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Reliability and Validity Study of PACER Smartphone Application to Count Steps in Overweight and Obese Young Adults

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Abstract

Background: While pedometer smartphone applications are popular, evidence of their ability to monitor accurately physical activity is still missing, especially in obese individuals. The objective of this study was to determine the reliability and validity of PACER smartphone application in free-living and controlled conditions to count steps, in overweight or obese young adults.

Methodology: 30 overweight or obese participants (50% males, mean age, 21.37±0.20 y) were recruited from a major university in the United Arab Emirates. They carried a smartphone with PACER application in their right pocket, and an OMRON HJ-320E pedometer on the right hip, for seven consecutive days, in free-living conditions. Participants were also recorded while walking for 30 minutes on a treadmill, at a speed of 3km/h with their smartphone and OMRON pedometer. Each experiment was repeated twice.

Results: In free-living conditions, reliability was fair to excellent (Intraclass Correlation Coefficients (ICC) from 0.43 to 0.77) while in controlled conditions it was less than poor in male (ICC=0.20), fair-to-good in female (ICC=0.55) and the whole group (ICC=0.42). Significant correlations (rho=0.64 in female, p≤0.01, and 0.94 in male, p≤0.001) were obtained in free-living conditions, between PACER and OMRON. Under controlled conditions, significant correlations were observed between PACER and the manual counting, but not OMRON, and in the whole sample and females, only (rho=0.48, p=0.01 and rho=0.72, p≤0.001, respectively).

Conclusion: PACER smartphone application is a fairly reliable and valid tool to count steps in free-living and controlled conditions in overweight and obese young adults.

Keywords: Obesity; PACER; Reliability; Smartphone application; Validity; Young adults

Background

Over the past decades, the proportion of individuals being overweight or obese has more than doubled. In 2014, 39% of adults aged 18 years and over were overweight and 13% were obese [1]. The Middle-East region and especially the United Arab Emirates (UAE) are facing a similar public health problem. Indeed, obesity is reaching particularly high levels in the UAE, with more than 40% of adult women being obese in 2010 [2]. It is well-established that overweight and obese individuals are more likely to develop serious health complications like type 2 diabetes, cardiovascular disease and cancer. Hence, prevention and treatment of obesity is a priority [3].

Physical Activity (PA) is defined as any bodily movement, made by the skeleton muscle, increasing the energy expenditure above the basal energy metabolism. The regular practice of PA contributes to the prevention and treatment of many chronic diseases, especially obesity and its related health complications [4,5], through a positive impact on body composition, blood lipid profile, insulin sensitivity and blood pressure [6].

The 2008 PA Guidelines stipulate that any adult should practice at least 30 minutes of moderate PA daily in combination with muscle strengthening exercise and that any child should practice at least 1 hour of PA daily, preferably vigorous, combined with muscle and bone strengthening exercise [7]. Nonetheless, most of people remain insufficiently active. Globally, in 2010, 23% of adults and 81% of adolescents were insufficiently active in the world [8]. It was recently highlighted that only 27% of university students satisfy the recommendations for aerobic activity [9]. Similarly, in the UAE, 25% of students, 12-24 years old, report a total sedentary lifestyle, with no PA and only 25% are involved in vigorous PA [10,11].

Hence, in the context of an alarming rate of obesity worldwide, the promotion of an active lifestyle is a necessity. Moreover, valid and reliable tools are needed to self-monitor PA. Pedometers are motion sensors that are typically worn on the waist to count the number of steps during locomotion and enable PA level measurement. They are designed to capture vertical motion of the hip joint with movement and are mainly used for self-monitoring, as motivational tool and to provide a feedback on daily PA levels [12,13]. Their validity has been demonstrated in adults to assess their PA level [14].

With the advances in technology, various novel methods have been developed to assess PA. Mobile technologies like smartphone applications, are now widely available and very popular, especially among young populations. These innovative tools offer a significant potential in increasing PA levels and thus, are highly recommended to include them into clinical practice, prevention strategies, interventions and research [15,16]. A great number of pedometers applications can be accessed on all smartphones, most of them being free. PACER is one of the best-rated pedometer application by users in Google Play and presents the advantage to be available on both iPhone and androids. The use of these applications has been associated to a higher level of PA and weight loss but with a moderate level of evidence in previous studies [17-19].

Reliability is the degree to which an assessment tool produces stable and consistent results while validity refers to how well a test measures what it is purported to measure [20]. Even though, both are necessary conditions for effective interventions and high level of scientific evidence in research, the great majority of the publication refer to validity only Besides, mainly iPhone-based applications were considered and in very different conditions of testing. Overall, available results on validity and reliability of PA smartphone applications are contradictory [21]. Finally, although overweight and obese people represent a significant part of the populations, only one study was conducted among obese individuals and in controlled conditions. A low accuracy of the application was reported [22].

The aim of this work was to investigate, the validity and reliability of the PACER smartphone pedometer application, in assessing number of steps, in both controlled and free-living conditions among overweight and obese young adults.

Materials and Methods

Participants

A sample of 40 overweight or obese students (20 females and 20 male) was recruited from a major university in the UAE. Weight and height were assessed at screening by using an impedance scale (TANITA DC-430M) and a stadiometer (SECA 217), respectively. An age between 18 and 25 years as well as a Body Mass Index (BMI) above 25kg/m^2 were required to be included. In case of any physical disability preventing from moving, or in case of pregnancy or chronic medical conditions, such arthritis, heart diseases, respiratory disorders, participants were excluded. The sample size allows for accurate, valid and representative results and was based on previous reliability and validity studies that have been carried out on smartphone applications [22-25]. In terms of reliability, a sample above 30 participants, with two repeated measurements, can be considered as sufficient to produce results within an acceptable subject error range and with stable validity [26,27].

The project was approved by the Al Ain Medical District Human Research Ethical Committee (Protocol 15/91 ERH_2015_3140). Each participant was informed about the protocol and signed a written informed consent form prior any data collection.

Experimental conditions

Participants used their own smartphones, regardless of the brand. In each trial, the smartphones were placed on the right pocket. Omron HJ-320E pedometer placed in the right hip was used as the reference in testing the validity of PACER to assess s number of steps, in both controlled and free-living conditions. OMRON pedometer has been previously shown to be a valid and reliable tool to count steps [28-30].

Test-retest reliability and validity of PACER application in controlled conditions

For this first trial, participants were asked to come to the testing site (the clinical nutrition laboratory of the university). They were requested to wear comfortable shoes and clothes to walk for 30 minutes on a treadmill, at a speed of 3 km/h. A video recording was conducted for each 30 minutes session. This trial was repeated after 1 week.

Test-retest reliability and validity of PACER application in free-living conditions

For this second trial, participants were used both PACER and Omron pedometer for one typical day. In addition, they were asked to fill a dairy indicating the times at which pedometer was on and off. This second trial was repeated after two weeks and was held on the same day of the week.

Statistical analysis

Data were analysed by using SPSS v.23 for Windows (SPSS Inc., Chicago, IL). Statistical significance was set at $p<0.05$. Means±s.e. were calculated and ANOVA was used to test gender differences. In reliability study, Intraclass Correlation Coefficients (ICC) and 95% confidence interval (95%CI) were calculated to determine the level of agreement between steps count measurement at the two separate occasions by using PACER, in controlled and free-living conditions. An ICC with a value of 0.40 was rated as poor agreement, with 0.40-0.75 as fair-to-good agreement and with 0.75 as excellent agreement [31].

In validity study, the means of the step counts obtained at the two separated occasions were considered, in both free-living and controlled conditions. Then, Spearman correlation coefficients were calculated. As correlational analysis alone may not reveal the potential bias, Bland-Altman method was used when any correlation coefficient was above 0.40 [32] and a Bland-Altman plot was generated. The differences between the results from the two methods of measurement (PACER vs OMRON, PACER vs videotape) were shown against the means of the results from the two methods of measurements. The mean +/- SD of the difference and the limits of agreement defined as mean +/-1.96 SD were calculated and added to the graphs.

Results

Table 1 represents the main characteristics of the sample. Among the 40 participants which were recruited, 5 males and 5 females dropped from the study. The mean age of the 30 participants who completed the study was 21.37±0.20 years old, with a BMI of 34.06±1.27 kg/m^2. Female participants had significantly ($p<0.05$) higher percentage of fat mass than their male counterparts. The resting heart rate was 93.47±2.72 bits/min at baseline.

Variable	Total (n=30)	Male (n=15)	Female (n=15)
Age (y)	21.37±0.20	21.60±0.34	21.13±0.19
Height (cm)	167.77±1.81	175.13±1.73	160.40±1.70*
Weight (kg)	96.34±4.62	108.86±6.31	83.81±5.13*
BMI (kg/m^2)	34.06±1.27	35.87±2.05	32.25±1.42
Fat (%)	35.02±1.65	30.79±2.40	39.2±1.74*
Baseline resting Heart Rate (bpm)	93.47±2.72	92.93±4.25	94.00±2.72
*Male and female were compared by using ANOVA; statistical significance was set at p<0.05			

Table 1: Characterisitcs of the sample.

Test-retest reliability of PACER

Table 2 shows the step count as obtained with PACER on the two separate occasions, in both controlled and free-living conditions. ICC (95%CI) are presented too. Based on the step-defined PA hierarchy which was proposed by Tudor-Locke C. in 2010 [20], 26.67% of male and 20% of female only were doing more than 10,000 steps/day according to PACER. Hence, near a quarter only of the sample could be considered as active. In controlled conditions, in the whole sample and in female, the level of agreement was fair to good. It became greater, but remained fair to good, in free-living conditions. The male group was associated with a poor agreement in controlled conditions and excellent agreement with free-living conditions.

	Total (n=30)			**Male** (n=15)			**Female** (n=15)		
	Mean±s.e.	ICC (95%CC)	p	Mean±s.e.	ICC (95%CC)	p	Mean±s.e.	ICC (95%CC)	P
Free living conditions		0.70 (0.46-0.84)	≤10^{-3}		0.77 (0.45-0.91)	≤10^{-3}		0.43 (-0.07-0.76)	0.04
PACER Steps 1	8161.8±879.6			8369.9±1638.6			7953.8±717.1		
PACER Steps 2	8703.3±1072.0			9252.8±1870.5			8153.9±1104.1		

Mean PACER Steps 1+2	8432.6±904.6			8811.3±1657.5			8053.8±789.0		
Laboratory Conditions									
		0.42 (0.08-0.67)	0.01		0.20 (-0.32-0.63)	0.22		0.55 (-0.32-0.63)	0.01
PACER Steps 1	3123.2±182.7			3373.9±214.2			2872.6±289.0		
PACER Steps 2	2783.4±154.0			2933.1±226.3			2633.7±209.2		
Mean PACER Steps 1+2	2953.3±142.6			3153.5±170.9			2753.1±222.0		
*Male and female were compared by using ANOVA; statistical significance was set at p<0.05									

Table 2: PACER Steps counts in the two separated occasions, ICC (95%CC) in free-living and controlled conditions.

Validity of PACER in counting steps

The correlations of step counts as recorded by PACER with steps counts as recorded from OMRON pedometer, in free-living conditions, are presented in Table 3.

	Total (n=30)		**Male** (n=15)		**Female** (n=15)	
	Mean±s.e.	*rho* with steps counts from OMRON	Mean±s.e.	*rho* with steps counts from OMRON	Mean±s.e.	*rho* with steps counts from OMRON
PACER Steps	8432.6±904.6	0.86***	8811.3±1657.5	0.94***	8053.8±789.0	0.64**
OMRON Steps	8589.0±932.6		8601.9±1704.9		8576.1±834.4	
*p<0.05, **p<0.01, *** p<0.001						

Table 3: Spearman's rank correlation coefficients (rho) of steps counts recorded by PACER with steps counts recorded by OMRON pedometer in free-living conditions.

Significant *rho* values ranging from 0.64 to 0.94 were obtained in the whole sample, male and female groups. Bland-Altman plots indicated two outliers in the whole sample and female group and only one in the male group (Figure 1). The limits of agreement were -3125.4 to 2812.6, -1280.4 to 1699.2 and -3125.4 to 2812.6 steps for the whole sample, male and female groups, respectively. The means of the differences were -156.4±1484.5, 209.4±744.9 and -552.2±1929.7 steps in the whole sample, male and female groups, respectively. This means that PACER tended to overestimate the number of steps compared to OMRON in the whole sample and female group whereas it tended to underestimate the number of steps compared to OMRON in the male group. However, in the three groups, the majority of the points (22, 27 and 28 out of 28, in the whole sample male and female groups, respectively) were within the range of the mean (3533.9-13487.5, 2205.4-15207.8 and 5321.8-11308 steps in the whole sample male and female groups, respectively). This is an agreement with the fair to good Spearman coefficients of correlation which were obtained here.

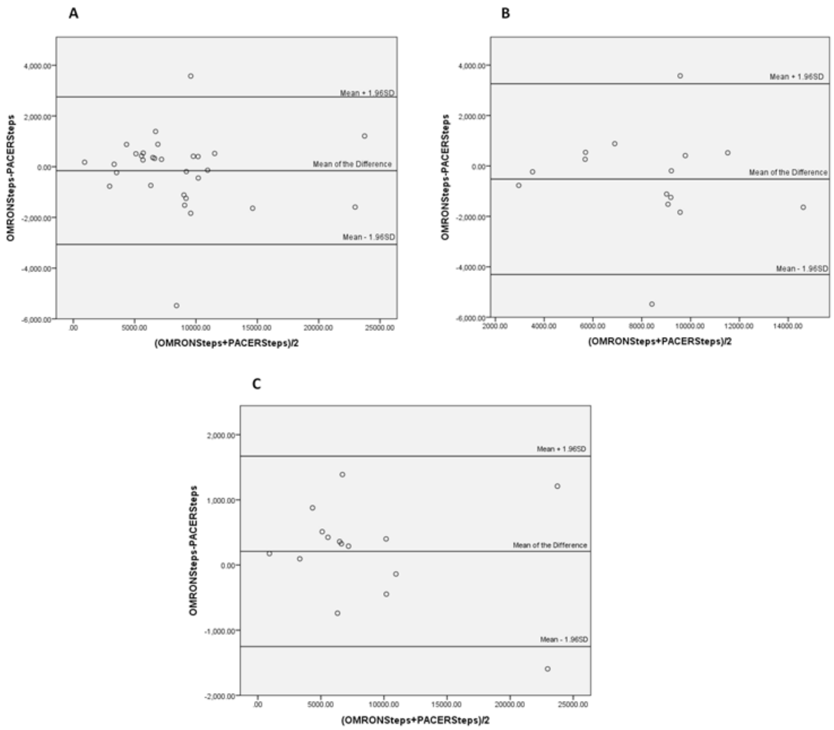

Figure 1: PACER validity against OMRON pedometer in free-living conditions in the whole sample (A), in female group (B) and male group (C). Bland-Altman plot is presented. The difference and the mean of the step counts recorded by PACER and OMRON pedometer were considered.

The correlations of steps counts as recorded by PACER with steps counts as recorded from OMRON pedometer and from video, in controlled conditions, are presented in Table 4. There was no significant correlation between PACER steps counts and OMRON. By contrast, there were significant correlations between PACER steps counts and manual counting (video) in the whole sample and female group (rho=0.48, p=0.01 and rho=0.72, p≤0.001, respectively). Bland-Altman plot was built for steps counts from PACER compared with manual steps counting by using the video in the whole sample and female group (Figure 2). In the whole sample, it shows that only two points were outliers: one was above the upper limit of agreement (1423.2 steps) and one was below the lower limit of agreement (-1588.4 steps). The mean of the difference ± SD was on average -82.6±752.9 steps, indicating that on average, the manual counting by using the video was lower than the steps counts from PACER. The majority of the points (23 out of 28) are within the range of the mean (2490.8-3333.0 steps) for step counts between PACER and manual counting. This agreement is considered as fair, according to Spearman correlations.

	Total (n=30)			**Male (n=15)**			**Female (n=15)**		
	Mean±s.e.	*rho* with OMRON Steps	*rho* with Video Steps	Mean±s.e.	*rho* with OMRON Steps	*rho* with Video Steps	Mean±s.e.	*rho* with OMRON Steps	*rho* with Video Steps
PACER Steps	2953.3±142.6	0.29	0.48*	3153.5±170.9	0.38	0.26	2753.1±222.0	0.32	0.72***
OMRON Steps	2925.4±52.0			2856.9±71.9			2994.0±73.4		
Video Steps	2870.6±30.8			2833.2±31.5			2908.0±52.3		
*p<0.05, **p<0.01, *** p<0.001									

Table 4: Spearman's rank correlation coefficients (rho) of steps counts recorded by PACER with steps counts recorded by OMRON pedometer and video, in controlled conditions.

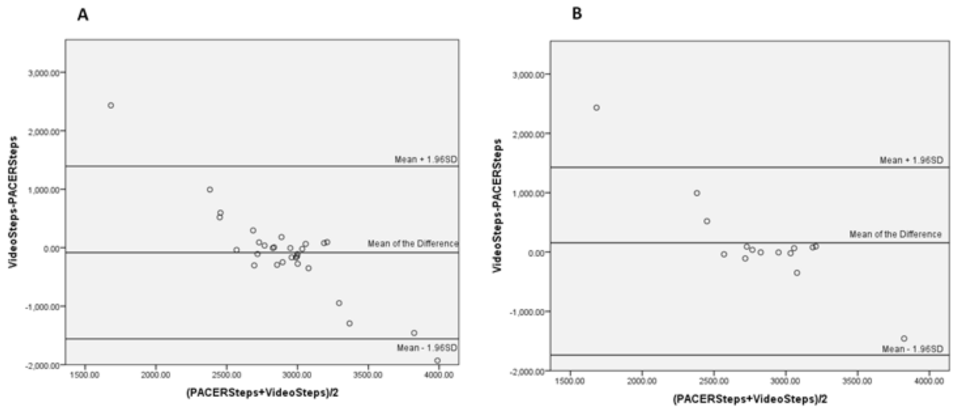

Figure 2: PACER validity against manual counting in the whole sample (A) and in female group (B). Bland–Altman plot is presented. The difference and the mean of the step counts recorded by PACER and video are considered.

In the female group, only one point was outlier above the upper limit of agreement (1768.1 steps). The mean of the difference±SD was on average -154.9±806.9 steps, indicating, that the manual counting was higher than the steps counts from PACER. However, the majority of the points (28 out of 29) were within the range of the mean (2353.5-3307.5 steps) between manual counting and step counts from PACER. This indicates another fair Spearman correlation coefficient.

Discussion

Pedometer smartphone applications are very popular and are frequently used to assess PA in many research works and interventions. Hence, they represent a particularly relevant tool to promote PA, especially in populations in overweight or obese individuals. Reliability and validity of any assessment tool are pre-requisites to an effective use in research and interventions. However, there are few studies only that are related to the reliability and validity of pedometer smartphone applications in free-living conditions and results remain contradictory. Besides, while overweight and obesity keep increasing worldwide, it received relatively little attention and almost no research to-date. Our work demonstrated that PACER, one of the widely used smartphone pedometer applications, which is freely available for both iPhone and androids is reliable and valid in obese young adults, especially in free-living conditions.

Reliability is an important factor to be considered when selecting a tool to count steps. It is a condition for a long-term use, like in interventions, and a pre-requisite for validity study. In spite of that, data on pedometer applications' reliability remain rare [22,23,25,33-35]. In our experiment, in free-living conditions, a fair to excellent reliability was observed. This means that PACER could be recommended to overweight and obese individuals to track their PA. The only one study that was conducted in similar natural conditions, considered three other pedometer smartphone applications and non-overweight and non-obese participants, which does not allow a fair comparison with our results [25]. Controlled conditions were associated with a lower reliability compared to free-living conditions in our experiment. This could be related to the movement of the treadmill belt, which is challenging participants' equilibrium and walk regularity. This could also explained why our ICC values were lower compared to the values reported by Konharn, et al. [22], in overweight and obese adults who performed shorter, 3 minutes only, walking sessions on treadmill.

Importantly, PACER was shown as an accurate tool to count steps in overweight and obese young adults, against pedometer, in free-living conditions, with *rho* value ranging from 0.64 in female to 0.94 in male. To-date, there are no other studies conducted in free-living conditions among overweight or obese adult participants. The great majority of the studies, which were conducted in free-living conditions and in healthy individuals, reported a very poor validity of the smartphone pedometer applications [23,24,36]. It is known that weight status is likely to influence the accuracy of pedometers [37]. Indeed, due to the presence of a thicker subcutaneous fat layer, as in overweight and obese individuals, the movement may be more difficult to detect and may request a pedometer technology with a higher sensitivity to get accurate results. Our results indicate that PACER may satisfy this requirement in free-living conditions.

In controlled conditions, PACER was not valid against the OMRON pedometer, Here, a relatively slow speed of 3km/h was used on treadmill. This speed makes the walking session feasible for overweight and obese adults but has been associated with a lower accuracy with other pedometer applications and also electronic pedometers [22,25,36,38-40]. This is most probably due to the higher difficulty in detecting slow movements. Furthermore, in overweight and obese individuals, Konharn, et al., reported a lack of accuracy on treadmill, within the speed range of 3.2 -8.0 km/h [22]. This is of a great concern since indoor treadmill exercise is one of the most popular type of exercise and the way that is usually recommended by health professionals, mainly due to the climate conditions. In addition, it may not be realistic and achievable for overweight and obese individuals to exercise at higher speed than 3 km/h running speed.

However, in our study, PACER was valid against manual counting on video. Video recording allowed counting the steps several times and by different observers. It can reasonably be considered that the step count obtained by using this method is more accurate than the value given by the OMRON pedometer. By consequence, even in controlled conditions, PACER could be recommended as a valid tool to overweight and obese individuals to count their steps.

In this study, differences were observed between gender. The less motivation which was reported with male participants may explain the lower reliability which has been observed in controlled conditions in males compared to females. Researchers had to provide more support to male participants to complete the 30 minutes walking session on treadmill and limit the brief walking breaks. A good validity of PACER was reported in controlled conditions against manual counting, in the whole sample, in female but not in male. The way of carrying the smartphone has been shown to affect the quality of the movements detection [23,25,40,41].

In the present study, during the treadmill sessions female subjects wore tighter clothes than the male counterparts who were more likely to wear baggy shorts and carry their smartphone loosely in a pocket. This may have resulted in an overestimation of movement by PACER compared to both the OMRON pedometer and manual counting. There are some limitations of the present study. First, although the sample size was acceptable and comparable to other studies, a greater validity and ability to generalize our results would have been achieved with a larger sample size. Secondly, although clear instructions on the use of pedometers were given by the researchers to the participants, this did not prevent fully the non-compliance with the instructions.

Conclusion

The results of present study indicate that smartphone application, PACER, is a fairly reliable and valid tool to count steps under both free-living and controlled conditions, for overweight and obese young adults. Therefore, PACER can be recommended to overweight and obese young adults to self-monitor their PA levels. It may also play a role in future interventions designed to increase PA levels.

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Not applicable

Authors contributions

Carine Platat: design of the study, coordination of the project, data interpretation, manuscript writing.

Amjad Jarrar: data collection, data analysis, manuscript review. Fatima Al Qshadi, Ghofran Kayed, Nour Abou Hussein: research assistants, screening of participants, data collection, review of the manuscript.

Habiba Ali: conception, obtaining funding, significant revision of the manuscript.

All authors read and approved the final manuscript.

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