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Activity Monitoring in Chronic Obstructive Pulmonary Disease

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Abstract

The measurement of daily physical activity (PA) has become a significant outcome in patients with chronic obstructive pulmonary disease (COPD). Recent data have shown the independent association between PA markers, hospitalizations, and mortality. Daily PA can be quantified by direct observation, assessment of energy expenditure, questionnaires, and activity monitors (motion sensors). This review aims to describe the methods used to quantify daily PA in COPD on the basis of the published literature and to suggest potential applications of activity monitoring methods in clinical research and daily care of COPD patients.

Keywords

accelerometers; activity monitoring; COPD; pedometers

Daily physical activity (PA), a predictor of survival in the general population,[1,2] has become a significant outcome measure in patients with chronic obstructive pulmonary disease (COPD). Epidemiological data have shown the independent association between PA, hospitalizations, and mortality.[3] In addition, markers of systemic inflammation have also been associated with low PA as assessed by a reliable activity monitor.[4] Patients with COPD and, in particular, those who use long-term oxygen, have significantly lower levels of PA than elderly volunteers.[5–7]

To clearly define the scope of this review, it is useful to define PA behavior and the distinction between PA, exercise, physical fitness, and physical function. The National Institutes of Health consensus statement[8] defines *physical activity* as "bodily movement produced by skeletal muscles that requires energy expenditure and produces progressive health benefits," whereas *exercise* is described as "planned PA with bodily movements that were structured and repetitively performed for the purpose of improving or maintaining physical fitness."[(p241)] *Physical fitness* is just 1 aspect of *physical function*, which may be defined as the ability of a patient to perform a task.[9] Physical activity is a broader term with clear relevance to older adults and it is most often assessed and measured in epidemiological and intervention studies.[6]

Physical activity and exercise capacity are closely associated,[5] but PA is determined by other factors in addition to exercise capacity. Emotional well-being, age, social support, comorbidities, and use of oxygen are factors associated with patient daily activity.[10,11] Behnke et al[12] showed that, following a brief exercise intervention, the improvement in PA was far greater than that determined from an exercise test. This suggests that PA is dependent on physiological *and* patient-centered factors, and that the *construct* of what is

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measured with activity monitors is related, but different from that measured by laboratory exercise studies.[13]

One particular benefit of measuring daily PA is the assessment of *nonexercise* or *lifestyle* PA, that is, the activity, other than purposeful exercise, which occurs throughout the day. For highly active individuals who regularly exercise, the relative contribution of nonexercise PA may not be enough to substantially further improve health, but it could be of great importance in less active and sedentary individuals such as patients with more advanced stages of COPD.[14] For example, cycling to work, a lifestyle activity, is often not considered "exercise" but is a strong independent predictor of mortality in an elderly cohort.[15]

This review aims to describe the methods used to *quantify* PA in patients with COPD on the basis of the published literature and to suggest potential applications of the various methods of activity monitoring in clinical research and daily care of these patients.

METHODOLOGY

An introductory exploration of the topic in PubMed identified 41 relevant studies using the search term COPD "and" and each of the following phrases: physiologic monitoring, motor activity, activity monitoring, ambulatory monitoring, activities of daily living, questionnaires, pedometer, and accelerometer. The PubMed citation record for each relevant study was examined by a medical librarian to harvest appropriate Medical Subject Heading (MeSH) terms and text words used in describing the concepts of COPD, ambulatory monitoring, and activity. The harvested list of search terms became the basis of an augmented and more comprehensive PubMed search. Where appropriate, the terms were entered as PubMed search terms, MeSH terms, or text words. We augmented the search by reviewing the reference lists of retrieved articles, including review articles.[16,17] A manual inspection of the articles was then undertaken to determine whether they met more selective inclusion criteria, namely, the following: (1) the population included patients who had COPD, (2) the participants were adults; (3) a self-report questionnaire or monitor was used to assess patient PA level; (4) the PA construct included measures such as frequency and duration (rather than physical function or fitness); and (5) the article described an empirical research study rather than a review or commentary.

Methods that did not aim primarily to quantify the amount and intensity of activity performed in daily life are not discussed in the present review. Those include tools to assess functional status,[18–21] self-efficacy,[22] performance and independence during activities of daily living,[23–25] and the impact of symptoms in usual activities,[26] as well as health-related quality-of-life questionnaires with subscales of PA[27,28] and methods to assess functional exercise capacity.[29,30]

QUANTIFYING PA

PA can be quantified by direct observation, the assessment of energy expenditure (EE), self-reported activity (questionnaires), and activity monitors (motion sensors). Direct observation and direct assessment of EE by calorimetry or the doubly labeled water (DLW) method are rarely used to assess activity in COPD clinical research or practice because of the impracticality of calorimetry in adults, and because of cost and/or availability of DLW. For that reason, this review will focus on the use of self-reported information (questionnaires) and motion sensors.

Questionnaires

Quantifying PA through questionnaires has the paramount advantage of being inexpensive and simple. However, there are no disease-specific PA questionnaires for patients with COPD. The ideal tool in COPD would be a standardized instrument that records the low-intensity activities typical of sedentary groups and provides consistent biological meaning to terms such as light, moderate, and heavy exercise.[31]

A large validation study in healthy elderly people that included 10 questionnaires showed that only the Stanford Usual Activity Questionnaire,[32] the Stanford Seven Day Recall Score,[33] and the Paffenbarger Physical Activity Questionnaire[32] had significant correlations with total EE assessed by the DLW. The Stanford Brief Physical Activity Survey has been validated and, given its simplicity, is suitable for use in daily clinical practice.[34,35] Brief tools (<15 items) for the evaluation of mild PA are potentially useful in COPD studies and clinical care and include the Stanford Brief Physical Activity Survey,[34] Physical Activity Scale in the Elderly,[36] modified Baecke Physical Activity Questionnaire,[37] and Zutphen Physical Activity Questionnaire.[6]

Studies that used questionnaires to quantify PA in COPD patients have not investigated test-retest reliability or validity but include the Physical Activity Scale in the Elderly,[36,38,39] Minnesota Leisure Time Physical Activity Questionnaire,[40] Yale Physical Activity Questionnaire,[41] Baecke Questionnaire,[15,40] and Saltin and Grimby Questionnaire.[3] The Yale Physical Activity Questionnaire was shown to have a significant correlation with PA measured by activity monitor,[35,41] and the Modified Baecke Physical Activity Questionnaire demonstrated a modest association with health-related quality of life, dyspnea score, and the 6-minute walk test in patients with COPD.[37,39] However, the validity of the Modified Baecke Questionnaire is modest. The questionnaire performed well in classifying individuals as low-active and high-active, but poorly for those who were moderately active.[42,37] The lengthy Minnesota Leisure-Time Physical Activity Questionnaire[43] has been modified for use in patients with COPD.[11] The Physical Activity Scale in the Elderly questionnaire[36,38] is a short instrument with documented validity in elderly populations. In addition, a subanalysis (multivariate) of the Copenhagen City Heart Study compared patients with spirometric diagnoses of COPD with individuals with very low PA, defined as less than 2 hours per week of walking and cycling. Subjects with very low PA had significantly poorer survival and increased risk of hospitalization than patients with COPD who performed 2 or more hours of PA per week.[3,44]

Important factors to consider when using activity questionnaires include the following:

- Recall bias: Is it likely that the patient may not recall properly more distant events, given that reliability of the information generally decreases with the length of the period surveyed?[35] The shorter the elicited recall, the better.
- Design: Simple questionnaires show the highest coefficient of reliability and validity.[35,45] Long tools confuse or bore subjects.
- Individual characteristics, like obesity or body frame, may account for significant variation in the translation of the activities/times continuum to reliable EEs.[46,47]
- Has the questionnaire under consideration for use been validated against an appropriate comparison method?
- Is the instrument reliable?

Activity Monitors (Motion Sensors)

Motion sensors are instruments used to detect body movement and objectively quantify PA over a period of time. These instruments basically include pedometers (measurement of steps) and accelerometers (detection of body acceleration).

Pedometers

Pedometers are small, simple, and inexpensive instruments. They contain a horizontal spring-suspended lever arm that deflects with vertical acceleration of the hips during walking (the up-and-down motion during ambulation). They are usually worn on the waist and assess the number of steps since pedometers were designed to detect vertical movement. The output from the device is easily understood as a motion count, representing a step. However, they provide no information about pattern of PA or time spent in different activities over the day, nor the intensity at which these activities are performed.

Pedometers have been promoted to stimulate and measure walking (steps) in the general population, with 10,000 steps per day suggested as an effective count for prevention of disease and promotion of a healthier lifestyle.[48] Furthermore, walking is a common, easily achievable form of light to moderate-intensity PA that has been extensively studied for its health benefits in several large cohort studies.[49] A large comparison study tested various models of pedometers: Accusplit Alliance 1510 (Accusplit, Livermore, CA); Freestyle Pacer Pro (FreeStyle, Long Island, NY); Kenz Lifecorder [KZ] (Aichi, Japan); New-Lifestyles NL-2000 [NL] (New-Lifestyles, Lees Summit, MO); Omron HJ-105 (Omron, Tokyo, Japan) Oregon Scientific PE316CA (Oregon Scientific, Cannon Beach, OR); Sportline 330 and 345 (Sportline, Yonkers, NY); Walk4Life LS 2525 (Walk4Life, Plainfields, IL); Yamax Skeletone EM-180 (Yamax, Tokyo, Japan); Yamax Digi-Walker SW-200 [YX200], using the criterion pedometer (Yamax, Tokyo, Japan); and the Yamax Digi-Walker SW-701 [YX701]) (Yamax, Tokyo, Japan). The study concluded that the KZ, NL, YX200, and YX701 appeared to be the most suitable for research purposes.[50]

Pedometer-based data offer adequate information to discriminate between levels of PA in healthy adults,[43] but the same has not been reported in COPD patients. Previous research has shown that pedometers may underestimate the amount of PA, particularly in patients with very slow walking,[51] which may represent a problem in COPD patients and may not be appropriate measuring devices for clinical research assessing PA in frail populations. However, several studies have reported that pedometers are sensitive devices in COPD patients.[52–55] A study that evaluated the performance of pedometers in measuring activity in patients with COPD with and without respiratory failure and healthy subjects showed that healthy individuals had 3 times greater activity than in either group of patient with COPD (with and without respiratory failure).[13] Test-retest reliability of the pedometers for activity counts was high (intraclass correlation coefficient of .94).

Accelerometers

Accelerometers are technologically more advanced devices that determine the quantity and intensity of movements. These devices are able to store data continuously over long periods of time, and the output, which is measured in vector magnitude units, provides an objective measure of mean activity for the period.

There are basically 2 types of accelerometers: uni-axial and multiaxial. Uniaxial sensors detect motion in only 1 body dimension (or plane) and can be inaccurate for activities with static trunk movement, such as cycling and rowing. The information provided is comparable to a pedometer, but with the advantages of assessing movement intensity and allowing more detailed analysis in different time frames. Multiaxial devices are able to detect motion in more than 1 plane of movement. Some multiaxial devices are able to detect a variety of body positions and physical activities. A major advantage of multiaxial accelerometers is that these devices are able to provide more detailed information than the uniaxial types. Disadvantages of accelerometers include the higher costs compared with pedometers, the need for technical expertise and specialized software, and the fact that they may erroneously count more nonstep movements as steps.

A recent report compared the performance of different accelerometers—Computer Science Applications (CSA) activity monitor (Shalimar, Florida), TriTrac-R3D (Professional Products, Madison, Wisconsin), RT3 Triaxial Research Tracker (RT3) (Stayhealthy, Monrovia, California), BioTrainer-Pro (IM Systems, Baltimore, Maryland), and SenseWear Armband (BodyMedia Inc, Pittsburgh, Pennsylvania)—during treadmill exercise. The study concluded that the CSA was best at estimating total EE during walking and jogging speeds, the TriTrac-R3D was best at estimating total EE at running speeds, and the SenseWear Armband was best at estimating total EE at most speeds.[56] When the SenseWear Armband accelerometer was combined with other physiological sensors, it was shown to be a valid measure of EE and PA in patients with COPD.[57]

The source of variability of the signal from accelerometers was studied by Matthews et al,[58] using the CSA accelerometer. The study showed that true differences in measured PA between subjects (interindividual) accounted for the majority of the variance observed (50%–60%). Behavioral variability (intraindividual) was the second largest source (30%–45%), and the "day of the week" effect was third, but smaller in comparison (1%–8%). At least 3 to 4 days of monitoring are required to achieve 80% reliability in the activity measures.[58] These results should be considered in the process of research design of studies that intend to include PA as an outcome. In addition, a comparison of the accuracy of the YX200 pedometer and the CSA accelerometer under controlled conditions in a non-COPD population found that both are useful for objectively assessing PA over a defined period of time.[59]

Several additional studies have reported the use of accelerometers in patients with COPD.[4,12,41,53,60–70] The Fitty 3 pedometer (Kasper & Richter, Uttenreuth, Germany) and TriTrac-R3D (Reining International, Madison, Wisconsin) were reported to have good test-retest results in a COPD population.[13,69] Day-to-day variation of PA measured by accelerometry was also reported nonsignificant in a population of patients with mild to moderate COPD.[62] The number of assessment days should be considered when measuring PA in daily life in COPD patients. At least 2 days of assessment with an activity monitor are necessary for an acceptable intraclass reliability coefficient (IRC >.70) while more days of assessment provide a higher coefficient.[5]

Accelerometer results in COPD patients correlated with the 6MWD ($R = 0.6$).[60] The correlation between PA measured by an RT3 accelerometer and a standardized walking test was even higher ($R = 0.85$).[69] Unfortunately, the same group recently reported a high signal-to-noise ratio for this device.[67] The TriTrac-R3D also correlated well with the 6MWD ($r = 0.74$; $P < .001$).[17] The uniaxial accelerometer Z80-32k V1 Int (Gaehwiler Electronics, Hombrechtikon, Switzerland) was able to distinguish between brisk walking and other types of domestic activities in a COPD population.[71] Actigraphy, an electronic device that consists of a piezoelectric accelerometer, has also been described to measure motor activity in COPD. Wrist actigraphy was reported to be a valid instrument to measure upper-extremity movement during pulmonary rehabilitation in COPD patients.[72]

The literature on sensitivity or responsiveness of activity monitors to different interventions showed disparate results from no effect,[61,67] to significant short-term effects,[52–54,64,70] and to long-term, but not short-term effects.[73] Acknowledging that the type of intervention is certainly an important factor that affects response, several accelerometers have been reported to be *sensitive* devices including the Z80-32k V1 Int,[64] the Dynaport,[70] the Actiwatch Uniaxial Accelerometer,[70] and the YX200 pedometer.[54]

CLINICAL APPLICATIONS OF ACTIVITY MONITORING

Coaching Plus Activity Monitoring

The successful use of coaching and activity monitoring in patients with COPD has been the subject of several studies.[52,53] The use of motivational interviewing (MI) techniques for increasing activity in addition to wearing a pedometer was found to be more beneficial compared to wearing the pedometer only (no MI) in a group of COPD patients.[54] Study patients in the experimental group wore a pedometer to record daily steps for the week before, during, and after pulmonary rehabilitation. Motivational interviewing techniques were also used in the experimental group to encourage patients to wear the pedometer, record steps each day, and increase PA. The control group wore only the pedometer the week before and the week after pulmonary rehabilitation. After pulmonary rehabilitation (10 weeks), subjects in the MI-pedometer group walked significantly more steps than the subjects in the control group. The YX200 showed responsiveness to a 12-week pedometer-based exercise counseling program in COPD patients (GOLD classification 1–3) who do not participate in a rehabilitation program.[52]

EE Estimation Using Activity Monitors

A study performed in the general population in which EE was estimated from the output of a validated activity monitor found that a higher PA-related EE was significantly associated with decreased mortality.[1] PA-related EE was calculated as recommended by the World Health Organization, where total EE is divided by the resting metabolic rate; a ratio of 1.4 to 1.69 is described as sedentary, 1.7 to 1.99 as active, and 2 to 2.4 as vigorously active.[1] An increase of 287 kcal per day was associated with a 32% lower risk of mortality after adjusting for age, sex, race, study site, weight, height, percentage of body fat, and sleep duration (hazard ratio = 0.68). Interestingly, a recent study by Watz et al[4] demonstrated that all categories of COPD (GOLD classification) had a sedentary activity level (<1.7), making the assessment of PA-related EE a significant outcome in COPD clinical research that is potentially modifiable.

Pulmonary Rehabilitation and Activity Monitoring

The monitoring of activity during pulmonary rehabilitation has been well reported in the literature.[61,55,74] Two recent studies showed improvement in accelerometer-measured PA after pulmonary rehabilitation.[70,73] Interestingly however, Walker et al[70] reported that the change in PA after rehabilitation was unrelated to improvement in muscle strength or walking distance. Rather, it was the intensity and amount of activity that the patient undertook at home, which produced results different from those expected on the basis of the patient walking distance, muscle strength, and health status questionnaires.

CONCLUSION

While more rigorous and objective methods such us multisensor devices and accelerometers exist for the measurement of PA and physical fitness, the use of collecting self-reported PA information (questionnaires) will remain the primary method to quantify PA in epidemiological studies. Reported information can be further validated through the use of multiple short-term recalls to assess habitual activity patterns since they provide useful information about sedentary and lower-intensity nonexercise activities with less errors than long-term recall.[74] Imbedding measurement sub-studies into the primary measurement protocol and using these data to apply measurement error correction methods to improve the estimates of PA are also helpful.[75,76]

The current data support the use of specific pedometers and accelerometers[52–54,64,70] as a simple and inexpensive (pedometers) way to incorporate the measurement of daily PA into routine clinical practice and rehabilitation programs, giving patients and healthcare providers the ability to quantify daily PA. Simple monitoring of PA, goal-setting, and self-management may help improve the maintenance of PA after pulmonary rehabilitation, a crucial long-term problem for the rehabilitation of COPD patients.

For clinical research, where high accuracy is needed, the use of the most advanced monitors (multiaxial accelerometers or combined accelerometers plus physiological sensors) is the likely method of capturing all the mechanistic information necessary to use in clinical trials and to understand the complex construct of what make people active in daily life. There is no specific questionnaire that has been found optimal to use in COPD. Pulmonary rehabilitation and COPD integrated care programs are likely the most appropriate settings to implement activity monitoring. The intense patient-provider interaction facilitates the introduction to the use of activity monitors and the information gained will help set goals and increase self-efficacy, which may translate into a more active lifestyle.

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