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What's the secret behind the benefits of whole-body vibration training in patients with COPD? A randomized, controlled trial

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ABSTRACT

Background: Several studies have shown that whole-body vibration training (WBVT) improves exercise capacity in patients with severe COPD. The aim of this study was to investigate the determinants of improved exercise capacity following WBVT.

Methods: Seventy-four COPD patients (FEV_1: 34 ± 9%predicted) were recruited during a 3-week inpatient pulmonary rehabilitation (PR) program. Conventional endurance and strength exercises were supplemented with self-paced dynamic squat training sessions (4bouts*2min, 3times/wk). Patients were randomly allocated to either a WBVT-group performing squat training on a side-alternating vibration platform (Galileo) at a high intensity (24–26 Hz) or a control group performing squat training without WBVT.

Results: Patients in the WBVT group significantly improved postural balance in several domains compared to the control-group (i.e. tandem stance: WBVT +20% (95%CI 14 to 26) vs. control −10% (95%CI 6 to 15), $p < 0.001$; one-leg stance: WBVT +11% (95%CI 4 to 19) vs. control −8% (95%CI -19 to 3), $p = 0.009$). Six-minute walk distance and muscle power but not muscle strength were also significantly improved compared to control group.

Conclusions: Implementation of WBVT improves postural balance performance and muscle power output. The neuromuscular adaptation related to improved balance performance may be an important mechanism of the improvement in exercise capacity after WBVT especially in COPD patients with impaired balance performance and low exercise capacity.

1. Introduction

Recently, there has been increased interest in whole-body vibration training (WBVT) as part of exercise therapy for patients with chronic obstructive pulmonary disease (COPD). During WBVT, subjects stand with both feet on a platform producing oscillating mechanical vibrations. The rapid up and down movement of the platform stretches the muscles of the lower extremities. The neuromuscular system reacts to these stretches in a reflexive chain of rapid muscle contractions [1]. Cardinale et al. proposed that the monosynaptic reflex-induced muscle contractile activities during WBVT would be an especially effective therapy in patients with impaired muscle performance, such as sedentary subjects with sarcopenia [2].

Since the 1990s WBVT has been widely studied in athletes, healthy subjects and patients with various chronic conditions [3,4]. However, the first study demonstrating benefits of WBVT in patients with COPD was published in 2012 [5]. In a recently published systematic review by our work group, in which six studies were

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Abbreviation

6MWD	six-minute walk distance
6MWT	six-minute walk test
APL	absolute path length
ATS	American Thoracic Society
BMI	body-mass-index
CON	control group
COPD	chronic obstructive pulmonary disease
FEV_1	forced expiratory volume in 1 s
FFMI	fat-free mass index
GOLD	Global Initiative for chronic Obstructive Lung Diseases
IVC	inspiratory vital capacity
LTOT	long-term oxygen therapy
PaO_2	partial pressure of oxygen
STST	sit to stand test
SpO_2	oxygen saturation
WBVT	whole-body vibration training

identified (including a total of 235 COPD patients), WBVT was applied using different approaches and settings [6]. It was found that WBVT was superior in improving functional exercise capacity (measured by the 6-minute walk test or sit-to-stand tests) in comparison to conventional exercise strategies. In other populations such as healthy elderly or patients with fibromyalgia, WBVT has been shown to improve balance performance [7,8]. However, the impact of WBVT on balance has never been investigated in patients with COPD. Furthermore, it is unknown whether potential improvements in balance are associated with benefits on exercise capacity after WBVT. Therefore, aim of this study was to evaluate the influence of a squat training protocol with and without WBVT on postural balance and exercise performance in patients with severe COPD. Our working hypothesis was that neuromuscular adaptation is largely responsible for the superior increases in exercise performance [6].

2. Material and methods

2.1. Study design

122 consecutive patients admitted to an inpatient rehabilitation program at the Schoen Klinik Berchtesgadener Land (Schoenau am Koenigssee, Germany) were screened for eligibility to participate in this three week randomized controlled trial (August 2015 until June 2016). All performance testing was done in same order at baseline (before randomization) and at three weeks. This study was conducted in accordance with the amended Declaration of Helsinki, was submitted to the German Clinical Trials Register (identification number DRKS7774) and approved by the Ethics Committee of the Bavarian Physician Association (ID15006).

2.2. Study population

Out of 122 eligible patients, 87 met the inclusion criteria and were included in the trial (Fig. 1). The inclusion criteria were: patients aged 50–80 years old with COPD stage III or IV according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines [9]. Exclusion criteria were defined as: major surgery, bone fracture or deep vein thrombosis (within the last 12 weeks) as well as existing arterial aneurysm, acute COPD exacerbation (within the last 4 weeks), or orthopedic co-morbidities that prevented patients from performing squat exercises, or inability to comply with the study protocol.

2.3. Intervention

Patients participated in a three-week multidisciplinary inpatient pulmonary rehabilitation (PR) program (standard duration in Germany), consisting of medical care, respiratory therapy, education, nutritional and psychological counseling. Patients performed conventional exercise training on 5 days per week consisting of endurance training (15 min cycling at 60% of peak power) [10] and strength training (four to six exercises at strength training machines with three sets of 15–20 repetitions for major muscle groups using the maximum tolerated load to momentary muscular failure) [11].

Furthermore, all patients underwent a supplemental supervised squat exercise program. Patients were randomized and allocated to either an experimental (WBVT) or a control group. The WBVT group performed squat exercises on a side-alternating vibration platform (Galileo®, Novotec Medical GmbH, Pforzheim, Germany) at high frequencies (24–26 Hz) and 5 mm peak-to-peak displacement (Fig. 2) wearing flat soled shoes. Controls performed the same squat exercises on a normal floor. The squat exercise consisted of four sets of 2-min duration, and was performed three times a week on non-consecutive days. An experienced exercise scientist supervised all sessions and corrected patients' movement if necessary. Patients performed knee and hip flexion between 90° and 120° during each squat movement without holding on to anything. Patients in both groups were instructed to perform squats at their own pace to increase comfort and feasibility. The number of repetitions within the allotted time (8 min/session) was recorded by the supervisor.

2.4. Outcomes and measures

2.4.1. Neuromuscular performance

Postural balance and muscular power were assessed using a ground reaction force platform (Leonardo Mechanograph®, Novotec Medical, Pforzheim, Germany). The platform uses 8 integrated force sensors (800 Hz each) to reliably calculate the center of force (= mean point where the patient generated forces are focusing on the plate) [12]. Each performance test on the platform was carried out three times but only the best test was used for analysis.

2.4.2. Postural balance

Patients were asked to stand as still as possible for 10 s while holding their arms against their sides in the following positions: 1) Romberg stance (eyes closed): feet side-by-side, 2) semi-tandem stance (eyes closed and eyes open): one foot beside and behind the other (Fig. 3) and 3) the one-leg stance (eyes open). During postural balance tests, the 'absolute path length (APL)' of the center of force induced on the force plate was measured in millimeters. The APL measures how much a subject sways during the 10 s period and its ability to stabilize in a specific posture (the smaller the APL, the better the balance capability and vice versa). The best test (with the lowest APL) out of three tests was used for analysis.

2.4.3. Muscle power (=muscular work per time)

A two-legged jump on the force plate was performed to assess muscle power. During this well-validated test [13] (also known as countermovement jump) patients were asked to jump as high as possible with using the arm-swing [14]. Outcomes are the jump height and peak Watt calculated by the force plate. The best test (highest jump height) out of three tests was used for analysis.