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Acute effects of whole-body vibration on trunk muscles in young healthy adults

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ABSTRACT

Little is known about the impact of whole body vibration (WBV) training on trunk muscles. Thus, this study investigated the acute effects of WBV on back and abdominal muscle activity. Twenty-five healthy subjects (24.7 ± 3.0 years, 17 men) conducted eight common static exercises for the back and abdominal muscles in a random order on a vibration platform, with and without vibration. Surface EMG was measured from back and abdominal muscles. Vibration-induced motion artefacts were removed from the EMG signal. Muscle activity with and without vibration was normalized to maximal voluntary contraction (MVC) and compared. The addition of vibration resulted in significant increases in muscle activity particularly in the exercises for the abdominal muscles of up to 7.2 ± 5.5% MVC (median ± semi-interquartile range). In the back muscles, the largest difference by adding vibration was 1.6 ± 1.4% MVC (median ± semi-interquartile range). The results of this study indicate a low to moderate increase in trunk muscle activation due to WBV. Presumably, this effect might depend on the distance from the corresponding muscle to the vibration platform and on how much the exercise position challenges body balance. However, the relevance of these findings has to be further investigated in training studies.

1. Introduction

In recent years, whole body vibration (WBV) has been promoted as a new, attractive and efficient training method and is currently widely used in sports and rehabilitation institutes (Nordlund and Thorstensson, 2007). Initially, WBV had been investigated particularly among healthy people such as elite athletes, where it proved to enhance muscle power output immediately after training (Bosco et al., 1999; Issurin and Tenenbaum, 1999; Cochrane and Stannard, 2005). Nowadays, the effects of WBV are also increasingly being studied among elderly people (Torvinen et al., 2002; Bruyere et al., 2005; Bogaerts et al., 2007) as well as in the rehabilitative context (Turbanski et al., 2005; Tihanyi et al., 2007; Jackson et al., 2008). Although there is no clear consensus on the mechanisms by which WBV affects the neuromuscular system, the observed increase in muscle power output is often linked to neuromuscular facilitation (Rehn et al., 2007), while recent studies instead suggest a warming-up effect (Cochrane et al., 2008; Rittweger, 2010).

Hence, in order to study whether WBV indeed has an impact on muscular activity, several studies applied surface electromyography (EMG) during WBV training. Most of these studies focused on leg muscles (Cardinale and Lim, 2003; Verschueren et al., 2004; Roelants et al., 2006) and no study was found that investigated trunk muscle activity during WBV training. Furthermore, the observed increase in muscle activity during WBV training might suggest an increase in neuromuscular activity (Cardinale and Lim, 2003; Verschueren et al., 2004; Roelants et al., 2006). However, the EMG signals recorded during WBV training require the elimination of vibration-induced movement artefacts in order to avoid overestimating the effects of WBV (Fratini et al., 2009), which has often been neglected in previous studies. Thus, the aim of the present study was to investigate for the first time the acute effects of WBV on trunk muscle activity in healthy subjects giving particular consideration to the issue of motion artefacts caused by WBV. It was hypothesized that without removing the motion artefacts from the EMG signal, muscle activity with WBV would be much higher than without WBV, analogously to lower leg studies (Cardinale and Lim, 2003; Roelants et al., 2006). After removing these motion artefacts, however, the benefit of adding WBV was supposed to be rather low.

2. Methods

2.1. Subjects

Twenty-five healthy subjects (age 24.7 ± 3.0 years, height 1.75 ± 0.09 m, weight 69.4 ± 11.7 kg, BMI 22.4 ± 2.0 kg/m^2, 17 men) without any history of back pain participated in the study. All procedures were in accordance with the Declaration of Helsinki and were approved by the local ethics committee. All subjects gave written informed consent prior to participation.

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2.2. Experimental procedure

For the EMG measurements, a telemetric EMG system with a sampling rate of 1500 Hz was used (Telemyo 2400 T, Noraxon Inc., Scottsdale, USA). After appropriate skin preparation with an abrasive gel (SPES Medica, Battipaglia, Italy) for the purpose of reducing skin impedance, the electrodes (Ag/AgCl, Ambu Blue Sensor N, Ballerup, Denmark) were put in place according to the European Recommendations for Surface Electromyography (Hermens et al., 1999) and if these were not available as for the abdominal muscles, according to literature data (Vera-Garcia et al., 2000; Lehman and McGill, 2001; Konrad, 2005; Freiwald et al., 2007). The electrodes were placed with an interelectrode distance of 20 mm on the right lumbar longissimus (2 finger width lateral from the processus spinosus of L1), multifidi (2–3 cm from the midline at the level of L5, placed on and aligned with a line from caudal tip posterior spina iliaca superior to the interspace between L1 and L2 interspace), upper part of rectus abdominis (2–3 cm lateral from the midline on the second segment of the muscle) (Lehman and McGill, 2001; Konrad, 2005), lower part of rectus abdominis (2–3 cm lateral from the midline, 2 cm inferior to the umbilicus) (Lehman and McGill, 2001; Konrad, 2005; Freiwald et al., 2007), obliquus externus (at 50% of the line from the anterior spina iliaca superior and the tip of the 11th rib) (Freiwald et al., 2007) and obliquus internus muscles (halfway between the spina iliaca superior and the midline, directly above the inguinal ligament) (Vera-Garcia et al., 2000; Konrad, 2005). In order to prevent the cables from swinging as much as possible, the preamplifiers (gain 500) and cables were fixed to the body. In addition, two accelerometers (10 g, Noraxon Inc., Scottsdale, USA) to measure vibration-induced acceleration in the horizontal and transversal body plane were attached to the third lumbar vertebra and to the iliac crest, respectively. After a short warm-up on an indoor rowing machine (Concept2, Morrisville, USA), maximal voluntary contraction (MVC) was determined for the back and abdominal muscles according to Freiwald et al. (2007) in order to be able to normalize the EMG data. For the back muscles, the subjects lay in a prone position with the ankles fixed to the table by a strap and maximally contracted the corresponding muscles against the resistance of the examiner at the shoulder blades (Freiwald et al., 2007). For the rectus abdominis muscle, the subjects lay with the knees bent and the feet fixed by a strap in a supine position. They maximally contracted the abdominal muscle against the resistance of the examiner at the shoulders (Freiwald et al., 2007). For the lateral abdominal muscles, the subjects lay with outstretched legs to the sides (ankles fixed to the table) and maximally contracted the muscles against the resistance of the examiner at the shoulder (Freiwald et al., 2007). For each muscle, the subjects had one test to become familiar with the testing procedure before performing three trials. In each trial, the maximal isometric contraction was hold for 2–3 s with a break in between of 5 s. No verbal motivation was given during any of the tests. The participants then performed eight static exercises for the back and abdominal muscles in a random order on the vibration platform (Fitvibe Excel Pro C, Bilzen, Belgium) at the frequency of 30 Hz (Cardinale and Lim, 2003) and the amplitude of 4 mm (without shoes, with an additional soft mat of 25 mm thickness provided by the manufacturer (Fitvibe Excel Pro C, Bilzen, Belgium)). The exercises were partial squat (knee angle 60°), deep squat (knee angle 90°), supine bridge (feet on vibration platform), prone bridge forward (elbows on platform), prone bridge backward (feet on platform), sit-up position, side bridge and twist position (Fig. 1). The subjects were instructed to hold the initial position during the exercise. Each exercise was performed twice with and twice without vibration according to an ABBA or BAAB scheme (alternate allocation). In total, each exercise was performed 40 s (4 times 10 s with 20 s break in the middle). In order to standardize the test positions, joint angles were controlled by means of a manual goniometer.

2.3. Data analysis

All EMG analyses were conducted using MyoResearch XP Master Software Version 1.07.17 (Noraxon Inc., Scottsdale, USA). First, the raw EMG signals were band-pass filtered between 10 and 500 Hz. The first 1.5 s of the exercise data were cut in order to eliminate vibration onset effects and the following 5 s were further analyzed. In one condition, vibration-induced motion artefacts were removed in MVC and trial data by filtering out the sharp peaks in the signal spectrum corresponding to the first three harmonics of the vibration frequency (f_0, $2f_0$, $3f_0$) by notch filters with a -6 dB band of 3 Hz (Fratini et al., 2009). In order to ensure comparability, the exercise data with and without vibration were subjected to an identical procedure. Subsequently both, the data of the MVC measurements and the exercise data were smoothed by means of a moving RMS (time window 500 ms). In the MVC data, maximal amplitude of each of the three bursts was determined and the average was calculated in order to account for variability. For each of the four exercise performances (twice with vibration and twice without vibration), the mean amplitude over the 5 s to be analyzed was determined. Subsequently, the mean amplitudes of the two performances with the same condition (with or without vibration) were averaged and expressed as a percentage of MVC. In two subjects, the EMG signal (with and without vibration) of one muscle for each subject (once obliquus externus muscle, once lower part of rectus abdominis muscle) could not be analyzed due to poor signal quality.

2.4. Statistics

For each exercise, only the muscles that showed higher activity than 5% MVC were considered to be active and were thus analyzed statistically. After testing for normal distribution by Shapiro–Wilk tests, the values obtained with and without vibration were compared using Wilcoxon signed rank test. This analysis was conducted for the EMG data with and without filtering out the first 3 harmonics of the vibration frequency, respectively. For all analyses, SPSS Statistics 17.0 (SPSS, Chicago, Illinois) was used and the significance level α was set at 0.05.

3. Results

No systematic differences between the ABBA and the BAAB procedure could be found. The EMG frequency spectrum without previous removal of the vibration-induced motion artefacts showed sharp peaks at the first three harmonics of the vibration frequency in agreement with Fratini et al. (2009), which were precisely at 29.3, 58.6 and 87.9 Hz, respectively. These peaks could be eliminated by removing the first three harmonics (Fig. 2).

3.1. EMG data with previous removal of vibration-induced motion artefacts

In general, the back muscles were activated to a relatively low extent in all exercises. Maximal activation for the erector spinae muscle was on average 18.6 ± 5.0% MVC (median ± semi-interquartile range (SQR)) in the deep squat without vibration (exercise 2, Fig. 1) and for the multifidus muscle 25.6 ± 3.0% MVC (median ± SQR) in the supine bridge with vibration (exercise 3) (Fig. 3). The addition of vibration thereby only showed relatively minor effects for the back muscles. The side bridge (exercise 7) showed the largest differences with respect to the addition of