate speeds, the pedometer continued to underestimate steps.

The concept of altering the mounting position of pedometers is a novel approach that may prove useful in situations where extreme abdominal obesity interferes with pedometer placement. Recently, Omron Healthcare developed two models of piezoelectric pedometers that are marketed to be worn at many different sites on and off the body. The manufacturers' guidelines for the single-sensor HJ-151 pedometer claim that accurate step counting will occur as long as the pedometer face remains perpendicular to the ground, suggesting sites at the right hip, the left hip, and the midback positions along the waistline. In addition to

Address for correspondence: Minsoo Kang, Ph.D., Department of Health and Human Performance, Middle Tennessee State University, 1500 Greenland Dr., PO Box 96, Murfreesboro, TN 37132; E-mail: mkang@mtsu.edu.

Submitted for publication March 2008.
Accepted for publication July 2008.

0195-9131/09/4103-0669/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0b013e3181886095

traditional right- and left-hip mounting sites, the HJ-720ITC pedometer features dual accelerometer sensors, thus offering midback, right pocket, and left pocket positions as well as an off-the-body backpack wearing option. Although the versatility of altering pedometer mounting positions is an attractive feature for monitoring ambulatory physical activity, pedometers worn at various wearing sites on and off the body should be examined further. Therefore, the purpose of the current investigation was to examine the validity and reliability evidence for the HJ-151 and the HJ-720ITC pedometers under prescribed and self-paced walking conditions and at various wearing positions on and off the body.

METHODS

Participants

Forty-seven healthy university students (24 males and 23 females) volunteered to participate in this study. After approval from the institutional review board at a university in the southeastern United States, participants provided written informed consent and completed a health history questionnaire. Age was recorded, along with measurements of height, weight, and body mass index (BMI). Sample characteristics are displayed in Table 1.

Instrumentation

The Omron HJ-151 and HJ-720ITC pedometers feature differing mechanisms for recognizing and recording step counts. The HJ-151 features a single piezoelectric sensor with 7-d memory for recall of daily step counts, aerobic step counts, prediction of caloric expenditure, and distance walked. The HJ-151 must be worn in a vertical position for accurate step counting to occur. The HJ-720ITC pedometer features dual piezoelectric sensors, allowing accurate step counting to occur when worn in both vertical and horizontal positions. The HJ-720ITC offers PC downloading capabilities, including a 7-d recall on the pedometer display and a 41-d storable memory for measures of daily step counts, aerobic step counts, prediction of caloric expenditure, and distance walked. Both models reset automatically at midnight and cannot be zeroed manually without resetting several components.

Procedures

Before data collection, a subset of eight participants completed two stages of manipulation checks, including a 2-min heel tapping, a 2-min leg swinging, and a 4-mile drive test for each pedometer model worn at the various mounting sites. Karabulut and Crouter (11) incorporated a similar protocol to elucidate potential sources of error during accuracy trials of waist- and ankle-mounted pedometers. In the current study, neither condition resulted in erroneous step counting for the HJ-151 or the HJ-720ITC model.

TABLE 1. Sample demographic information (mean ± SD).

	Male (n = 24)	Female (n = 23)
Age (yr)	26 ± 6.5	22.1 ± 2.1
Height (cm)	182.5 ± 6.6	165.3 ± 7.2
Weight (kg)	90.8 ± 12.9	64.2 ± 6.7
BMI ($kg \cdot m^{-2}$)	27.3 ± 3.9	23.7 ± 3.6

Prescribed walking condition. To examine validity evidence for the HJ-151 and the HJ-720ITC under controlled conditions, a subset of 34 participants (males = 17, females = 17) completed three 100-m walking trials for each pedometer model. Participants completed trials on an outdoor track at three prescribed, randomized walking speeds (2.0, 3.0, and 4.0 mph). Walking speeds were chosen to reflect past investigations concerning pedometer validity (3,6,7,12,13). A scripted protocol was used to prompt participants' walking speeds in accordance to the pace cues outlined in the compendium of physical activities, where "slow," "moderate," and "very brisk" prompts were reflective of 2.0, 3.0, and 4.0 mph, respectively (1). Before beginning a trial, participants were prompted to walk at a slow, a moderate, or a very brisk pace, with no further instruction. Actual walking speed for each trial was recorded using the Speedtrap-2 timing system (Brower Timing Systems, Draper, UT).

Pedometers were worn at different positions on the body according to manufacturing guidelines, including right hip (RH), left hip (LH), and midback (MB) positions on the waistband. In addition to the three waist-mounted sites, the HJ-720ITC also included positions at the right and the left pockets (RP and LP) and in a backpack worn over the shoulders (BP). Both pedometer models could not be easily manually reset; therefore, measurements of pedometer-determined step counts for each trial were calculated as pretrial steps minus posttrial steps and were recorded in addition to actual step counts and walking speed. Actual step counts, a criterion measure, were assessed by an investigator walking behind the participant using a hand tally counter (16). So as to incorporate each of the prescribed walking intensities (slow, moderate, and very brisk), participants completed three separate randomized walking trials for the HJ-151 and the HJ-720ITC models. To examine interdevice reliability evidence, three HJ-151 pedometers were chosen at random from a pool of 54 devices before respective walking trials (one for each site); similarly, six HJ-720ITC pedometers were chosen at random from a pool of 24 devices.

Self-paced walking condition. To examine validity evidence in a self-paced setting, a subset of 31 participants (males = 18, females = 13) completed two 1-mile walks (one walk per model) over a standardized course. The course incorporated flat concrete walking, stair ascent/decent, up- and down-hill grass walking, and cued stops at road crossings. Pedometer wearing sites were repeated for the HJ-151 (RH, LH, and MB) and the HJ-720ITC (RH,

TABLE 2. Actual and HJ-151 pedometer-determined step counts under prescribed and self-paced walking conditions.

Condition	Actual Steps	HJ-151		
Prescribed (n = 34)		Right Hip	Left Hip	Midback
Slow	142 ± 12	143 ± 13	142 ± 13	143 ± 13
Moderate	129 ± 10	128 ± 10	129 ± 10	129 ± 10
Very brisk	116 ± 9	115 ± 9	115 ± 9	116 ± 8
Self-paced (n = 31)	1240 ± 69	1242 ± 75	1251 ± 67	1260 ± 74

Values are presented as mean ± SD.

TABLE 4. Between-site and absolute APE and CoV of HJ-151 pedometer.

Condition	APE			CoV
Prescribed (n = 34)	Right Hip	Left Hip	Midback	
Slow	1.4 ± 1.5	1.3 ± 1.1	1.8 ± 2.2	1.3 ± 1.2
Moderate	1.0 ± 0.8	1.5 ± 1.9	1.3 ± 1.8	1.2 ± 1.4
Very brisk	1.3 ± 1.9	1.3 ± 1.6	1.5 ± 2.1	1.1 ± 1.1
Self-paced (n = 31)	0.8 ± 1.5	1.2 ± 1.8	1.7 ± 2.8	1.3 ± 2.0

Values are mean ± SD expressed as percentages.
APE, absolute percent error; CoV, coefficient of variation.

LH, MB, RP, LP, and BP). Participants walked at self-selected speeds, and actual step counts were measured by an investigator using a hand tally counter while walking behind the participant (16). Similar to trials in the prescribed walking condition, interdevice reliability was examined under self-paced conditions by randomly selecting three HJ-151 pedometers from a pool of 54 devices or six HJ-720ITC pedometers from a pool of 24 devices during respective trials.

Data Analysis

Data screening and analyses were performed using SPSS (version 15.0) and Microsoft Excel for Windows. Descriptive statistics, incorporating means and SD, were calculated for all variables. For validity evidence of the HJ-151 and the HJ-720ITC pedometers, absolute percent error (APE) was calculated between actual steps and pedometer-determined steps (APE = [(pedometer steps − actual steps) / actual steps] × 100) and was used as an outcome measure. A smaller APE represents better accuracy, and less than 3% is considered acceptable (7,8). Across walking speeds in the prescribed walking condition as well as in a self-paced setting, repeated-measures ANOVA were performed to detect statistically significant differences in APE for the various wearing sites for each model. When there was a significant difference, the Bonferroni procedure was used to locate statistically significant differences in APE.

Coefficient of variation (CoV) was used to examine interdevice reliability of the HJ-151 and the HJ-720ITC under prescribed and self-paced walking conditions. Averaged across wearing positions for each condition, a smaller CoV (SD divided by the mean) represents less variation among devices. A repeated-measures ANOVA was performed to determine significant differences in CoV across walking speeds under prescribed walking conditions for each model. If a significant difference was shown, a follow-up Bonferroni test was analyzed to locate significant differences in CoV across walking speeds. For all analyses, a significance level was set at 0.05.

RESULTS

Actual and pedometer-determined step counts for the HJ-151 and the HJ-720ITC under prescribed and self-paced walking conditions are expressed in Tables 2 and 3, respectively. Site-specific APE scores for the HJ-151 (RH, LH, and MB) and the HJ-720ITC (RH, LH, MB, RP, LP, and BP) under prescribed and self-paced walking conditions are displayed in Table 4 and Table 5, respectively.

Validity evidence. Under prescribed walking conditions, walking speeds ranged from 1.7 to 5.4 mph, reflecting scripted trials at slow (mean = 2.7 mph), moderate (mean = 3.3), and very brisk (mean = 4.1) pace cues. APE across walking speeds and mounting positions for the HJ-151 model ranged from 1.0% to 1.8%, with an overall APE of 1.4% ± 1.7% across walking speeds. The least amount of error for the HJ-151 was observed at the RH position during moderate walking trials (1.0% ± 0.8%). Conversely, the largest APE for the HJ-151 was observed during slow walking trials at the MB position (1.8% ± 2.1%). For the HJ-720ITC model, APE ranged from 1.1% to 3.5%, with an overall APE of 2.3% ± 2.8% across walking speeds. The smallest APE for the HJ-720ITC was observed in the MB position during moderate walking trials (1.1% ± 1.1%), whereas the largest APE occurred during slow walking trials in the BP position (3.5% ± 3.2%).

Repeated-measures ANOVA (3 speeds × 3 positions) illustrated no statistically significant differences in APE for the HJ-151 at any position (RH, LH, MB) under prescribed walking conditions (P = 0.803). There was a significant difference in APE for the HJ-720ITC model, however, F = 8.164, P < 0.001 (3 speeds × 6 positions). Results of the follow-up Bonferroni test illustrated significant differences in APE for the RP compared with the RH (P = 0.038),

TABLE 3. Actual and HJ-720ITC pedometer-determined step counts under prescribed and self-paced walking conditions.

Condition	Actual Steps	HJ-720ITC					
Prescribed (n = 34)		Right Hip	Left Hip	Midback	Right Pocket	Left Pocket	Backpack
Slow	146 ± 21	147 ± 21	145 ± 19	146 ± 22	146 ± 21	146 ± 21	147 ± 20
Moderate	128 ± 10	128 ± 10	128 ± 11	127 ± 11	127 ± 12	128 ± 12	130 ± 12
Very brisk	116 ± 10	115 ± 10	115 ± 10	116 ± 10	116 ± 12	115 ± 11	119 ± 12
Self-paced (n = 31)	1238 ± 83	1247 ± 81	1248 ± 81	1250 ± 91	1239 ± 85	1237 ± 86	1241 ± 85

Vales are presented as mean ± SD.

TABLE 5. Between-site and absolute APE and CoV of HJ-720ITC pedometer.

Condition	APE						CoV
Prescribed (n = 34)	Right Hip	Left Hip	Midback	Right Pocket	Left Pocket	Backpack	
Slow	2.0 ± 2.7	2.0 ± 2.5	2.6 ± 3.5	2.5 ± 2.6	2.9 ± 3.6	3.5 ± 3.2	3.3 ± 1.7
Moderate	1.3 ± 0.9	1.2 ± 1.6	1.1 ± 1.1	3.2 ± 3.5	2.5 ± 3.1	3.3 ± 2.7	2.8 ± 1.3
Very brisk	1.9 ± 2.2	1.6 ± 2.3	1.5 ± 1.7	2.9 ± 3.3	2.9 ± 2.8	3.4 ± 3.1	2.8 ± 1.8
Self-paced (n = 31)	1.0 ± 1.4	1.1 ± 1.9	1.2 ± 2.3	1.8 ± 2.4	2.0 ± 2.0	1.3 ± 1.4	1.4 ± 0.9

Values are mean ± SD expressed as percentages.
APE, absolute percent error; CoV, coefficient of variation.

the LH (P = 0.039), and the MB (P = 0.047) positions as well as for the BP compared with the RH (P = 0.002), the LH (P < 0.001), and the MB (P < 0.001). Across walking speeds, repeated-measures ANOVA revealed no significant differences in APE among slow, moderate, and very brisk speeds for either model (P = 0.264 and P = 0.381 for HJ-151 and HJ-720ITC, respectively).

Under self-paced walking conditions, APE ranged from 0.8% to 1.7% for the HJ-151 model and from 1.0% to 2.0% for the HJ-720ITC. Repeated-measures ANOVA illustrated no significant differences in APE across positions for the HJ-151 (P = 0.163); however, significant differences were observed for the HJ-720ITC model, F = 3.326, P = 0.019. Results of the Bonferroni test illustrated significant differences in APE at the RH compared with the RP (P = 0.017) and the LP (P = 0.042) positions.

Reliability evidence. In the prescribed walking setting, CoV across slow, moderate, and very brisk walking speeds for the HJ-151 model was 1.3%, 1.2%, and 1.1%, respectively. The corresponding CoV of the HJ-720ITC pedometer was 3.3%, 2.8%, and 2.8%. Under self-paced walking conditions, CoV of the HJ-151 and the HJ-720ITC pedometers was 1.3% and 1.4%, respectively. Repeated-measures ANOVA revealed no significant differences in CoV across walking speeds for either pedometer model (P = 0.669 and P = 0.354 for HJ-151 and HJ-720ITC, respectively).

DISCUSSION

Walking-based health interventions have become a popular means to improve the general well-being and quality of life of US adults. Due to the inherent feasibility and inexpensive nature of pedometer monitoring, the use of such tools among researchers, practitioners, and goal-seeking individuals has become increasingly pervasive. The results of the current investigation collectively illustrate that HJ-151 and HJ-720ITC pedometers can serve as accurate and reliable means for measuring ambulatory activity under prescribed and self-paced walking conditions.

Under prescribed walking conditions, the validity and reliability evidence was established for both Omron pedometers through a range of slow to very brisk walking speeds. Compared with conventional quality control guidelines of the Japanese pedometer industry, APE of 3% or less (or fewer than 3 missed steps per every 100) has become an accepted criterion for pedometer validity (7,8). This stringent guideline ensures pedometer validity within 3% of actual walking steps; therefore, for an individual seeking to adhere to a 10,000 steps per day walking program, over- or underestimation by the pedometer cannot exceed 300 steps per day. On the basis of this recommended threshold, pedometer validity was established for the HJ-151 and the HJ-720ITC across the range of prescribed walking speeds for each mounting position (all APE values < 3%, with exception of the HJ-720ITC in the BP position). Moreover, CoV of less than 10% has been reported as an accepted criterion for pedometer reliability (2). According to this guideline, both models were found to be reliable (all CoV values <2.1%).

To address the higher APE scores observed for the HJ-720ITC in the BP position (mean = 3.4%), Omron manufacturing guidelines acknowledge that the pedometer face must be perpendicular to the ground in order for the device to accurately report step counts. Although HJ-720ITC pedometers were placed into the shoulder-mounted backpack with the pedometer face perpendicular to the ground, it is possible that the pedometer could have shifted during trials. This may account for some of the variance between the BP and other mounting positions. It is in light of this acknowledgement that the results of the HJ-720ITC model in the BP position should be regarded with some caution.

Past investigations have illustrated increases in pedometer accuracy with increasing walking speed (3,6,7,11). Specifically, slow walking speeds tend to elicit a greater APE compared with faster walking speeds. In the current investigation, the association between walking speed and pedometer accuracy was not clearly observed. In general, the lowest APE values were produced at moderate versus very brisk walking speeds, with the only exceptions being the HJ-151 at the LH and the HJ-720ITC at the RP. Conversely, CoV improved in both models with increasing walking speed, illustrating a higher level of interdevice reliability at very brisk versus slow and moderate walking speeds, respectively. It is possible that the speed–accuracy association was not clearly observable under prescribed walking conditions in response to the scripted protocol used. Indeed, large variations in actual walking speed were observed across prescribed walking trials, illustrating significant variations among individuals' perceptions of intensity corresponding to each pace cue. Specifically, when instructed to walk at slow, moderate, and very brisk speeds,

participants walked considerably faster (mean = 2.3, 3.3, and 4.1 mph, respectively) than the corresponding speed outlined in the compendium of physical activities (1), equating to 2.0, 3.0, and 4.0 mph. This observation may support the higher level of accuracy observed for both Omron models during self-paced walking trials in comparison to pedometers featured in earlier validation studies (7,12,14). Additionally, this finding suggests that the laypersons' perception of current physical activity guidelines may be skewed toward higher intensities of activity.

Finally, previous investigators (11,13) have acknowledged that nonlocomotor behaviors may yield erroneous pedometer step counting (i.e., heel tapping, leg swinging, motor vehicle travel). In the current study, neither condition resulted in erroneous step counting for the HJ-151 or the HJ-720ITC model. This observation reflects the low level of sensitivity of both models to nonambulatory movement, a key factor in the establishment of pedometer validity.

In summary, the objective of our study was to examine validity and reliability evidence for the Omron Healthcare HJ-151 and HJ-720ITC piezoelectric pedometers under prescribed and self-paced walking conditions. The results indicate that the HJ-151 and the HJ-720ITC models are appropriate devices for measuring ambulatory activity, offering many alternative mounting positions to the traditional right- and left-hip mounting sites. The versatility of these devices may prove to be useful in future epidemiological studies of physical activity because it provides the opportunity for accurate step counting at alterative mounting positions in healthy and overweight adult populations.

The results of the present study do not constitute endorsement by ACSM.

REFERENCES

1. Ainsworth BE, Haskell WL, Whitt MC. Compendium of physical activities: update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(9S):S498–S516.
2. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med*. 1998;26(4):217–38.
3. Bassett DR Jr, Ainsworth BE, Leggett SR. Accuracy of five electronic pedometers for measuring distance walked. *Med Sci Sports Exerc*. 1996;28(8):1071–7.
4. Bravata DM, Smith-Spangler C, Sundaram V. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA*. 2007;298(19):2296–304.
5. Brown DW, Balluz LS, Heath GW. Associations between recommended levels of physical activity and health-related quality of life: findings from the 2001 Behavioral Risk Factor Surveillance System survey. *Prev Med*. 2003;37(5):520–8.
6. Crouter SE, Schneider PL, Bassett DR Jr. Spring-levered versus piezo-electric pedometer accuracy in overweight and obese adults. *Med Sci Sports Exerc*. 2005;37(10):1673–9.
7. Crouter SE, Schneider PL, Karabulut M, Bassett DR Jr. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. *Med Sci Sports Exerc*. 2003;35(8):1455–60.
8. Hatano Y. Prevalence and use of pedometer. *Res J Walking*. 1997;1:45–54.
9. Iwane M, Arita M, Tomimoto S. Walking 10,000 steps/day or more reduces blood pressure and sympathetic nerve activity in mild essential hypertension. *Hypertens Res*. 2000;23(6):573–80.
10. Kang M, Marshall SJ, Barreira TV, Lee JO. Effect of pedometer-based physical activity interventions: a meta-analysis. *Res Q Exerc Sport*. (in press).
11. Karabulut M, Crouter SE. Comparison of two waist-mounted and two ankle-mounted electronic pedometers. *Eur J Appl Physiol*. 2005;95(4):335–43.
12. Le Masurier GC, Lee SM, Tudor-Locke C. Motion sensor accuracy under controlled and free-living conditions. *Med Sci Sports Exerc*. 2003;36(5):905–10.
13. Le Masurier GC, Tudor-Locke C. Comparison of pedometer and accelerometer accuracy under controlled conditions. *Med Sci Sports Exerc*. 2003;35(5):867–71.
14. 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.
15. Moreau KL, Degarmo R, Langley J, et al. Increasing daily walking lowers blood pressure in postmenopausal women. *Med Sci Sports Exerc*. 2001;33(11):1825–31.
16. Schneider PL, Crouter SE, Lukajic O, Bassett DR Jr. Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. *Med Sci Sports Exerc*. 2003;35(10):1779–84.
17. Swartz AM, Bassett DR Jr, More B, Thompson DL, Strath SJ. Effects of body mass index on the accuracy of an electronic pedometer. *Int J Sports Med*. 2003;24(8):588–92.
18. Tudor-Locke C, Bassett DR Jr. How many steps per day are enough? Preliminary pedometer indices for public health. *Sports Med*. 2004;34:1–8.
19. Tudor-Locke C, Hatano Y, Pangrazi RP, Kang M. Re-visiting "How many steps are enough?". *Med Sci Sports Exerc*. 2008;40(7):S537–43.
20. Vuillemin A, Boini S, Bertrais S. Leisure time physical activity and health-related quality of life. *Prev Med*. 2005;41(2):562–9.