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ACUTE EFFECT OF VIBRATORY STIMULATION ON ELBOW JOINT FLEXOR PERFORMANCE

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A novel design of vibratory stimulation training system which can provide precisely controlled smooth force profile to the participants is introduced. All participants received 4 treatments with 20s of vibratory stimulation at a specific frequency and amplitude. The experimental data were analyzed through the two-way repeated-measures ANOVA analysis, with the independent variables being vibratory frequency and amplitude, and the dependent variables EMG_{rms}, F_{max}, $RFD_{0.5s}$, and F_{ave}. An optimal vibratory stimulation pattern was found from this study that has the most significant acute effect on the elbow joint flexor muscle performance: a 60% maximal force loading combined with vibratory stimulation at a frequency of 2.5 Hz and amplitude of 1 N sustained over 20s.

KEYWORDS: strength training, design, force.

INTRODUCTION: Strength training can be used to enhance sports performance, promote good heath, and improve quality of life. There are many types of strength training, including resistance training, plyometric drills, and vibratory training. A number of recent studies have suggested that vibratory training can enhance training effects with a higher degree of safety (Issurin, Liebermann, & Tenenbaum 1994; Trans et al., 2009). The vibratory platform is designed to provide the athlete with an unstable environment and produce vertical excitation. This stimulates the muscle spindle, enhancing circulation (Cardinale & Bosco, 2003) and relieving muscle tension (Bishop, 1974).
Over the last 20 years, research has suggested that vibratory training can increase muscle power and improve competition performance (Issurin & Tenenbaum, 1999; Torvinen et al., 2002; Giorgos & Elias, 2007). Most types of vibratory training use whole body vibratory training [WBVT] and it can be a useful modality as applied during the pre-competition warm-up (David, Holmes, & Eric, 2008). Furthermore the WBVT has been linked to improved muscle strength in the lower extremities, muscle power, and jump height (Runge, Rehfeld, & Resnicek, 2000; Rittweger et al., 2002; Iwamoto et al., 2004). Human bodies contain large amounts of damping tissue, which decreases the effects of vibratory on the upper extremities. Improved muscle strength in this area contributes to improved sports performance and lower risk of injury.
There are two disadvantages in the existing vibratory mechanisms. Firstly, they may potentially produce unsmooth signal profiles that may harmful to the trainees; and, secondly, they are unable to accurately control the frequency and amplitude of the force profile (Hsu, 2005; Hsu, & Tu, 2006). To address this problem, a novel design of vibratory stimulation training system (VSTS) which can provide precisely controlled smooth force profile to the trainee is introduced. The acute effect on the non-dominant upper arm elbow joint flexor was investigated experimentally.

METHODS: The participants were 14 healthy male college students (age: 22.05 ± 1.2 year; weight: 62 ± 3.4 kg; height: 170 ± 4.7 cm), who had not experienced any upper arm injury or disease in the previous six months. All the experiments conducted in this project have been

approved by the Research Ethics Committee of the National Pingtung University of Education.
The designed VSTS consists of a pay load set, an AC servo-motor (GYS401DC2-T2A, Fuji Electric, Japan), a reduction gear set (SB090-L2-25, USC Motion Inc., Taiwan), a torque sensor (RT-50, Cap 50 Nm, JIHSENSE, Taiwan), a motor driver and a force controller (Fig.1). With this system, the total force applied to the participants includes two parts: an offset afforded by the pay load and the vibratory force with precisely controlled frequency and amplitude provided by the servo-motor through the reduction gear set. The force controller is basically a proportional-integral (PI) controller which controls the amplitude of the vibratory force to follow the command values by use the feedback signal from the torque sensor. With the feedback force control system and the fact that the servo-motor can offer smooth sinusoidal force pattern, the load to the participants can be expected to be smooth and precisely controlled. An EMG sensor (biovision, D-61273, Wehrheim, Germany) and a force sensor (TEDEA, MODEL614, 1200 Hz, 50-300 Kg) were used for the tests. These two sensors were synchronized by a personal computer via the Labview system (NI, American).

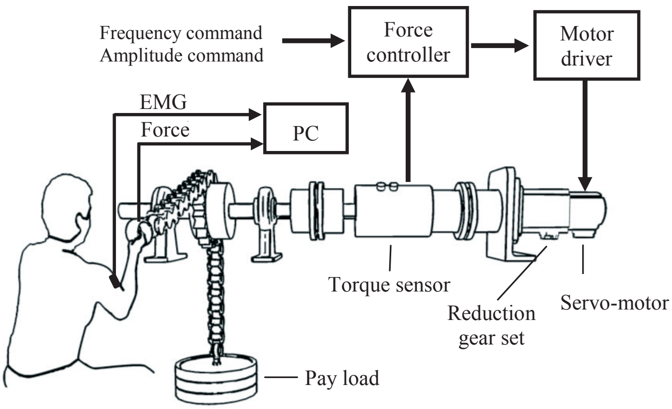

Figure 1: Schematic of the vibratory stimulation system [VSTS].

The experiment followed a protocol. Firstly, the participants should complete a series of 10-minute warm-up exercises. After warm-up, the participants took a pre-test for their non-dominate arm to obtain the related parameter as will be described later. Then, they received one kind of 20s of vibratory stimulation, with specified values of pay load (60% pre-test maximal force), different amplitudes and frequencies of the vibratory force. Finally, the participants were subjected to post-test to investigate the acute effect of the designed vibratory stimulation system on the non-dominant upper arm elbow joint flexor. In this study, the participants randomly received one of the following treatment in one day: high frequency high amplitude [HfHa, 30 Hz, 5 N]; high frequency low amplitude [HfLa, 30 Hz, 1 N]; low frequency high amplitude [LfHa, 2.5 Hz, 5 N]; low frequency low amplitude [LfLa, 2.5 Hz, 1 N]; and no treatment as a control group. All participants totally received 5 treatments in five days. The indices for evaluating the acute effect include root mean square of EMG [EMG_{rms}], maximal force [F_{max}], average force within 5s [F_{ave}], and rate of force development in 0.5 seconds [$RFD_{0.5s}$]. Furthermore, the index used for evaluating the percentage improvement contributed by the vibratory stimulation is calculated by eq.(1):

$$I = \frac{V_{post-test} - V_{pre-test}}{V_{pre-test}} \times 100\% \tag{1}$$

Where *V* stands for the variables just defined. On finishing the tests, the recorded data were analyzed using two-way repeated-measures ANOVA, with a significance level of α=0.05. The independent variables were 5 different treatments, and the dependent variables were EMG_{rms}, F_{max}, $RFD_{0.5s}$, and F_{ave}.

RESULTS: The results of this study were as following (fig. 2):
EMG_{rms}: Following vibratory stimulation, ANOVA results showed a significant difference in EMG_{rms} rates between pre- and post-vibratory stimulation ($F_{(4,52)}$=2.90, p=.031). The test result indicated that the EMG_{rms} rates for HfHa, HfLa, LfHa, and CON were significantly higher than for LfLa (p<.05). Except the LfLa group, the EMG_{rms} rate are positive, it showed that the LfLa stimulation treatment can activate the muscle group effectively than other stimulation treatment types.
F_{max}: The stimulation treatments can elevate maximal contraction force of biceps brachii. Following vibratory stimulation, the ANOVA showed a significant difference in F_{max} rates between pre- and post-vibratory stimulation ($F_{(4,52)}$=3.44, p=.014). The result indicated that the F_{max} rates for HfHa, HfLa, LfHa, and CON were significantly lower than for LfLa (p<.05).
F_{ave}: The stimulation treatments can elevate average contraction force of biceps brachii, and the value of LfLa group is higher than the other groups. Following vibratory stimulation, the ANOVA showed no significant difference in F_{ave} rates between pre- and post-vibratory stimulation ($F_{(4,52)}$=2.04, p=.103).
$RFD_{0.5s}$: Except the CON group, the $RFD_{0.5s}$ rate are positive. Following vibratory stimulation, ANOVA showed a significant difference in $RFD_{0.5s}$ between pre- and post-vibratory stimulation ($F_{(4,52)}$=2.57, p=.049). The post-hoc test indicated that the $RFD_{0.5s}$ rates for LfHa and LfLa were significantly greater than for CON (p<.05).

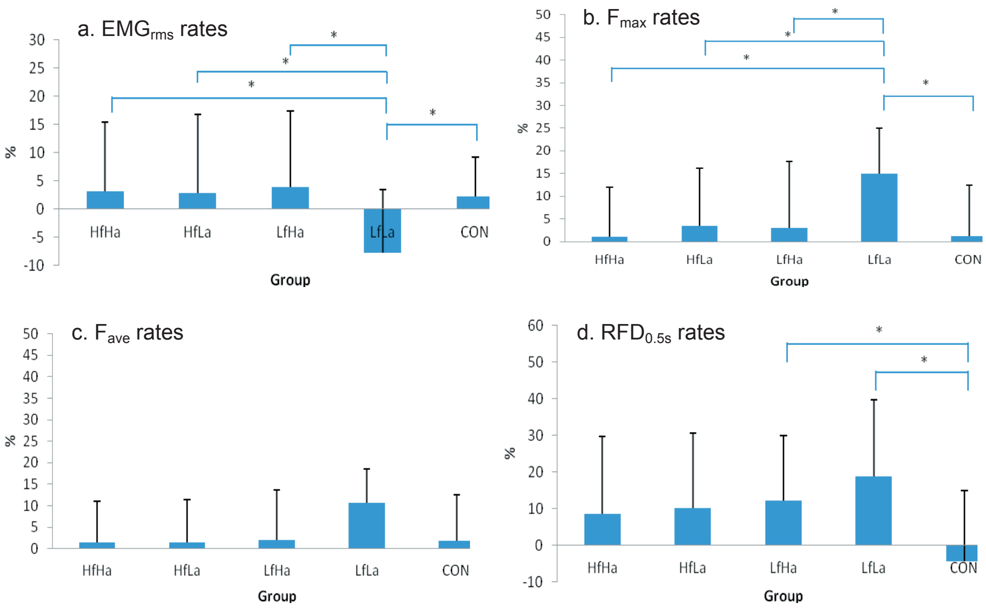

Figure 2: Four parameters for each group of pre- and post-vibratory stimulation.
(* indicates a significant difference)

DISCUSSION: A comparison of the acute effects of different types of vibratory stimulation shows that LfLa vibrated stimulation increased explosive contraction muscle strength ($RFD_{0.5s}$ =17%, F_{max} =15%). There has been no effect on F_{ave} but its rate had 10% increase, after LfLa vibrated stimulation. Stimulation at a frequency of 2.5 Hz with amplitudes of 5 N and 1 N enhanced explosive force, but stimulation at a frequency of 30 Hz with amplitudes of 5 N and 1 N did not achieve the same result. This demonstrates that stimulation frequency is the dominant factor affecting the study outcome. Previous studies have indicated that high frequency vibratory stimulation can enhance elite athletes' acute maximal force in the lower extremities (Mester, Spitzen, Schwarzer, & Seifriz, 1999) and explosive force in the upper

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extremities (Bosco, Cardinale, & Tsarpela, 1999). In this study, the participants, who were healthy college student, received vibratory stimulation at a lower frequency, which allowed for gains in explosive force while minimizing fatigue. In the tonic vibratory reflex [TVR] the muscle belly or tendon is stimulated by the Iα afferent neuron. The TVR is transmitted to the spindle by the α motor neuron, activating the fiber (Rittweger, Schiessl, & Felsenberg, 2001; Cardinale & Bosco, 2003). This muscle-neural phenomenon can be examined using EMG analysis. Following 20s of vibratory stimulation in the upper extremity at a frequency of 2.5 Hz and amplitude of 1 N, the EMGrms index decreased by 8%. Other related studies have shown similar results; for example, Bosco, Cardinale, and Tsarpela (2008) found that 60 seconds of vibratory stimulation raised the EMG mean power frequency, but decreased the EMG_{rms} of the biceps brachii. Vibratory stimulation can activate α motor neuron through TVR and enhance nervous system adaptation (Romaiguere, Vedel, Azulay, & Pagni, 1991). Activation of the nervous system can elevate neuronal firing frequency and increase the synchronized neuronal units. The optimal level of vibratory stimulation loading can improve muscle adaptation, and decrease activation to avoid loss of muscle strength. This can improve effectiveness of muscle group. Overall results showed that low frequency and low amplitude vibratory stimulation [LfLa; 2.5 Hz, 1 N] which by the vibratory stimulation system of this study can have benefits for participants' muscle strength and maximal force in the biceps brachii. This study shows that 60% maximal force loading, combined with vibratory stimulation at a frequency of 2.5 Hz and amplitude of 1 N sustained over 20s, is the best acute vibratory stimulation for the flexor muscle of the elbow joint.

CONCLUSION: This study presents a well-designed system and the associated methodology for examining the acute effect of vibratory stimulation on elbow joint flexor performance. An optimal vibratory stimulation pattern has been found with most significant acute effect in terms of explosive contraction muscle strength and maximal force. For practical applications, because the VSTS can provide with smooth, precisely controlled frequency and amplitude of vibratory force, it is safe and comfortable to the athlete. Furthermore, the results provide a method in finding an optimal vibratory stimulation pattern for an athlete in warm up exercises to enhance his/her sports performance.

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