Inhibitory Effects of Prolonged Vibratory Stimulus on the Maximal Voluntary Contraction Force and Muscle Activity of the Triceps Brachii: An Experimental Study

Rikiya Shirato, OT, PhD,^a Hiroya Sakamoto, OT,^b Tatsuya Sugiyama, OT,^c Misato Suzuki, OT,^d Runa Takahashi, OT,^e and Tatsuya Tanaka, OT^f

ABSTRACT

Objective: The purpose of this study was to quantify the effects of prolonged vibratory stimulus on the maximal voluntary contraction (MVC) force and muscle activity of the triceps brachii and to clarify the effective stimulus time.

Methods: Twenty-five healthy volunteers with a mean age of 21.4 years participated. A vibratory stimulus at 86 Hz was applied to the triceps brachii tendon for 5 and 10 minutes. Before and after these stimuli, the elbow extension MVC force was measured using a handheld dynamometer. Muscle activities of the lateral, long, and medial heads of the triceps brachii were also recorded by surface electromyography.

Results: The median MVC force significantly decreased to 82.7% after 5 minutes of vibratory stimulus and to 83.3% after 10 minutes of vibratory stimulus ($P < .001$). The median percentage of integrated electromyography of the triceps also significantly decreased to 78.2 (lateral head), 83.8 (long head), and 81.5 (medial head) after 5 minutes of vibratory stimulus and to 77.7, 81.4, and 77.2, respectively, after 10 minutes of vibratory stimulus ($P < .001$). There were no differences in the decrease in the MVC force and median percentage of integrated electromyography between 5 and 10 minutes of vibratory stimulus ($P > .05$).

Conclusion: Prolonged vibratory stimulus (5 minutes) to the triceps brachii tendon appeared to have an inhibitory effect on MVC force and muscle activity. The present results suggest that prolonged vibratory stimulus could be an effective treatment capable of reducing muscle tonus of the triceps brachii. (J Chiropr Med 2019;18:97-105)

Key Indexing Terms: Elbow; Electromyography; Muscle Contraction; Muscle Strength Dynamometer; Vibration

INTRODUCTION

Elbow motion deficits represent the most common complication after traumatic injuries such as fractures or dislocations to the elbow.¹ Reasons for the loss of elbow

motion include prolonged immobilization, soft tissue trauma, intra-articular trauma, and heterotopic bone formation.² Muscle co-contraction is also recognized as an important cause of the loss of elbow motion.^{1,3} In clinical practice, muscle guarding of the triceps brachii is often observed to cause elbow co-contraction with the biceps brachii and brachialis, which are agonist muscles of elbow flexion.¹ Page et al showed that patients with elbow stiffness had greater electromyographic activity in the antagonist muscles, equivalent to that in the agonist muscles during elbow flexion and extension, in comparison with healthy controls.⁴

For treatment of elbow co-contraction owing to muscle guarding of the triceps brachii, relaxation,³ sustained low-load stretching,^{1,3} and proprioceptive neuromuscular facilitation, such as contract-relax or hold-relax techniques, are performed to improve the reciprocal activities between the agonist and antagonist muscles.^{1,3,5} Based on reports that the functional flexion angle of the elbow is 120° and the elbow flexion angle found satisfactory by patients is 115°,^{6,7} the goal of rehabilitation is to restore these flexion angles.

Traditionally, vibration massage has been used to relieve muscle spasms in physical therapy.^{8,9} Two wide categories

^a Department of Occupational Therapy, Faculty of Human Science, Hokkaido Bunkyo University, Eniwa, Japan.

^b Department of Rehabilitation, Hitsujigaoka Hospital, Sapporo, Japan.

^c Department of Rehabilitation, Hakodate Ryohoku Hospital, Hakodate, Japan.

^d Department of Rehabilitation, Sapporo City General Hospital, Sapporo, Japan.

^e Department of Rehabilitation, Ichijodori Hospital, Asahikawa, Japan.

^f Department of Rehabilitation, Anzai Orthopaedic Clinic, Sapporo, Japan.

Corresponding author: Rikiya Shirato, OT, PhD, 196-1, Kogane-Chuo, Eniwa 061-1449, Japan. Tel.: +81 11 611 2111. (e-mail: rshirato@do-bunkyo.ac.jp).

Paper submitted June 7, 2018; in revised form September 19, 2018; accepted October 28, 2018.

1556-3707

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<https://doi.org/10.1016/j.jcm.2018.10.003>

of vibrating devices providing whole body vibration^{10,11} and local vibration have been used. Recently, local vibration has been widely used for the reduction of spasticity,¹²⁻¹⁵ enhancement of muscular contraction,¹⁶ and facilitation of motor control tasks in neurorehabilitation.¹⁷⁻¹⁹

Prolonged application of vibration to the skeletal muscle depresses synaptic transmission in both the monosynaptic and polysynaptic Ia excitatory pathways.²⁰ Vibration also produces presynaptic inhibition of Ia terminals and suppresses α motor neuron activity.²⁰⁻²² In addition, Ib afferents from the Golgi tendon organ are excited, resulting in suppression of the α motor neurons via interneurons.²³ These mechanisms cause a decrease in muscle tonus and peak force of the maximal voluntary contraction (MVC).²⁴⁻²⁸ On the other hand, vibratory stimulus to the muscle induces tonic vibration reflex (TVR) owing to excitation of the muscle spindles and enhanced Ia discharges,²⁹ resulting in increases in the MVC force and motor neuron activity.^{26,30,31} Vibratory stimulus to the muscle and tendon have been demonstrated to have different effects on these organs owing to variations in stimulation conditions, such as vibratory amplitude, frequency, and duration.³² Generally, it has been reported that an inhibitory mechanism is activated when a vibratory stimulus with large amplitude, low frequency, and long duration is applied.^{16,33} This prolonged vibratory stimulus could provide inhibitory effects on the muscle activity of the triceps brachii and is considered to be effective in reducing the muscle tonus caused by muscle guarding of the triceps brachii.

In previous studies on the effects of vibratory stimulus on the triceps brachii, Griffin et al³¹ demonstrated that vibratory stimulus at 110 Hz to the triceps brachii tendons for 2 seconds every 10 seconds increased the MVC force of these muscles. Ribot-Ciscar et al¹⁶ also reported that vibration at 80 Hz for 9 seconds facilitated the contraction strength of some partially paralyzed triceps brachii muscles after chronic cervical spinal cord injury. The vibratory stimulus applied to the triceps brachii muscle in these previous studies was of short duration, and the reaction of the triceps brachii muscle in response to prolonged stimulus has not been elucidated.

The purpose of this study was to quantify the effect of prolonged vibratory stimulus at low frequency on the MVC force and muscle activity of the triceps brachii muscle and to clarify the effective stimulation time. We hypothesized that if vibratory stimulus to the triceps brachii muscle is applied at a lower frequency and for a longer stimulation time, suppression of the MVC force and muscle activity of this muscle could be achieved.

volunteered to participate in the study. Twenty-four participants were right-hand dominant and one participant was left-hand dominant. None of the participants had a history of injury or surgery to the corresponding upper extremities or had neuromuscular diseases. The mean height of the participants was 171.5 ± 6.5 cm, and the mean body weight was 63.9 ± 6.8 kg. The mean forearm length, which was defined as the distance from the olecranon to the ulnar styloid process, was 25.4 ± 1.1 cm. All the experimental procedures in this study were approved by the research ethics review committee of Hokkaido Bunkyo University (Approval No. 28007). Written informed consent was obtained from all participants.

Vibratory Stimulus to the Triceps Brachii Tendon

The triceps brachii on the nondominant hand side was tested in this study. Participants were placed in a prone position on the bed with the shoulder at 90° of abduction and a towel under the upper arm, and the forearm was allowed to hang from the side of the bed so that the elbow was at 90° of flexion. In this position, vibratory stimulus was applied to the triceps brachii tendon of each participant for 5 and 10 minutes. These stimulus times were set with reference to Nakabayashi et al,³⁴ who demonstrated temporal changes in the H-wave to M-wave amplitude (H/M) ratio of the soleus (Sol) muscle by application of vibratory stimulus to the Achilles tendon, with a significant decrease observed until 10 minutes after the start of stimulation. In addition, stimulus for 5 minutes was set to assess the inhibitory effects of vibration for less than 10 minutes of stimulus in this study.

An electric vibrator (MD-001, Daito Electric Machine Industry, Osaka, Japan) was used to apply vibratory stimulus (Fig 1).³⁴ This device was 420 g, with a vibration displacement of 2 mm and vibration frequencies of 86 Hz and 111 Hz. The frequency was set at 86 Hz in this experiment because low-frequency vibration was previously shown to be effective in suppressing muscular force and activity.²⁰ On the basis of the triceps brachii tendon being approximately 15.0 cm in length,³⁵ we marked a point 7.5 cm proximal from the olecranon, corresponding to the center of the tendon, with a magic marker, and the vibratory stimulus was applied at this point (Fig 1). The stimulator was set vertically, and the examiner held it to apply pressure using the weight of the device itself.

Handheld Dynamometer Testing of MVC Force

The MVC force of elbow extension was measured using a handheld dynamometer (HHD) (μ Tas F-1, Anima, Tokyo, Japan) before and after vibratory stimulus for 5 and 10 minutes (Fig 2). The examiner manually grasped the sensor pad and fixed the pad to the distal-posterior forearm,

METHODS

Participants

Twenty-five healthy male university students with a mean age of 21.4 years $\pm$ 3.3 (range, 20-37 years)

Fig 1. Point at which the vibratory stimulus was applied. Vibratory stimulus was applied to the center of the triceps brachii tendon at 7.5 cm proximal to the olecranon.

connecting the radial and the ulnar styloid processes. In the same manner as a “make test,”³⁶ the isometric MVC force was measured at elbow extension, with forearm supination and the shoulder at 90° abduction (Fig 2). This isometric MVC was sustained for 3 seconds. Three trials were conducted before and after vibratory stimulus, respectively, and each measurement was conducted at 10-second

Fig 2. Measurement of maximal voluntary contraction force of elbow extension using a handheld dynamometer. The sensor pad of the HHD was fixed to the distal-posterior forearm, and the isometric elbow extension MVC force was measured for 3 seconds with forearm supination and the shoulder at 90° of abduction.

intervals. Measurement of each participant under vibratory stimulus for 5 or 10 minutes was randomly performed at intervals of more than 6 days. All measurements were carried out by an experienced therapist (S.R.).

The MVC force-to-body weight ratio (N·cm/kg) was then calculated using the following formula: MVC force value (N) obtained by the HHD × forearm length (cm)/body weight (kg). In addition, the rate of change (%) of the MVC force-to-body weight ratio after vibratory stimulus was calculated using the following formula: poststimulus MVC force-to-body weight ratio / pre-stimulus MVC force-to-body weight ratio × 100.

Intraexaminer Reliability of the HHD

We performed a preliminary study that was designed to examine intraexaminer reliability of the HHD for measurement of the MVC force of elbow extension before the main experiment. Eleven healthy male students with a mean age of 20.8 years (10 right-hand dominant and 1 left-hand dominant) volunteered to participate in the preliminary study. We measured the isometric MVC force of elbow extension with the HHD 3 times in the same upper-extremity position as used in the main experiment. The interval between each measurement was 10 seconds. All measurements were administered by the same experienced therapist (S. R.). The intraclass correlation coefficients (ICCs; 1, 1) were calculated using SPSS Statistics 22 software (IBM Corp, Armonk, New York). The ICC (1, 1) for the values of 3 consecutive MVC force measurements using the HHD was 0.93 (95% CI: 0.82-0.98). Based on the recommendation (ICC > 0.75) of Portney et al,³⁷ the ICC value obtained in the preliminary experiment was regarded as showing good reliability.

Electromyography Signal Sampling

The muscle action potentials of the lateral, long, and medial heads of the triceps brachii during the isometric MVC were recorded simultaneously with the HHD testing using a wireless surface electromyography (EMG; MQ AirSystem, Kissei Comtec, Matsumoto, Japan). Electromyography signals were captured in a bipolar configuration using disposable electrodes (LecTrode, Admedec, Tokyo, Japan). Before placing the electrodes, the skin was cleaned and prepared with scrubbing gel (Skinpure, Nihon Kohden, Tokyo, Japan) to lower skin impedance. Based on the report of Perotto,³⁸ the electrodes were placed at an interelectrode distance of 2 cm along the belly of each muscle after palpation of each head of the triceps brachii (Fig 3). The recorded EMG signals were wirelessly transmitted to a personal computer by Bluetooth with A/D conversion at a sampling frequency of 1000 Hz. These digital data were converted into files with electrical signal recording software (VitalRecorder2, Kissei Comtec) and saved onto the hard

Fig 3. Attachment of the surface electrodes to the lateral, long, and medial heads of the triceps brachii muscle.

disk. These data were then full-wave rectified to the integrated electromyography (IEMG) using myoelectric analysis software (KineAnalyzer, Kissei Comtec), and the IEMG in the middle 1 second, excluding each 1 second recorded before and after, was obtained. Furthermore, the % IEMG value for each head of the triceps brachii after vibratory stimulus was calculated using the following formula: post-stimulus IEMG/pre-stimulus IEMG $\times$ 100.

Evaluation of Discomfort After Vibratory Stimulus

Discomfort around the elbow immediately after and at 15 minutes after vibratory stimulus of the triceps tendon was evaluated using a numerical rating scale³⁹ (NRS; 0: no discomfort, 10: intolerable discomfort).

Statistical Analysis

The sample size was calculated using G*power software (version 3.1.4) for Windows (Heinrich Heine University Düsseldorf, Dusseldorf, Germany) before starting the study

procedures.⁴⁰ The test revealed that 25 participants were required for the study assuming a 2-tailed test, an α level of 5%, and a power of 80%.

The mean value of 3 measurements before and after each vibratory stimulus in MVC force and %IEMG was obtained. As the Shapiro-Wilk test indicated nonnormal data distribution, nonparametric analysis was used. The Wilcoxon signed-rank test was used to compare the differences in MVC force and %IEMG value between pre- and poststimulus with 5 and 10 minutes of vibratory stimulus, respectively. Regarding the %IEMG, we took the prestimulus %IEMG value as 100 for comparison with the poststimulus %IEMG value. The rate of change in MVC force and %IEMG post-stimulus were also compared between 5 and 10 minutes of stimulus using the Wilcoxon signed-rank test. Moreover, the Wilcoxon signed-rank test was used to compare the differences in NRS score between immediately after and at 15 minutes poststimulus. Numerical rating scale scores for immediately after and at 15 minutes poststimulus were also compared between for 5 and 10 minutes of stimulus using the Wilcoxon signed-rank test. All analyses were performed using IBM SPSS Statistics 22 software. The level of significance was set at $P < .05$.

RESULTS

Fluctuations in the Elbow Extension MVC Force

The median elbow extension MVC force was significantly decreased from 29.6 N·cm/kg (interquartile range

Fig 4. Elbow extension MVC force pre- and postvibratory stimulus for 5 and 10 minutes. The upper ends of the boxes indicate the 75 percentile values, the lower ends show the 25 percentile values, and the box widths indicate the interquartile ranges. The lines in the boxes show the median values. The upper and lower whiskers indicate the maximum and minimum values, respectively. *Significant differences between pre- and postvibration for each stimulus time are illustrated. MVC, maximal voluntary contraction; stim., stimulus.

[IQR] 27.7-38.5) to 26.1 N·cm/kg (IQR 22.3-32.1) after the application of vibratory stimulus for 5 minutes ($P < .001$). Similarly, it was significantly reduced from 31.0 N·cm/kg (IQR 27.3-34.6) to 25.0 N·cm/kg (IQR 21.5-30.1) after vibratory stimulus for 10 minutes ($P < .001$). The median rate of change of the MVC force was 82.7% (IQR 77.2-92.8) after stimulus for 5 minutes and 83.3% (IQR 76.9-91.7) after stimulus for 10 minutes, with no significant differences observed in the rate of change between stimulus for 5 and 10 minutes ($P = .86$; Fig 4).

Fluctuations in the Muscle Activity of the Triceps Brachii

The median value of %IEMG after stimulus for 5 minutes was 78.2 (IQR 70.0-97.6) for the lateral head, 83.8 (IQR 77.5-90.4) for the long head, and 81.5 (IQR 72.2-91.4) for the medial head of the triceps brachii muscle. These reflected significant decreases compared with the prestimulus %IEMG value take as 100 ($P < .001$ for the lateral head, $P < .001$ for the long head, and $P = .001$ for the medial head). Similarly, the median value of %IEMG of each head of the triceps brachii after stimulus for 10 minutes was 77.7 (IQR 70.8-89.6), 81.4 (IQR 66.7-93.9), and 77.2 (IQR 62.9-93.3), respectively ($P = .002$, $P = .001$, and $P = .001$, respectively). There were no significant differences in %IEMG values among the heads of the triceps brachii between stimulus for 5 and 10 minutes ($P = .26$ for the lateral head, $P = .60$ for the long head, and $P = .48$ for the medial head) (Fig 5).

Fig 5. %IEMG values of the lateral, long, and medial heads of the triceps brachii post-vibratory stimulus for 5 and 10 minutes. The upper ends of the boxes indicate the 75 percentile values, the lower ends show the 25 percentile values, and the box widths indicate the interquartile ranges. The lines in the boxes show the median values. The upper and lower whiskers indicate the maximum and minimum values, respectively. There were no significant differences in %IEMG values among the heads of the triceps brachii between vibratory stimulus for 5 and 10 minutes. IEMG, integrated electromyography; min., minutes; stim., stimulus.

Fig 6. NRS scores for discomfort immediately after and at 15 minutes post-vibratory stimulus. The upper ends of the boxes indicate the 75 percentile values, the lower ends show the 25 percentile values, and the box widths indicate the interquartile ranges. The lines in the boxes show the median values. The upper and lower whiskers indicate the maximum and minimum values, respectively. *Significant differences between immediately after and at 15 minutes postvibration for each stimulus time are illustrated. NRS, numerical rating scale; min., minutes; stim., stimulus.

Discomfort After Vibratory Stimulus

The median NRS score for discomfort after vibratory stimulus for 5 minutes was significantly decreased from 3.0 (IQR 2.0-5.0) immediately after to 0.0 (IQR 0.0-0.5) at 15 minutes post-stimulus ($P < .001$). The median NRS score after vibratory stimulus for 10 minutes was also significantly lowered from 2.5 (IQR 1.0-4.0) immediately after to 0.0 (IQR 0.0-1.0) at 15 minutes post-stimulus ($P < .001$). The median NRS score immediately after and at 15 minutes post-stimulus, respectively, showed no significant differences between vibratory stimulus for 5 and 10 minutes ($P = .49$ and $P = 1.00$, respectively; Fig 6).

DISCUSSION

In the present study, the MVC force of elbow extension and the %IEMG of all heads of the triceps brachii were significantly decreased by the application of vibratory stimulus to the triceps brachii tendon for 5 and 10 minutes. From these results, it was suggested that prolonged vibratory stimulus to the triceps brachii tendon leads to the inhibition of muscle strength and activity in the triceps brachii. In addition, an adequate inhibitory effect could be expected from the application of vibratory stimulus for 5 minutes because there were no significant differences in the decrease in elbow extension MVC force and %IEMG between vibratory stimulus for 5 and 10 minutes. Although it is difficult to precisely estimate the neural circuit in which suppression occurred in the present study using MVC force

and EMG measurements, it was considered that the prolonged vibratory stimulus to the triceps brachii tendon triggered some spinal inhibitory system through afferent neural input from the homonymous muscle.

Influence on Vibrated Muscle

Motor performance, such as peak force during MVC, is influenced by the pattern of motor unit activity in the responsible muscles.^{41,42} The motor unit activity is determined by the integration of excitatory and inhibitory neural inputs to the α motor neurons.³² The major excitatory neural inputs to the α motor neurons include motor commands from the supraspinal cortex and Ia afferents from the intrafusal muscle spindles.³² Although major inhibitory neural inputs to the α motor neurons include Ia presynaptic inhibition,²⁰⁻²² reciprocal Ia inhibition,⁴³ and Ib inhibition from the Golgi tendon organs via interneurons,²³ recurrent inhibition via Renshaw cells⁴⁴ has also been reported.

The application of short-term vibration (of less than 20 seconds) at a high frequency of more than 100 Hz to the tendon has been shown to be a noninvasive and viable means of artificially increasing the activation of muscle spindle afferents, particularly the Ia afferents.³⁰ Exlund et al²⁹ demonstrated that an increase in the amplitude and frequency of the vibration increased the TVR, resulting in an increase in force and EMG. Bongiovanni et al²⁶ also reported that the brief application of vibratory stimulus at 150 Hz to the fatigued tibialis anterior muscles increased the discharge rate of motor units during voluntary contractions of these muscles. Moreover, Griffin et al³¹ reported that vibratory stimulus at 110 Hz to the triceps brachii tendons for 2 seconds every 10 seconds increased the MVC of these muscles.

On the other hand, prolonged muscle vibration causes a reduction in EMG activity, motor unit firing rates, and contraction force.²⁴⁻²⁹ In particular, when vibration at low frequency is continuously applied to the skeletal muscle for 30 seconds or more, the excitatory input to the α motor neurons decreases and motor neuron activity is suppressed.^{33,45} After 30 seconds of vibration at 80 Hz, the resting discharge rate of the muscle spindles was shown to decrease in Ia fibers originating from multiple leg muscles.⁴⁵ Vibratory stimulus at 90 Hz to the Achilles tendon for 15 minutes was also found to decrease the TVR of the Sol muscle.³³ In addition, Desmedt et al²⁰ investigated the presynaptic inhibition of Ia afferents from the H-wave derived from the Sol muscle when a vibratory stimulus with an amplitude of 0.2 to 2 mm and a frequency of 20 to 180 Hz was applied. The inhibitory effect was shown to increase with the amplitude of vibration, but decrease when the vibration frequency was increased.²⁰ Kouzaki et al²⁸ reported that vibration at 30 Hz with an amplitude of 2 to 3 mm applied to the rectus femoris muscle for 30 minutes induced a decrease in the MVC force and EMG amplitude of this muscle. They also emphasized that with prolonged vibratory stimulus, “transmitter depletion” must be considered as a mechanism

contributing to the reduction in Ia synaptic efficacy. This “transmitter depletion” was also described by Curtis et al.⁴⁶ Moreover, Hayward et al²³ advocated that prolonged vibration produced disfacilitation, a form of autogenetic inhibition caused by withdrawal of Ia afferent activation owing to elevation of group Ia axonal thresholds and increased selectivity of Ib afferent fiber stimulation. Bongiovanni et al²⁶ also demonstrated that the decline in motor output observed during sustained MVC in part depends on a gradual reduction of the fusimotor-driven afferent inflow from the spindles, and it was suggested that this reduction in turn might depend on intrafusal muscle fatigue.

The vibratory stimulus used in the present study had an amplitude of 2 mm and a frequency of 86 Hz and was applied to the triceps brachii tendon for 5 or 10 minutes. Such stimulus, generally at low frequency and for a prolonged time, produces a significant inhibition in both MVC force and muscle activity. Based on earlier neurophysiological studies, the inhibitory effects induced by prolonged vibratory stimulus are considered to be due to (1) presynaptic inhibition of Ia terminals,²⁰⁻²² (2) transmitter depletion at Ia synapses,^{28,46} (3) increased discharge threshold of Ia fibers,²³ (4) intrafusal muscle fatigue,²⁶ and (5) Ib inhibition from the Golgi tendon organs.²³

In our experiment, no differences in the inhibitory effects on MVC force and muscle activity were observed between vibratory stimulus for 5 and 10 minutes, with sufficient inhibitory effects confirmed for 5 minutes of stimulus. These findings suggested that the ceiling effect could have already been reached within 5 minutes of vibratory stimulus.

Decreases in MVC Force and IEMG

Bongiovanni et al²⁷ demonstrated that the peak force decreased by 25% and the discharge rate of high-threshold motor units declined more than did that of the low-threshold motor units on application of prolonged vibration to the tendon of the ankle dorsiflexor muscles. Because high-threshold motor units supply powerful, fast-twitch muscle fibers,^{47,48} it is understandable that sustained vibratory stimulus selectively decreased the activity of fast-twitch muscle fibers in combination with a reduction in peak MVC force. Yoshitake et al²⁴ also reported that vibration at 100 Hz to the Achilles tendon for 30 minutes reduced the plantar flexion force by 19% (standard deviation [SD] 10), and the rectified EMGs of the medial gastrocnemius (MG), lateral gastrocnemius (LG), and soleus (Sol) muscles decreased by 32% (SD 25), 12% (SD 19), and 12% (SD 16), respectively. Ushiyama et al²⁵ also applied vibratory stimulus to the Achilles tendon using a similar protocol and revealed that the plantar flexion MVC torque was decreased by 16.6% (SD 3.7) after the vibration. However, the observed reductions in EMG during MVC were 12.7% (SD 4.0) for the MG, 11.4% (SD 3.9) for the LG, and only 3.4% (SD 3.0) for the Sol muscles. These results demonstrated that

prolonged vibration-induced MVC suppression was attributable mainly to the reduction in muscle activity in the MG and LG muscles, both of which have a larger proportion of fast-twitch muscle fibers (type II fibers) than does the Sol muscle.²⁵ The triceps brachii muscle that we tested also contains a lot of fast-twitch muscle fibers.⁴⁹ Because prolonged vibratory stimulus selectively reduced the activity of these muscle fibers,^{25,27} inhibitory effects on MVC force and muscle activity comparable to these previous reports could have been generated in the triceps brachii in our experiment.

Discomfort After Vibratory Stimulus

An equivalent degree of discomfort was noted immediately after vibratory stimulus for 5 and 10 minutes, but the discomfort in both cases was significantly reduced at 15 minutes post-stimulus, at which point it had almost disappeared. Unlike whole body vibration, which some studies have suggested could be harmful,¹⁵ the local vibratory stimulus used in this study was safe and caused no body damage.⁵⁰

Clinical Implications

The results of this study proposed that vibratory stimulus to the triceps brachii tendon for 5 minutes could be an effective noninvasive treatment capable of suppressing muscle tonus caused by muscle guarding of the triceps brachii and improving the co-contraction. Although the degree of the inhibitory effects induced by vibratory stimulus alone may not have been great in the present study, greater effectiveness could be obtained for patients with muscle guarding of the triceps brachii by combining vibratory stimulus with other therapeutic treatments such as sustained passive stretching and proprioceptive neuromuscular facilitation. The literature provides evidence that applying vibratory stimulus leads to pain reduction in patients with acute and chronic musculoskeletal pain or with myofascial pain syndromes.⁵¹⁻⁵³ Therefore, not only does the vibratory stimulus to the triceps brachii tendon not have any complications such as discomfort and body damage, but also it could have potential beneficial effects. However, this stimulus could have the potential risk of enhancing the irritation of soft tissue by internal fixation materials in patients with postoperative distal humerus fracture or olecranon fracture. In addition, the influence of vibratory stimulus given during the inflammatory phase immediately after trauma around the elbow is unknown, and the load during this phase may exacerbate inflammation. Therefore, the application of vibratory stimulus to patients with these conditions should be carefully assessed.

Limitations

There was no control group in the present study; therefore, the results obtained in this study can only be regarded as tentative. Participants included only young men. The composition of type II muscle fibers is generally less in women than in men⁵⁴ and decreases with age.^{55,56} Therefore, the inhibitory effects of vibratory stimulus may be less in women and the elderly. Sufficient inhibitory effects were obtained with vibratory stimulus for 5 minutes in the present study, but similar inhibitory effects may be obtained within 5 minutes. This study showed inhibitory effects immediately after stimulation, but whether or not these inhibitory effects are sustained remains to be clarified. Inhibitory effects induced by prolonged vibration last as long as 20 minutes.^{23,25,57} The clinical effects of vibratory stimulus on the triceps brachii muscle of patients with muscle guarding or co-contraction are unknown. Further studies are needed for comparison with control groups for which no vibratory stimulus is applied. Studies are also needed to determine the most effective duration of vibratory stimulus within the 5-minute period examined in this study and to examine the sustained inhibitory effects of this vibratory stimulus. Moreover, it is necessary to verify the clinical effects in patients on muscle guarding of the triceps brachii muscle.

CONCLUSION

The elbow extension MVC force and the %IEMG of the triceps brachii significantly decreased after vibratory stimulus for both 5 and 10 minutes, but no significant differences were observed in these reductions between stimulus for 5 and 10 minutes. Prolonged vibratory stimulus for 5 minutes to the triceps brachii tendon appeared to have inhibitory effects on the MVC force and muscle activity of the triceps brachii.

FUNDING SOURCES AND CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): R.S.

Design (planned the methods to generate the results): R.S., H.S., T.S., M.S., R.T., T.T.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): R.S.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): R.S., H.S., T.S., M.S., R.T., T.T.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): R.S., M.S., R.T.

Literature search (performed the literature search): R.S., H.S., T.S., T.T.

Writing (responsible for writing a substantive part of the manuscript): R.S., H.S.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): R.S., H.S., T.S., M.S., R.T., T.T.

Practical Applications

- The MVC force and %IEMG were significantly decreased by the application of vibratory stimulus for 5 and 10 minutes to the triceps brachii tendon.
- There were no differences in the decrease in elbow extension MVC force and %IEMG between vibratory stimulus for 5 and 10 minutes.
- Prolonged vibratory stimulus could be an effective treatment capable of suppressing muscle tonus of the triceps brachii.

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