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Effects of whole body vibration on muscle contractile properties in exercise induced muscle damaged females

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ABSTRACT

Determining muscle contractile properties following exercise is critical in understanding neuromuscular function. Following high intensity training, individuals often experience exercise induced muscle damage (EIMD). The purpose of this investigation was to determine the effect of whole-body vibration (WBV) on muscle contractile properties following EIMD. Twenty-seven females volunteered for 7 sessions and were randomly assigned to a treatment or control group. Muscle contractile properties were assessed via voluntary torque (VT), peak twitch torque (TT), time to reach peak torque, half relaxation time of twitch torque, percent activation (%ACT), rate of rise (RR), rate of decline (RD), mean and peak electromyography during maximum voluntary isometric contraction. Two testing sets were collected each day, consisting of pre measures followed by WBV or control and post measures. A mixed factor analysis of variance was conducted for each variable. %ACT measures found baseline being less than day 1 in both measures in the control group. TT was found to be greater in the control group compared to WBV group. TT and VT baseline measures were greater than all other time points. RR showed control group had higher values than WBV group. These results indicate that WBV following EIMD had some positive effects on muscle contractile properties.

1. Introduction

Over the last decade, whole-body vibration (WBV) has increasingly been implemented with exercise by applying oscillatory motions of specific frequencies and amplitudes as a mean to improve performance. Research has shown positive effects on strength (Delecluse et al., 2003), power development (Bosco et al., 1999a), vertical jump height (Dabbs et al., 2011), and flexibility (Fagnani et al., 2006) following WBV. Although the exact mechanism of how the body responds to the vibration stimulus remains unclear, it has been suggested that it elicits neuromuscular facilitation (Cardinale and Bosco, 2003). It has been previously shown that when vibration is directly applied to a tendon or muscle belly, vibration induces activity of the muscle spindle Ia fibers, mediated by monosynaptic and polysynaptic pathways (Seidel, 1998). This increase in muscle spindle activity indicates a reflexive muscle contraction known as the tonic vibration reflex arising from the direct vibratory stimulus. When WBV is implemented, it is theorized that vibrations are transferred from the platform to specific lower body muscle groups, especially ones that are in close contact with the platform. The frequency, amplitude and duration are critical elements when utilizing WBV and have been shown to have different effects depending on these variables (Adams et al., 2009). Consequently, WBV stimulates the sensory receptors and afferent pathways, which may lead to a more efficient use of the stretch reflex, recruitment and synchronization of motor units (Bosco et al., 1999a). Effects on muscle contractile properties have been examined following the use of vibration and have found mixed results. One study found no influence of WBV on peak force (PF), electro-mechanical delay, rate of force development (RFD), muscle electromyography (EMG), time to peak tension (TPT), and half relaxation time (HRT) during evoked twitch and voluntary contractions (Hannah et al., 2011). Whereas, another study found no influence on direct vibration for twitch parameters but found differences in voluntary parameters, suggesting neural adaptations with an improvement of muscle activation (Lapole and Perot, 2010).

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Function of the neuromuscular system is critical in muscular performance; this may be important in sport performance or activities of daily living. Performance of resistance training for health and fitness benefits by athletes and clinical populations has gained in popularity in recent years. Research has shown that repeated eccentric muscle contractions, which often occur during resistance training, may cause muscle damage resulting in decreased force production (Proske and Morgan, 2001). This muscle damage is evident as a disruption of the normal alignment of the skeletal muscle and disruption of the z-lines of sarcomeres (Stauber et al., 1990). This process initiates an inflammatory process and leads to delayed onset muscle soreness (DOMS). It is suggested that the loss of force may be due to voluntary activation, perhaps due to impairment of or damage to specific sites in the muscle. Impairment in the muscle may be due to the limited release and/or reuptake sarcoplasmic reticulum Ca^{++} process.

WBV has shown positive effects in assisting on exercise when applied prophylactically and therapeutically. Previous literature suggests that WBV increases muscle spindle activity, which results in less muscle fiber disruption to excitation-contraction coupling (Aminian-Far et al., 2011) when WBV is applied prior to muscle damage. It has been suggested that an increase in muscle pre-activation, theoretically increasing the number of motor units and muscle fibers recruited, could lead to an increased muscle recovery by decreasing myofibril stress during repeated muscle actions (Bosco et al., 1999b). This indicates that a decreased amount of force loss may occur following EIMD when WBV is utilized. It has also been suggested that WBV increases blood flow to the musculature (Bakhtiary et al., 2007), which could accelerate repair and remodeling in the muscle (Davis et al., 2008). Another proposed mechanisms in some clinical populations suggest that WBV inhibits pain receptors, allowing for a higher pain tolerance when DOMS is experienced (Rhea et al., 2009).

Literature involving WBV and muscle recovery following exercise induced muscle damage have conflicting results. Thus, concrete conclusions can't be drawn involving WBV and exercise induced muscle damage. Furthermore, there are no studies that have examined the effects of WBV on muscle contractile properties following exercise induced muscle damage. The aim of this investigation was to determine the effect of whole-body vibration on muscle contractile properties following EIMD in the quadriceps. The authors hypothesized that following EIMD all measures would decrease more in the control group compared to the treatment group. Additionally, the authors hypothesized that if the treatment group had less of a decline in measures, then in the second set of post measures would return back to baseline of that day.

2. Methodology

2.1. Participants

Twenty-seven recreationally trained females (age 21 ± 2 yrs, height 172.38 ± 92.27 cm, mass 58.67 ± 11.53 kg) volunteered to participate in a 7-session protocol and provided written, informed consent that was approved by the University's Institutional Review Board. Recreationally trained individuals were defined as meeting American College of Sports Medicine recommendations for healthy living and did not exceed 5 workouts a week on a regular basis in the last 6 months. Participant with a recent history of lower body musculoskeletal or orthopedic injury or taking medications that alter balance, musculoskeletal system, or central nervous system functions relating to posture and motor control were excluded from participating. Additionally, individuals taking prescription pain and/or psychiatric medications were excluded. All participants were screened by questionnaire for potential risk factors to the exercise protocol. Participants were asked to not perform any exercise or take any pain medications 48 h prior to testing sessions and during all testing days and to keep all food and water intake consistent during testing sessions. To be included in data analysis, participants needed to have experienced exercise induced muscle damage, which occurs when there is a decrease in force generating capacity. Participants were excluded from data analysis if they did not decrease voluntary torque at least 5% between 24 and 48 h from baseline. Three subjects did not meet this criteria and were excluded from data analysis, resulting in twenty-seven participants.

2.2. Measures

2.2.1. Voluntary torque and motor unit activation

An interpolated-twitch electrical stimulation protocol was employed to assess maximal voluntary isometric contraction (MVIC), the percentage of motor unit activation (%ACT) and voluntary torque (VT) during MVIC (Black et al., 2015). Additionally, peak twitch torque (TT) in the relaxed muscle, the time to peak tension, and half relaxation time were also assessed on all 7 visits to the laboratory. Knee extensor measurements were performed on a modified knee-extension/leg curl machine (Body Solid; model GLCE-365; Forest Park, IL). Participants were seated with the hip at 90° of flexion and knee fixed in a flexed position at an angle of 60° below horizontal. The lever arm of the machine was fixed to a force transducer (Transducer Techniques; model SBO-750, Temecula, CA) parallel to the line of pull and perpendicular to the lever arm, allowing for assessment of isometric torque. A strap was used to secure the participant's right ankle to the lever arm. Stimulation electrodes were placed on the skin over the distal vastus medialis and the proximal vastus lateralis to enable electrical stimulation of the quadriceps. All electrode positions were marked with ink to ensure similar placement for subsequent days.

Prior to the initial assessment of MVIC, TT, %ACT, TPT, and HRT on each testing day, the stimulation current required to elicit a maximal torque value was determined by applying a series of brief electrical stimulations (paired pulses, consisting of two 0.2 ms pulses with an interpulse interval of 10 ms) to the knee extensors. Stimulation was applied using a constant current stimulator (model DS7AH; Digitimer, Hertfordshire, England) controlled by a computer using iWorx data acquisition software (iWorx System, Inc, Dover, NH, USA). Torque data was sampled at 5 kHz from the force transducer. The series of stimulations began with the current set at 40 mA and the current was progressively increased by 20 mA until the measured torque plateaus. Each subsequent contraction was separated by 20 s. The current eliciting the highest torque value was used to represent a supra-maximal stimulation current and was used for all subsequent stimulations applied that day. Next, participants performed a 3 s MVIC with knee extensors. At 2.5 s into the contraction a paired-pulse stimulation was applied, and the increase in torque over MVIC (interpolated-twitch torque; ITT) was assessed. At 2 and 4 s after completion of the MVIC, additional paired-pulse stimulations were applied to the relaxed muscle. Peak TT was determined as the average of the two post-MVIC stimulations and was used in subsequent analyses. %ACT was calculated as $100\% \times (1 - \text{ITT}/\text{TT})$ (Black et al., 2015). MVIC was determined as the peak torque during the 3 s MVIC. TPT was determined as the time from the onset of torque production to the time corresponding to peak twitch torque. Half relaxation time was determined as the time taken from peak twitch torque to reach 50% of baseline torque. Rate of twitch rise (RR) and rate of twitch decline (RD) were also calculated from the collected data. RR was calculated by 60% of twitch torque/rise time (N m) and RD was calculated by 50% of twitch torque/rise time (N m). Data from the two post-MVIC stimulations were averaged to determine TT, TPT, and