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PHYSICAL ACTIVITY MONITORING: ADDRESSING THE DIFFICULTIES OF ACCURATELY DETECTING SLOW WALKING SPEEDS.

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ABSTRACT

Objective: This study aimed to test the sensitivity and reproducibility of a multi-sensor activity monitor (SWM) in patients with Chronic Obstructive Pulmonary Disease (COPD).

Background: Activity monitors need to detect slow speeds of walking to be of use in patients with COPD.

Methods: 57 COPD patients [mean (SD) age 70.5 (9.3) years, FEV_1 60.9 (19.3) % predicted, 30 male] completed an incremental shuttle walk test (ISWT) wearing a SWM. 20 patients repeated an ISWT wearing the same SWM.

Results: *Sensitivity to detect speed variation:* Differences were detected between metabolic equivalents (METS) and between step count for levels of the ISWT ($p<0.001$). *Reproducibility:* Within monitor reproducibility between two ISWT was satisfactory for total energy expenditure and step count ($p<0.001$).

Conclusions: The SWM is able to detect slow (standardised) speeds of walking and is an acceptable method for measuring physical activity in individuals disabled by COPD.

KEY WORDS

Chronic Obstructive Pulmonary Disease

Incremental shuttle walk test

Physical activity

Reliability and validity

Sensitivity

Sensitivity, reproducibility of the SWM

ABBREVIATIONS

Chronic obstructive pulmonary disease: COPD

Coefficient of variance: CV

Endurance shuttle walking test: ESWT

Forced expiratory volume in 1 second: FEV_1

Forced expiratory volume in 1 second / forced vital capacity: FEV_1/FVC ratio

Global Initiative for Obstructive Lung Disease: GOLD

Incremental shuttle walking test: ISWT

Metabolic Equivalents: METS

Pulmonary Rehabilitation: PR

Respiratory exchange ratio: RER

The multi-sensor activity monitor (SenseWear PRO2 Armband): SWM

Six minute walk test: 6MWT

INTRODUCTION

A reduction in physical activity has been linked with decline in lung function (1), hospitalisation (2) and mortality (2;3) in people with chronic obstructive pulmonary disease (COPD). There is evidence that habitual physical activity is modifiable by interventions such as pulmonary rehabilitation (PR) leading to significant health benefits (4). Self-reported assessment of physical activity may be inaccurate in patients with COPD (5) and therefore a more objective measurement is desirable.

A device must be able to detect all activity performed by patients to be meaningful. The pedometer provides a step count which has been shown to have moderate reproducibility in patients with COPD but it may not be as accurate in patients, as it is in healthy individuals (6;7). It is possible that the pedometer is not sensitive enough to detect the lower intensity movement of the disabled patient (8).

Previous reports have described the use of physical activity monitors to identify brisk walking in patients with COPD, as well as in healthy individuals (9-12). Various physical activity monitors are commercially available but the multi-sensor activity monitor (SenseWear PRO2 Armband) (SWM) (BodyMedia, Pittsburg, US) has recently been found to have the greatest validity during standardise physical activity (12). However, currently we are still unsure about the sensitivity of this device, particularly at detecting steps and energy expenditure at walking speeds less than 3.27km/h.

The SWM has been shown to detect changes in walking speed but speeds were not standardised or wide ranging (13;14). The SWM has been described as being a reliable and valid way of collecting step and energy expenditure data in patients with COPD measured during standard exercise tests; the incremental shuttle walking test (ISWT) and the six minute walk test (6MWT) (15). However, due to the cumulative reporting of the data it was not confirmed whether the monitors can detect slow speeds of walking.

We know patients with COPD sacrifice speed of walking for duration (16). These findings confirm the importance of accurately detecting slow speeds of walking in this population. Authors have documented concerns about the accuracy of the SWM at slower speeds of walking (17). Although the literature suggests that individuals with COPD accumulate a much lower number of steps than is recommended we cannot be sure whether patients have low levels of activity or if the device failed to detect activity at a low intensity (7).

The problem remains that the SWM has not yet been evaluated at slow speeds of walking. This is an increasingly popular outcome measure and the robustness of the device must be understood to be confident in this outcome. Therefore, the aim of this study was to test the sensitivity and reproducibility of the SWM to determine whether the device is able to detect slower speeds of walking commonly adopted by individuals with COPD.

METHODS

Study design

A prospective observational study design was employed. Monitor sensitivity was assessed with 57 clinically stable patients with a diagnosis of COPD (forced expiratory volume in 1 second (FEV_1) < 80% or forced expiratory volume/forced vital capacity (FEV_1/FVC) ratio < 70% (18). Within monitor reproducibility was assessed with 20 of the patients. All patients were eligible for pulmonary rehabilitation, suggesting they were disabled by breathlessness and had no physical and psychosocial co-morbidities affecting their ability to participate in a walking programme. Patients who were unable to complete one level of the ISWT were excluded (19).

Activity Monitor

The SWM is a commercially available device which estimates energy expenditure (Kcal), METS and step count from an accelerometer. The cost is approximately £660 per monitor and an additional £1000 covers the software required to download data. Demographic characteristics (gender, age, height and weight) are required to be programmed into the device to estimate energy expenditure using a generalised propriety equation (Innerview ® Software Version 5) developed by the manufacturer.

Incremental shuttle walking test [ISWT (19)]

Sensitivity, reproducibility of the SWM

The ISWT is an objective test of maximum exercise capacity and requires subjects to walk up and down a 10 metre course which is marked out by two cones placed nine metres apart. The walking speed is externally paced and dictated by a pre-recorded audio signal (a 'bleep'). There are 12 levels at increasing speeds of walking, each levels lasts for one minute. The test is terminated due to symptoms or failure to maintain walking speed.

Sample

Fifty seven clinically stable patients with a diagnosis of COPD completed the ISWT wearing a SWM. The device is worn halfway between the elbow and the shoulder on the back of the right arm. Energy expenditure, METS and step count were recorded and only taken from complete shuttle levels walked. Twenty of the patients repeated the ISWT wearing the same activity monitor after a 30 minute rest period. The start of the ISWT was time stamped to ensure accurate data extraction. For each of the 20 patients comparisons were made between ISWT one and ISWT two at the end of each completed level for both energy expenditure and step count.

Statistical analysis

Sample size was determined by the results from a previous pilot study (n=26) showing a difference of approximately 0.5 MET between each level of the ISWT (20). Based on these results the study was powered to detect a difference of 0.5 MET between each of the five different walking speeds employed in the ISWT. It was calculated that 57 subjects would be required in total (80% power alpha=0.05).

Sensitivity, reproducibility of the SWM

Data was analysed using SPSS version 18.0. An ANOVA with Tukey post hoc comparisons assessed the sensitivity of the SWM by detecting differences in METS and step count between walking speeds used during the ISWT.

Reproducibility data for the ISWT was assessed using the intra-class correlation coefficient (ICC) and the results were plotted using a plot of agreement.

Ethics

All procedures for the experimental methods were approved by Leicestershire, Northamptonshire and Rutland Research Ethics Committee 1 (approval no. 07/Q2501/6) and Coventry University Ethics Committee (approval no. S12.07).

RESULTS

Patient characteristics

The characteristics of the patients are presented in Table 1. Fifty seven patients completed levels one and two (at 1.8km/h and 2.44km/h respectively) of the ISWT, 55 completed at level three (3.03km/h), 47 and 37 completed levels four (3.63km/h) and five (4.25km/h) respectively. The mean ISWT distance achieved was 343.4m (± 150.7m (range = 80-660m)).

Sensitivity, reproducibility of the SWM

Sensitivity to different speeds of walking

Differences were identified between METS and between step count across all five levels of the ISWT (METS: F (2,8) = 31.11, p<0.001. Step count: F (2,8) = 117.37, p<0.001). A difference of 0.9 METS was found between the slowest speeds of the ISWT (1.80km/h + 2.44km/h) (p<0.001). Small and no significant differences were detected at the faster speeds (Figure 1). Differences in step count were between all speeds (p<0.05) (Figure 2). However in seven of the 57 patients the step count was not detected by the device at the slowest speed of walking (1.80km/h). These patients were not significantly different in terms of their BMI, FEV_1% predicted, age, distance walked on the ISWT or MRC dyspnoea grade.

Reproducibility

Good within monitor test-retest reproducibility was demonstrated using the ISWT. The ICC was r=0.98 (p<0.001) for the total energy expenditure at the end of each completed level (Figure 3) and r=0.94 (p<0.001) for the total step count at the end of each completed level.

For information relating to the validity of the device please refer to S1.

DISCUSSION

In this study we have reported the sensitivity and reproducibility of the SWM in detecting slow speeds of walking. The importance of objective measurement of physical activity in patients with COPD is increasingly recognised. For such measurements to be accurate in patient populations, the device should be able to measure activity at slow speeds of walking. However, authors have expressed concerns about the accuracy on the SWM in detecting the slow speeds of walking adopted by the disabled patient (8;12;17)

The SWM has been shown to detect changes in different types of physical activity, including walking (13). The walking speeds used in the latter study were selected by the individual as either fast or slow. These values correspond roughly to levels 4 and 5 of the ISWT and do not represent a wide range of speeds. More recently Van Remoortel and colleagues tested the monitor at a slower walking speed (3.27km/h) but this still only equates to level 3 of the ISWT (14). Uniquely we report the sensitivity of the monitor at even slower speeds, 1.80km/hr through to 4.25km/hr (levels 1-5 of the ISWT) (Figure 2).

Furlanetto et al reported that the SWM was inaccurate at counting steps but accurate at estimating energy expenditure. This is in contrast to our study which found step count to be more sensitive to change in walking speed (17). During Furlanetto et al's study subjects walked on a treadmill. We believe it is important to test the device during free walking on the ground as gait and energy requirements are different during treadmill walking (23-25) and may not truly reflect domestic physical activity. Furthermore standardised walking speeds were not applied, making it difficult to conclude if the SWM can distinguish between speeds and subjects were only monitored for 1 minute, therefore, steady state could not have been reached (17).

Despite the sensitivity of step count, it maybe worth considering that in approximately 12% of patients step count was not detected at the slowest speed (1.80Km/h). This supports previous research which found the SWM to significantly undercount steps when compared with a visual step count (21). Combined, these findings highlight the importance of reporting multiple variables indicative of physical activity levels.

We have established that the SWM is reproducible in reporting energy expenditure and step count at slow speeds of walking, tested during the ISWT. In fact, variability was less at lower levels of activity, increasing as energy expenditure reached an excess of 20Kcal. Patel et al found the SWM to be a reproducible measure of energy expenditure during exercise testing in patients with COPD. However, they have reported cumulative activity rather than the accuracy of the monitor at slow walking speeds, potentially underestimating activity if not all detected (15).

A potential limitation of the study is that the statistical power of the results reduced as walking speed increased. As speed increased fewer patients were able to achieve that speed (e.g. 3.63Km/hr n=47 and 4.25Km/h n=37). However the particular aim of this study was to assess the accuracy of the SWM at slower speeds. We have not compared actual step count with step count detected by the monitor. Therefore we can not be certain that as speed increases patients are taking more steps, it maybe that the monitor is better at capturing the data at faster walking speeds. However, we would expect patients to take more steps at faster speeds as the distance patients cover is increased by 10 meters each level of the ISWT.

Whilst accelerometers are still primarily a research tool there has been evidence of the clinical use of pedometers (26), and the development of accelerometers within clinical services is currently being evaluated (22). Within the context of rehabilitation, the devices may have a number of applications. Firstly as an outcome measure but also as an aid to exercise prescription and monitoring. A recent review suggests that PR may increase physical activity indicating a change in patients behaviour (23). However, in order to be confident of these results clinicians need to trust the accuracy of the devices used to measure physical activity. It is therefore important to understand the properties of the devices at various slow speeds of walking commonly replicated during a rehabilitation programme and everyday life. It is not uncommon to prescribe a walking programme from performance on the ISWT (24), if we can therefore generate a value for energy expenditure and steps at a particular speed we can be more confident in the accuracy of the device.

Choosing which accelerometer to use is difficult as a number are currently available and each have different strengths and weaknesses depending on the speed of walking and the variable measured (11) . The present study supports the use of the SWM after evaluating the device in terms of sensitivity and reproducibility at standardised slow speeds of walking typical of individuals with COPD. The device is an acceptable method for measuring slow standardised speeds of walking and by considering all available variables (step count, METS, energy expenditure) it can confidently be used in detecting and describing physical activity at slow speeds in patients with COPD.

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Conflicts of interests

SH, EH, RS, CS, MS, MM, SS have no actual or potential conflicts of interest.

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FIGURE LEGENDS

Figure 1. Mean METS for each walking speed of the ISWT.

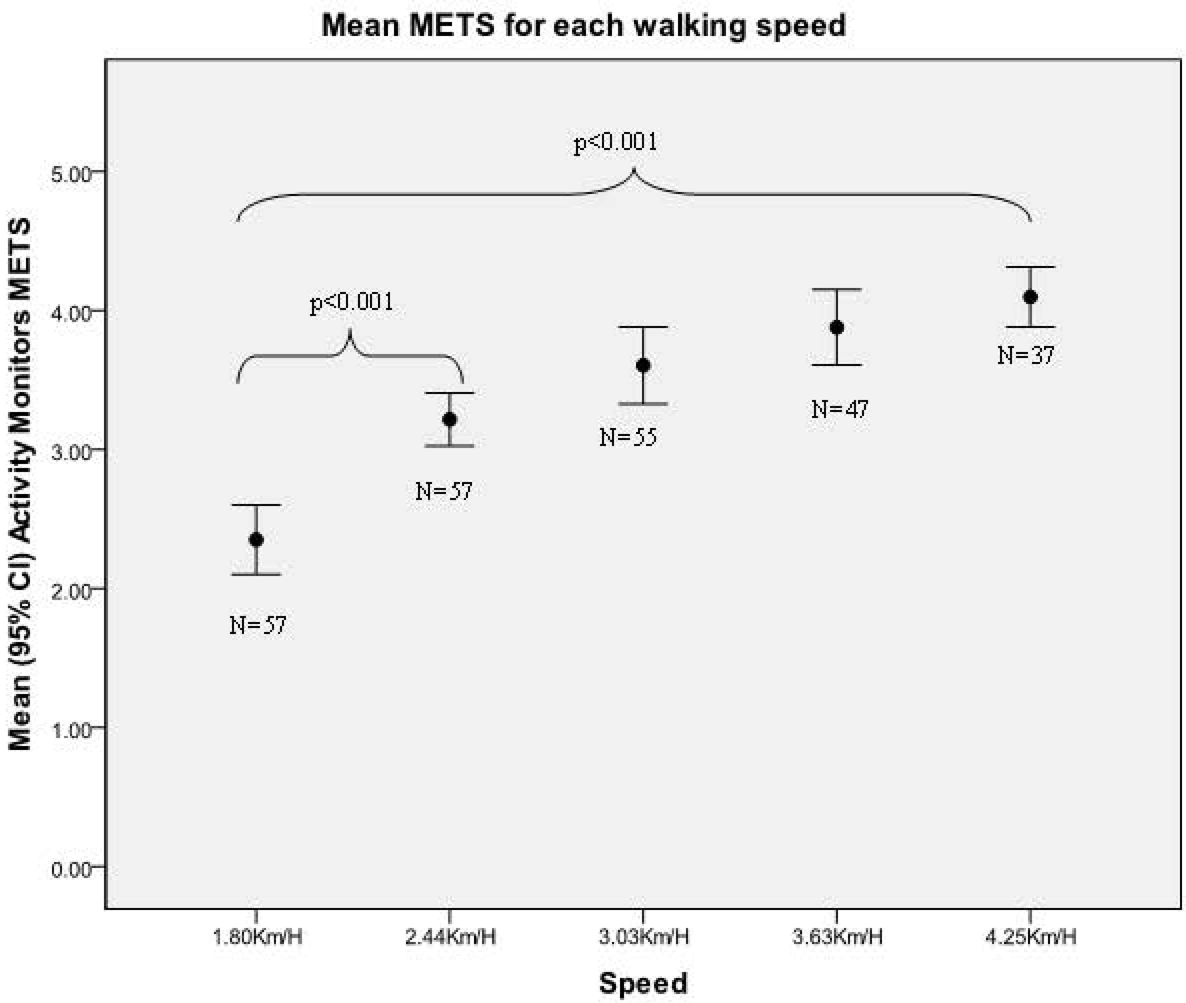
Figure 2. Mean steps for each walking speed of the ISWT.

Figure 3. The differences in total EE at iso work between ISWT 1 and 2. 1 patient completed up to level 1 only, 1 patient completed up to level 2, 4 patients completed up to level 3, 2 patients completed up to level 4, 12 patients completed up to level 5. The solid line demonstrates mean difference (0.87). The dotted lines represent +/- 2 SD from the mean difference (+5.57, -3.83).

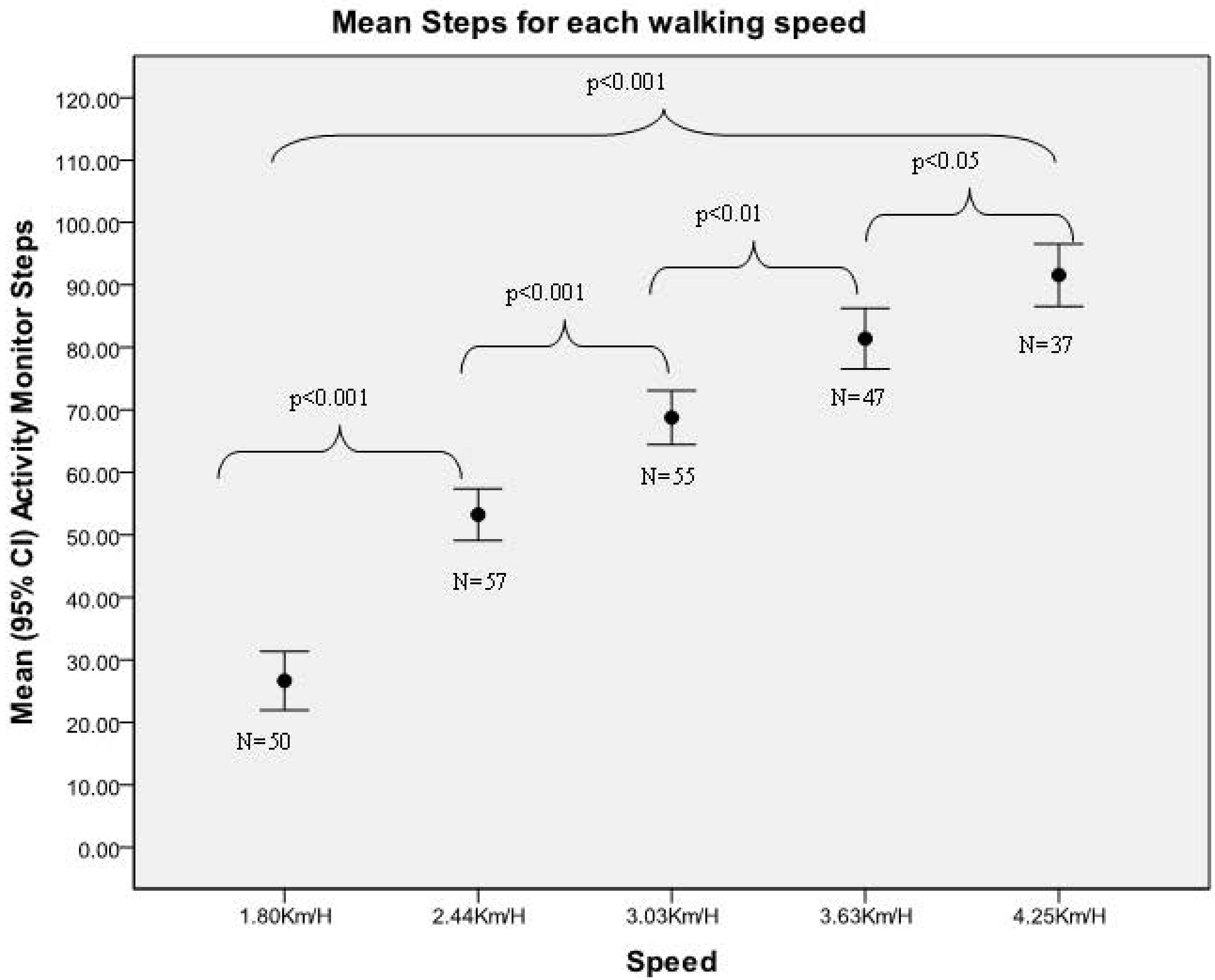
Table 1. Patients' demographics

	Mean (SD)
n	57 (30 male) #
Age (years)	70.5 (9.3)
FEV_1 (l)	1.5 (0.6)
FEV_1 % Predicted	60.9 (19.3)
BMI (Kg/m^2)	26.8 (5.9)
ISWT (m)	343.4 (150.7)
MRC 1 (n=2) 2 (n=23) 3 (n=17) 4 (n=13) 5 (n=2)	2.8 (1-5) ~

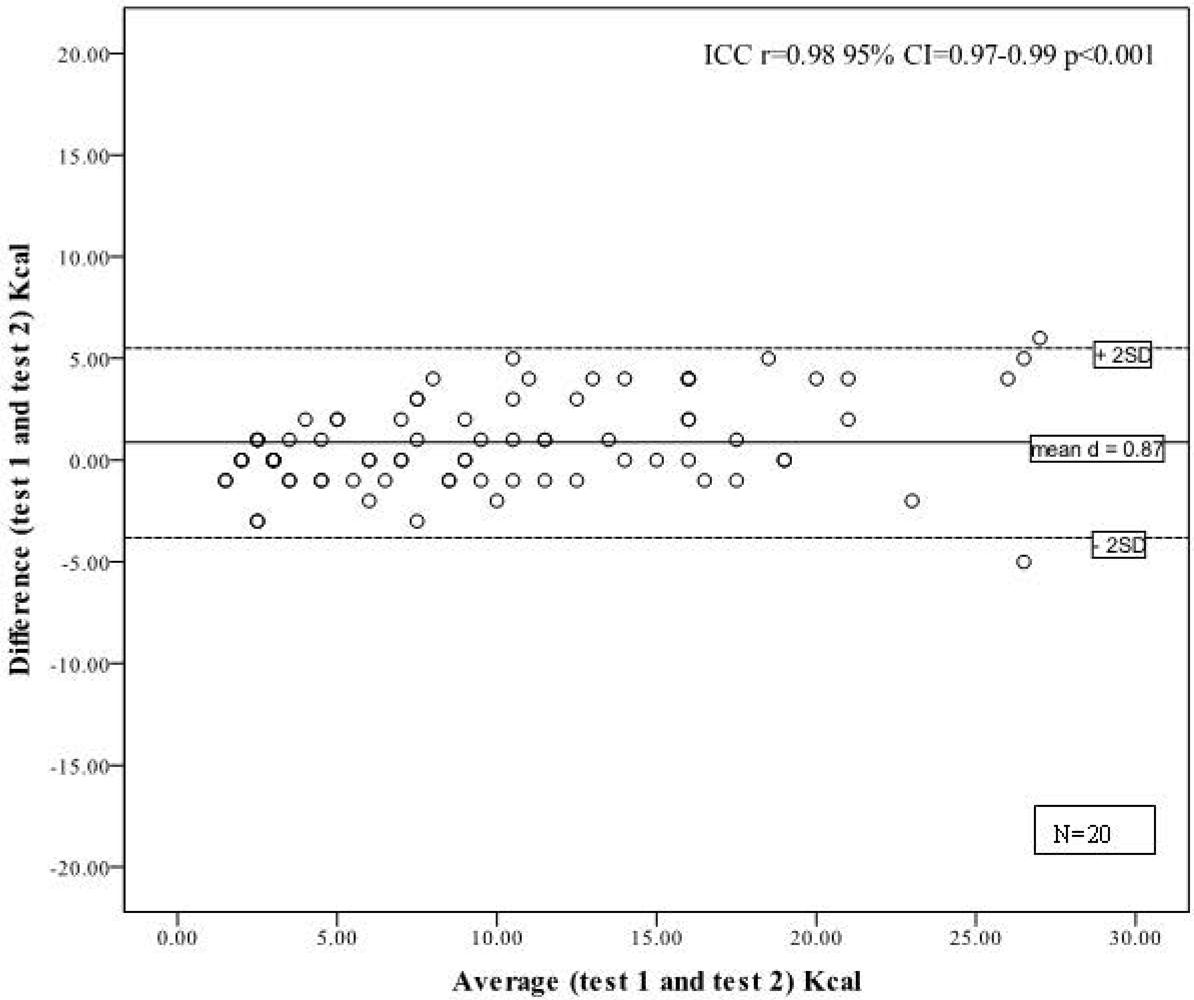
FEV_1 = forced expiratory volume in 1 second; BMI = body mass index;
MRC = Medical Research Council.
# = actual values, ~ = median (IQR)



Mean METS for each walking speed
Mean (95% CI) Activity Monitors METS
5.00
4.00
3.00
2.00
1.00
0.00
p<0.001
p<0.001
N=57
N=57
N=55
N=47
N=37
1.80Km/H
2.44Km/H
3.03Km/H
3.63Km/H
4.25Km/H
Speed



Mean Steps for each walking speed
Mean (95% CI) Activity Monitor Steps
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
p<0.001
p<0.05
p<0.01
p<0.001
p<0.001
N=50
N=57
N=55
N=47
N=37
1.80Km/H
2.44Km/H
3.03Km/H
3.63Km/H
4.25Km/H
Speed


ICC r=0.98 95% CI=0.97-0.99 p<0.001
+ 2SD
mean d = 0.87
- 2SD
N=20
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Difference (test 1 and test 2) Kcal
Average (test 1 and test 2) Kcal