Validation of a novel device to measure and provide feedback on sedentary behavior

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Short title: Validation of the SitFIT

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Abstract

Purpose. Pedometers, which enable self-monitoring of step counts, are effective in facilitating increases in physical activity. Similar devices which provide real-time feedback on sedentary (sitting) behavior are limited. This study aimed to develop and validate a novel device – the SitFIT – which could accurately measure and provide feedback on sedentary behavior and physical activity.

Methods. The SitFIT is a tri-axial accelerometer, developed by PAL Technologies, which is worn in the front trouser pocket. This enables tracking of thigh inclination and therefore differentiation between sitting and upright postures, as well as tracking of step count. It has a display to provide user feedback. To determine the validity of the SitFIT for measuring sedentary behavior and step counts, 21 men, aged 30-65 years, with body mass index 26.6±3.9 $kg.m^{-2}$ wore a SitFIT in a front trouser pocket and an activPAL accelerometer attached to their thigh for up to seven days. Outputs from the SitFIT were compared with the activPAL, which was assumed to provide gold-standard measurements of sitting and step counts.

Results. Mean step counts were ~4% lower with the SitFIT than activPAL, with correlation between the two methods being very high (r=0.98) and no obvious bias from the line of equality (regression line: y=1.0035x+418.35). Mean sedentary time was ~5% higher with the SitFIT than activPAL, correlation between methods was high (r=0.84) and the equation of the regression line was close to the line of equality (y=0.8728x+38.445).

Conclusions. The SitFIT has excellent validity for measurement of free-living step counts and sedentary time and therefore addresses a clear need for a device that can be used as a tool to provide feedback on sedentary behavior to facilitate behavior change.

Keywords: sedentary; sitting; objective measurement; validation; behavior change

Introduction

Sedentary behavior has been defined as waking activities in a sitting, reclining or lying posture with energy expenditure ≤1.5 METS (where 1 MET is resting energy expenditure) (1). Existing research, from both observational and experimental studies, demonstrate that high levels of sedentary behavior are associated with a range of adverse health outcomes including mortality, cardiovascular disease, type 2 diabetes and obesity (2-8), and that interventions which reduce sedentary behavior can induce positive changes to markers of health and disease risk (9-15). However, effective intervention tools to facilitate reductions in sedentary behavior are currently limited (16).

A considerable body of evidence from randomised controlled trials has shown that pedometer-based interventions – which enable individuals to self-monitor their physical activity level (i.e. steps taken per day), set physical activity targets and provide real-time feedback of progress towards their goal – are effective for increasing physical activity, and improving health outcomes in a range of population groups (17-19). Pedometers are also highly valued for self-monitoring by those taking part in behavioral interventions (20). There are a plethora of devices available which build on the pedometer to provide feedback of a number of indices of physical activity measurement such as steps, distance travelled and energy expenditure (21). However, consumer devices to enable the self-monitoring of free-living sedentary behavior are more limited, with the majority of devices using an acceleration-based, rather than posture-based, approach to estimate time spent sedentary (21,22). Thus most currently available devices cannot distinguish between sitting and quiet standing, so cannot be used as a self-monitoring tool in interventions aiming to reduce time spent sitting. A small number of devices are available that use pressure sensors in a sock or shoe to determine standing or a pressure sensor on a chair to determine sitting (on a particular chair) (21) and, one device worn on the lower back using an elasticated belt (originally developed to monitor posture) has also been used to monitor time spent sitting (21,22). Thus devices available to monitor and provide feedback on time spent sitting under free-living conditions throughout the day are limited and there is a clear need to develop and validate a device for the self-monitoring of sitting behavior, preferably in combination with step counts to target both physical activity and sedentary behavior with a single device.

The European Fans in Training (EuroFIT) study is a large-scale randomised controlled trial aiming to increase physical activity and reduce sedentary behavior over 12 months in middle-aged male fans of football (soccer) clubs in England, the Netherlands, Norway and Portugal (23). To facilitate self-monitoring of physical activity and sedentary behavior in the EuroFIT trial (and future studies), we aimed to develop and validate a novel low-cost pocket-worn device with an integrated display – called the SitFIT – which could measure daily sedentary behavior and physical activity accurately, and provide real-time feedback to enable prompts for and self-monitoring of behavior change for both. This paper describes the development of the SitFIT, and the determination of its criterion validity (compared with the ActivPAL) for measurement of steps and sedentary time in a sample of adult males.

Methods

Development of the SitFIT

The SitFIT is a tri-axial accelerometer, developed by PAL Technologies, which uses static and dynamic accelerations in the three orthogonal axes to calculate wear (and non-wear) time, posture allocation (upright or sedentary), transportation and stepping. It has been designed to be worn in the front trouser pocket to enable the device orientation to track the inclination of the thigh allowing detection of sitting/lying and upright postures by assessment of the axes through which gravitational acceleration is detected (Figure 1). This is the same concept underpinning the activPAL activity monitor (PAL Technologies, Glasgow, UK), a small tri-axial accelerometer affixed to the front of the thigh, which is regarded as a gold-standard device for the measurement of free-living sitting behavior (in addition to its measurement of physical activity) because its thigh-based position is optimal for distinguishing between sitting and upright postures (24,25). However, as the activPAL is affixed to the thigh under clothing, it is not readily accessible; this, together with its lack of a display to provide feedback, makes it unsuitable for providing real-time feedback on sedentary behavior during everyday activities. The front trouser pocket location of the SitFIT tracks thigh inclination, but provides the advantage of providing easy access for the user to enable provision of feedback. The pocket is also more likely to be acceptable for daily long-term wear than attachment to the thigh via a surgical dressing. Unlike the activPAL which has no facility to provide feedback on a screen on the device, the SitFIT was designed with a display to provide real-time visual feedback of stepping and sedentary/upright behaviors, a vibrotactile actuator to provide customisable haptic feedback of time spent sitting, and a Bluetooth SMART module to enable communication with external devices such as smartphones, tablets and PCs. The key characteristics of the ActivPAL and SitFIT are shown in Table 1.

Also unlike the activPAL, which is held in a fixed orientation on the thigh, the SitFIT can move in the trouser pocket, thus changing its orientation relative to the thigh. To overcome this, algorithms were developed by PAL Technologies to allow the device to be carried at random orientations in the pocket and to rotate during use. The SitFIT produces outcomes that are mainly based on the device’s ability to count steps and to determine the wearer’s posture from its trouser pocket location. The SitFIT counts steps using all three (XYZ) axes of space accelerations, with the step counting algorithm samplings each of the three axes separately 10 times every second. The algorithm looks for a swing leg phase expressed as a relative smooth variation of the axis acceleration value, followed by a sharp acceleration change attributed to heel strike. Depending on device orientation in the pocket, any axis can be dominant, hence the step count algorithm looks for all combinations of swing-heel strike patterns over three axes and their inversions. The count of steps is the sum of the steps counted across all axes, meaning that steps from all three axes are added but the same step is not counted more than once. A time-based filter is applied to cut-off high frequency noise in the step counting arising from the device's free movement inside the pocket that would otherwise produce extra step counts; practically, a refractory period is created between steps, preventing erroneous reporting of high frequency stepping. An automatic gain control feature is implemented based on inter-step intervals that makes the algorithm more sensitive during slow stepping. Additionally, there is a maximum time-period between two successive heel strikes that can lead to the registration of a step. Beyond this maximum, period step signals are regarded as individual noise bursts and do not contribute to step counting.

The determination of posture from a randomly placed device in the pocket is a greater challenge than step counting. The posture estimation algorithm uses containers (i.e. periods of time where activity is of a single class) of upright, sedentary, transport and non-wear using historical and future criteria to set the limits for the sequential containers. The criteria used to characterise a container are: a) the presence of steps; b) high frequency low level background noise; c) sporadic noise bursts; d) a combination of changes to the static accelerations of the three axes. The highest weighted criterion to identify the upright container is the existence of steps. The algorithm identifies a container as upright when there are steps within it, and tracks back in time until the last sufficient change in static accelerations is found to indicate the change in posture. A prolonged period without significant dynamic accelerations is weighted towards a sedentary container. Any significant dynamic acceleration or stepping resets the weighting. A prolonged period totally without dynamic accelerations, following an identified sedentary period, weighs towards a non-wear container. Persistent high frequency – low level dynamic accelerations without stepping is weighted towards a transport container. Sporadic noise bursts that do not constitute stepping are weighted towards upright (quiet standing). If no stepping is identified before a significant static acceleration change, the container is reassigned as sedentary. This algorithm is summarised in Figure 2.

Validation of stepping and sitting/upright time algorithms in free-living conditions

Once algorithms for detection of sitting vs upright time, and step counts with the SitFIT were fully developed, we sought to validate their accuracy under real-world free-living conditions by comparing sitting time and step count outputs from the SitFIT with those from the activPAL, which was assumed to provide gold-standard measures of sitting time and step-counts, over several days. To do this, we asked 21 men, aged 30-65 years, with body mass index 26.6 ± 3.9 $kg.m^{-2}$ who were willing to wear trousers with front pockets, and had no contraindications to engaging in physical activity (as assessed by the Physical Activity Readiness Questionnaire), to each concurrently wear a SitFIT device in a front trouser pocket and an activPAL accelerometer attached to their thigh for up to seven days. This participant group was chosen as the first intended use of the SitFIT was in the EuroFIT study which was a randomized controlled trial designed to increase physical activity and reduce sedentary behavior in overweight and obese middle-aged male soccer fans (23). Participants were recruited via email invitation or word-of-mouth and were primarily employees of the University of Edinburgh. All provided written informed consent, and the study was approved by the Research Ethics Committee of the Moray House School of Education, University of Edinburgh.

Participants were instructed to affix an activPAL activity monitor (model activPAL3, PAL Technologies, Glasgow, UK) to the front of their thigh using a surgical dressing for 24 hours per day for seven days. Over the same time-period, they were asked to carry a SitFIT device in their front trouser pocket during all waking hours, putting the device on as soon as they woke in the morning and removing it before they went to bed at night. Valid data were obtained for 7 days in 18 participants, 8 days in 1 participant, 6 days in 1 participant and 5 days in 1 participant, providing a total of 145 valid days where SitFIT and activPAL data could be compared.

Data were processed using proprietary software developed by PAL Technologies, which summarised data in 5-minute epochs throughout the day, quantifying the duration of time spent sitting (or lying), standing, stepping and of non-wear, as well as the number of steps taken, in each epoch for both the activPAL and SitFIT devices. The software automatically detected periods of non-wear, using the algorithms described above, and data were cleaned to remove periods identified as non-wear for either device. Thus data analysis only included the waking periods where both devices were worn: this step was necessary to ensure comparability of SitFIT and activPAL data, as SitFIT devices were removed at night. To determine whether it was necessary to account for nesting of multiple observation days per participant in our analysis, we explored the effect of including a term for ‘participant’ in analysis of the linear regression between SitFIT and ActivPAL outputs for step count and sedentary time, and when comparing the mean difference in outputs between the two devices. This had no material effect of on the findings (for example, r^2 for the correlation between

SitFIT and ActivPAL sedentary time measurements was 0.7007 when all data points were considered independent and 0.7010 taking nesting into account. For step count, r^2 was 0.9608 when all data points were considered independent and 0.9610 accounting for nesting). We therefore took the parsimonious approach of considering the each of the 145 observation days as independent data points in our data analysis. Cumulative sitting time and cumulative step count throughout each day was calculated for the SitFIT and activPAL devices for each of the 145 days, and mean ± SD values reported graphically. Mean (± SD) values for the difference in cumulative sitting time and step count were also shown in graphical form. Mean absolute errors for cumulative sitting time and step count were calculated as the mean of the absolute differences between SitFIT and ActivPAL measurements (i.e. ignoring the direction of error for each individual measurement). A Bland and Altman limits of agreement approach was used to ascertain bias and variability in the SitFIT measures of sitting time and step counts compared with the activPAL (26). The relationships between daily sitting time and step count outputs between activPAL and SitFIT were assessed by plotting scatter graphs and assessing Pearson correlations (r) between the two measures and proximity of the relationship to the line of equality ($y = x$).

Results

Over the 145 measurement days, mean (± SD) daily wear time for the SitFIT was 16.1 ± 4.2 hours and for the ActivPAL was 22.9 ± 3.0 hours. The median-time for putting on the SitFIT in the morning was 07:35; the median-time for removing it in the evening was 22:55. Comparisons between the SitFIT and ActivPAL for step-counts and sedentary time were made over the time-period when both devices were worn on each day. Figure 3A shows mean cumulative step-count values over the 145 days measured using SitFIT and activPAL devices with the mean ± SD for differences in cumulative step counts between the two devices over the course of the day. Throughout the day, differences in cumulative step count between the devices were small, with no clear bias in either a positive or negative direction. Mean (± SD) daily step counts for the two devices over the 145 observation periods are shown in Table 1. Figure 3B shows a Bland-Altman plot of the mean difference and 95% Limits of Agreement for 24-hour step counts between SitFIT and ActivPAL devices, with values summarised in Table 2 Overall, mean step counts were ~4% lower with the SitFIT than ActivPAL, with the 95% Limits of Agreement for step counts between the devices ranging from -2667 to +1817 steps per day. Mean absolute error in step count for the SitFIT compared with the ActivPAL was 826 steps per day. Step counts between the two devices differed by less than 1000 steps per day on 69% (100 out of 145) of days and by less than 2000 steps on 94% (137/145) of days. Pearson correlation between step counts for the two methods was very high ($r = 0.98$, $r^2 = 0.96$), with no obvious bias from the line of equality (equation of regression line: $y = 1.0035x + 418.35$) (Figure 3C).

Figure 4A shows mean cumulative sedentary time values over the 145 days measured using SitFIT and activPAL devices with the mean and standard deviation for differences in cumulative sedentary time between the two devices. Over the course of the day, there was no clear bias in sedentary time between the two devices: mean (±SD) daily values for sedentary time for the SitFIT and activPAL are shown in Table 2. A Bland-Altman plot of the mean difference and 95% Limits of Agreement for sedentary time is shown in Figure 4B, with values summarised in Table 2. Overall, mean sedentary time was ~5% higher with the SitFIT than activPAL, with 95% Limits of Agreement ranging from -159 minutes to +180 minutes per day. Mean absolute error in sedentary time for the SitFIT compared with the ActivPAL was 66 minutes per day. Sedentary time measures between the two devices differed by less than 60 minutes on 61% (89/145) and by less than 120 minutes on 86% (125/145) of days. Correlation between upright time for the two methods was high ($r = 0.84$, $r^2 = 0.70$), although lower than observed for step count, with the equation of the regression line being close to the line of equality ($y = 0.8728x + 38.445$) (Figure 4C).

Discussion

The aim of this paper was to describe the development and validation of the SitFIT – a novel pocket-worn device to measure and provide real-time feedback on sedentary behavior and stepping activities. While the SitFIT was initially designed for use in the EuroFIT trial (23), it can be used as a monitoring tool for sedentary behavior and stepping in widespread settings. Novel algorithms were developed to detect sitting and upright postures, which accounted for changes in device orientation within the pocket, and the accuracy of the SitFIT for measurement of step counts and sedentary behavior was assessed under free-living conditions. Our data revealed that the SitFIT had excellent validity for counting steps, with a mean difference in step counts between SitFIT and activPAL devices of ~4%, a correlation coefficient for step counts between the two devices of 0.98, and daily step counts differing between the two devices by less than 2000 steps on 94% of measurement days. Previous studies have reported that the most accurate commercially-available pedometers have a 95% confidence interval for free-living 24-hour step counts of ~ ± 3000-4000 steps per day compared with a criterion measure and suggested that devices with mean differences in step counts within ± 10% of the criterion measure have acceptable validity (27,28). More recently, correlation coefficients with criterion measures for 24-hour steps counts for commercially-available wearable activity monitors have been reported in the range of 0.94-0.99 with 95% confidence intervals for the difference in 24-hour step counts typically within

~ ± 1000-3000 steps per day (29). Thus, overall these data indicate that the SitFIT device has excellent validity for measuring step-counts under free-living conditions which is at least as good as other devices on the market.

While there are a number of acceptable options available which monitor and provide feedback on indices of physical activity, such as step counts, devices which provide real-time feedback on sedentary behavior are more limited. The activPAL is generally regarded as the gold-standard device for the measurement of sedentary behavior (24,25): one version of this device – the activPAL VT (http://www.paltechnologies.com/products/) – provides vibrotactile feedback to the wearer when they have sat continuously for 15 or 30 minutes to provide information and a prompt to stand up. The SitFIT builds on activPAL VT in two important ways. First, its pocket location is more amenable to long-term wear than having a device affixed to the front of the thigh, and second, it has a display which provides real time feedback on step count and time spent sitting (or upright) – analogous to a pedometer – which can thus be used to work towards daily targets. The LUMOback activity tracker (LUMO Bodytech, Mountain View, CA, USA) – a device worn as a belt around the waist which is synced to a smartphone to provide feedback on sitting, standing and stepping – was used in one randomised controlled trial as an intervention tool to facilitate reductions in sitting time amongst office workers (30). However, this device, which was originally developed as a posture monitor, has now been discontinued by the manufacturer, and its replacement, the Lumo Lift, with its placement near the collarbone is not suitable for objective monitoring of sitting behavior (http://www.lumobodytech.com/lumo-back/, accessed 14.03.17). Most other devices purporting to provide feedback on sedentary behavior to the user do so by equating sedentary time as a lack of dynamic movement, rather than by measurement of a sitting posture (21,22), and therefore do not provide a direct measurement of sedentary behavior in line with the Sedentary Behavior Research Network definition (1). This has potentially important implications, as these other devices would record a period of quiet standing as being sedentary, and there is increasing evidence that breaking up sitting with periods of quiet standing can produce metabolic benefits (13-15,31). Thus, such devices would not be able to provide effective feedback on a standing desk intervention, for example. Therefore, there is a clear need for a simple device that can provide users with feedback on sitting behavior, and the SitFIT addresses this gap.

The accuracy of the SitFIT for measurement of time spent sitting was also very good. Mean sedentary time as measured by the SitFIT and activPAL differed by ~5%, with a correlation coefficient between the two measures of 0.84. This compares favourably with validation of the LUMOback against the activPAL which reported a mean difference of 9.5% between the two devices for measurement of sedentary behavior over a 24-hour cycle (22). The difference in daily sitting time between the SitFIT and activPAL was less than 60 minutes on 61% of day and less than 120 minutes on 86% of days. Other devices use an acceleration-based, rather than posture-based, approach to estimate time spent sedentary (21,22) and thus cannot distinguish between sitting and quiet standing. When such devices are validated against the activPAL, their accuracy in determining sedentary behavior is considerably poorer (22), which limits their potential for use in intervention aimed at reducing sitting time. It is of note that the accuracy of the SitFIT in measuring step counts was somewhat higher than its accuracy in determining time spent sitting. This is understandable given the greater technical challenges associated with quantification of sitting time compared with quantification of step count. The pocket location of the SitFIT has a number of advantages with respect to long-term usability: it can be carried inconspicuously, it is not directly attached to the skin (as the activPAL is) and is easily accessible for the provision of feedback to the user. However, as the SitFIT is free to move and change orientation in the pocket, the technical challenge of detecting posture allocation (sitting vs upright) is substantially greater than for the detection of steps, and for the detection of posture allocation using the gold-standard activPAL where the location and orientation of the device on the thigh is constant. To address this problem, an algorithm was developed to account for the random orientation of SitFIT in the pocket, as described in the methods. In this context, we feel that the validity of this algorithm, assessed here under real-world free-living conditions, for detection of sitting and upright time (the latter simply being wear time minus sitting time) is excellent and certainly acceptable for use as a tool to provide users with feedback on sedentary behavior in behavior change intervention programs.

This study provides an important first step in validating the SitFIT but further work is needed to validate the device in groups of users other than middle-aged men and to provide construct as well as criterion validity for the device. There are also some limitations with the SitFIT which need to be considered. Firstly, as the device is pocket-worn, it may not be suitable for use for people who do not usually wear trousers with front pockets. To address this issue, a new device called the Activator, which is based on the same sensing platform as the SitFIT, but can be attached to clothing or worn discretely on the thigh using an integrated elastic loop (in addition to being pocket-worn), is currently being developed by PAL Technologies. Secondly, while the accuracy of the SitFIT for measurement of sedentary behavior is acceptable for providing user feedback in the context of a behavior change intervention, it is not equivalent to the ActivPAL in this context, so for measurement of sedentary behavior as a research outcome, it should not be considered to be an ActivPAL replacement.

For the output display on the SitFIT, we deliberately chose to provide users with simple, actionable, feedback with the aim of facilitating behavior change. Pedometers, which provide a simple output of step count are effective at increasing physical activity (17-19): with the SitFIT we sought to provide an additional simple summary measure of sedentary time which could be used for goal setting and feedback. Further work is needed to validate the device for other outputs, such as number of sit-to-stand transitions, which have been shown to be associated with metabolic outcomes (15,32) and are a viable target for a sedentary behavior change intervention. In addition, further work is needed to develop and validate outputs related to intensity of physical activity, in addition to total step count, for the SitFIT. Increasing the number and complexity of data outputs would necessarily complicate the output display and end-user input would be needed to develop the best ways of visualising such data outputs for the user. Trials would also be needed to determine whether provision of more detailed feedback beyond step count and total sedentary time resulted in greater behavior change.

In conclusion, the SitFIT – a novel device to monitor and provide real-time feedback of stepping and sedentary behavior – has excellent validity for the measurement of step counts and sitting and upright time. While there are a number of devices available which can provide feedback to the user on step counts, there is a lack of devices available which can provide feedback on time spent sitting and being upright. Thus the SitFIT addresses a clear need for a device that can be used as a tool to provide feedback to the user on sedentary behavior to facilitate behavior change. As such, the SitFIT can be considered to be a complementary device to the ActivPAL, which remains the gold-standard device for measurement of sedentary behavior as a research outcome. Randomised controlled trials –

such as the EuroFIT study (23) – are now needed to determine the effectiveness of such technology-supported approaches for eliciting long-term sedentary behavior change.

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Figure Legends

Figure 1. The pocket-worn SitFIT device during sitting, standing and stepping activities. The SitFIT tracks the orientation of the upper thigh, so changes orientation when posture changes from sitting to upright. The display provides real-time feedback of sitting (or upright) time and of step count.

Figure 2. Flow-diagram illustrating the algorithm for decision-rules used by the SitFIT to determine posture allocation.

Figure 3. Panel A: Cumulative step counts and differences in cumulative step counts over the course of the day measured using the SitFIT and activPAL devices. N = 145, values are mean for step counts for each device and mean ± SD for the difference in step count. **Panel B: Scatterplot showing the relationship between daily step counts measured using SitFIT and activPAL devices.** Black line is line of best fit; dotted red line is line of equality; N = 145. **Panel C: Bland-Altman plot of difference in step counts between SitFIT and activPAL devices against ActivPAL (gold-standard) step counts.** N = 145, black dotted line represents mean difference between devices; red dotted lines represent 95% limits of agreement.

Figure 4. Panel A: Cumulative sedentary time and differences in cumulative sedentary time over the course of the day measured using the SitFIT and activPAL devices. N = 145, values are mean for sedentary time for each device and mean ± SD for the difference in step count sedentary time. **Panel B: Scatterplot showing the relationship between daily sedentary time measured using SitFIT and activPAL devices.** Black line is line of best fit; dotted red line is line of equality; N = 145. **Panel C: Bland-Altman plot of difference in sedentary time between SitFIT and activPAL devices against ActivPAL (gold-standard) sedentary time.** N = 145, black dotted line represents mean difference between devices; red dotted lines represent 95% limits of agreement.

Table 1. Characteristics of the ActivPAL and SitFIT

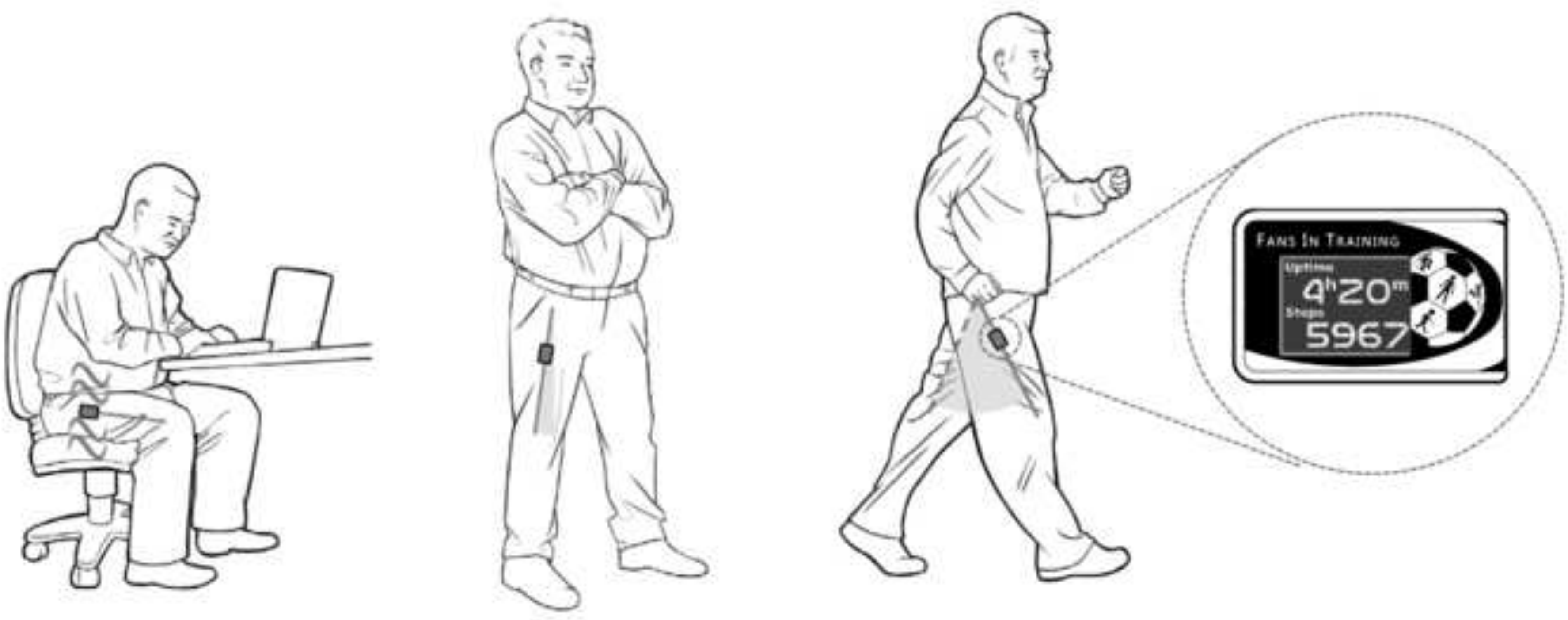
ActivPAL	**SitFIT**
Worn on front of thigh	Worn in front trouser pocket
Attached firmly using a surgical dressing	Free to move in pocket
Fixed orientation relative to thigh	Random orientation relative to thigh
Worn 24 hours per day	Worn during waking hours, removed at night
Data on sedentary behaviour or step count provided to the researcher via download to PC at the end of monitoring period	Screen to provide real-time feedback to user on sedentary behavior and step count (data also stored on device and is downloadable)
Provides gold-standard measurement of sedentary (and stepping) behavior for use in research studies	To be used as a tool to facilitate sedentary and physical activity behavior change in interventions
Provides 1-2 week snapshots of sedentary and stepping behaviour to the researcher	Suitable for long-term self-monitoring of sedentary and stepping behaviour by the user

Table 2. Comparison of ActivPAL and SitFIT derived measures of step counts and sedentary time over 145 24-hour observation periods.

	ActivPAL (mean ± SD)	SitFIT (mean ± SD)	Difference (SitFIT minus ActivPAL) (mean (95% Limits of Agreement))	Correlation coefficient (r)
Step count (steps.day^{-1})	10250 ± 5571	9797 ± 5579	-452 (-2669, 1762)	0.98
Sedentary time (min.day^{-1})	462 ± 166	485 ± 159	23 (-159, 180)	0.84

Limits of Agreement expressed as the mean difference ± 1.96 x SD

Figure 1



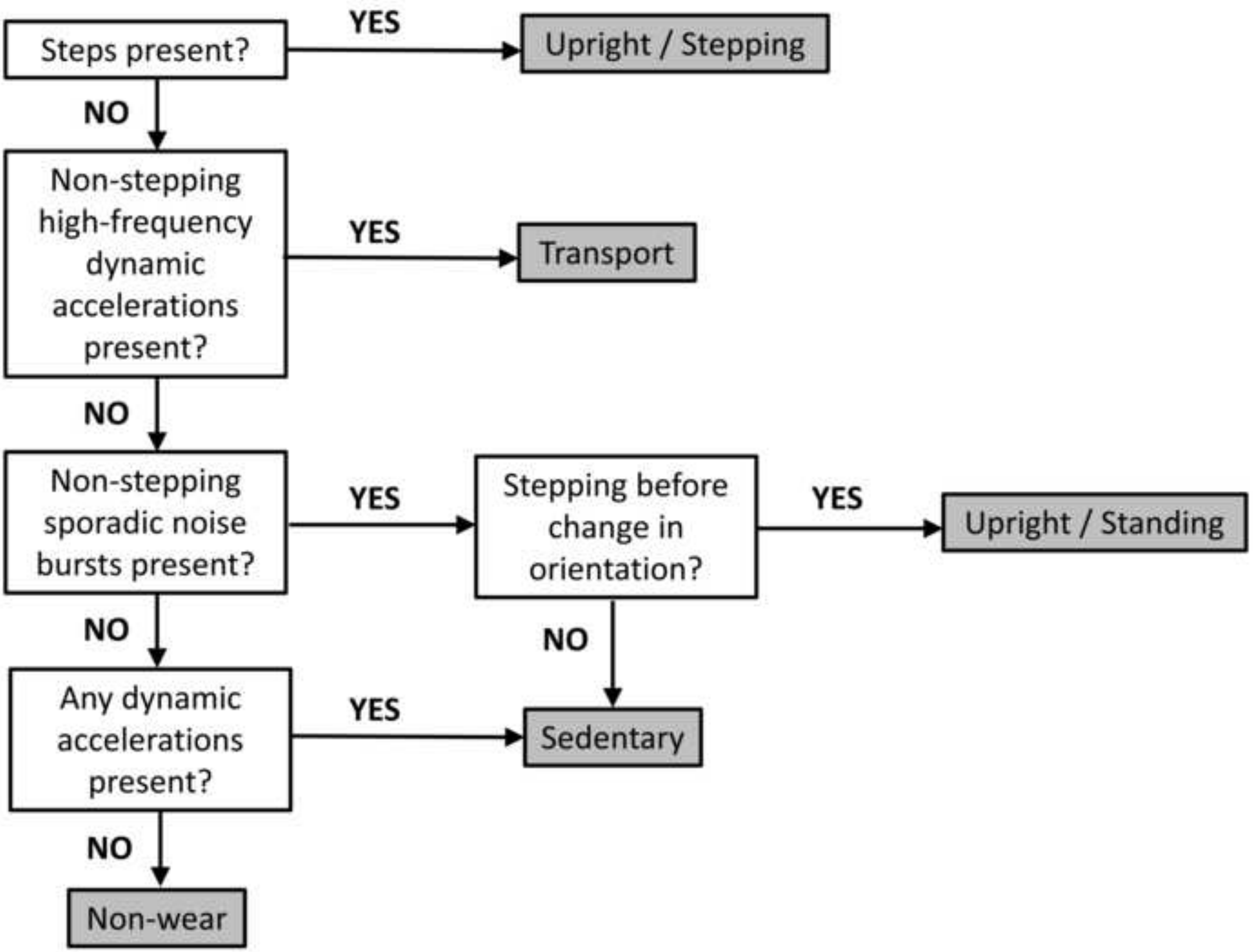

Steps present?
YES
Upright / Stepping
NO
Non-stepping high-frequency dynamic accelerations present?
YES
Transport
NO
Non-stepping sporadic noise bursts present?
YES
Stepping before change in orientation?
YES
Upright / Standing
NO
NO
Any dynamic accelerations present?
YES
Sedentary
NO
Non-wear

Figure 3

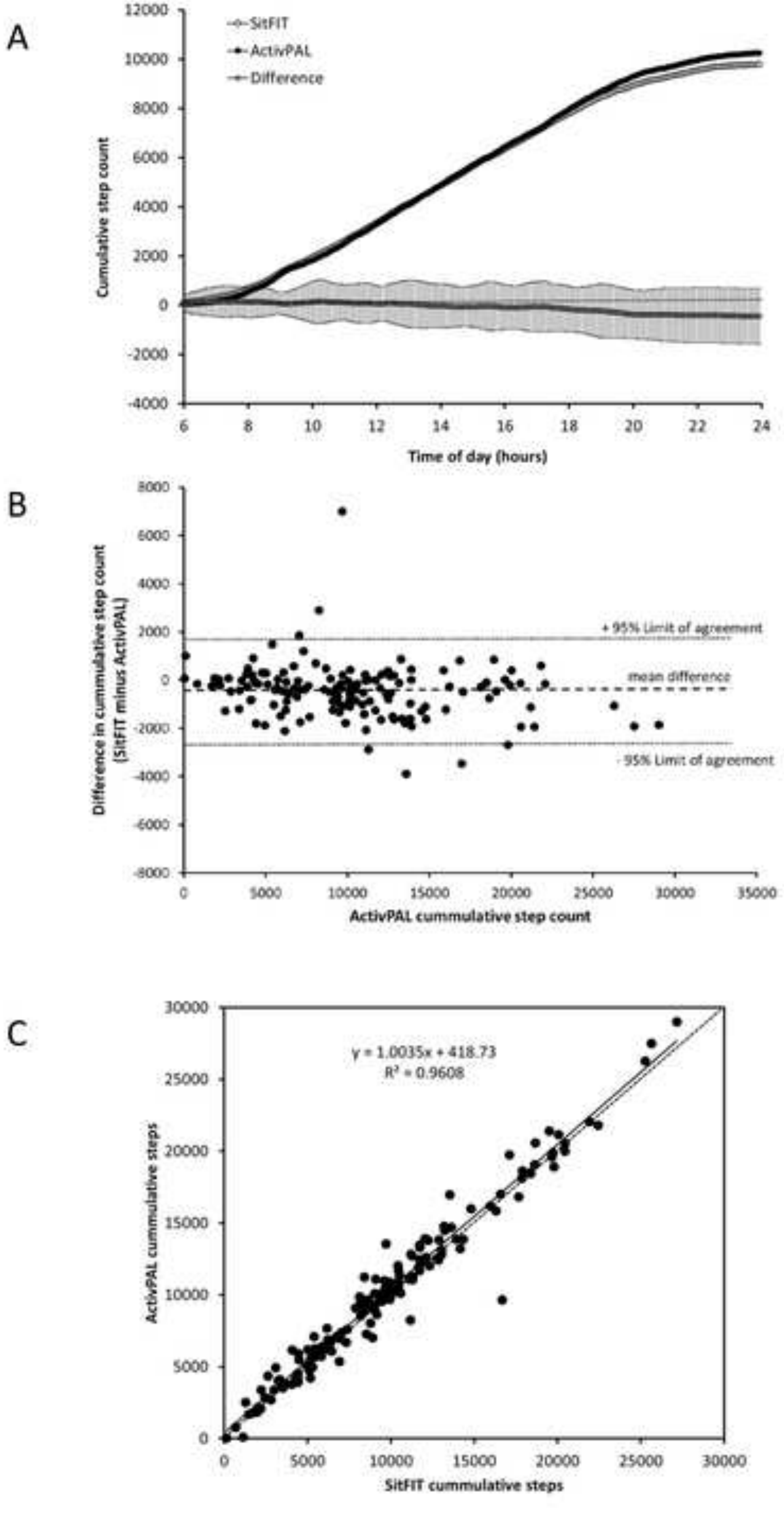
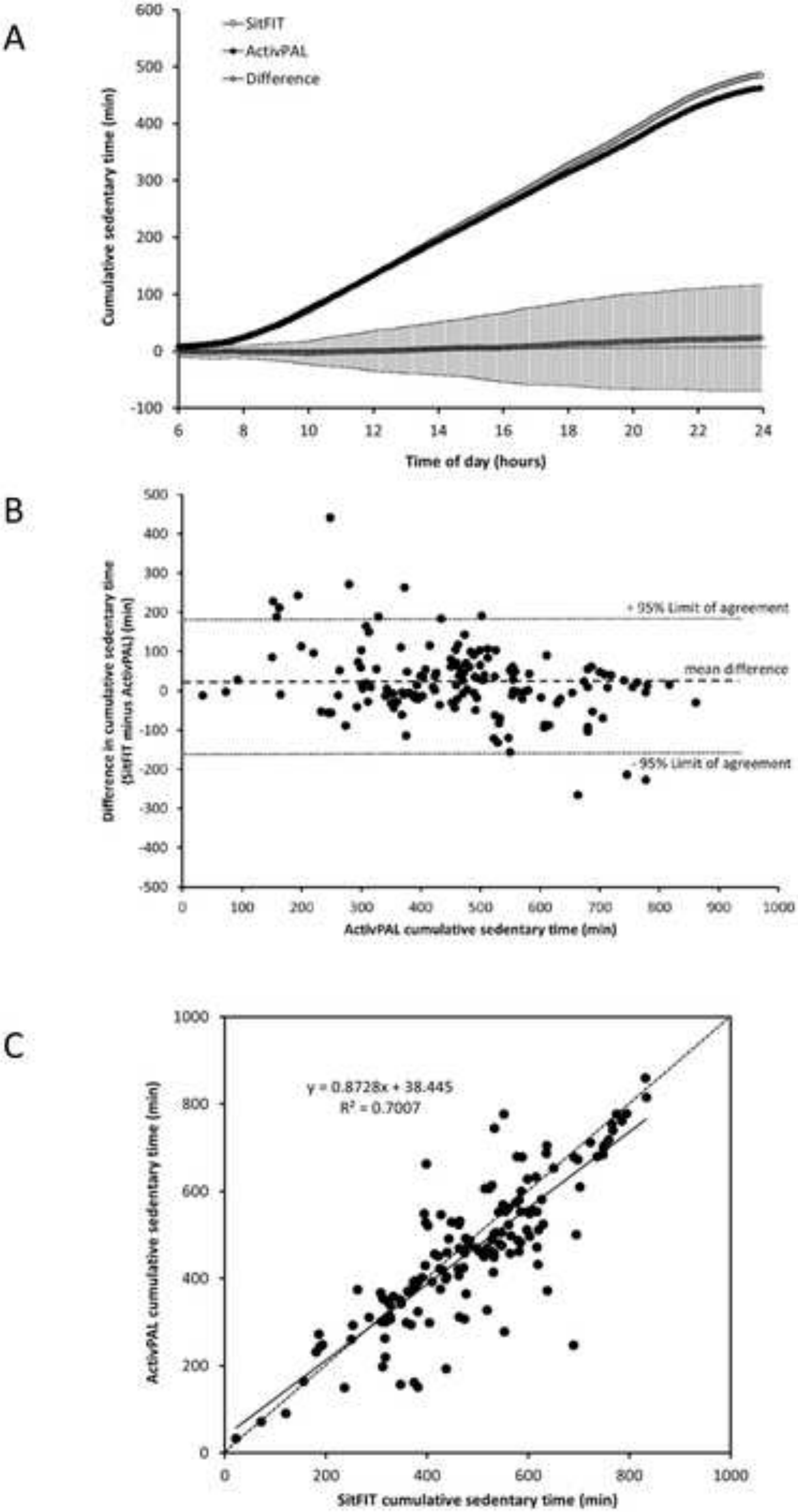

A
SitFIT
ActivPAL
Difference
Cumulative step count
12000
10000
8000
6000
4000
2000
0
-2000
-4000
6
8
10
12
14
16
18
20
22
24
Time of day (hours)
B
Difference in cummulative step count (SitFIT minus ActivPAL)
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
+ 95% Limit of agreement
mean difference
- 95% Limit of agreement
0
5000
10000
15000
20000
25000
30000
35000
ActivPAL cummulative step count
C
y = 1.0035x + 418.73
R² = 0.9608
ActivPAL cummulative steps
SitFIT cummulative steps
30000
25000
20000
15000
10000
5000
0

Figure 4


A
SitFIT
ActivPAL
Difference
Cumulative sedentary time (min)
600
500
400
300
200
100
0
-100
6
8
10
12
14
16
18
20
22
24
Time of day (hours)
B
Difference in cumulative sedentary time (SitFIT minus ActivPAL) (min)
500
400
300
200
100
0
-100
-200
-300
-400
-500
+ 95% Limit of agreement
mean difference
- 95% Limit of agreement
0
100
200
300
400
500
600
700
800
900
1000
ActivPAL cumulative sedentary time (min)
C
y = 0.8728x + 38.445
R² = 0.7007
ActivPAL cumulative sedentary time (min)
1000
800
600
400
200
0
0
200
400
600
800
1000
SitFIT cumulative sedentary time (min)