



## A comparison of training intensity between whole-body vibration and conventional squat exercise

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### ARTICLE INFO

#### Article history:

Received 23 September 2010

Received in revised form 2 December 2010

Accepted 28 December 2010

#### Keywords:

EMG

Lumbar activity

Acceleration

Perceived exertion

### ABSTRACT

The aim of this study was to investigate surface electromyographic activity (sEMG) and rate of perceived exertion (RPE) during semi-squat exercise on vibration platform compared with semi-squat exercise performed on a Smith machine. Twenty-three recreationally active students (15 males and 8 females) were exposed to six different loads in one of both exercise modes: vibration or Smith machine. The subject performed a squat in six experimental conditions; the load differed per experimental condition. For each subject the exercise mode ( $n = 2$ ) and the different loads per mode ( $n = 6$ ) were assigned in a random order to check the influence of vibration magnitude (acceleration:  $\text{m s}^{-2}$ ) as well as weight (kg) on sEMG and RPE. Two-way ANOVA for RPE, lumbar and lower-body sEMG revealed a significant weight main effect ( $P < 0.01$ ) and a significant acceleration main effect ( $P < 0.01$ ). The results from this study demonstrate that the training stimulus resulting from an isometric semi-squat exercise on a vibration platform (acceleration: from 12 to 89  $\text{m s}^{-2}$ ) is similar to the training stimulus of an isometric semi-squat exercise on Smith machine (weight: from 20 to 70 kg) according to lower-body sEMG and RPE. However, the impact of semi-squat on vibration platform exercise for lumbar muscle is relatively small compared with semi-squat on Smith machine.

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### 1. Introduction

The squat is one of the most popular exercises to develop muscle strength of the lower limbs. The squat exercise can be performed in unloaded conditions, but to guarantee an optimal training intensity, squatting is mostly executed with an additional load by means of free weights, cable machine, Smith machine, vibration platform, etc. The variation in training stimulus during squat exercise that was performed in different conditions or on specific devices has been studied by several authors (McCurdy et al., 2010; Roelants et al., 2006; Schwanbeck et al., 2009). Anderson and Behm (2005) compared surface electromyographic activity (sEMG) of the soleus, vastus lateralis, biceps femoris, abdominal stabilizers, upper lumbar erector spinae, and lumbosacral erector spinae muscles during squat exercises using free weights and the Smith machine. They found that sEMG of the trunk musculature was the highest ( $P < 0.05$ ) during the free weight

squat; however, sEMG of the vastus lateralis was the highest during the Smith machine squats.

Recently, there has been a growing interest in the training effects of squat exercise executed on a vibrating platform. This method is called 'whole-body vibration' (WBV) and is considered to be beneficial in training (Delecluse et al., 2003; Marin and Rhea, 2010a,b; Petit et al., 2010) and rehabilitation (Bogaerts et al., 2009; Machado et al., 2010; Totosty de Zepetnek et al., 2009). Earlier research indicated that direct mechanical vibrations applied to the muscle belly elicit reflex muscle contractions, resulting into a 'tonic vibration reflex' (TVR), mediated by mono- and poly-synaptic pathways (Gillies et al., 1971a,b; Kossev et al., 2001). Muscle spindle Ia reflexes have been indicated as the major determinant of this vibration-induced neuromuscular activation leading to the TVR (Burke and Gandevia, 1995). In contrast to these direct vibrations, WBV-exercise consists mainly of squat exercises performed on a vibration platform that evokes a mechanical oscillation. The up- and downward acceleration of the platform depends on the amplitude (mm) and the frequency (Hz) of the oscillation. The training stimulus during WBV is determined by the magnitude of the acceleration (Marin and Rhea, 2010a,b; Petit et al., 2010). Considering the numerous possible combinations of amplitude and frequency

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with the current technology, there is a need for scientific studies that analyze the responses during vibration exercise to elicit adequate responses and to achieve optimal training effects.

One study analyzed differences in leg muscle activity within a variation of squat exercises performed on a vibrating platform (Roelants et al., 2006). The authors concluded that WBV (frequency of 35 Hz and amplitude of 2.5 mm) resulted in an activation of the different leg muscles to a magnitude that varied between 12.6% and 82.4% of maximal voluntary contraction.

Research findings indicate that squat exercises, performed on a vibrating platform, increase the strength of the leg extensors to a similar extent as can be realized by means of conventional resistance exercise at moderate intensity (Delecluse et al., 2003). However to develop a structured training methodology by means of progressive loading through WBV, we need to understand how the magnitude of acceleration ( $\text{m s}^{-2}$ ) impacts on muscle activation and to compare this with the training stimulus of squat exercise through traditional loading (kg). To the best of our knowledge, no study has compared neuromuscular effect of vibration exercise versus conventional resistance exercise at different loads. The aim of this study was to investigate muscle activation and rate of perceived exertion (RPE) during semi-squat exercise on vibration platform compared with semi-squat exercise performed on a Smith machine.

## 2. Methods

### 2.1. Subjects

Twenty-three recreationally active students (15 males and 8 females). The subjects' mean ( $\pm$ SD) age, height, and weight were  $24.3 \pm 2.3$  years;  $174.5 \pm 8.3$  cm; and  $69.9 \pm 8.1$  kg, respectively. Exclusion criteria were diabetes, epilepsy, gallstones, kidney stones, cardiovascular diseases, joint implants, recent thrombosis, as well as any musculoskeletal problems that could affect performance. Prior to data collection subjects were informed of the requirements associated with participation and provided written informed consent. Moreover, subjects were not allowed to change their sleeping, eating, or drinking habits throughout the duration of their participation to the study. The research project was conducted according to the Declaration of Helsinki and it was approved by the University Review Board for research involving human subjects.

### 2.2. Exercise protocol

Each participant attended two laboratory test sessions. Initially, the skin of the subject was prepared and sEMG electrodes were placed. Before testing, all subjects performed a standardized warm-up, consisting of a 5-min walking at  $6 \text{ km h}^{-1}$ . After that, subjects were exposed to six different loads in one of both exercise modes: vibration (Fitvibe, GymnaUniphy NV, Bilzen, Belgium) or Smith machine (Nautilus NT 1800; Nautilus, Inc., Vancouver, WA, USA). In the vibration mode the training load is quantified by means of the acceleration of the platform ( $\text{m s}^{-2}$ ). On the Smith machine the different loads are determined by the weight (kg) that rests on the subject's shoulders. The subject performed a squat in six experimental conditions; the load differed per experimental condition. For each subject the exercise mode ( $n = 2$ ) and the different loads per mode ( $n = 6$ ) were assigned in a random order to check the influence of vibration magnitude (acceleration:  $\text{m s}^{-2}$ ) as well as weight (kg) on sEMG and RPE. Load of each experimental condition is presented in Table 1. Each experimental condition lasted 15s, with 60s of rest between each condition. The vibration and weight exercises were performed with the subjects standing with their feet, separated to shoulder-width, on the vibration platform or on the floor, respectively. The knee angle was pre-set at  $30^\circ$

**Table 1**

Parameters for each exercise mode.

| Vibration exercise |           |                                    | Weight exercise |
|--------------------|-----------|------------------------------------|-----------------|
| Frequency (Hz)     | Amplitude | Acceleration ( $\text{m s}^{-2}$ ) | Weight (kg)     |
| 25                 | Low       | 12.5                               | 20              |
| 35                 | Low       | 20.2                               | 30              |
| 45                 | Low       | 30.9                               | 40              |
| 25                 | High      | 36.3                               | 50              |
| 35                 | High      | 60.1                               | 60              |
| 45                 | High      | 88.4                               | 70              |

High amplitude (3.1 mm [peak to peak]); low amplitude (1.0 mm [peak to peak]).

flexion. All subjects were asked to wear athletic shoes. All exercises were performed with a bar resting across the upper trapezius muscle. In the case of vibration exercise, an unloaded bar was used to maintain the same position during both exercises modes.

The vertical component of the acceleration of vibration platform was measured by means of an accelerometer in accordance with ISO2954, (Vibration meter, VT-6360, Hong Kong, China).

### 2.3. Surface electromyographic activity (sEMG)

Muscle activity of the vastus medialis (VM), vastus lateralis (VL), biceps femoris long head (BF), medial gastrocnemius (MG), and lumbar paravertebral (LP) muscles were measured using sEMG. One set (two measuring electrodes and a reference electrode) of surface electrodes (Ag/AgCl, Skintact, Austria) was placed longitudinally to the muscle fibers direction approximately halfway from the motor point area to the distal part of the muscle. An inter-electrode distance of 2 cm was maintained. The reference electrode was placed in a neutral area away from the measuring electrodes. Before electrode placement, the area was cleaned with isopropyl alcohol, shaved and abraded in order to reduce skin impedance until it was lower than 5 k $\Omega$  (De Luca, 1997).

The surface electrodes were connected to a 14-bit AD converter (ME6000 Biomonitor, Mega Electronics, Kuopio, Finland). Raw EMG signals were pre-amplified close to the electrodes (gain of 375, in the bandwidth of 8–500 Hz) and sampled at 2000 Hz before being stored in a memory card (compact flash memory, 256 MB). On the basis of the frequency analysis, a band width of  $\pm 0.8$  Hz around each harmonic was excluded from the root-mean-square calculation (Abercromby et al., 2007). sEMG data analysis was performed across the use of specific software (MegaWin V 2.21, Mega Electronics, Kuopio, Finland). The middle 10 s of the exercise (from 2.5 s to 12.5 s) were chosen for data analysis. sEMG raw data was averaged by root mean square in order to obtain averaged amplitude of the sEMG signal. The sEMG values were compared with equivalent baseline during unloaded squatting (no vibration and no weight), normalization relative to maximal voluntary contractions was unnecessary (Abercromby et al., 2007; Marín et al., 2009). Lower-body sEMG were calculated as the mean sEMG of VM, VL, BF, and MG.

### 2.4. Rating of perceived exertion (RPE)

The OMNI-RES perceived exertion scale was verbally anchored (Robertson et al., 2003). OMNI-RES consists of 10 reporting options between 1 (extremely easy) to 10 (extremely hard). One week before the testing session, subjects attended two familiarization sessions, one for vibration exercises and one for weight exercises. Each subject was read a set of scale-specific instructions for the use of the OMNI-RES scale. For vibration exercises, participants were instructed to assign a rating of 1 to any perceptions of exertion that were less than those experienced during the semi-squat position (knee angle at  $30^\circ$  flexion; without vibration) and a rating of 10 was associated with semi-squat position at the maximum vibration

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