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Original Article

The 1-min sit-to-stand test in cystic fibrosis — Insights into cardiorespiratory responses

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Abstract

Background: We aimed to characterize the cardiopulmonary response during a 1-min sit-to-stand (STS) test and compare peak exercise cardiorespiratory variables to a maximal cardiopulmonary exercise test (CPET) in cystic fibrosis (CF). We further aimed to assess the validity of the STS power index ($Power_{STS}$) as a measure of exercise capacity.
Methods: Fifteen adult CF patients performed spirometry, CPET and the 1-min STS test with respiratory gas analysis.
Results: Peak-exercise cardiorespiratory variables during the 1-min STS test correlated strongly (r = 0.69–0.98) with those measured during the CPET. Oxygen uptake, carbon dioxide production, heart rate, ventilation, and tidal volume at peak exercise were 24%, 26%, 9%, 10% and 21% lower in the 1-min STS test, while respiratory frequencies were 14% higher. $Power_{STS}$ showed strong to very strong correlations with CPET-derived absolute peak oxygen uptake and maximal workload.
Conclusions: The 1-min STS test elicits a substantial but lower cardiorespiratory response compared to a maximal cycle ergometry CPET. While $Power_{STS}$ and STS repetitions are both valid outcome measures of functional capacity, STS repetitions are clinically more practical.

Keywords: Exercise testing; Validity; Lung disease; Functional capacity

1. Introduction

Regular exercise testing is recommended for patients with cystic fibrosis (CF), ideally employing a standardized cardiopulmonary exercise test (CPET) with respiratory gas analysis and with continuous monitoring of oxygen saturation (SpO_2) [1]. CPET is considered the gold standard method to assess an individual's cardiorespiratory fitness (i.e., peak oxygen uptake, $V'O_{2peak}$), to determine causes of exercise limitation(s) and risks associated with exercise [1,2]. In recent years, since the discovery of the CF transmembrane conductance regulator gene in human skeletal muscle [3,4], there appears to be growing interest in the measurement of muscle function in CF. Reduced limb muscle mass [5,6] and muscle strength [7] are common in CF and muscle strength is related to $V'O_{2peak}$ [8,9], a strong and independent predictor of survival in CF [10,11]. Lower limb muscle strength can be assessed by various methods such as dynamometry or supramaximal sprint tests [7–9]. These tests, however, have been rarely used in the clinical setting.

The 1-min sit-to-stand (STS) test has the potential to provide an easy applicable alternative to measure lower limb muscle function and functional exercise capacity [12–15]. In the last years, the STS test has been increasingly studied in chronic obstructive pulmonary disease (COPD) patients [12,13,16]. In COPD, STS test performance correlates with quadriceps muscle force [12,13], health-related quality of life (HRQoL) [12,16] and is a strong predictor of 2-year mortality [16]. Our group recently established the measurement properties and the

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minimal important difference for the 1-min STS test in adults with CF and we reported strong correlations between 1-min STS repetitions and CPET-derived $V'O_{2peak}$ (% predicted) and maximal workload ($Watt_{max}$, % predicted) [14]. However, the cardiorespiratory stress imposed by the 1-min STS test and measured by respiratory gas analysis is unknown in CF.

In practice, the 1-min STS test is usually performed using a commercially available chair without adjustment of the seat height to the individual's body size. This leads to individual differences in the distance of the center of gravity during STS motion. Moreover, differences in body mass between individuals are likely to result in different mechanical work during a STS test. To overcome these problems, the measurement of mechanical power, the product of force over time has been introduced [17,18].

The aim of this study was twofold: First, we sought to characterize the cardiorespiratory response during a 1-min STS test in comparison with a maximal cycle ergometer CPET in adults with CF. Furthermore, we assessed the validity of the STS power index ($Power_{STS}$) as a measure of exercise capacity in comparison to STS repetitions, the primary outcome measure of a 1-min STS test.

2. Patients and methods

We included patients with CF who participated in a three-week pulmonary rehabilitation program in November/December 2015. The program is described in detail elsewhere [14]. All tests were performed at the beginning (day 1 and 2) and the end (day 19 and 20) of the program and post-rehabilitation data were used for this study. Ethical approval was obtained from the cantonal ethical committee of Zurich, Switzerland and all patient's provided written informed consent.

2.1. The 1-minute sit-to-stand test

The 1-min STS test was performed on a conventional chair without armrest (height of the seat: 40 cm). The chair was placed against a wall to prevent movements during the test. All patients were familiar with the 1-min STS test but one additional test (without respiratory gas analysis) was performed 15 min before the baseline 1-min STS test to minimize learning effects [14]. Each STS test consisted of a 3-min rest phase with the participant sitting quietly on a chair followed by the 1-min STS exercise and a 3-min recovery phase with the participant sitting on the chair. During the active phase, the participants were instructed to stand-up and sit-down as often as possible at a self-chosen speed over 1 min and they were allowed to stop anytime during the test. After 45 s the patients were informed about the remaining exercise time. When standing up, the legs had to be fully straight and when sitting down, the buttock had to have clear contact with the chair. Respiratory parameters were measured breath-by-breath (METAMAX® 3B, Cortex Biophysik GmbH, Leipzig Germany) and data were exported as 10 s averages. The averages of the last 10 s of the 1-min STS task were considered peak values. Heart rate was measured with a Suunto heart rate monitor (Ambit2 S). SpO_2 was continuously measured with two different devices connected to the earlobe (Nonin® Xpod® PureSAT®) and finger (Nellcor™, PM10N, Covidien, US). We report values for earlobe SpO_2 due to better signal quality during the STS test. Oxygen desaturation was defined as $SpO_2 < 90\%$. At the end of the 1-min STS task, ratings of perceived exertion and dyspnea were evaluated by means of a 0–10 Borg scale [19].

2.2. Measures to calculate $Power_{STS}$

Body mass was measured in light exercise clothing to the nearest 0.1 kg using a digital balanced scale and height was measured to the nearest 0.5 cm using a stadiometer. We measured the patient's leg length in standing position as the distance between the great trochanter of the femur and the malleolus lateralis using a tape measure [17]. We calculated a $Power_{STS}$ using the following equation (adapted from [17]):

$$\mathrm{Power_{STS}(Watt)} = \frac{(\mathrm{LL}-0.4)*\mathrm{body\ mass}*g*\mathrm{STS_{reps}}}{\mathrm{Time_{STS}}}$$

LL represents the leg length (in m); 0.4 the seat height (in m); g the acceleration of gravity (9.81 $m.s^{-2}$); STS_{reps} the number of repetitions during the 1-min STS test and $Time_{STS}$ the duration of the test (60s).

2.3. Validation measures

2.3.1. Cardiopulmonary exercise testing

Cardiopulmonary exercise testing (CPET) was performed on a cycle ergometer (Lode Corival 906900, Lode BV, Groningen, Netherlands) using the Godfrey protocol [20]. The metabolic cart (METAMAX® 3B, Cortex Biophysik GmbH, Leipzig Germany) was calibrated with gases of known standard concentrations before each test. Heart rate and SpO_2 were continuously measured using the devices described above. We report values for earlobe SpO_2 consistent with the 1-min STS test. Ratings of perceived exertion and dyspnea were evaluated at peak exercise by means of a 0–10 Borg scale [19]. Three of the following criteria had to be fulfilled to ensure the test was maximal: 1) plateau in oxygen uptake ($V'O_2$) despite an increase in workload; 2) peak heart rate over 85% of predicted [21], respiratory exchange ratio (RER) > 1.05, 4) peak ventilation exceeded predicted maximum voluntary ventilation (calculated as $FEV_1 \times 35$) and 5) subjective impression of the test supervisor. Data for $V'O_{2peak}$ and $Watt_{max}$ are presented as % predicted values [22,23].

2.3.2. Spirometry

Spirometry was performed in sitting position using a commercially available system (METAMAX® 3B, Cortex Biophysik GmbH, Leipzig Germany) according to ATS/ERS standards [24]. Percent predicted values were calculated for forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC) based on equations published by Quanjer et al. [25].

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