ORIGINAL ARTICLES

Recording the Daily Physical Activity of COPD Patients With an Accelerometer: An Analysis of Agreement and Repeatability

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OBJECTIVE: The purpose of this study was to assess the agreement between different measurements of mean daily physical activity taken over a week in chronic obstructive pulmonary disease (COPD) patients with an accelerometer and to analyze the medium-term repeatability of these measurements.

PATIENTS AND METHODS: The study enrolled 12 healthy control subjects and 23 patients with stable COPD (mean [SD] forced expiratory volume in 1 second [FEV_1] of 45% [13%] of predicted and a ratio of FEV_1 to forced vital capacity of 53% [13%]). Accelerometer output, measured in vector magnitude units, was recorded in a physical activity log for a 1-week period. The results were then analyzed to compare output for a conventional recording period (Friday to Sunday) to that for 2 other periods (Monday to Wednesday and Tuesday to Thursday). The measurements were repeated 3 to 5 weeks later.

RESULTS: Activity counts were lower in the COPD patients than in the control subjects (184 [99] vs 314 [75]; *P*<.001). In the COPD patients, the results for the Friday to Sunday period correlated well with the results for both the Monday to Wednesday period (95% confidence interval, –29.21 to 28.81) and the Tuesday to Thursday period (95% confidence interval, –32.13 to 28.43). There were no significant differences in terms of medium-term repeatability of accelerometer readings between the COPD group and the control group (repeatability coefficient of 11.2% [4.6%] and 8.5% [4.7%], respectively).

CONCLUSIONS: Both agreement between the different measurements of physical activity taken during a 1-week period and medium-term repeatability for COPD patients and control subjects were very good.

Key words: *Chronic obstructive pulmonary disease (COPD). Physical activity. Exercise. Follow-up. Repeatability.*

Registro de la actividad física cotidiana mediante un acelerómetro en pacientes con EPOC. Análisis de concordancia y reproducibilidad

OBJETIVO: Evaluar la concordancia intrasemanal de la medida con un acelerómetro de la actividad física cotidiana en pacientes con enfermedad pulmonar obstructiva crónica (EPOC). Analizar la reproducibilidad del registro a medio plazo.

PACIENTES Y MÉTODOS: Se estudió a 23 pacientes con EPOC estable –cifra media (± desviación estándar) de volumen espiratorio forzado en el primer segundo del 45 ± 13% y cociente entre este parámetro y la capacidad vital forzada del 53 ± 13%– y 12 sujetos sanos. Se efectuó un registro con acelerómetro durante una semana y se analizó el vector de desplazamiento (VMU) en el período convencional (viernes a sábado) y en 2 períodos alternativos (lunes a miércoles y martes a jueves). El registro se repitió a las 3-5 semanas.

RESULTADOS: El VMU fue menor en los pacientes con EPOC que en los controles (184 ± 99 frente a 314 ± 75; p < 0,001). En el grupo con EPOC el registro de viernes a domingo mantenía una buena relación con el efectuado de lunes a miércoles (intervalo de concordancia del 95%, –29,21 a 28,81) y con el realizado de martes a jueves (intervalo de concordancia del 95%, –32,13 a 28,43). El coeficiente de reproducibilidad del VMU a medio plazo de los pacientes con EPOC (11,2 ± 4,6%) no resultó ser significativamente diferente del de los controles (8,5 ± 4,7%).

CONCLUSIONES: El registro de la actividad física cotidiana mediante un acelerómetro alcanza una elevada concordancia entre períodos de análisis comprendidos dentro de una misma semana y muestra una notable reproducibilidad a medio plazo, tanto en sujetos sanos como en pacientes con EPOC.

Palabras clave: *EPOC. Actividad física. Ejercicio. Seguimiento. Reproducibilidad.*

This study was partially funded by grants from the Spanish Society of Pulmonology and Thoracic Surgery (SEPAR) (2004) and NeumoMadrid.

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Manuscript received March 24, 2006. Accepted for publication July 20, 2006.

Introduction

Spirometry continues to be an essential tool for diagnosing and evaluating patients with chronic obstructive pulmonary disease (COPD).[1-6] A relationship between spirometric values and aspects

Figure 1. RT3 accelerometer attached to a study participant's belt.

such as the ability to perform everyday tasks, health-related quality of life, and health resource utilization, however, is weak or absent.[7-9] Most of the limitations experienced by COPD patients are related to dyspnea[10-12] and an impaired ability to exercise.[13-16] The final consequence is a progressive reduction in everyday physical activity.

Being able to measure physical activity is particularly important when assessing the impact of interventions applied to weak and sedentary patients, such as those with COPD. Direct observation, self-report questionnaires and diaries, radioisotope techniques, and heart rate monitoring are examples of methods currently used to record everyday activity. A practical alternative to these methods is the accelerometer. An accelerometer is a motion sensor that incorporates a piezoelectric transducer designed to detect acceleration in 3 dimensions. It can be used to record continuous activity over several days, and its output, measured in vector magnitude units (VMU), provides an objective measure of mean activity for this period. The method is relatively inexpensive and has proven to be highly accurate for a wide range of activity levels.[17-19]

Several studies have sought to validate the use of accelerometers[20] although no clear consensus has emerged on how they should be used. The first study dealing with the use of triaxial accelerometers in COPD patients was conducted by Steele and colleagues.[19] They chose to test the devices over a 5-day period (from Thursday to Monday), an approach that included 3 full days for analysis (Friday, Saturday, and Sunday).

To our knowledge, no analysis has been made of the variability of accelerometer measurements taken at different times in the same week or in different weeks. Understandably, the limited 3-day period analyzed by Steele and colleagues has not favored the widespread use of accelerometers in clinical practice for measuring daily physical activity levels in COPD patients.

Our study aimed to record daily physical activity in COPD patients with an accelerometer and to evaluate agreement between measurements taken during a conventional recording period (Friday to Sunday) and alternative periods. The study also aimed to assess the medium-term repeatability of these measurements.

Patients and Methods

Patients

The study enrolled 23 patients seen consecutively in a specialized COPD clinic and 12 healthy control subjects. Forced spirometry confirmed that all the patients had incompletely reversible airway obstruction. They had been stable for a period of at least 8 weeks and did not require changes in treatment regimen, which was in accordance with the recommendations of the Global Initiative for Chronic Obstructive Lung Disease (GOLD).[1] Exclusion criteria included suspected bronchial asthma, a positive bronchodilation test, known heart failure, ischemic or valvular heart disease, neuromuscular disease, peripheral vascular disease, or any incapacitating disease. Withdrawal criteria included disease exacerbation and the need for treatment regimen changes during the study period.

The study was approved by the ethics committee at our hospital and all the participants signed the corresponding informed consent form.

Procedures

We collected data related to anthropometric characteristics (weight, height, and body mass index), smoking, regular medication, and number of years since diagnosis of COPD. All the participants underwent spirometry on a model 4.2 MasterLab spirometer (Jaeger, Würzberg, Germany) according to the recommendations of the American Thoracic Society.[21] We used the reference values published by the European Community for Steel and Coal[22] and the GOLD classification system.[1]

Daily physical activity was recorded in VMU using an RT3 accelerometer (Stayhealthy, Monrovia, California, USA). All the patients were fitted with an accelerometer from Monday to Monday and the test was repeated within 3 to 5 weeks using the same device. During both study periods, the participants recorded the different activities they did each day in a special log.

The accelerometer was attached to the patients' belts with a clip (Figure 1) and they were asked to remove it only when sleeping or showering. They were also asked to press a special button on the accelerometer to indicate when they were traveling in a vehicle that could cause an increase in accelerations. Each device was set to mode 4, which recorded 1 triaxial VMU measure every minute. Once the data had been recovered from the accelerometer, any measurements marked as transport accelerations were eliminated and the mean VMU was calculated. VMU readings 20 times greater than the mean of the 10 preceding readings were also eliminated as it was presumed that they corresponded to the use of transport that had not been marked as such. Week-to-week repeatability was assessed by calculating the 95% repeatability interval and the repeatability coefficient.[24]

Statistical Analysis

Results were expressed as means (SD). Statistical analysis was performed using version 11.0 of the Statistical Package for Social Sciences (SPSS, Chicago, Illinois, USA). Statistical significance was set at a value of P less than .05.

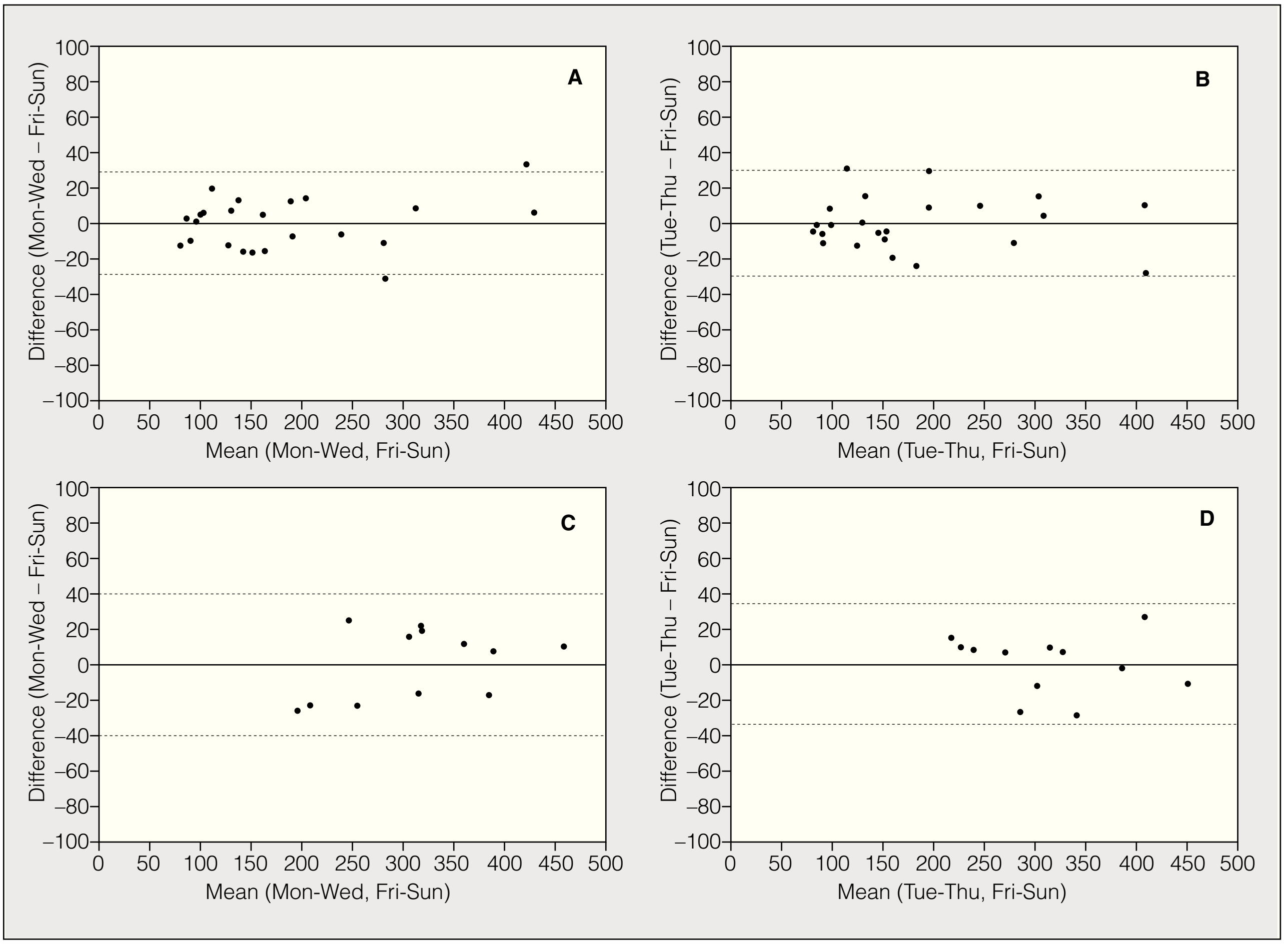

Figure 2. Bland-Altman plots showing agreement between measurements corresponding to 2 different recording periods in the same week for chronic obstructive pulmonary disease patients (A and B) and control subjects (C and D). The continuous horizontal line represents the mean of the differences. The dotted lines represent the upper and lower agreement limits.

The study and control groups were compared using the Mann-Whitney test for quantitative variables and the χ^2 test for qualitative variables. The relationship between variables was analyzed using the Spearman rank correlation test.[23]

Agreement between different measurements taken in the same week was analyzed using Bland-Altman plots[24] and the limits of agreement for 95% of the cases between the 2 periods (mean difference ±2 SD) were calculated. The coefficient of within-week variation was also calculated (100×SD/mean).[22] We analyzed within-week accelerometer output reliability for each group by using the Cronbach α statistic of internal consistency and calculating the mean intraclass correlation coefficient.

Week-to-week repeatability was assessed by calculating the limits of agreement for 95% of the cases between weeks and the repeatability coefficient.[24]

Results

Of the 23 patients in the COPD group, 9 had moderate COPD (GOLD stage II), 9 had severe COPD (GOLD stage III), and 5 had very severe COPD (GOLD stage IV). The mean number of years since diagnosis was 6 (4). The table compares the study and control groups in terms of main anthropometric characteristics and spirometric values. Results were similar for anthropometric characteristics and smoking frequency and intensity.

Accelerometer activity counts for Friday to Sunday were lower in the COPD group than in the control group (184 [99] vs 314 [75]; *P*<.001).

Figure 2 shows the Bland-Altman plots assessing agreement between the within-week recording periods. In the COPD group, the results for the Monday to Wednesday and the Tuesday to Thursday periods correlated well with the results for the Friday to Sunday period (*r*=0.979; *P*<.001; 95% CI [CI], –29.21 to 28.81 and *r*=0.975; *P*<.001; 95% CI, –32.13-28.43, respectively). In the control group, the results for the Friday to Sunday period also correlated well with the results for both the Monday to Wednesday period (95% CI, –39.46 to 39.47) and the Tuesday to Thursday period (95% CI, –33.96 to 33.75). The coefficient of variation between the 3 within-week measurement periods was very low and similar in both the COPD group and the control group (0.06 [0.03] vs 0.05 [0.02]). The mean intraclass correlation coefficient for

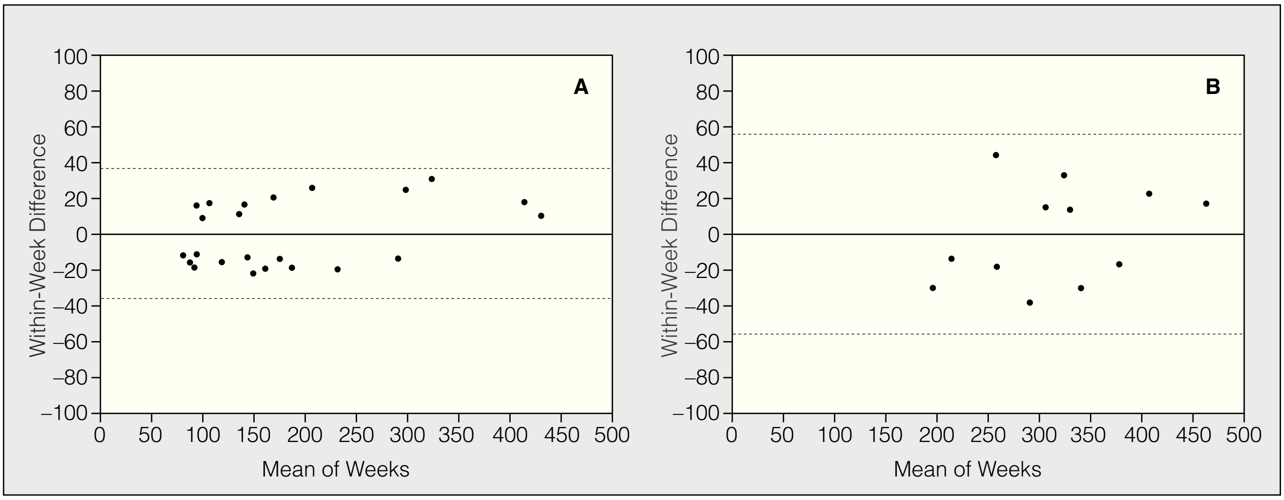

Figure 3. Repeatability of daily physical activity measurements taken during 2 different weeks in chronic obstructive pulmonary disease patients (A) and control subjects (B). The continuous horizontal line represents the mean of the differences and the dotted lines represent the upper and lower limits of agreement.

the 3 measurements was 0.9958 (95% CI, 0.9916-0.9981) for the COPD patients and 0.9847 (95% CI, 0.9603-0.9952) for the control subjects.

The results of the repeatability tests conducted after a period of 3 to 5 weeks are shown in Figure 3. There were no significant differences in terms of medium-term repeatability between the COPD group and the control group (repeatability coefficient of 11.2% [4.6%] and 8.5% [4.7%], respectively).

Discussion

Our findings confirmed that COPD patients perform less daily physical exercise than healthy subjects and showed that the use of an accelerometer to record this activity produced good results in terms of agreement between different recording periods during a 1-week period and acceptable medium-term repeatability.

TABLE
Intergroup Comparison of Anthropometric Characteristics and Spirometric Values*

	COPD Group, n=23	Control Group, n=12	*P*
Women/men	3/20	3/9	NS
Age, y	62 (7)	59 (7)	NS
Weight, kg	77 (11)	75 (9)	NS
Height, m	1.66 (0.07)	1.67 (0.08)	NS
BMI, kg/m^2	27.7 (3.6)	27.0 (3.7)	NS
Active smokers	26%	33%	NS
Pack years	48 (16)	42 (15)	NS
FVC, L	2.41 (0.60)	3.58 (0.85)	<.001
FVC, % predicted	68 (14)	103 (12)	<.001
FEV_1, L	1.25 (0.38)	2.80 (0.67)	<.001
FVC_1, % predicted	45 (13)	101 (13)	<.001
FEV_1/FVC, %	53 (13)	79 (12)	<.001

*Data are means (SD), except the ratio of women to men. COPD indicates chronic obstructive pulmonary disease; FVC, forced vital capacity; NS, not significant; FEV_1, forced expiratory volume in 1 second; BMI, body mass index.

Researchers can choose from among a range of accelerometers, including uniaxial and triaxial models. Uniaxial accelerometers measure movement in a single dimension, while triaxial devices measure movement in 3 dimensions and are considered to be more sensitive to subtle changes.[18] The Caltrac accelerometer (Sports Research Corporation, San Pedro, California, USA), for example, is a uniaxial accelerometer that has been used to study physical activity and energy expenditure in healthy subjects and COPD patients.[17] Triaxial accelerometers have also been used to record activity in COPD patients.[19] The type of accelerometer used, however, does not seem to have a significant impact on results. Welk and colleagues[25] assessed agreement between results produced by 3 types of accelerometers (CSA, Tritrac, and Biotrainer) and found very high levels of agreement for moderate exercise (r=0.86) and daily physical activity (r=0.70). Those results contrasted with ours, however, in that they found significant differences between measurements taken on different days of the week. This discrepancy could be due to differences in the study population as all the participants in the study by Welks and colleagues were healthy volunteers under the age of 65 years. In other words, they were all occupationally active. One would expect to see similar day-to-day activity patterns in elderly persons who are not occupationally active (because of retirement or disability) and whose ability to perform daily physical activity is limited by disease.

Differences attributable to day of the week seem to be unremarkable for healthy subjects, however, or at least that is the case for healthy males. Matthews and colleagues,[26] for example, recorded physical activity levels in 92 healthy subjects using a uniaxial accelerometer and evaluated their results according to calorimetry measures. They found no significant day-of-the-week differences for men although they did find that women spent more time performing physical activities on Saturday and so were slightly more active overall on that day. Their findings are consistent with ours, and particularly if we consider that both our groups included a majority of men. Matthews and colleagues estimated that accelerometer activity counts in healthy subjects varied by between 1% and 8% as a result of day-of-the-week effects.

We chose the RT3 accelerometer because of its high sensitivity, reliability, and validity. Nichols and colleagues[27] evaluated different aspects of the Tritrac R3D accelerometer (since replaced by the RT3 model) in 60 young adults engaged in different levels of exercise. They found high day-to-day reliability and high sensitivity to changes in speed. They also found that the accelerometer was able to correctly differentiate between light, moderate, and vigorous activity and provide acceptable estimates of energy expenditure.[27] Kochersberger and colleagues[28] compared the Tritrac and a uniaxial accelerometer in terms of the reliability, stability, and validity of their measure of physical activity in a group of elderly patients. They found that the triaxial model was better at discriminating between different levels of activity and had better week-to-week repeatability.

Not many studies have used accelerometers to measure daily physical activity in COPD patients. Steel and colleagues[19] recorded daily activity and walking in a group of patients with severe stable COPD (forced expiratory volume in 1 second of 37% of predicted) that were enrolled in a rehabilitation program. They found that the accelerometer's output correlated well with 6-minute walk distance, dyspnea, and degree of airway obstruction. Other authors, however, were unable to find any correlation between physical activity and COPD severity, probably due to the small size of their sample.[20] Another interesting finding in Steele and colleagues' study was the lack of correlation between physical activity measured by an accelerometer and physical activity recorded by patients in a log, although this could be related to the subjective nature of the latter and its reliance on memory. In any case, the accelerometer seems to be a reliable, stable, and valid means of measuring physical activity in COPD patients, something which, to date, has not been easy to quantify.

Steele and colleagues chose to fit an accelerometer to COPD patients from Thursday to Monday and to test its validity over a period of 3 full days (Friday to Sunday). The need to maintain this fixed measurement period, however, is a limitation that has restricted the use of accelerometers in clinical practice. Our findings, however, may promote wider use of this method as we have shown good agreement between 3 different measurements taken in a 1-week period. Our limits of agreement were within a range of 20 VMU. Given that the mean value was 184 (99) VMU, this result is very acceptable from a clinical perspective and confirms the stability of the measurement.

As can be seen in Figure 3, medium-term repeatability (3 to 5 weeks) was slightly better in the study group than in the control group. The fact that our healthy subjects exhibited more heterogenous behavior was probably due to the fact that they led a more active lifestyle (job obligations and lack of disease-related limitations), just like the participants in Welk and colleagues' study.[25] It should be stressed, however, that the repeatability coefficients in both our groups were very similar. Also of interest is a study by Washburn and colleagues[29] that found a high level of within-day repeatability for healthy subjects.

In conclusion, both agreement between the different measurements of physical activity taken during a 1-week period and the medium-term repeatability of these measurements were very good for both COPD patients and control subjects. It is also worth pointing out that accelerometers are harmless, unobtrusive, comfortable to wear, and extremely easy to use.

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