Activity Monitoring for Assessment of Physical Activities in Daily Life in Patients With Chronic Obstructive Pulmonary Disease

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ABSTRACT. Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R. Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease (COPD): video recordings (criterion standard), the DynaPort Activity Monitor (DAM), and patient self-report.

Objective: To investigate the degree of agreement between different methods of assessing physical activities in daily life in patients with chronic obstructive pulmonary disease (COPD): video recordings (criterion standard), the DynaPort Activity Monitor (DAM), and patient self-report.

Design: Study A: outcomes from video recordings were compared with DAM outcomes and with patient estimation of time spent on each activity after a 1-hour protocol including walking, cycling, standing, sitting, and lying. Study B: DAM outcomes and patient self-report were compared during 1 day in real life.

Setting: Outpatient clinic in a university hospital.

Participants: Study A: 10 patients with COPD (mean age, 62±6y; forced expiratory volume in the first second [FEV1]=40%±16% of predicted). Study B: 13 patients with COPD (mean age, 61±8y; FEV1=33%±10% of predicted).

Interventions: Not applicable.

Main Outcome Measures: Time spent on different activities and movement intensity during walking and cycling.

Results: Study A: time estimated by the patients in the sitting position was significantly lower than the time showed by the video recordings and the DAM (both P<.001). For the other variables, there were no statistically significant differences (all P>.05). However, Bland and Altman plots and intraclass correlation coefficients showed large disagreement between video recordings and patients’ estimations, in contrast to the high degree of agreement between video recordings and DAM. Changes in walking speed correlated highly to changes in DAM movement intensity (r=.81, P<.01). Study B: patients significantly overestimated walking time (22±47min, P=.04) and underestimated standing time (~45±71min, P=.04).

Conclusions: The DAM showed high accuracy in objectively assessing time spent on different activities and changes in walking speed in patients with COPD. Patients’ estimations of time spent on physical activities in daily life disagreed with objective assessment.

Key Words: Activities of daily living; Physical effort; Pulmonary disease; chronic obstructive; Rehabilitation; Validity of results.

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METHODS

Participants and Design

All patients who volunteered to take part in the study were recruited from the outpatient rehabilitation program at the University Hospital Gasthuisberg, Leuven, Belgium. All of them gave informed consent to participate in the study. Patients all were retired or disabled and no longer employed. The inclusion criteria were (1) clinically stable condition, with no infection or exacerbation in the last 3 months before inclusion; (2) no recent cardiac complaints; and (3) absence of other pathologic conditions that could impair physical activity performance (eg, cerebrovascular diseases, rheumatism, arthritis).

Study A. Two different studies were performed. In study A, a group of 10 patients with COPD in GOLD stages II through IV (6 men; mean age, 62 ± 6y; forced expiratory volume in the first second \( \text{FEV}_{1} \) = 40% ± 16% of predicted value) underwent a 1-hour standardized protocol in which they performed different activities (walking, cycling) and stayed in different positions (standing, sitting, lying) during a given time, which was not disclosed to the patients. Patients wore the DAM during the protocol, and video recordings were made simultaneously. Time spent on the various activities and postures obtained through careful digital chronometer analysis of the video recording was used as the criterion standard. In addition, walking and cycling were performed twice during the protocol at 2 different self-selected speeds: 1 time at a speed considered comfortable by each patient (“slow”) and 1 time at a speed that each patient considered fast (“fast”). Walking was performed in a corridor previously measured in meters and the mean speed performed by each patient was determined by analysis of the video (distance covered divided by time spent to cover the distance). For cycling, patients were asked to keep the chosen number of revolutions per minute (rpm) constant during each of the 2 self-selected speeds (slow, fast). In both conditions (slow, fast), walking and cycling speed were compared with the movement intensity given by the DAM. After the protocol, patients reported how many minutes they thought were spent in each activity (walking, cycling) and position (standing, sitting, lying) during the 1-hour protocol (see Materials, Patients’ Reports). This estimation was also compared with the digital chronometer results obtained via video recordings.

Study B. In study B, physical activities in daily life were measured with the DAM on a representative day (from waking time until 12h after that) in a different group of 13 consecutive COPD patients who were also in GOLD stages II through IV (10 men; mean age, 61 ± 8y; \( \text{FEV}_{1} \) = 33% ± 10% of predicted value) (see table 1). Patients were strongly encouraged to keep their normal pattern of daily activities. During the measurement period, patients also filled out the logbook, reporting hourly the time spent in each activity or body position (see Materials, Patients’ Reports). Time spent in the different activities and body positions measured with the DAM was compared afterward with each patient’s report. Patients also filled

![The DAM device is worn under the clothes.](image)
analyzed with the DynaScope software. The software trans-
and the positions and accelerations of the 3 sensors were
of 32Hz. The data collected were downloaded to a computer,
stored in 10-, 16-, or 32-Mb memory cards at a sampling rate.
0.02g. The signals captured by the sensors are recorded and
by externally imposed acceleration. This is explained by the

Movement intensity during walking or cycling (in m/s²) is
(walking, cycling) and postures (standing, sitting, lying) and
lates the recorded acceleration signals into basic activities
OMITTED

Materials
Assessment of physical activities with the activity moni-
. The accelerometer-based activity monitor used was the
DM. It consists of a small, light-weight box enclosed in a belt
worn on the frontal part of the waist and a leg sensor (total
weight, 375g) (fig 1). The device records signals of 3 unidi-
dimensional piezoresistive acceleration sensors: 2 placed in
the belt around the waist and 1 placed in the upper part of the
left leg, measuring gravitational and body segment accelerations.
The sensors have a range of ±8g (78.5m/s²) and a resolution of
0.2g. The signals captured by the sensors are recorded and
stored in 10-, 16-, or 32-Mb memory cards at a sampling rate
of 32Hz. The data collected were downloaded to a computer,
and the positions and accelerations of the 3 sensors were
analyzed with the DynaScope software. The software trans-
lates the recorded acceleration signals into basic activities
(walking, cycling) and postures (standing, sitting, lying) and
quantifies the time spent in each of these activities or postures.
Movement intensity during walking or cycling (in m/s²) is
determined based on accelerations recorded during these ac-
ivities. Therefore, unlike other devices, the DAM does not
assess vector magnitude units (VMU) or number of counts but
provides a detailed analysis of time and intensity of activities
performed. In pilot experiments we investigated the sensitivity
of the DAM to 10-minute periods of car trip, wheelchair riding,
and taking an elevator. These are activities that might affect the
outcomes of accelerometry when VMU or counts are used. It
was shown that 100% of the time during car trips and wheel-
chair riding were correctly interpreted as sitting time; taking an
 elevator was correctly interpreted as standing time 100% of the
time. Hence, outcomes of the DAM seem not to be influenced
by externally imposed acceleration. This is explained by the

Results

Table 2: Study A: Data Obtained from the Analysis of Video
Recordings, DAM, and Patients’ Estimation After the 1-Hour
Standardized Protocol

<table>
<thead>
<tr>
<th>Variables</th>
<th>Video Recordings</th>
<th>DAM</th>
<th>Patients’ Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking time</td>
<td>Mean ± SD (min)</td>
<td>7±2</td>
<td>7±2</td>
</tr>
<tr>
<td></td>
<td>95% CI (min)</td>
<td>(5–8)</td>
<td>(5–8)</td>
</tr>
<tr>
<td></td>
<td>SE (min)</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Cycling time</td>
<td>Mean ± SD (min)</td>
<td>6±1</td>
<td>6±1</td>
</tr>
<tr>
<td></td>
<td>95% CI (min)</td>
<td>(5–7)</td>
<td>(5–7)</td>
</tr>
<tr>
<td></td>
<td>SE (min)</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Standing time</td>
<td>Mean ± SD (min)</td>
<td>9±1</td>
<td>9±1</td>
</tr>
<tr>
<td></td>
<td>95% CI (min)</td>
<td>(8–10)</td>
<td>(8–10)</td>
</tr>
<tr>
<td></td>
<td>SE (min)</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Sitting time</td>
<td>Mean ± SD (min)</td>
<td>22±3</td>
<td>23±5</td>
</tr>
<tr>
<td></td>
<td>95% CI (min)</td>
<td>(19–25)</td>
<td>(19–27)</td>
</tr>
<tr>
<td></td>
<td>SE (min)</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>Lying time</td>
<td>Mean ± SD (min)</td>
<td>12±3</td>
<td>11±4</td>
</tr>
<tr>
<td></td>
<td>95% CI (min)</td>
<td>(10–15)</td>
<td>(8–15)</td>
</tr>
<tr>
<td></td>
<td>SE (min)</td>
<td>0.9</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Abbreviation: SE, standard error.

*P<0.001 vs video recordings and vs DAM.
1P=0.2 vs video recordings and vs DAM.

out a checklist verifying whether the day was representative
describing any possible hindrance of the activity monitor.

Patients’ reports (logbook). The report of activities and
body positions filled out by the patients was based on the diary
developed by Follick et al. The category “pain rating,”
included in the original diary, was left out, because in this study
we were interested mainly in the time spent by the patients on
5 physical activities in daily life: walking, cycling, standing,
sitting, and lying.

In study A, patients reported the number of minutes they
thought were spent in each different activity (walking, cycling)
and body position (standing, sitting, lying) during the protocol.
In study B, patients reported hourly the number of minutes they
thought were spent in each different activity and body position
in the last hour. Use of the logbook was carefully explained to
the patients during instruction sessions, and study staff was
available at all times during the measurement days to respond
to possible queries by telephone. Patients were asked to be as
accurate as possible in their reports, and anonymity was
warranted.

Other measures. Pulmonary function, maximal inspira-
tory and expiratory pressures, quadriceps force, and 6-
minute walking distance were assessed to characterize the
population. All methods and equipment have been previously
described.

Statistical Analysis

Statistical analysis was performed using the SAS, version 8,
statistical package and GraphPad Prism 3. Data are expressed
as mean ± standard deviation (SD).

In study A, comparison of outcomes from video record-
plings, DAM, and patients’ estimations was performed with
the repeated-measures analysis of variance (ANOVA) pro-
cedure. Standard errors and 95% confidence intervals (CIs)
are also shown. In study B, comparison of time obtained
from the DAM and patients’ estimations was performed with
the paired t test. Correlations were analyzed with the Pearson
correlation coefficient. Level of significance was set at
P less than .05.

To compare the assessment techniques, the Bland and Alt-
man method was used in both protocols A and B. In this
graphic method, the closer the points and the mean are to the 0
line in the y axis, the higher the agreement between the tech-
niques. The Bland and Altman plot is a recommended method
for comparing techniques because it provides a detailed view
on the degree of agreement between outcomes of these tech-
niques. In addition, the intraclass correlation coefficient
(ICC) and its CI between outcomes from DAM and video
recordings and patients’ estimations and video recordings were
also calculated.

RESULTS

Patients reported that the DAM did not hinder them notably
in their activities. In study A, 2 patients reported being unable
Fig 2. Bland and Altman plots for comparison of (A) walking time, (B) standing time, and (C) sitting time assessed by video recordings (criterion standard), DAM, and patients' reports. Left panels: comparison between video recordings and DAM. Right panels: comparison between video recordings and patients' estimations. Abbreviations: LL, lower limit (–1.96 SDs); UL, upper limit (+1.96 SDs).
to differentiate the time spent among the different activities performed, choosing not to fill out the patient’s estimation report. These patients were excluded from the ANOVA procedure, which was performed with 8 patients. In study B, several patients reported having difficulties filling out the logbook at home, mostly because it was time consuming. Baseline characteristics of both groups are found in table 1.

Study A

ANOVA results performed comparing outcomes from video recordings, DAM, and patients’ estimations are shown in table 2. The time that patients estimated spending in the sitting position was significantly lower than the time shown by the video recordings and the DAM (both P<.001). For the other variables, there were no statistically significant differences (all P>0.05). However, in the Bland and Altman plots, a large disagreement between video recordings and patients’ estimations (fig 2, right panels) was shown, in contrast to the very small disagreement between the video recordings and DAM (see fig 2, left panels). ICCs (CIs) between outcomes from DAM and video recordings were as follows: .999 (.998–1) for walking time, .990 (.979–1) for cycling time, .998 (.996–1) for standing time, .77 (.510–1) for sitting time, and .75 (.480–1) for lying time. ICCs (CIs) between outcomes from patients’ estimations and video recordings were as follows: −.21 (−.86 to .44) for walking time, −.07 (−.72 to .58) for standing time, −.06 (−.73 to .61) for cycling time, and .55 (.03–1) for lying time. ICC for cycling time between patients’ estimations and video recordings could not be calculated because the procedure did not converge.

The DAM had a very small but systematic overestimation of walking time compared with the video recordings (3.7±2.4s in 420s [7min] of walking, P<.05) and cycling time (7.9±3.4s in 360s [6min] of cycling, P<.05).

Movement intensity correlated significantly with walking speed during fast (1.3±0.1m/s) walking (r=.72, P<.05) but not during slow (0.9±0.1m/s) walking (r=.21, not significant [NS]). Increase in walking speed highly correlated with increase in movement intensity measured by the DAM (r=.81, P<.01). On the other hand, DAM movement intensity did not correlate either with slow (37±4rpm) cycling (r=−.25, NS) or with fast (63±8 rpm) cycling (r=.02, NS). Increase in cycling speed did not correlate with increase in DAM movement intensity (r=−.04, NS).

Study B

Mean values of the DAM outcomes and logbook outcomes during 12 hours of measurement in each patient’s environment are summarized in table 3. Statistically significant differences were found for walking time, which was overestimated by the patients, and standing time, which was underestimated (both P=.04). The Bland and Altman plot for walking time assessed by the 2 methods showed a significant relation between the degree of overestimation and walking time (r=−.71, P<.01), indicating that overestimation of walking time was especially present in the more active patients (fig 3).

DISCUSSION

The results of our study show 2 main findings. First, the DAM is an accurate method for measuring the time spent in walking, cycling, standing, sitting, and lying in patients with COPD, as well as changes in movement intensity during walking. Important aspects of the device’s validity were shown: its high degree of agreement with the criterion standard and its stability, with high ICCs and narrow CIs. Second, patients’ estimations of time spent on these activities show important inaccuracy compared with the objectively assessed values. Because the use of video recordings was not feasible during long-term assessment in the patients’ environments and because the DAM was highly accurate in protocol A, the DAM was used as a surrogate for video recordings in study B. It appears that patients significantly overestimate their walking time in daily life (see fig 3). This warrants caution when using self reports by patients with COPD of time spent in activity or inactivity in daily life.

Time spent in physical activity during daily life (eg, walking), together with intensity and frequency, are fundamental parts of recommendations of physical activity for health maintenance.26 Assessment of habitual physical activity has been performed frequently with questionnaires or activity diaries. Our study has shown that individual patients were unable to report accurately the amount of activities performed over 12 hours and even over 1 hour. Although mean values of outcomes from patients’ estimations and video recordings in study A (see table 2) did not differ significantly (except for sitting time), the analysis of the Bland and Altman plot shows that the degree of agreement is not strong (fig 2, right panel), compared with the degree of agreement between the DAM and video recordings (fig 2, left panel). Accuracy can be defined as the degree of agreement of a measured value with the true value.28 Therefore, in study A, the DAM was shown to be accurate, whereas patients’ estimations were not. The very small overestimation observed in walking and cycling time for the DAM when compared with video recordings in study A has no clinical relevance, and it was probably due to the very few seconds missed by clocking analysis of the video during transitions of activities.

In study B, 9 of 13 patients (69%) overestimated their walking time compared with the objectively assessed values. This lack of accuracy in patients with COPD may be due to natural shortcomings of the human memory,4 lower cognitive function in patients with COPD when compared with healthy subjects,11 difficulties in distinguishing time spent on walking and standing (table 3), and the “social desirability” to report high time spent in physical activity, because benefits of exercise are well known. The fact that this inactive29 population tends to overestimate their walking time is in agreement with findings in healthy subjects, both adults30 and elderly.31 Furthermore, the subjective perceptions of patients with COPD may influence their capacity to report time spent in different activities. For example, a “tiring” (exhaustive) activity, hard to perform for these patients, can be interpreted by them as taking longer time than it really did. However, whatever the explanation, discrepancy between objective and subjective methods of assessment of physical activities was found in this population. Therefore, objective measures to obtain accurate data from real life are indicated.
The results of our study do not minimize the importance of questionnaires as a measure of the patients’ subjective perceptions of their limitations and difficulties. Patients can report their perceived limitations and symptoms in daily life or even to give an appropriate classification to their disability. However, in our study, patients with COPD did not report accurately the amount of time spent in activities compared with outcomes from the objective methods. Hence, although objective and subjective methods are useful and assess complementary aspects reflecting physical activity, they do not provide similar estimates of time spent actively (or inactively) in daily life.

The activity-monitoring technique used in our study has some limitations. These limitations include the inability to assess movements of the upper extremities and a lower accuracy in the assessment of the movement intensity during cycling and slow walking, despite measuring acceleration in the vertical and horizontal axis. The low accuracy during cycling occurs because, in the current software program, the movement intensity analysis does not include accelerations captured by the leg sensor but only by the other 2 accelerometers placed at the waist. Therefore, cycling speed cannot be properly assessed. The lower accuracy of the measurements during slow walking may occur because of the smooth movement of the body’s center of gravity, which may not be properly detected by the accelerometer. This issue deserves further evaluation in subsequent studies. The device, however, was sensitive to increases in acceleration during walking, and this measurement is highly correlated with increase in walking speed. Although it is clear that speed and acceleration are not the same, an increase (or decrease) in speed is generally linked to an increase (or decrease) in acceleration. Because the DAM was sensitive to acceleration and deceleration during walking, we believe it allows us to use this outcome as a surrogate for changes in walking speed in daily life. Furthermore, the device is relatively unbiased, with the only important misinterpretation of the device occurring in a single patient with a prominent abdominal volume (body mass index, 28 kg/m²), where portions of the lying time were interpreted as sitting time. This isolated observation led to the small and nonsignificant differences in sitting and lying time between DAM and video (see table 2). Therefore, caution may be necessary when using the DAM in obese subjects. Because the comparison between outcomes of the DAM and video recordings was performed in only a limited number of situations, further studies should focus on more varied situations than the ones used in study A (e.g., walking in bumpy terrain, moving around in a furnished room, cycling on a nonstationary bike, sitting in different kinds of chairs and sofas).

CONCLUSIONS

The DAM accurately assessed the time spent in different postures and activities in patients with COPD. Therefore, it is a promising tool for providing accurate data on the amount of daily activity in these patients. The estimations by patients with COPD of time spent in different physical activities in daily life had large disagreement compared with objective assessment.

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Suppliers


b. SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513.

c. GraphPad Software Inc, S 11452 El Camino Real, #215, San Diego, CA 92130.