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Validation of PiezoRx Pedometer Derived Sedentary Time

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ABSTRACT

International Journal of Exercise Science 11(7): 552-560, 2018. Although pedometers are valid tools for measuring physical activity, to date they have not been used to assess sedentary time. The primary purpose of this study was to determine if the PiezoRx pedometer is a valid and reliable measure of sedentary time compared to the hip-worn Actical accelerometer. A secondary purpose was to compare sedentary time derived via the Fitbit Flex with that of the Actical. Finally, a third purpose was to compare sedentary time derived from the above devices, with that of the ActivPAL inclinometer. Thirty-five participants ages 11-69 years (M_{age}= 23.3; 21 Female) wore five devices for up to one week: two PiezoRx pedometers, an Actical, an ActivPAL and a Fitbit Flex. Participants recorded daily wear-time of each device using a log sheet. The average sedentary time calculated from the PiezoRx (716±137.68 min/day) was not different from the Actical (694 ±136.11 min/day, $p>0.05$), although it was higher than the ActivPAL (475±171.52 min/day) and Fitbit Flex (530±149.94 min/day, all $p<0.001$). Sedentary time from all devices were significantly correlated with each other, with the strongest relationship seen between the Actical and PiezoRx ($R^2=0.93$, $p<0.001$). In comparison to the ActivPAL, error in PiezoRx- ($R^2=0.96$), Actical- ($R^2=0.96$) and Fitbit Flex- ($R^2=0.34$) determined sedentary time was strongly associated with standing time (all $p<0.001$). Sedentary time derived using the PiezoRx pedometer may be statistically equivalent to the Actical accelerometer, but not the ActivPAL inclinometer or Fitbit Flex.

KEY WORDS: Sedentary behaviour, physical activity, accelerometer, inclinometer

INTRODUCTION

Sedentary behaviour is defined as any waking behaviour that results in energy expenditure ≤ 1.5 METS while in a sitting, reclining or lying posture (2, 9, 13, 14). Individuals who engage in high amounts of sedentary behaviour have increased risk of diabetes, cardiovascular disease, and all-cause mortality, after controlling for physical activity levels (3). These findings suggest that sedentary behaviour is an important risk factor for chronic disease, and that the objective measurement of sedentary behaviour should be included along with physical activity in population surveillance studies. To date, national population surveillance studies have often employed hip-worn accelerometers to objectively measure sedentary time (5-6,10). For example, the Actical accelerometer (Philips Respironics Inc, Murrysville, USA) is a hip-worn omni-directional accelerometer that has been validated for measuring both physical activity (8) and sedentary behaviour (4,16), and is often used in population surveillance studies (5,6). Though widely used, hip-worn accelerometers have a number of limitations, including a relatively high cost, the need for specialized software, and the inability to distinguish between sitting and standing still (7).

In addition to hip-worn accelerometers, several other devices are available for objectively measuring sedentary behaviour (11), although these too have distinct limitations. The ActivPAL (PAL Technologies Ltd, Glasgow, UK) is a research-grade thigh-worn inclinometer that has been validated as an accurate tool for assessing time spent sitting, lying down, standing, and walking (1, 9). However, thigh-mounted devices result in increased participant burden when compared to hip-worn devices and at present are not widely used in population-based research. The Fitbit Flex (Fitbit Inc., San Francisco, USA), a consumer-focused wrist-worn device, is designed to assess both physical activity and sedentary behaviour; however, its measurement of sedentary behaviour has yet to be validated. Although the popularity of personal fitness trackers continues to grow, it is unclear whether they provide accurate information related to daily sedentary time. Further, like accelerometers, both the ActivPAL and Fitbit are relatively expensive and require specialized software for data to be downloaded and analyzed.

In contrast to the above devices, pedometers are relatively inexpensive, with prices ranging from one-third to one-tenth of the price of the devices listed above. Further, they do not require the use of specialized software for downloading or analyzing data and have a battery life lasting several months. This could make pedometers an attractive option for population-based research if they could accurately assess sedentary time. To date pedometers have been used to measure physical activity, but not sedentary time. New pedometers, such as the PiezoRx (Stepscount Inc, Deep River, Canada), are able to assess the total amount of light (LPA) and moderate and vigorous physical activity (MVPA) based on the number of steps per minute (12). If wear time, LPA, and MVPA are all known, it may be possible to calculate sedentary time by subtracting total activity time (i.e. LPA + MVPA) from wear-time. This could provide a useful and economical approach for the objective measurement of sedentary behaviour in population-based studies. The validity and reliability of this method has yet to be investigated.

The primary purpose of this study was to determine if the PiezoRx pedometer is a valid and reliable measure of sedentary time compared to the Actical accelerometer. The Actical was chosen as the criterion measure, given that it is a valid tool used in large population-based trials (6). A secondary purpose was to similarly compare sedentary time derived via the Fitbit Flex with that of the Actical. Finally, a third purpose was to compare sedentary time derived from the above devices, with that of the ActivPAL inclinometer.

METHODS

Participants

The inclusion criteria were that participants be over 8 years of age and capable of walking independently. Such a broad age range was used to determine if the PiezoRx was valid in all age groups. Thirty-five participants were recruited, ten of whom were between the ages of 11 and 18 years. Participants ranged in age from 11 to 69 (M_{age} = 23.3; SD = 10.1) years.

Protocol

Participants were recruited locally through flyers and word of mouth. Ethics approval was provided by the University of Prince Edward Island Research Ethics Board. Participants 16 years of age and older provided written consent prior to study participation while participants under the age of 16 years provided written assent and parental consent. Participants arrived to the lab and signed informed consent forms. Anthropometric measurements were then assessed: height was measured using a stadiometer and measured to the nearest 0.1cm, while weight was assessed using a digital scale and measured to the nearest 0.5 kg. Waist circumference was measured at the top of the iliac crest to the nearest 0.1 cm using a tape measure. Anthropometric measurements were taken to examine whether they influenced the accuracy of the measurement of sedentary time by individual devices.

Upon completion of the anthropometrics, each participant was given two PiezoRx pedometers, an Actical accelerometer, an ActivPAL inclinometer, and a Fitbit Flex which they were asked to wear for one week. The Actical and ActivPAL were synchronized to start recording data at the same time. The participants were instructed to wear one PiezoRx on each hip, the Actical on the right hip, the ActivPAL on the right thigh, and the Fitbit on the wrist on which it felt most comfortable. The ActivPAL was placed on the thigh using Tegaderm patches (3M, Elyria, USA) and was not removed during data collection. Prior to use, the ActivPAL was waterproofed and placed mid-way between the hip and knee on the right leg of each participant. To waterproof the device, two finger cots were placed over the device followed by a waterproof Tegaderm bandage placed directly on the leg and another placed over top of the device. Each participant was given extra bandages in case they needed to be changed during the seven-day period. Using a log sheet, participants recorded when they put on the PiezoRx, Actical, and Fitbit each morning and when they took them off at night. Participants also recorded if and when they took the devices off during the day and for how long; this information was used to determine daily wear and non-wear time for all devices. A valid day was defined as ≥10 hours of daily wear-time. To be included, participants required at least three valid days of activity data, which has been shown to provide reliable pedometer data (15).

LPA and MVPA were added to calculate total physical activity (TPA) for each day that the pedometers were worn by the participant. Total sedentary time for the pedometers was calculated by subtracting TPA from the total wear time that was reported by the participant on the log sheet for that particular day. The data from the Actical was downloaded in 15-second epochs using Actical 3.10 software and analyzed using Microsoft Excel (Microsoft Corp, Redmond, USA). Sedentary time was identified using established cut-points (5, 6) and then summed across each minute of self-reported wear-time for each day. The data from the ActivPAL was downloaded into 15-second epochs using ActivPAL3 software, and analyzed in Microsoft Excel. Each epoch was coded as sitting, standing or walking, and summed for all minutes of self-reported wear-time for each day. Data from the Fitbit Flex was downloaded into 60-second epochs using Fitabase (Small Steps Labs LLC, San Diego, USA) and analyzed using Microsoft Excel. Sedentary time was identified using Fitbit internal algorithms and then summed across each day of self-reported wear-time. The Fitbit Flex has a limited storage capacity; once this capacity is reached, minute-level data are deleted while summary data for each day is retained. This storage limit resulted in the loss of minute-level data for 26 participant-days of data for the Fitbit Flex. These days have been omitted from the analyses for the Fitbit Flex, but not for the other activity monitors.

Statistical Analysis

Concurrent validity was assessed by comparing the performance of the PiezoRx to that of the Actical accelerometer, while reliability was assessed by comparing the performance of two PiezoRx pedometers worn simultaneously. Pearson correlations were used to examine associations across the 4 devices, and between device performance and demographic and anthropometric characteristics. ANOVAs were performed to determine whether there were significant differences in estimates of daily sedentary time across the 4 devices. Mean absolute percent error (MAPE) was calculated to assess the accuracy of each device, while equivalence testing was used to determine whether any two devices provided comparable results (11). Briefly, the equivalence range for a device was calculated as mean ± 10%; any monitor that provided values within the range but significantly different ($p<0.05$) from the upper and lower limits of the range were considered to be functionally equivalent. Bland-Altman plots with 95% limits of agreement (± 1.96 standard deviations) were created in Microsoft Excel to assess bias. All tests were performed in SPSS 23 (IBM Corp, Armonk, USA) with an alpha level of .05 for significance.

RESULTS

Participant characteristics are presented in Table 1. Participants had an average age of 23.3 years, and a BMI of 25.6 kg/m^2. There was a total of 331 person-days of wear-time for the Actical, PiezoRx and ActivPAL, and 305 for the Fitbit Flex. The average sedentary time recorded by the PiezoRx (716±137 mins/day) was not significantly different from the Actical (694±136 min/day) ($p>0.05$). Further, sedentary time derived using the PiezoRx was significantly different from the upper and lower limits of the Actical equivalence range, indicating functional equivalence between the two devices. In contrast, sedentary time calculated using the PiezoRx was significantly higher than both the ActivPAL (474±171 min/day; $p<0.001$) and Fitbit Flex (530±149 min/day; $p<0.001$) (Figure 1). In comparison to the Actical, the mean absolute percent error for each device was: PiezoRx: 3.1%; ActivPAL: 33.5%; Fitbit: 23.3%.

Figure 2 displays the bivariate associations between sedentary time recorded using each of the 4 devices (all $p<0.001$). Although sedentary time from all devices were significantly correlated with each other, the strongest relationship was observed between the Actical and PiezoRx ($R^2=0.93$, $p<0.001$). The two PiezoRx pedometers worn at the same time also showed a strong association ($R^2=0.96$, $p<0.001$) with respect to sedentary time.

Table 1. Participant characteristics.

N=35 (14 Male, 21 Female)		
Anthropometrics	Mean	SD
Age (years)	23.3	±10.1
Height (cm)	170.2	±9.4
Weight (kg)	74.2	±18.9
Waist Circumference (cm)	80.2	±10.4
BMI (kg/m^2)	25.6	±5.6

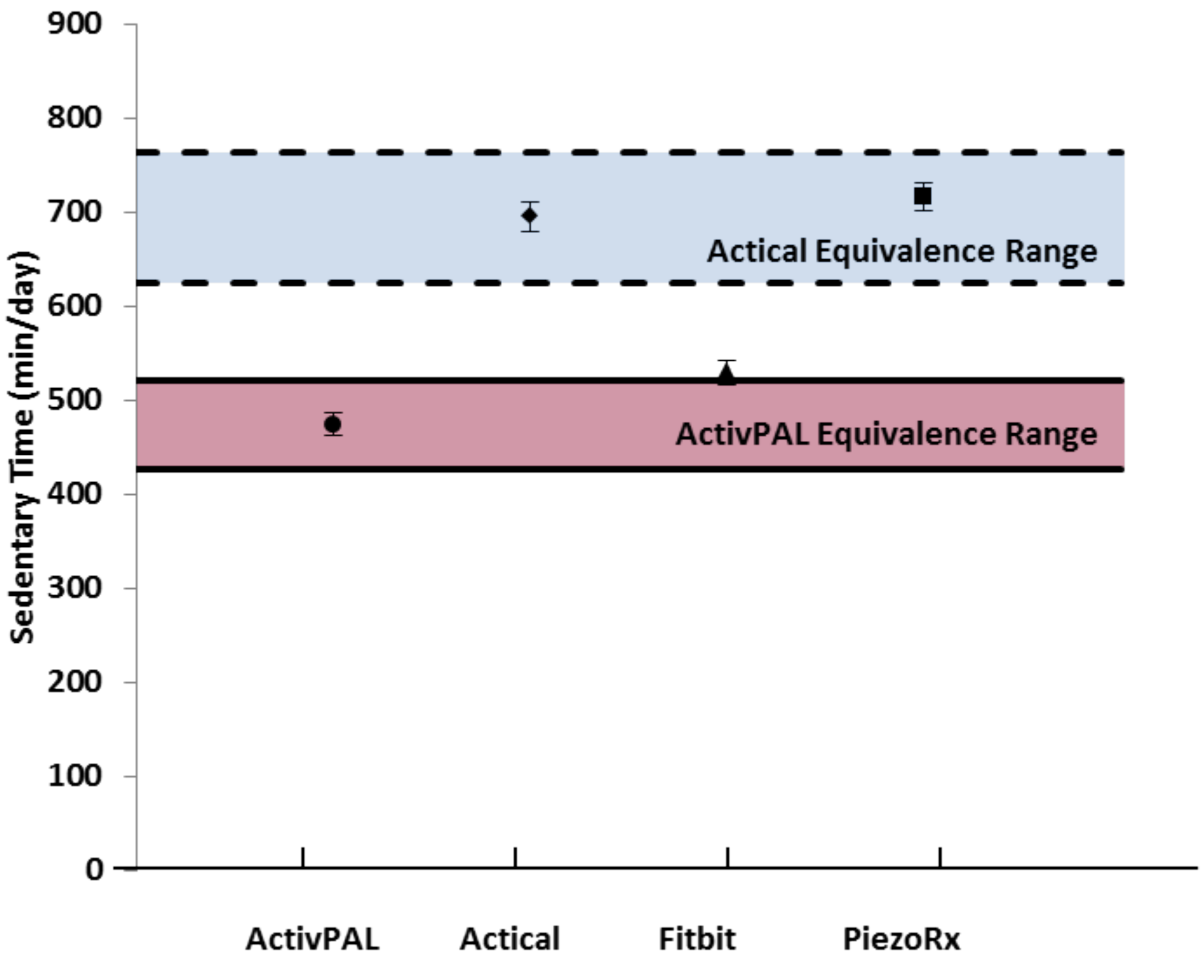

Figure 1. Equivalence of the PiezoRx, ActivPAL, Actical and Fitbit Flex. Equivalence ranges for the Actical and ActivPAL were calculated as mean ± 10%; monitors that provide values which are significantly different ($p<0.05$) from the upper and lower limits of the range are considered to be functionally equivalent. Data are presented as mean ± 90% confidence interval.

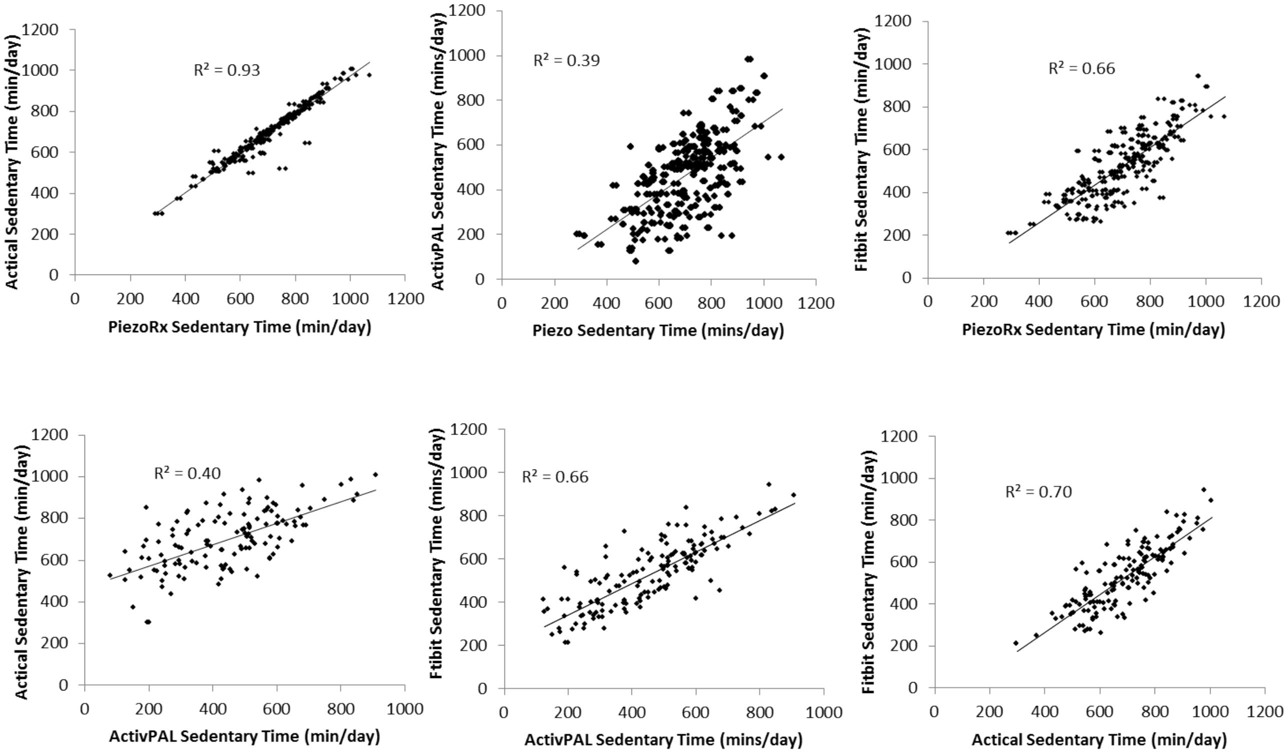

Figure 2. Scatterplots showing the correlations between all combinations of activity monitors

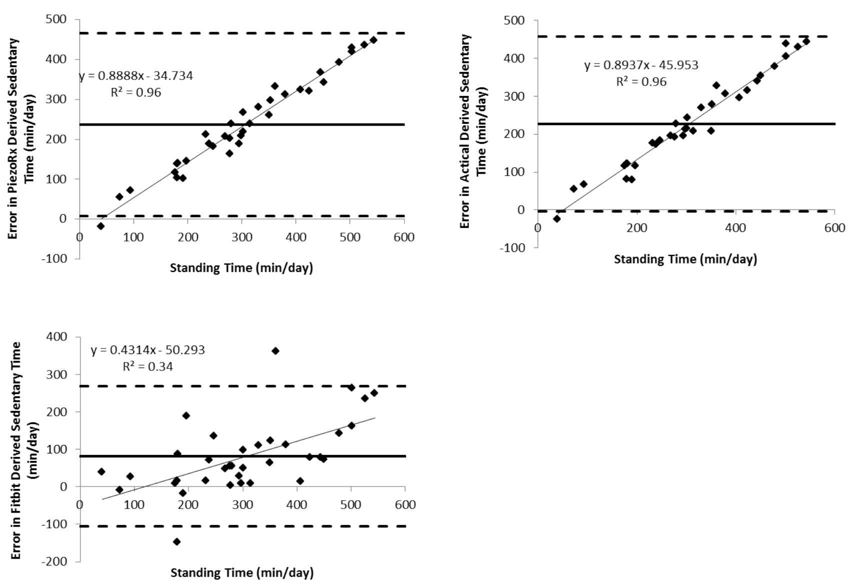

Figure 3. Bland-Altman plots of error in sedentary time when compared to ActivPAL-derived standing time. A: PiezoRx; B: Actical; C: Fitbit Flex

Bland-Altman plots illustrating the bias in PiezoRx-, Actical- and Fitbit Flex-derived sedentary time when compared to the ActivPAL-derived standing time are shown in Figure 3. Error in PiezoRx- and Actical-determined sedentary time were both strongly correlated with daily standing time (R^2=0.96), with a smaller association observed for the Fitbit Flex (R^2=0.34) (all p<0.001). Error in PiezoRx-, Actical- and Fitbit Flex-derived sedentary time had moderate associations with age: PiezoRx (R^2=0.34, p=0.001), Actical (R^2=0.29, p=0.001), Fitbit Flex (R^2=0.18, p=0.01). Error was not associated with BMI or waist circumference for any device (all p>0.05).

DISCUSSION

The primary purpose of this study was to determine if the PiezoRx pedometer is a valid and reliable instrument to quantify sedentary time in comparison to the Actical accelerometer. Based on the equivalence results in Figure 1, the sedentary time collected via the PiezoRx is equivalent to sedentary time assessed using the Actical accelerometer. The mean absolute percent error of the PiezoRx compared to the Actical (3.1%) further supports the conclusion that these two monitors are equivalent in their ability to assess sedentary time. Furthermore, there was a very strong correlation (R^2 = 0.96, p<0.001) between the two PiezoRx activity monitors that were worn on the left and right hips of each participant, indicating that the PiezoRx is also a reliable activity monitor for assessing sedentary time. The PiezoRx could provide a valid and reliable measure of sedentary time in population based studies, equivalent to those provided by the Actical accelerometer, which is currently used for population-based analyses in Canada (5,6).

Our study also sought to compare sedentary time derived from the PiezoRx, Actical, and Fitbit Flex with the thigh-worn ActivPAL inclinometer. Results were consistent with Rosenberger et al., (11) who reported that the hip-worn Actigraph accelerometer over-estimated daily sedentary time in comparison to the ActivPAL. The over-estimation of the hip- and wrist-worn devices is likely due to their inability to distinguish between sitting and standing, as outlined by the Figure 3. The error in daily values obtained from the PiezoRx and Actical compared to the ActivPAL, were strongly associated with the amount of time spent standing still. The mean absolute percent error of the ActivPAL was the highest of all the devices when compared to the Actical. This is likely due to the reason mentioned above: that the ActivPAL is able to distinguish between sitting and standing whereas the Actical is not. It is interesting to note that measurement error for the PiezoRx, Actical, and Fitbit Flex all increased with age. It is likely that this is due to increased time spent standing stationary among adults, in comparison to children.

Although not equivalent to the Actical or ActivPAL, the Fitbit Flex showed the strongest correlation with ActivPAL-derived sedentary time and demonstrated less bias as a result of time spent standing. Despite being a consumer-focused device, this suggests that the Fitbit Flex may be a useful device for assessing sedentary behaviour in population-based studies, although results will not be directly comparable to those provided by either the ActivPAL or Actical. Unfortunately, the reliability of Fitbit Flex-derived sedentary time was not assessed; this should be investigated in future studies. The PiezoRx was the only device that was comparable to the criterion standard in regards to quantifying sedentary time. The PiezoRx can provide an affordable option for those looking to track their sedentary time. For example, if a study wanted to examine the average daily sedentary time in a large group of school-aged children; the PiezoRx could be used to do so in a cost-effective manner.

Our results are strengthened by the inclusion of devices which are widely used for both research (Actical and ActivPAL) and personal use (Fitbit Flex). Validating these fitness monitors will help to provide information regarding their usefulness and aid researchers and consumers in understanding which devices are most appropriate for specific uses. The present study utilized a convenience sample of participants; despite a range of ages and body weights, the sample was predominately of European descent, and was limited to individuals within driving distance of the research unit. Although the wide age-range may have increased variability, it also permitted us to investigate whether device accuracy differed by age. Future research should consider separately studying children and adults. Further, future research could employ direct observation to determine whether pedometers are able to correctly distinguish between specific sedentary and non-sedentary activities. As noted above, the Fitbit Flex has a limited data storage capacity which resulted in a loss of 26 person-days of activity data.

We conclude that sedentary time derived using the PiezoRx pedometer is equivalent to the Actical accelerometer, but not equivalent to the ActivPAL or Fitbit Flex. The PiezoRx also demonstrated a high level of reliability. The PiezoRx provides a measure of sedentary time which is statistically equivalent to that found using the Actical accelerometer, and may therefore be a useful tool for measuring sedentary behaviour in field-based studies.

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