Accuracy and responsiveness of the StepWatch Activity Monitor and ActivPAL in patients with COPD when walking with and without a rollator

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ABSTRACT

Purpose: Evaluate the measurement properties of the StepWatch[TM] Activity Monitor (SAM) and ActivPAL in COPD.

Method: Whilst wearing both monitors, participants performed walking tasks at two self-selected speeds, with and without a rollator. Steps obtained using the monitors were compared with that measured by direct observation.

Results: Twenty participants aged 73 ± 9 yr ($FEV_1=35\pm13\%$pred; 8 males) completed the study. Average speeds for the slow and normal walking tasks were 34 ± 7 m·min^{-1}and 46 ± 10 m·min^{-1}, respectively. Agreement between steps recorded by the SAM with steps counted was similar irrespective of speed or rollator use (p=0.63) with a mean difference and limit of agreement (LOA) of 2 steps·min^{-1} and 6 steps·min^{-1}, respectively. Agreement for the ActivPAL was worse at slow speeds (mean difference 7 steps·min^{-1}; LOA 10 steps·min^{-1}) compared with normal speeds (mean difference 4 steps·min^{-1}; LOA 5 steps·min^{-1}) (p=0.03),

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but was unaffected by rollator use. The change in step rate between slow and normal walking via direct observation was 12 ± 7 steps·min^{-1} which was similar to that detected by the SAM (12 ± 6 steps·min^{-1}) and ActivPAL (14 ± 7 steps·min^{-1}).

Conclusions: The SAM can be used to detect steps in people who walk very slowly including those who use a rollator. Both devices were sensitive to small changes.

Key words: COPD; Motor activity; Ambulatory/Instrumentation

Figures: 3

Tables: 2

INTRODUCTION

For people with chronic obstructive pulmonary disease (COPD), physical activity (PA) has evolved as an important outcome measure in the evaluation of interventions such as pulmonary rehabilitation.[1] It is defined as any bodily movement produced by skeletal muscles that results in energy expenditure beyond the resting state.[2] In people with COPD, the level of daily PA has been demonstrated to influence healthcare utilization, morbidity and mortality.[3, 4] Despite the importance of optimizing daily PA in this population, selecting an appropriate device to obtain valid measures remains a challenge. This is especially true for those individuals who walk slowly or use a rollator to assist with ambulation.[5-7] Earlier work has shown that activity monitors that attach to the waist underestimate PA in individuals who adopt slow walking speeds.[6-10] This is because slow walking produces movement of insufficient magnitude of the centre of mass to be detected by these devices. Measuring PA is particularly problematic in those who use a rollator to assist with ambulation.[6, 7] This is likely to relate to the slower walking speeds characteristic of people who require gait aids,[11] as well as alterations in the normal gait pattern.

As slow walking diminishes movement in the limbs to a lesser extent than movement at the centre of mass,[11] we proposed that activity monitors which attach to the leg, rather than the waist, may yield accurate measures in people with COPD who are known to adopt slow walking cadences during daily life.[12] Following a review of the literature,[5, 9, 13-15] we decided to explore the measurement properties of two activity monitors that attached to the leg as they have yielded encouraging data in other clinical populations. Specifically, data reported by Resnick and colleagues[13] suggested that the StepWatch[TM] Activity Monitor

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(SAM; OrthocareInnovations, Seattle, Washington) may yield accurate measures of PA in individuals who walk slowly, including those who use a gait aid. This device attaches to the ankle. Similarly, the ActivPAL (PAL Technologies Ltd, Glasgow, Scotland), has been shown to yield accurate measures of PA in a healthy elderly population who walked at slow speeds.[15] This device attaches to the anterior aspect of the thigh. Both the SAM and ActivPAL are inexpensive, small, easily concealed by clothing and simple to use; features that make them attractive for monitoring PA in both the research and clinical setting. Nevertheless, the capacity of these devices to collect accurate information in people with COPD, who may use a rollator to assist with ambulation, is unknown. Further, the capacity of these devices to detect a small increase in PA is unknown. This is particularly important if these devices are used to evaluate the effect of therapies aimed at increasing PA in people with COPD.

Therefore, the aims of this study were to; (i) explore the accuracy and responsiveness of the SAM and ActivPAL in people with COPD and, (ii) determine if using a rollator during ambulation impairs the performance of these devices. To achieve both of these aims, our gold standard measure was manual step counting via direct observation. The results of this study will assist healthcare professionals to select the most appropriate device to measure PA in those people with COPD who walk slowly and/or use a rollator before and after pulmonary rehabilitation.

METHODS

Design:

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A cross-sectional observational study was undertaken during which data collection for each participant was completed during a single one-hour session. The study was approved by the appropriate Human Research Ethics Committees.

Participants:

Participants were recruited from referrals to out-patient pulmonary rehabilitation programs. Inclusion criteria comprised of a diagnosis of COPD and functional limitation defined as a six-minute walk distance (6MWD) $\leq$ 450 m prior to rehabilitation. This 6MWD threshold was selected as it indicates an impairment in walking capacity when compared with the 6MWD achieved by a population of healthy local Australians of similar age.[16] Individuals with any co-morbid condition that limited mobility were excluded from the study.

Protocol:

Once written informed consent was obtained, measurements were collected of height and weight. The most recent measurements of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were extracted from the medical notes. The activity monitors, the SAM and ActivPAL, were attached to each participant. The participants then completed four constant-pace walking tasks, performed in a standardized order.

Each walking task was performed for five minutes within a 20 m level, enclosed corridor. Tasks were separated by a 30-minute rest; a time period previously used to allow

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cardiorespiratory responses to return to resting values between successive walking-based assessments of exercise capacity.[17] As this study did not aim to measure functional exercise capacity, there was no need to conduct these walking tasks over six minutes. The first two walking tasks were undertaken at a speed considered to be 'slow' by the participants with the final two walking tasks undertaken at a speed considered to be 'normal' by the participants. The first walk at both speeds was completed without a rollator and the second walk at both speeds was completed using a rollator.

The process used to determine walking speeds and ensure that a constant pace was maintained has been described elsewhere.[7] This method was chosen to allow each participant to walk at an individualized slow and normal pace, which, in contrast to arbitrary walk speeds selected by the investigators, was more likely to be reflective of daily life.[7] Briefly, the time taken for each participant to; (i) walk for 40 m at a pace that they considered to be slow and, (ii) walk for 40 m at a pace that they considered to be normal were used to calculate the slow and normal walking speeds, respectively. Thereafter the 20 m corridor was marked at 5 m intervals with orange cones. The speed during each walking task was kept constant by using audio-signals that corresponded to a specific walking speed. That is, each audio-signal emitted a beep corresponding to when the participant needed to pass a cone in order to maintain the speed. The investigator walked with each participant for the first minute to provide verbal feedback regarding the use of the audio-signals. All participants were encouraged to maintain the pace dictated by the audio-signals, but to adopt a natural walking pattern. During each walking task, for each participant, the investigator counted the number of steps taken over three separate 30-second intervals (i.e. at the beginning of the second,

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third and fourth minutes). The average of these three samples was used to determine the average step rate, for each participant, for each walking task.

Equipment and measurements:

StepWatch^{TM} Activity Monitor

The SAM was attached to the participant's right ankle using a Velcro strap. It is a small (75 × 50 × 20 mm), light (38g) microprocessor controlled step counter that responds to time, acceleration and position. During the calibration procedure undertaken prior to data collection, the participant's height was entered and the settings that pertained to 'range of walking speed' and 'leg motion' were selected as 'moderate' and 'normal', respectively. For each participant, the first 40 steps taken whilst wearing the SAM were observed to ensure that the device was detecting steps, as indicated by a flashing light emitting diode on heel strike.[18] The SAM has a sampling frequency of 128 Hz and data are available in one-minute epochs.

ActivPAL

The ActivPAL was attached to the anterior aspect of the participant's thigh using a 10 cm by 14 cm transparent film dressing (3M Tegaderm^{TM}, 3M, St. Paul, Minnesota). The device is a small (35 × 53 × 7 mm), light (20 g) uni-axial piezoresistive accelerometer. The ActivPAL has a sampling frequency of 10 Hz and data are available in fifteen-second epochs.

Data management and analysis:

Raw data from the SAM and ActivPAL were exported to Microsoft Excel® for further analyses. Data collected during the whole minutes of each walking task were averaged and converted into step rate. Analyses were performed using the Statistical Package for Social Sciences (SPSS version 17.0; Chicago, Illinois) with $p < 0.05$ used to denote statistical significance. Data are expressed as mean ± standard deviation unless otherwise stated.

Accuracy

We used repeated measures analysis of variance (ANOVA) to examine the effect of rollator, walking speed and the interaction between the two, on the difference in step rate between SAM and direct observation. The same procedure was undertaken using data collected from the ActivPAL. Agreement analyses were undertaken according to the methods described by Bland and Altman.[19]

Responsiveness

To determine if the SAM and ActivPAL could detect a difference in step rate between walking speeds with and without the rollator, a repeated measures ANOVA was used to examine the effect of rollator, walking speed and the interaction between the two, on step rate.

Sample size calculation

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Prospective sample size calculations were conducted to attain a precision around our estimate of the limit of agreement ≤ 6 steps·min^{-1}. This value was chosen as earlier work demonstrated that an increase of 12 steps·min^{-1} during self-selected walk tasks was perceived as the difference between slow and normal paced walking in people with COPD.[7] Therefore we speculated that a difference less than half this value would not be perceived as a different walking speed by the average person with COPD. Using data available in the literature, we estimated the SD of the difference to be 3 steps·min^{-1} (52 steps/20 minutes).[6] Using the methods described by Bland and Altman,[19] we determined that a sample size of 20 participants was needed for the 95% confidence interval around the limit of agreement (LOA) to span 5 steps·min^{-1}.

RESULTS

Participants:

Twenty-two participants consented to participate in this study. Data from two people were excluded as they were unable to complete the walking tasks without resting and therefore, their walking cadence was not constant during the tasks. All other participants were able to maintain a constant walking speed during each task (figure 1a-b) and there were no adverse events. The characteristics of the 20 participants who completed the study are summarized in table 1. Five (25%) people used a rollator in their home environment. *Insert table 1 and figure 1a-b about here*

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Agreement:

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There was no interaction (rollator $\times$ walking speed; $F_{1, 19} = 0.24$; $p = 0.63$), effect of rollator ($F_{1, 19} = 0.12$; $p = 0.73$) or walking speed ($F_{1, 19} = 0.03$; $p = 0.86$) on the difference between step rate derived using the SAM and via direct observation. This indicated that the difference between step rate derived using the SAM and direct observation was similar across all walking tasks and therefore we grouped data from all four walks in the Bland-Altman analysis (figure 2). The mean difference (i.e. bias) between the step rate derived using the SAM and direct observation was 2 steps·min^{-1} with the LOA of 6 steps·min^{-1}. The upper and lower LOA occurred at 8 (95% confidence interval (CI); 6 to 9) and -4 (95% CI; -5 to -2) steps·min^{-1}, respectively. *Insert figure 2 about here*

ActivPAL

There was no interaction (rollator $\times$ walking speed; $F_{1, 19} = 0.58$; $p = 0.46$) or effect of rollator ($F_{1, 19} = 0.01$; $p = 0.91$) on the difference between step rate derived using the ActivPAL and direct observation. This indicates that the difference between the step rate derived using the ActivPAL and direct observation was not affected by the use of a rollator. However, there was a significant effect of walking speed ($F_{1, 19} = 5.75$; $p = 0.03$) on the difference between step rate derived using the ActivPAL and direct observation. This indicates that the difference between the step rate derived using the ActivPAL and direct observation differed between walking speeds and therefore, we prepared separate Bland-Altman plots for slow and normal

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walking speeds (figure 3a and 3b, respectively). The mean difference (i.e. bias) in step rate derived using the ActivPAL and direct observation at slow walking speeds was 7 steps·min^{-1} with the LOA of 10 steps·min^{-1}. The upper and lower LOA occurred at 17 (95% CI; 14 to 20) and -4 (95% confidence interval; -7 to -1) steps·min^{-1}, respectively. The mean difference in step rate derived using the ActivPAL and direct observation at normal walking speeds was 4 steps·min^{-1} and the LOA of 5 steps·min^{-1}. The upper and lower LOA occurred at 10 (95% confidence interval; 8 to 11) and -1 (95% CI; -3 to 0) steps·min^{-1}, respectively. *Insert figure 3a-b about here*

Responsiveness:

For data collected using the SAM, there was no interaction (rollator × walking speed; $F_{1, 19}$ = 0.23; p = 0.63) but a significant effect of rollator ($F_{1, 19}$ =12.39; p = 0.02) and walking speed ($F_{1, 19}$ = 88.69; p < 0.01) on step rate. This indicates that the SAM was able to detect the difference in step rate associated with changing walking speeds and using a rollator. Likewise, for data collected using the ActivPAL, there was no interaction (rollator × walking speed; $F_{1, 19}$ = 0.01; p = 0.93) but a significant effect of rollator ($F_{1, 19}$ = 12.10; p = 0.003) and walking speed ($F_{1, 19}$ = 102.86; p < 0.001) on step rate. This indicates that the ActivPAL was able to detect differences in step rate associated with changing walking speeds and using a rollator. Step rate for each walking task are presented in table 2. *Insert table 2 about here*

DISCUSSION

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This is the first study to examine the measurement properties of the SAM and ActivPAL in individuals with COPD at two self-selected walking pace according to previous walking speed. Further, this study determined whether or not the use of a rollator to assist with ambulation affected the accuracy or responsiveness of these devices. The important findings of this study are; (i) the capacity of the SAM to detect steps was similar regardless of walk speed or rollator use, (ii) the capacity of the ActivPAL to detect steps was affected by walk speed but not rollator use and, (iii) both devices were able to detect small changes in step rate.

Accuracy of the devices:

A study by Pitta et al on 22 COPD patients found that these individuals tend to walk 1- to 2-minute blocks over a 24-hour period,[20] thus the monitors we chose would be valid to measure PA in COPD patients. Our data reveal that the capacity of the SAM to measure step rate was similar at slow and normal walk speeds, regardless of whether or not a rollator was used. The mean difference between step rate derived using the SAM and direct observation was 2 steps·min^{-1}, which is trivial compared with that reported for other commercially-available for devices such as the Minimod, SenseWear armband and Digiwalker pedometer.[6, 21] The excellent agreement in step rate derived using the SAM and direct observation extends the findings of Resnick et al[13] who reported a strong correlation between these variables (r = 0.98) in a group of elderly people (aged 86 ± 6 yr) of whom 22 (73%) used a walking aid to assist with ambulation. Although a strong correlation indicates that these measures were related, Bland-Altman analyses are needed to demonstrated agreement and therefore we report our results in terms of mean difference (i.e. bias) and

LOA. In contrast with the SAM, our data indicate that the capacity of the ActivPAL to detect steps was impaired at slow walking with the bias increasing from 4 to 7 steps·min^{-1} between normal and slow walking speeds, respectively. It is likely that the shorter stride lengths associated with walking at slower speeds[22] reduced movement at the thigh and thus impaired the capacity of the ActivPAL to detect steps. The shorter stride lengths will reduce movement at the ankle to a lesser extent; a factor that may explain why the SAM, which attaches to the ankle, had a similar capacity to detect steps at both walking speeds.[23] In addition to the position of the devices, the difference in the capacity of the SAM and ActivPAL to detect steps at the two walking speeds may also reflect the superior sampling frequency of the SAM (128 Hz) compared with the ActivPAL (10 Hz).

Although our data indicates that the ActivPAL underestimated step rate at slow walk speeds, it is important to note that the walk speed selected by our participants for both the 'normal' (46 ± 10 m·min^{-1}) and 'slow' (34 ± 6 m·min^{-1}) walks was considerably slower than that used in other studies. For example, in the study by Langer et al,[6] the participant who walked the slowest at 42 m·min^{-1} was considered an outlier and excluded from the statistical analysis. In this individual, the Minimod underestimated step rate by approximately 39 steps·min^{-1}, and SenseWear armband underestimated step rate by approximately 56 steps·min^{-1}.[6] This compares favourably with our data, demonstrating that the ActivPAL underestimated step rate by 7 and 15 steps·min^{-1} with the rollator and 4 and 26 steps·min^{-1} without the rollator in the two individuals who walked the slowest (25 m·min^{-1}) in our study; a speed considerably slower than the outlier in the study by Langer et al.[6] Therefore, although ActivPAL does underestimate steps at very slow walking speeds, it seems to outperform other popular, more expensive, commercially-available devices, such as the Minimod and SenseWear armband.

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An important and novel finding of our study is that the use of a rollator did not affect the capacity of the SAM or the ActivPAL to detect step rate. People with COPD who are characterized by a low 6MWD and marked dyspnea on exertion benefited from using a rollator both in terms of exercise capacity and reduction in dyspnea.[24, 25] Further, there is a high level of satisfaction associated with their use in the community.[26] Given the increasing use of rollators by people with COPD, it is important that clinicians and researchers are able to obtain accurate measures of PA in this subgroup. To our knowledge, this study is the first to identify two activity monitors that yield accurate measures of PA in people with COPD who use a rollator.

Responsiveness:

For both activity monitors, there was a significant effect of walk speed, suggesting that the SAM and ActivPAL could detect the difference in step rate associated with changing from the slow to normal walk speed, regardless of whether the participant was using a rollator. The change in step rate between slow and normal walking, calculated via direct observation was 12 ± 7 steps·min^{-1}; a difference of similar magnitude as detected by the SAM (12 ± 6 steps·min^{-1}) and ActivPAL (14 ± 7 steps·min^{-1}). A more impressive result is that there was a significant effect of rollator, suggesting that the SAM and ActivPAL could detect the trivial decrease in step rate associated with changing to use a rollator to assist with ambulation, regardless of walk speed. The change in step rate between using and not using the rollator, calculated via direct observation was 3 ± 3 steps·min^{-1}; a difference of similar magnitude as detected by the SAM (3 ± 4 steps·min^{-1}) and ActivPAL (3 ± 5 steps·min^{-1}). Studies that have

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examined the measurement properties of activity monitors usually focus on accuracy or validity of the devices. Our study extends earlier work [5, 9, 13-15] by confirming the excellent responsiveness of these two devices to detect very small changes in step rate.

LIMITATIONS

We examine the measurement properties of the SAM and ActivPAL exclusively during walking tasks as this is a common activity of daily living.[3] We did not explore the measurement properties of these devices during other activities, such as cycling and also, did not determine the extent to which these devices may mis-classify movement associated with travelling in a car as steps.

CONCLUSIONS

Both the SAM and ActivPAL underestimated step rates in the participants with COPD, however the difference was very small. Both devices were responsive to small changes in step rate. The SAM was accurate in detecting step rate regardless of walking speed or rollator use. In contrast, the accuracy of the ActivPAL to detect step rate was affected by walking speed but not rollator use. These devices can be used to assess physical activity in individuals with COPD, including those who use a walking aid such as a rollator.

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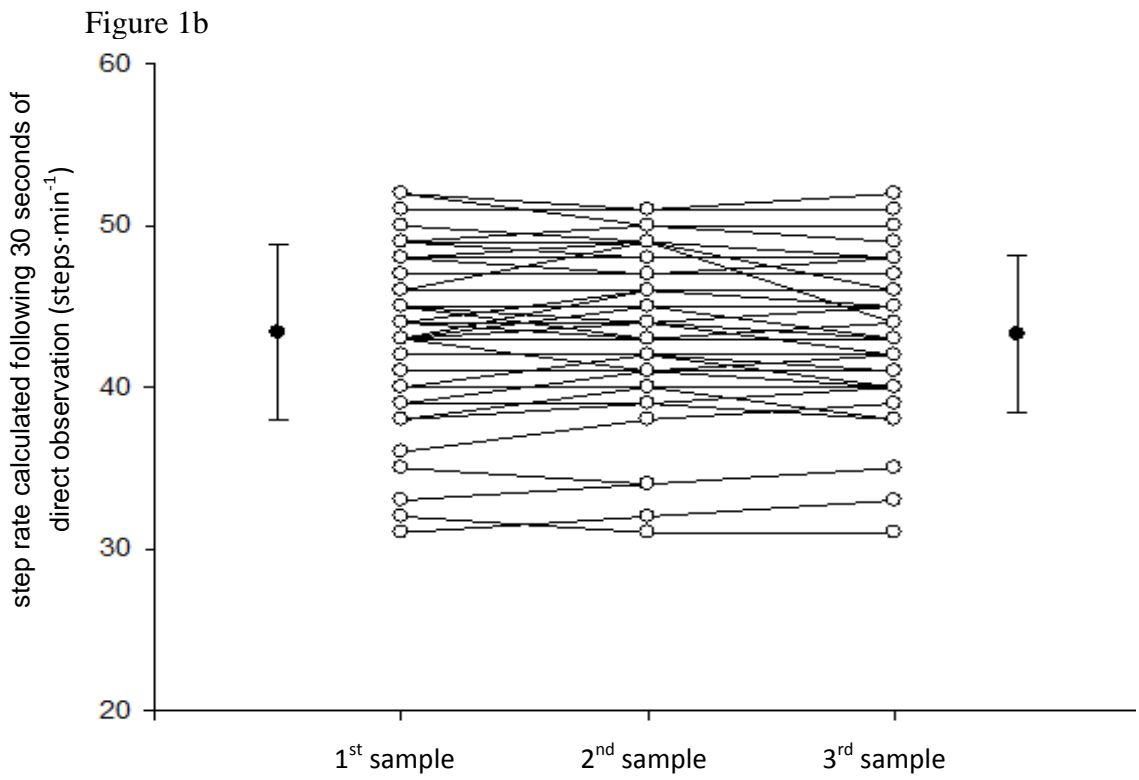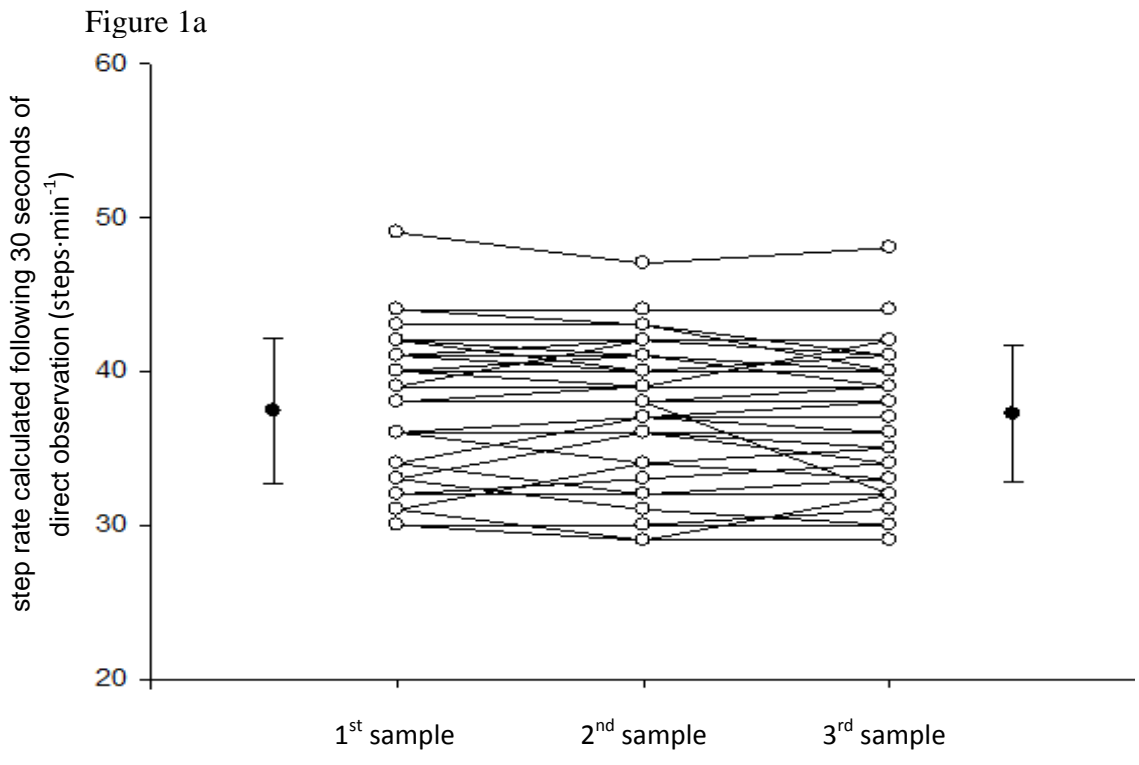
Figure 1a

Figure 1b

Figure 1: Step rate calculated using the three 30-second samples of direct observation for walking tasks undertaken at slow speed (1a) and normal speed (1b). Each subject contributed two lines to Figure 1a and 1b (i.e. for the walking task performed with and without the rollator). Also shown are the group mean (closed circles) and standard deviation (error bars) for the 1st and 3rd 30-second samples. Note the consistency in step rate during the tasks.

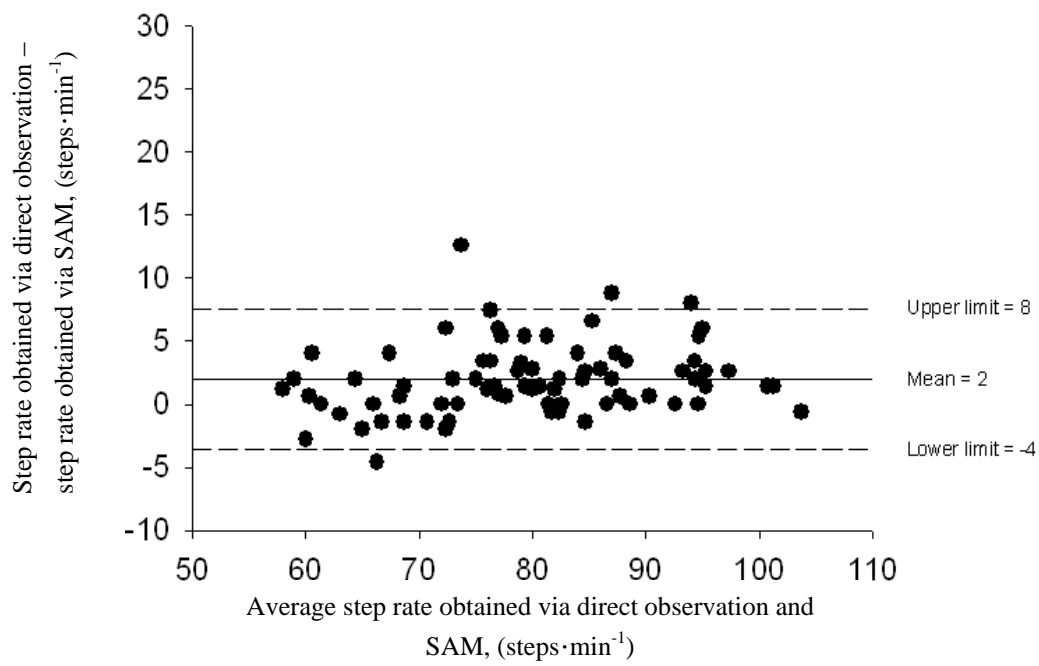Measurement properties of accelerometers

Figure 2

Figure 2: Bland Altman plot for step rate obtained via direct observation and via the StepWatch Activity Monitor (SAM). Data from all four walking tasks are included.
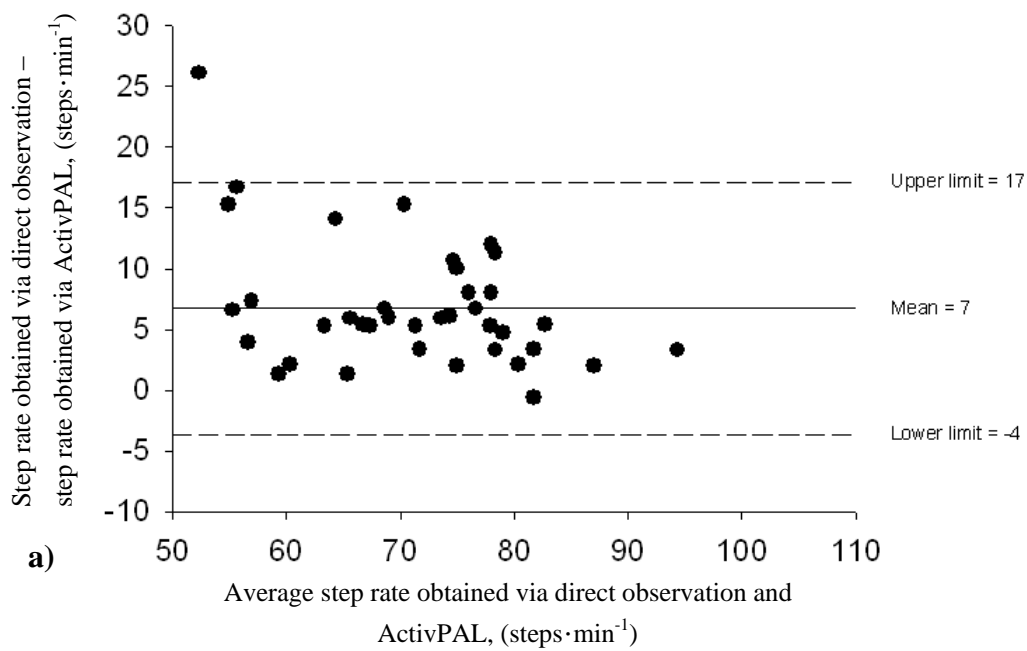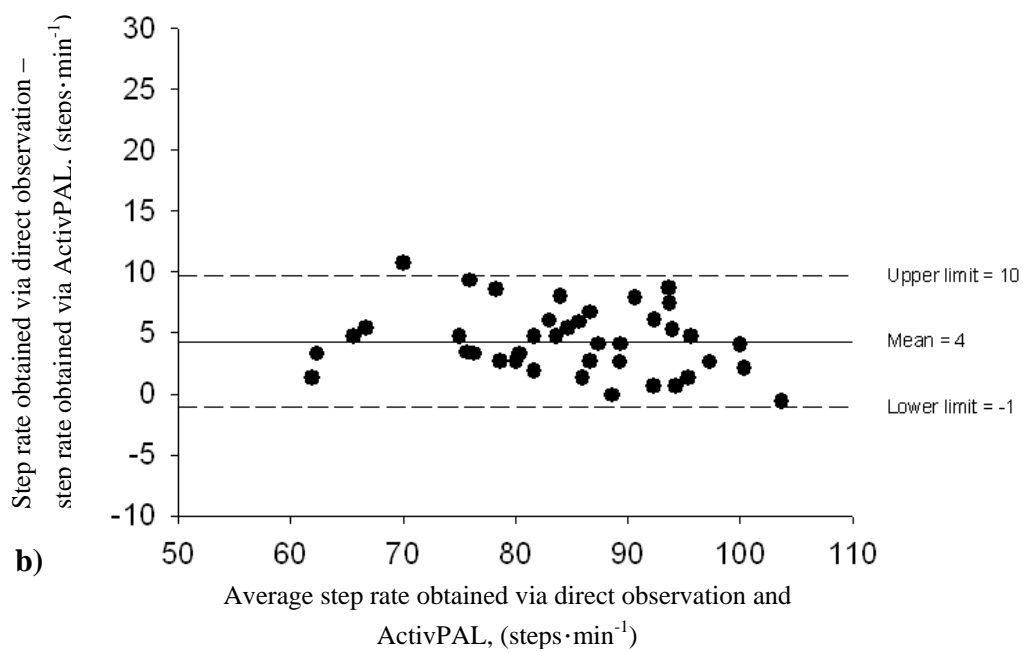
Figure 3a

a)

Figure 3b

b)

Figure 3: Bland Altman plots for step rate obtained via direct observation and the ActivPAL at (a); slow walk speed (with and without rollator) and (b), normal walk speed (with and without rollator).

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Table 1: Characteristics of study participants (n = 20; 8 males)

Variable	Mean ± SD
Age, yr	73.0 ± 8.5
Height, m	1.67 ± 0.09
Weight, kg	69.0 ± 20.2
Body mass index, $kg \cdot m^{-2}$	24.6 ± 6.2
Long term oxygen therapy (n)	6
FEV_1, L	0.84 ± 0.30
FEV_1 % predicted	35 ± 13
FVC, L	2.17 ± 0.63
FVC% predicted	63 ± 20
FEV_1/FVC	40 ± 12
6-minute walk distance, m	338 ± 85
6-minute walk distance predicted, %[†]	55 ± 14
Slow walking speed, $m \cdot min^{-1}$	34 ± 6
Normal walking speed, $m \cdot min^{-1}$	46 ± 10
Modified MRC Dyspnea Grade (0 – 4)*	2.5 (2 – 3)
BODE score*	4.5 (4 – 6)

[*] Median (Inter quartile range) [†]Percent predicted based on formula obtained from Jenkins et al.[21]

MRC, Medical Research Council; BODE, body mass index, airflow obstruction, dyspnea & exercise capacity index.

Median time between participation in the study and most recent measurement of 6 minute walk distance and lung function and was one and four months, respectively.

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Table 2: Step rates (in steps·min^{-1}) for all walking tasks

	Observed	SAM	ActivPAL
Slow walk[*]	75 ± 8	73 ± 8	68 ± 11
Normal walk[*]	85 ± 10	85 ± 10	83 ± 11
Difference (normal - slow)[*]	$12 ± 7^{\gamma}$	$12 ± 6^{\gamma}$	$14 ± 7^{\gamma}$
Walk without rollator[†]	83 ± 12	80 ± 11	74 ± 12
Walk with rollator[†]	79 ±11	77 ± 10	77 ± 14
Difference (without - with rollator)[†]	$3 ± 3^{\gamma}$	$3 ± 4^{\gamma}$	$3 ± 5^{\gamma}$

Data are mean ± SD.

*: includes data collected irrespective of whether a rollator was used.

†: includes data collected irrespective of walking speed

γ: denotes significance within group (p<0.001)

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