ORIGINAL ARTICLE

Objective Physical Activity Assessment in Patients With Chronic Organ Failure: A Validation Study of a New Single-Unit Activity Monitor

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ABSTRACT. Annegarn J, Spruit MA, Uszko-Lencer NHMK, Vanbelle S, Savelberg HHCM, Schols AMWJ, Wouters EFM, Meijer K. Objective physical activity assessment in patients with chronic organ failure: a validation study of a new single-unit activity monitor. Arch Phys Med Rehabil 2011;92:1852-7.

Objective: To validate a new activity monitor (CAM) in patients with chronic organ failure during 1 hour of unconstrained activity assessment.

Design: A validation study in which participants wore a CAM (placed on the thigh) for 1 hour while they were videotaped. Participants were instructed to continue their normal daily routine at the rehabilitation center.

Setting: CIRO+, A Centre of Expertise for Chronic Organ Failure.

Participants: Chronic organ failure patients (N=10) with a large range of functional exercise capacity.

Interventions: Not applicable.

Main Outcome Measure: Agreement in time spent on activities and postures according to video and CAM.

Results: Cohen kappa coefficients for transient events resulted in an almost perfect agreement (0.85±0.08) between the CAM and video.

Conclusions: The CAM is a promising single-sensor unobtrusive tool for providing accurate data on the type and duration of daily activities in the home environment of patients with chronic organ failure.

Key Words: Heart failure; Pulmonary disease, chronic obstructive; Rehabilitation.

PATIENTS WITH CHRONIC organ failure, like chronic heart failure (CHF) or chronic obstructive pulmonary disease (COPD), are generally characterized by an inactive lifestyle in order to avoid the unpleasant sensation of dyspnea.[1,2] Indeed, walking is the number one problematic activity of daily life.[3] Decreased weight-bearing activities and postures in daily life (eg, walking and standing) are important triggers in the development and/or progression of lower-limb muscle atrophy, muscle weakness, and exercise intolerance in patients with CHF or COPD.[4-6] Indeed, a downward disease spiral has been postulated, in which advancing dyspnea leads to a sedentary lifestyle and the deconditioning of the lower-limb muscles, and thus further daily physical inactivity.[7] Moreover, exercise-based cardiopulmonary rehabilitation programs have been shown to effectively improve quadriceps muscle mass, lower-limb muscle function, and exercise capacity in patients with CHF or COPD.[8,9]

To date, daily physical activity levels have not yet been implemented as an outcome measure of cardiopulmonary rehabilitation.[10,11] Indeed, more traditional measures of exercise performance, such as the six-minute walk test (6MWT), are assumed to reflect daily physical activity levels in patients with CHF or COPD.[1,6,12] However, an increased exercise capacity after cardiopulmonary rehabilitation does not necessarily result in a more active lifestyle.[13,14] Therefore, it seems reasonable to add the objective assessment of daily physical activity levels to the outcomes assessed before and after cardiopulmonary rehabilitation.[15] Furthermore, objective assessment of daily physical activity levels may also be useful as a coaching tool to maintain and/or enhance a more physically active lifestyle.[16]

Questionnaires show limited validity and reliability to objectively assess daily physical activity levels,[17] while wearable devices gain in popularity as a method to objectify daily life activity.[1,6,18-24] Unfortunately, most commercially available devices that aim to assess physical activity in CHF and/or COPD patients have technical and/or methodologic limitations. For example, the Dynaport Activity Monitor accurately reflects time spend in different postures and activities in COPD patients during a standardized protocol.[17] However, it consists of multiple units and, in turn, will be more obtrusive for patients compared with single-unit devices. Moreover, the Dynaport Activity Monitor has never been validated during free-living

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List of Abbreviations

BMI	body mass index
CAM_{leg}	CAM on the frontal part of the thigh
CAM_{trunk}	CAM on the lower back
CHF	chronic heart failure
COPD	chronic obstructive pulmonary disease
GLMM	generalized linear mixed models
GOLD	Global initiative for chronic Obstructive Lung Disease (GOLD)
SMA	signal magnitude area
6MWT	six-minute walk test

conditions in which subjects follow their normal routine (eg, not restricted to perform specific activities); a drop-out rate of 19% of the subjects has been reported for 2 days of activity assessment because of misplacement or technical problems.[25] The SenseWear is a single-unit activity monitor that does not provide information on time spent in postures, and the amounts of steps counted by the device are inaccurate.[26] The Minimod is also a single-unit device that does provide accurate information on time spent in different postures and activities.[26] However, this device seems to become less accurate in patients that walk slowly, and it has also never been validated during free-living conditions.[26] Therefore, the aim of this study was to validate a new single-unit activity monitor in both healthy subjects during a standardized protocol and in CHF or COPD patients with a wide range in functional exercise capacity during free-living conditions.

METHODS

Design and Participants

Two studies were designed to validate a new single-unit activity monitor (CAM). Study A evaluated the accuracy of the activity monitor using a standardized protocol in a group of 5 healthy subjects (all students; 3 men; mean age ± SD, 23.8±3.6y; body mass index [BMI], 21.0±2.0kg/m^2). Study B evaluated the accuracy of the activity monitor during 1 hour of unconstrained activity and posture assessment in 5 patients with CHF (4 men; mean age ± SD, 54.2±16.8y; Left ventricular ejection fraction, 32.4%±7.6%; NYHA class I, n=1; NYHA class II, n=2, and New York Heart Association class III, n=2; BMI, 30.4±6.9kg/m^2) and 5 patients with COPD (2 men; mean age ± SD, 60.0±9.9y; forced expiratory volume in first second, 51.6%±36.2% of predicted value; Global initiative for chronic Obstructive Lung Disease (GOLD) stage I, n=1; GOLD stage II, n=1; GOLD stage III, n=1; and GOLD stage IV, n=2; BMI, 19.7±1.9kg/m^2). All patients were clinically stable. In both studies the results of the 2 attachment sides of the CAM were compared: on the frontal part of the thigh just above the knee (CAM_{leg}) and on the lower back at the height of the second lumbar vertebra, nearby the body's center of mass (CAM_{trunk}). The current protocol was approved by the Medical Ethical Committee of Maastricht University Medical Centre and conformed to the principles outlined in the World Medical Association declaration of Helsinki, which have been revised in Seoul (approval no. NL30747.068.09).

New Single-Unit Activity Monitor

Recently, a new single-unit activity monitor was developed by Maastricht Instruments B.V.: the CAM. It contains a triaxial piezoresistive accelerometer, weighs 102g, and has a range of ±4 times gravity with a resolution of 0.02 gravity. The measured signal is stored on a 2 gigabyte micro SD cart at a sample rate of 102H. The CAM classifies activities and/or postures using a windowing technique in which a threshold on several accelerometer features is applied. The basic methodology is described in more detail by Preece et al.[27] A hierarchical classification scheme is used (supplement fig 1), which first differentiates between dynamic activities and static postures using a parameter for intensity of motion: the signal magnitude area (SMA). Subsequently static postures are differentiated into weight-bearing and nonweight-bearing postures using a parameter for orientation of the CAM: the mean accelerometer signal of the respective axis.

Study A. A group of 5 healthy subjects underwent a standardized protocol at the Department of Human Movement Sciences of the Maastricht University: standing upright (120s), sitting upright (120s), supine position (120s), walking at a self-selected speed (120s), and unloaded cycling at a self-selected number of revolutions per minute (120s). Between different activities and/or postures, subjects had 30 seconds transition time. These transitions were excluded from further analyses. The accuracy of the CAM_{leg} and CAM_{trunk} (worn simultaneously) was calculated and expressed as the percentage of correctly classified seconds. In addition, we investigated whether the CAM_{leg} and CAM_{trunk} could accurately reflect subject's movement intensity. For this purpose, all subjects walked on a treadmill at 5 different walking speeds (1.5, 2.5, 3.5, 4.5, 5.5, and 6.5km/h). Subjects walked each speed for 120 seconds with 30 seconds transition time in between.

Study B. Five patients with CHF and 5 patients with COPD were recruited during their rehabilitation program at CIRO+, A Centre of Expertise for Chronic Organ Failure in Horn, The Netherlands. All patients were free of disease-related hospitalizations for at least 4 weeks. The 6MWT was performed as a measure of functional exercise capacity in accordance with the guidelines of the American Thoracic Society,[28] including a practice walk. Moreover, all patients wore the CAM_{leg} and the CAM_{trunk} simultaneously for at least 1 hour and were instructed to continue their normal daily routine. After wearing the CAM devices, patients estimated the percentage of time spent on nonweight-bearing postures (eg, sitting or lying), weight-bearing postures (eg, standing), and dynamic activities (eg, walking). Video recordings were used as the criterion standard.[17,29] Patients were videotaped by the researcher while they wore the CAM_{leg} and the CAM_{trunk}. If the patient decided to go somewhere (lunch, appointment, etc), the researcher followed the patient with the camera. After the recordings, the tapes were analyzed by an examiner, who was blinded to the values obtained by the CAMs and patients' estimation. In addition, a video recording of 1 subject was classified by another researcher to establish the interexaminer reliability and to ensure there was no examiner bias in analyzing the video recordings.[30] A second by second analyses showed an overall agreement of 99.8% between the 2 examiners.

Statistical Analysis

Results were expressed as mean ± SD for quantitative variables, while frequencies and proportions were used for categorical variables. The association between walking speeds and the movement intensity parameter SMA was analyzed by means of the generalized linear mixed models (GLMM) approach, accounting for repeated data within each subject. The accuracy of the CAM_{leg} and CAM_{trunk} during the standardized protocol was defined as the proportion of seconds correctly classified postures and activities with respect to the actual performed postures and activities, as defined in the protocol.

The time spent in weight-bearing postures, nonweight-bearing postures, and dynamic activities was determined for each subject using video recordings, $CAM_{leg,}$ CAM_{trunk}, and patients' estimation. If the examiner could not identify patients' posture or activity (eg, because of toilet visit), the seconds (samples) were removed from further analyses. Because the subjects were not all observed during exactly 3600 seconds (mean duration, 3672s; range, 3416–3815s), the time spent in the different postures and activities were recalculated on a standard period of 3600 seconds. Mean differences between video recordings, $CAM_{leg,}$ CAM_{trunk}, and patients' estimation were studied using the GLMM to account for repeated measures within subjects. Bland and Altman plots[31] were displayed to depict disagreements between video recordings and $CAM_{leg,}$