ORIGINAL ARTICLE

Step Counting and Energy Expenditure Estimation in Patients With Chronic Obstructive Pulmonary Disease and Healthy Elderly: Accuracy of 2 Motion Sensors

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ABSTRACT. Furlanetto KC, Bisca GW, Oldemberg N, Sant'Anna TJ, Morakami FK, Camillo CA, Cavalheri V, Hernandes NA, Probst VS, Ramos EM, Brunetto AF, Pitta F. Step counting and energy expenditure estimation in patients with chronic obstructive pulmonary disease and healthy elderly: accuracy of 2 motion sensors. Arch Phys Med Rehabil 2010;91:261-7.

Objective: To compare the accuracy of 2 motion sensors (a pedometer and a multisensor) in terms of step counting and estimation of energy expenditure (EE) in patients with chronic obstructive pulmonary disease (COPD) and in healthy elderly.

Design: In this descriptive study, all participants wore both motion sensors while performing a treadmill walking protocol at 3 different speeds corresponding to 30%, 60%, and 100% of the average speed achieved during a six-minute walk test. As criterion methods, EE was estimated by indirect calorimetry, and steps were registered by videotape.

Setting: Research laboratory at a university hospital.

Participants: Patients with COPD (n=30; 17 men; mean age ± SD, 67±8y; mean forced expiratory volume in the first second [FEV_1] predicted ± SD, 46%±17%; mean body mass index [BMI] ± SD, 24±4kg·m^2) and matched healthy elderly (n=30; 15 men; mean age ± SD, 68±7y; mean FEV_1 predicted ± SD, 104%±21%; mean BMI ± SD, 25±3kg·m^2).

Interventions: Not applicable.

Main Outcome Measure: Step counting and EE estimation during a treadmill walking protocol.

Results: The pedometer was accurate for step counting and EE estimation in both patients with COPD and healthy elderly at the higher speed. However, it showed significant underestimation at the 2 slower speeds in both groups. The multisensor did not detect steps accurately at any speed, although it accurately estimated EE at all speeds in healthy elderly and at the intermediate and higher speeds in patients with COPD.

Conclusions: In both patients with COPD and healthy elderly, the multisensor showed better EE estimates during most walking speeds than the pedometer. Conversely, for step counting, accuracy is observed only with the pedometer during the higher walking speed in both groups.

Key Words: Pulmonary disease, chronic obstructive; Rehabilitation.

PHYSICAL ACTIVITY IN daily life can be considered as the totality of voluntary movement produced by skeletal muscles during everyday functioning.[1] Its correct quantification has become a challenge in order to obtain an adequate assessment of the relationship between free-living physical activity and health.[2]

COPD is characterized by air flow limitation; dyspnea; and reduced exercise capacity, muscle strength, and quality of life.[3] Patients with COPD spend less time walking in daily life than age-matched subjects and walk at a lower intensity.[4] Moreover, previous studies[5-8] have shown that physical inactivity is an important predictor of hospital readmission and morbidity/mortality risk in this population. Because of the close relationships among physical inactivity, disability, and mortality, the interest in objective measurement of daily physical activity in patients with COPD has gained growing interest.[9]

Energy expenditure and step counting are common outcomes when assessing physical activity in daily life. To obtain an accurate assessment of these outcomes, the application of reference methods is recommended. For energy expenditure assessment, the literature usually recommends the doubly-labeled water method or indirect calorimetry assessment.[10-13] For step counting, direct observation and videotaping have been considered as reference methods.[14] However, these techniques are not easily used in everyday life because of their methodologic complexity, limited practicality, and/or high cost. Recently, the use of motion sensors has gained widespread recognition. These are instruments for detection of body movement. They are used to quantify physical activity in daily life objectively during a period[14] of time. Pedometers (eg, Digiwalker SW701)[a] and multisensors (eg, SenseWear Armband)[b] are among the most used motion sensors. Both of them quantify steps and estimate total energy expenditure, providing information from free living conditions and not just information derived from laboratory tests. However, the instruments

List of Abbreviations

BMI	body mass index
COPD	chronic obstructive pulmonary disease
FEV_1	forced expiratory volume in the first second
MET	metabolic equivalent
6MWT	six-minute walk test

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present marked differences concerning technologic complexity and cost. The SenseWear is more costly because it is composed of a biaxial accelerometer and diverse physiologic sensors, in contrast with the lower cost and technologic simplicity of the pedometer, which involves a simple system for detection of the hip vertical movement as a step.[13-16]

Schneider et al[15] showed that the Digiwalker SW701 pedometer is more accurate for step counting in healthy adults than a diversity of other devices. The SenseWear, on the other hand, was compared with uniaxial, biaxial, and triaxial accelerometers and showed the most accurate total energy expenditure estimation at most treadmill speeds.[17] However, there are no previous studies comparing the accuracy of a simple instrument such as the Digiwalker SW701 pedometer and a technologically advanced multisensor such as the SenseWear concerning step counting and energy expenditure estimation during physical activity, especially in subjects characterized by inactivity and slow walking such as patients with COPD. Such information could help inform decision-making when choosing an activity monitoring device for this patient group.

Because of the increasing need for objective techniques which accurately detect physical activity, the objective of this study was to investigate the accuracy of the Digiwalker SW701 pedometer and the SenseWear multisensor in estimating energy expenditure and counting steps compared with reference methods and with each other in patients with COPD and healthy elderly subjects.

METHODS

Participants

The study involved 43 patients with COPD from the Outpatient Respiratory Physiotherapy Clinic at the Hospital Universitário de Londrina (Brazil) and 39 healthy elderly subjects who were relatives or acquaintances of students from the aforementioned university hospital. Groups were paired for age, BMI, and sex. Inclusion criteria for healthy subjects were (1) absence of spirometry abnormalities; (2) absence of bone, nervous, and/or muscle dysfunction that could interfere on the assessment of physical activity; and (3) BMI less than $30 kg \cdot m^{-2}$. Besides criteria 2 and 3, inclusion criteria in the COPD group were (1) diagnosis of COPD based on spirometry, clinical, and radiologic internationally accepted criteria,[3] and (2) clinical stability (absence of exacerbations) for at least 3 months before inclusion in the study. All subjects were informed about study procedures and provided written formal consent to their participation. The study was approved by the Ethics and Research Committee of Universidade Estadual de Londrina/HU-UEL.

Study Design and Protocol

In this descriptive study, all subjects were submitted to an initial assessment of lung function and functional exercise capacity (6MWT) as screening measures. For step size determination, subjects were instructed to walk (as in their daily walking) 10 steps in a straight line. Total distance was measured and divided by 10. Afterward, each subject performed the following protocol: walk on a treadmill[c] with no inclination at 3 different speeds corresponding to 30%, 60%, and 100% of the average speed achieved during the 6MWT (speeds 1, 2, and 3, respectively). Each speed was sustained for 1 minute, with 1 minute of rest in between. During the treadmill walking protocol, subjects wore both motion sensors as study measures: the Digiwalker SW701 pedometer at the right side of the waist (hemiclavicle line) and the SenseWear multisensor on the right arm. As a criterion method for energy expenditure estimation, simultaneous indirect calorimetry was performed by a portable gas analyzer. The device was calibrated before each test in accordance with manufacturer instructions. Energy expenditure (in kilocalories for standardization of units) was derived from oxygen uptake assessment ($mL \cdot kg^{-1} \cdot min^{-1}$). The exact beginning and ending of walking at each speed were synchronized in all devices because of the presence of at least 3 investigators during each test (ie, 1 investigator initiating the portable gas analyzer, 1 initiating the camera, 1 initiating the 2 motion sensors simultaneously). At the same time, the treadmill walking protocol was videotaped by a digital camera (Sony Cyber Shot, DSC-W50[d]) as criterion method for step counting. The results from both motion sensors (energy expenditure and number of steps) were compared with the criterion methods and with each other.

METHODS

Lung Function Assessment

Simple spirometry was performed by the Pony spirometer.[e] The technique was in accordance with American Thoracic Society.[18] FEV_1 and forced vital capacity were obtained postbronchodilator. Reference values were those by Knudson et al.[19]

Six-minute walk test. The 6MWT was performed in accordance with international standards.[20] Patients were encouraged to walk 6 minutes as fast as they could in a straight leveled 30-m corridor. Two tests were performed with each subject, and the longest distance was used to calculate speed average and, consequently, the 3 protocol walking speeds. Normative values were those by Troosters et al.[21]

Multisensor SenseWear armband. The Multisensor SenseWear armband is a small (8.8×5.6×2.1cm) and light (82g) monitor that is worn on the upper-posterior region of the right arm. Information regarding various parameters including accelerometry, multiple physiological sensors, and demographic characteristics such as sex, age, weight, height, and dominant arm are used to estimate energy expenditure through algorithms developed by the manufacturer.[11,14] Among the device's main outcomes, the most commonly used are total energy expenditure, average of MET, energy expenditure in activities requiring above 3 MET, time spent in sedentary (<3 MET), moderate (3–6 MET) and vigorous activities (6–9 MET), as well as the number of detected steps. A final report is obtained through analysis of the data by a specific software (Inner View).[b]

Pedometer Digiwalker SW701. The Digiwalker SW701 is a simple and relatively inexpensive device, worn attached to the waist, providing the number of steps performed, distance, and energy expenditure estimation in a determined period. For this, the device requires a few characteristics of the wearer such as weight and step length. Its mechanism consists of an internal spring-levered system that is sensitive to vertical hip movements. This spring lever is connected to an electric circuit that computes each deflection as a step. Furthermore, based on the device movement counting, it also provides an active energy expenditure estimation.

Portable gas analyzer. The portable metabolic system VO_{2000} AeroGraph[f] is a transducer for metabolic analysis of pulmonary gas exchanges, projected to operate connected to a computer, previously tested and validated.[11] The system provides energy expenditure estimation by indirect calorimetry executing continuous analysis of oxygen uptake, carbon dioxide production, and expired volume.

Statistical Analysis

The analysis was performed with Prism software.[g] The Kolmogorov-Smirnov test was used to analyze normality of the data.