

Original Article

Effect of Vibration Frequency on Serratus Anterior Muscle Activity during Performance of the Push-up Plus with a Redcord Sling

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Abstract. [Purpose] We investigated the effect of vibration at various frequencies on serratus anterior (SA) muscle activity. [Subjects] Ten male subjects were recruited. [Methods] The subjects performed the push-up plus exercise supported by straps above the surface and vertical ropes in the Redcord sling. During the push-up plus, vibrations of 0, 30, 50, or 90 Hz were applied to the Redcord sling using a mechanical vibration apparatus attached to the rope. SA muscle activity was recorded using electromyography. [Results] SA muscle activity at the 50 Hz vibration frequency was significantly higher than that of no vibration. [Conclusion] Performing the push-up plus using a Redcord sling with mechanical vibration of 50 Hz effectively increased SA muscle activity.

Key words: Push-up plus, Mechanical vibration, Serratus anterior

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INTRODUCTION

The push-up plus, an axial load exercise, is a closed kinetic chain exercise (CKCE) because the position of the hands on the wall or chair and floor is fixed¹⁻³⁾. CKCE to increase activation of the shoulder musculature has been investigated while throwing a baseball³⁾, on unstable and oscillating unstable surfaces²⁾, and using a suspension rope⁴⁾. The push-up plus strengthens the scapulothoracic musculature, which is critical for smooth motion and stability of the shoulder girdle complex in the efficient movement of the glenohumeral joint¹⁾. The serratus anterior (SA) muscle stabilizes the scapula, which is responsible for scapular position and movement^{1, 2, 4)}. SA muscle weakness alters scapular movement through insufficient muscle recruitment, which leads to shoulder impingement and pain syndrome²⁾. The SA muscles can be strengthened using a stable surface, such as the floor or hand bar, or an unstable surface, such as a Swiss ball and suspension rope, or an oscillating unstable surface^{2, 4, 5)}. Furthermore, exercises performed on an unstable surface have been shown to be more effective at recruiting stabilizing muscles than those performed on a stable surface^{5, 6)}. Recently, the Neurac (neuromuscular activation) treatment system, comprising a Redcord sling and mechanical vibration device, was developed to facilitate neuromuscular control of the trunk⁷⁾ and increase tonic

contraction⁸⁾. We investigated the effect of various vibration frequencies on SA muscle activity during the push-up plus performed with a Redcord sling.

SUBJECTS AND METHODS

We recruited 10 male volunteers (age, 24.1 ± 3.2 years; weight, 69.3 ± 13.6 kg; height, 173.6 ± 5.3 cm). Exclusion criteria were any history of upper extremity trauma within the last 6 months, previous surgery, cervical spine injury, or continuous pain. Our study was approved by the Inje University Faculty of Health Science Human Ethics Committee, and the subjects provided their written informed consent before participation. A wireless electromyography (EMG) system (Trigno™ Wireless, Delsys, Boston, MA, USA) was used. EMG signals were sampled at 2,000 Hz, amplified, and band-pass filtered (20–450 Hz), and the root mean square (RMS) was calculated. Electrodes were placed on the SA muscle along the midaxillary line on the fifth rib of the participants' dominant side. Maximum voluntary isometric contraction (MVIC) was performed for normalization of the SA muscle. The participants were positioned in the Redcord sling with the straps and vertical rope 10 cm above the surface. Vibration stimuli were applied using a Redcord Stimula (Redcord AS, Staubø, Norway) attached to the vertical ropes above the head of the participant. Prior to commencement of the exercise, the examiner adjusted the vibrator frequency and released the pedal switch on the Redcord Stimula. Participants were then instructed to perform the push-up plus for 5 s (Fig. 1). During the push-up plus exercise, vibration frequencies of 0, 30, 50, and 90 Hz were applied to the Redcord sling using the mechanical vibration apparatus. High force amplitude with low fre-

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Fig. 1. Push-up plus performed with the Redcord sling and Redcord stimuli device

quency may be dangerous. Type Ia afferents are most sensitive to vibrations at 80–100 Hz, whereas type II afferents are most sensitive to vibrations around 50 Hz⁹). Thus, we investigated the effect of vibration at 0 (no vibration), 30, 50, and 90 Hz. The push-up plus exercise was performed with the hands placed shoulder-width apart, the elbows fully extended, a straight body alignment, and with the feet placed pelvis-width apart. The participants were instructed to perform maximum scapular protraction and hold it for 5 s. The trial order was randomized across frequencies for each participant, and each trial was repeated five times with a 3-min rest between trials. All statistical analyses were using the Statistical Package for the Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA), and the effect of the various vibration frequencies on SA muscle activity during the push-up plus exercise were assessed using the repeated measures General Linear Model with the Bonferroni post hoc test. P values <0.05 were deemed to indicate statistical significance.

RESULTS

Our results show that SA muscle activity increased significantly during stimulation at 50 Hz ($85.6 \pm 18.8\%$) compared with no vibration ($64.8 \pm 16.7\%$; $p < 0.05$). However, SA muscle activities at 30 ($76.5 \pm 15.6\%$) and 90 ($66.1 \pm 17.6\%$) Hz frequencies were not significantly different from that under the no vibration ($64.8 \pm 16.7\%$; $p > 0.05$) condition.

DISCUSSION

Mechanical vibration applied to the muscle and tendon triggers the tonic vibration reflex, which activates the muscle spindles and evokes the stretch-reflex loop⁸). Muscular activity that depends on vibration frequency shows a variable EMG response^{9, 10}). The body's muscular tuning mechanism adjusts mechanical vibration through changes in muscle activity excitatory frequency ranging from 10–65 Hz occurring in the human body. Thus, when the body is exposed to the same vibration frequency, this mechanism is activated to increase muscle activity and minimize resonance¹⁰). Di Giminiani et al.⁹) reported a higher isometric

squat EMG response during whole-body vibration at 50 Hz than at 30 Hz. A vibration frequency of 50 Hz stimulated higher muscle activity in the proximal musculature.

We found that SA muscle activity was significantly lower during vibration at 90 Hz than at vibrations of 30 and 50 Hz, suggesting that high frequency vibration (>90 Hz) may effectively inhibit or alleviate pain by decreasing muscle activity. Further evidence that our findings were elicited by neural factors affecting muscle activity is that the muscle-tendon unit may increase excitatory inflow, thereby demonstrating an increase in the EMG response. When maximum tension is reached, inhibitory inflow is activated to reduce muscle activity^{9, 10}). Thus, the shape of parabolic indicates a neuromuscular pattern of mechanical vibration⁹). Four levels of muscle activation have been defined: low (<20% MVC), moderate (20–40% MVC), high (41–60% MVC), and very high (>60% MVC)¹¹). Our findings indicate that the push-up plus exercise performed using the Redcord system with mechanical vibration at 50 Hz increases SA muscle activity. Thus, we recommend this protocol for effective shoulder and scapula rehabilitation.

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