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The interaction between body position and vibration frequency on acute response to whole body vibration

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ABSTRACT

Purpose: The present study was designed to investigate the electromyographic (EMG) response in leg muscles to whole-body vibration while using different body positions and vibration frequencies.
Methods: Twenty male sport sciences students voluntarily participated in this single-group, repeated-measures study in which EMG data from the vastus lateralis (VL) and the lateral gastrocnemius (LG) were collected over a total of 36 trials for each subject (4 static positions × 9 frequencies).
Results: We found that vibration frequency, body position and the muscle stimulated had a significant effect (P-values ranged from 0.001 to 0.031) on the EMG response. Similarly, the muscle × frequency and position × muscle interactions were significant ($P < 0.001$). Interestingly, the frequency × positions interactions were not significant ($P > 0.05$).
Conclusions: Our results indicate that lower frequencies of vibration (25–35 Hz) result in maximal activation of LG, whereas higher frequencies (45–55 Hz) elicit the highest responses in the VL. In addition, the position P2 (half squat position with the heels raised) is beneficial both for VL and LG, independently of the vibration frequency.

1. Introduction

During whole-body vibration, the gravitational load (hypergravity condition) imposed on the neuromuscular system is determined by the vibration amplitude and the frequency of the vibrating plate. Therefore, the high accelerations that have been reported in the literature (up to 15 g, where g is Earth's gravitational field, or 9.81 m/s^2) have been realised by manipulating various combinations of frequency (from 20 to 50 Hz) and amplitude (from 2 to 10 mm) (Cardinale and Bosco, 2003; Luo et al., 2005; Prisby et al., 2008; Cochrane, 2011).

In the literature addressing the acute response to whole-body vibration, only a few studies have used surface electromyography (EMG) to measure the level of neuromuscular activity, which can be used to evaluate training parameters such as vibration frequency and body position (Cardinale and Lim, 2003; Roelants et al., 2006; Abercromby et al., 2007; Di Giminiani et al., 2009, 2010; Pollock et al., 2010). In this way, EMG can be used to identify the conditions that maximise neuromuscular responses and avoid the problems of chronic exposure that are highlighted in occupational medicine (Dandanell and Engstrom, 1986; Anderson et al., 1987; Seidel et al., 1988).

Abercromby et al. (2007) is the most comprehensive investigation of the acute neuromuscular responses to whole-body vibration in different leg muscles; however, the study did not evaluate two key issues: the effect of EMG activity on the two most common positions that are used when applying whole-body vibration [high (knee angle at 120°) and low (knee angle at 90°) isometric squats] and the frequency of vibration that provides the greatest stimulus for changes in muscle activity.

The tonic vibration reflex (TVR) that is elicited in a specific muscle under isometric testing conditions varies with the initial position of the joint (De Gail et al., 1966; Eklund and Hagbarth, 1966). In other words, the strength of the response that is assessed by the EMG activity and the force that is developed increase with increasing muscle length.

Two studies by Burke et al. (1976a,b) showed that the sensitivity of muscle spindles, which were assumed to be the main source of strength of the TVR (Eklund and Hagbarth, 1966; Johnston et al., 1970), was higher when the muscle was passively stretched (1976a) or moderately contracted under isometric conditions (1976b).

The moment about the knee joint is greater in the half squat position, resulting in higher tension, and the knee extensors work

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over a longer length; therefore, it can be assumed that the knee extensors have a greater response in the half squat position than in the high squat position. Additionally, it can be assumed that the plantar flexors are activated to a higher level (in the high squat position) because of the vibration that occurs when the heels are raised from the ground. Ritzmann et al. (2010) explored the origin of the EMG signal in the extensor muscles of the leg during whole-body vibration. They showed that the main part of this periodic EMG activity appears to be caused by a TVR, which is similar to the reflex that is induced by directly applying vibration to the muscle tendon (Eklund and Hagbarth, 1966; Hagbarth and Eklund, 1968; Hagbarth, 1994). In addition, Wakeling et al. (2002) reported that peaks in the EMG muscle activity and an increased damping of vibration in leg muscles occur when the frequency of whole-body vibration is close to the natural frequency of soft tissues. Therefore, the muscle activity patterns in the lower extremity muscles are modified as a response to changes in the excitation frequency of input signals.

Assuming that the neuromuscular response during whole-body vibration is mediated by Ia afferents, which is the case when the vibration stimulus is directly applied to the muscle, we hypothesised that the EMG responses of leg muscles (the vastus lateralis and the lateral gastrocnemius) are dependent on vibration frequency and body position on the vibrating plate. To test our hypothesis, we studied the effects of various body positions and different vibration frequencies on the EMG responses in leg muscles under isometric conditions.

2. Methods

2.1. Subjects

Twenty male sport sciences students (20 ± 1.5 y; 175 ± 6.2 cm; 72.8 ± 5.3 kg) voluntarily participated in this experiment. The subjects were aware of the purpose of the study, and they all provided written informed consent. The exclusion criteria included a history of back pain, acute inflammation in the pelvis and/or lower extremities, acute thrombosis, tumours, recent fractures, recent implants, gallstones, kidney or bladder stones, any disease of the spine, peripheral vascular disease, and severe delayed onset of muscle soreness in leg muscles.

2.2. Experimental design

A single-group, repeated-measures study design was used in which the EMGrms of two leg muscles were the dependent variables. The independent variables were the frequency of whole-body vibration (0, 20, 25, 30, 35, 40, 45, 50, and 55 Hz) and body position (positions 1, 2, 3, and 4). Subject recruitment and experimental measurements were performed in the Laboratory of Biomechanics of the University. For each subject, the experiment was performed over 2 days to reduce the potential effects of boredom and fatigue. On the first day, each subject was instructed to assume the 4 different body positions on the vibrating plate. On the second day, the data were collected over a total of 36 trials for each subject (4 positions × 9 frequencies).

2.3. Whole-body vibration stimulation and body position

The subjects were exposed to vertical sinusoidal whole-body vibration using a vibratory platform (Nemes-Lsb, Technology Langesund, Norway). The vertical component of the acceleration was measured using an accelerometer (Type ET-Acc-02, Ergotest, Technology Langesund, Norway), which was placed in the middle of the vibration platform during a progressive incremental frequency protocol in which the frequency was increased from 20 to 55 Hz. The acceleration of the vibrating plate ranged from approximately 1.1–60 m/s^2, and the peak-to-peak displacement was approximately 1 mm.

The subjects assumed 4 different positions (P1, P2, P3, and P4) (Fig. 1) for the following conditions: no vibration (i.e., 0 Hz), 20, 25, 30, 35, 40, 45, 50, and 55 Hz. There was a 2 min pause between trials, and each trial lasted 20 s. The order of the trials for each subject was randomised across the frequencies and the positions. To

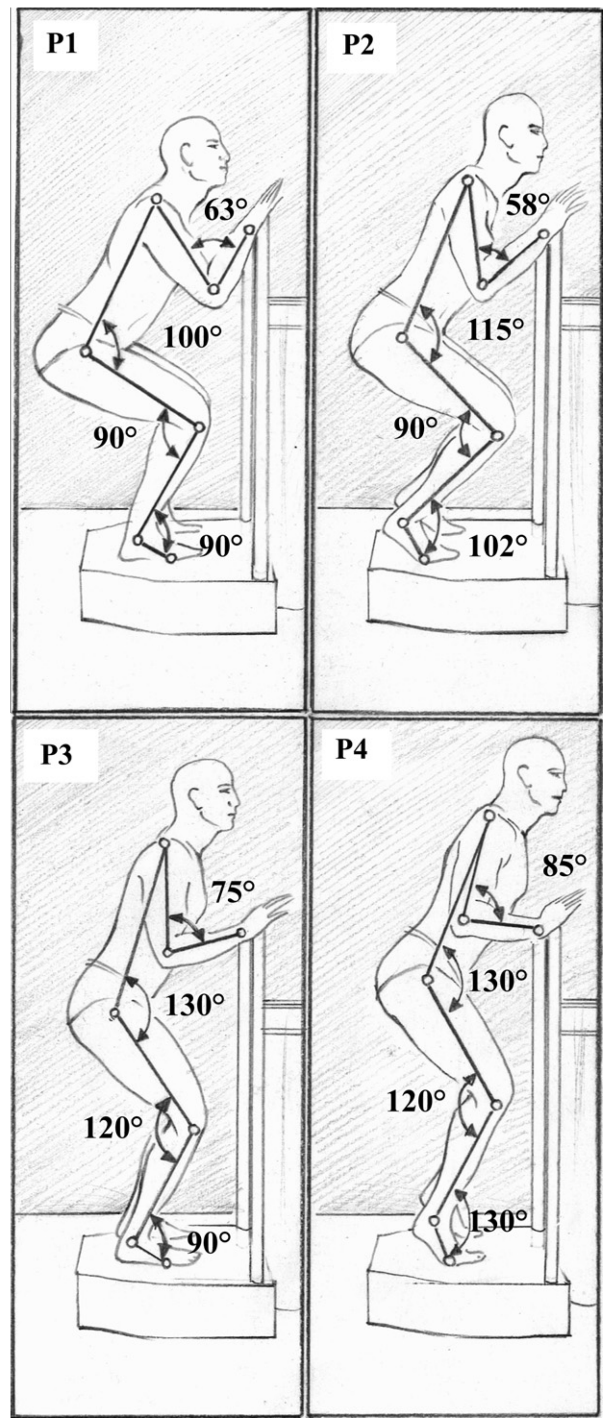

Fig. 1. Body positions in which the vibration was applied. The vibration occurred in half squat (P1 and P2) or high squat positions (P3 and P4). In these positions, the body was supported on either the entire sole (heels on the ground, P1 and P3) or the first part of the feet (heels in the air, P2 and P4).