

The immediate effects of local vibration on ankle plantar flexor muscle activation and peak torque in healthy adults

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Objective: The vibration device is one of the most commonly used warm-up devices not only for healthy athletes but also for healthy individuals. Therefore, this study aimed to investigate the immediate effects of local vibration on ankle plantar flexor muscle activation and peak torque in healthy adults.

Design: One-group pretest-posttest design.

Methods: This was a single-group study comprising a total of 36 (16 males and 20 females) participants. The average age of the 36 participants was 22.3 years. All the participants' concentric and eccentric peak torques of the gastrocnemius lateralis muscle were measured using an isokinetic device. Simultaneously, the participants' muscle activity was measured by surface electromyography. After the pre-experimental data were collected, the participants comfortably sat on the prepared chair with their hips and knees flexed to 90°. While in sitting position, local vibration was applied for 10 minutes using a 1:1 ratio intermittent pulsing mode device based on a previous study. Then, the post-experimental data were collected immediately after the local vibration by performing a similar process performed during the pre-experimental data collection.

Results: The results showed a significant difference in muscle activity and eccentric peak torque ($p < 0.05$). On the contrary, concentric peak torque values showed an insignificant difference with pre- and post-value.

Conclusions: The results of this study demonstrated that local vibration can be possibly considered as one of the effective ways to increase ankle plantar flexor muscle activity and muscle performance, specifically the eccentric peak torque, in healthy adults.

Key Words: Electromyography, Gastrocnemius muscle, Muscle strength, Power, Vibration

Introduction

Since the inception of the new millennium the use and application of vibration therapy for medical, clinical, and rehabilitative purposes has been consistently developed [1]. A mechanical stimulus characterized by an oscillatory motion is referred to as vibration that physiologically stimulates the human body to induce changes and achieve treatment goals [2]. The intensity of vibration is determined by its own biomechanical variables' frequency and amplitude. In oscillatory motion, extension range determines the amplitude (peak

to peak displacement, in mm) of the vibration. The repetition rate of the cycles of oscillation determines the frequency of the vibration measured in hertz (Hz) [3]. Scientific objectives include the long-term and short-term effects of vibration therapy on gross motor function, strength, gait, and postural control, and the vibration therapy's effects on the bones and muscles [4]. Vibration therapy not only enhances muscle strength, power, joint position sense, blood flow under the skin [5], and act on human neuromuscular structure [6-8], but also effectively treats delayed onset muscle soreness [9]. Additionally, studies have shown that vibration therapy can

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enhance motoneuron excitability.

Vibration therapy can be performed in two different ways. First, vibration therapy can be indirectly performed using vibrating platforms, dumbbells, and vibratory devices that are fixed to resistance training machines [1]. Second, vibration therapy can be directly performed in muscle bellies and/or tendons [10].

Regarding indirect vibration therapy, whole-body vibration (WBV) is the most commonly used type of vibration training [11]. Furthermore, in recent years, there has been an increased interest in the use of WBV because it not only increases athletic performance but also relates to untrained adults or recreational athletes [12,13]. However, WBV training has been widely used in sports medicine and rehabilitation [14]. However, WBV programs may not be suitable to everyone. Certainly, some participants are unable to bear weight because of the following reasons: (1) long-term immobilization (lower limb trauma), (2) immobilization by a cast, or (3) being in the early rehabilitation period after surgery (anterior cruciate ligament reconstruction). WBV participants will be stimulated three-dimensionally when standing or squatting on a vibration platform [15]. When vibration is activated, it begins to stimulate the muscle spindles and activates the alpha (α)-motoneurons. While the exact underlying mechanisms of vibration remain unclear, reflex muscular contractions have been proposed [16]. A previous study has shown almost identical latency responses between the actual stretch reflexes and WBV-induced reflexes [17]. Furthermore, other studies have shown a strong association between the timing of motor unit firings and the phase of the vibration cycle by performing intramuscular surface electromyography (s-EMG) [18].

WBV has the following significant advantages: it increases muscular strength [19-21], improves body composition [21, 22] changes muscle performance and balance [23-26], improves human athletic performance such as jumping and running parameters [26,27], and changes the peripheral circulation [28]. According to several studies, WBV exercises significantly increase muscle activity during the exposure with the help of s-EMG recordings [29,30]. According to a previous study, calf muscles experience higher acceleration due to their proximity to the platform, increased reflex activity [31], and/or increased muscle damping [32], further explaining why it has been previously found that the muscles in close proximity to the platform were more affected by WBV than the muscles that are not in close proximity to the platform [21,33]. Moreover, vibration exercise generally us-

ing the WBV protocols, has been proposed as a potential warm-up modality [34].

When local vibration is applied to the muscle belly or its tendon, several mechanisms have to be considered. First, when vibration is directly applied to the target muscle or tendon, it elicits a reflex muscle contraction [35] that potentially increases muscle function [36]. This particular reflex activity has been referred to as the “tonic vibration reflex”, which is the most frequently cited mechanism. Second, local vibration induces cortical activation due to the cortical projection of the muscle afferents [15]. Furthermore, it is also important to note that because vibration is directly applied to the muscle or tendon, a larger vibration amplitude is not required, different from indirect vibration where vibration transmission can be reduced to achieve its target destination by passing through other muscles and joints [37]. Moreover, the cost, portability and localization of vibration are considered to be the potential limitations that may restrict the use of indirect vibration [1]. Considering the limitations of WBV, several local vibrations were considered. The devices used for providing local vibration are powered by batteries, they are portable, and are easy to use; thus, these devices are considered to be beneficial in the current vibration therapy equipment [1]. However, currently, studies assessing the duration, vibration frequency, amplitude of local vibration [1] and its mode of the application are relatively few.

Thus, this study aimed to investigate the immediate changes of concentric peak torque, eccentric peak torque, and muscle activation of the ankle plantar flexor muscle using intermittent local vibration.

Methods

Participants

In the beginning, a total of 40 subjects (20 males, 20 females) between the age of 20-39 years old volunteered to participate in the experiment from Sahmyook University (Seoul, Korea). The exclusion criteria were as follows: (1) subjects complaining of neurological or vascular symptoms, (2) those with muscular pain or surgery in the calf (3) those with dermatopathy or infectious diseases, (4) those who participated in similar experiments or experienced physical therapy in 3 months on the calf area, and (5) those with reduced cognitive capacity that did not understand the information given about the experiment.

The present study was approved by the Sahmyook University Institutional Review Board (2-7001793-AB-

N-012019106HR). The aim of this study and procedure were informed to the subjects before the experiment, and all participants provided their written consent as follows with the ethical principles of the Declaration of Helsinki.

Experimental procedure and method

Four subjects were excluded for not meeting the selection criteria, leaving a total of thirty-six subjects for the study. All baseline data of concentric, eccentric peak torque, and muscle activity of the dominant side lateral gastrocnemius muscle were collected for each participant. The peak torque values were collected using an isokinetic device, and the muscle activity values were collected with s-EMG. After the pre-test, an intermittent mode of 1:1 ratio local vibration was activated around the calf for 10 minutes while sitting in the recommended sitting position, and all subjects were instructed to avoid physical activity before and during participation. Post-test values were repeatedly measure the right after the vibration device went off automatically, which was the same exact way as the pre-test values were measured. The trial was implemented for 4 times with submaximal contraction, and completion of 4 repetitions of maximal contraction was recorded for analysis. Between every experiment there was a rest period of 60 seconds. To get accustomed to the experimental procedures, trials of the process were conducted two weeks prior of the study. The participants were assigned to receive the whole similar process and the intervention was performed by one researcher and one assistant who were in charge of measuring s-EMG and were trained to prevent possible accidents during the whole experimental procedure.

Local vibration

Regarding local vibration, a vibratory device (Myovolt; Christchurch, NewZealand) was positioned on the right calf, which was held in place by a band pro-wrap (Myovolt, Christchurch, NewZealand). During local vibration, participants comfortably sat in a chair with hips and knees flexed at 90°. Based on a previous study [8] and according to the manufacturer's instructions, the 1:1 ratio intermittent pulsing mode device was activated for 10 minutes [8]. The vibration frequency passed through a range of 30-100 Hz at an amplitude of 0-0.12 mm in 0.5 second, which created a pulsing effect.

Measurement of muscle activity

In this study, muscle activation was measured using a

wireless s-EMG (2017; Mini Wave Infinity waterproof, Cometa, Italy). Before proceeding with the experiment, all participants' gastrocnemius lateralis muscles were gently abraded and wiped with alcohol swabs. Subsequently, s-EMG was attached to the gastrocnemius lateralis muscle. To reduce the noise of the wireless EMG, an adhesive tape was used to fix the sensor. The muscle activity of the plantar flexor, specifically the gastrocnemius lateralis, was measured using s-EMG while simultaneously measuring both concentric and eccentric contractions. After the preparation has been completely performed, the s-EMG was positioned at a point 1/3 between the fibular head and heel, which was in accordance to the guideline of the SENIAM [38]. All measurements were performed four times. EMG signals were amplified with an amplifier, band-pass filtered, and (analog to digital) converted. The analog signal from raw data was converted to the American Standard Code for Information Interchange form. Subsequently, the data were sent to a personal computer for editing and signal processing stage using the MyoResearch XP, Noraxon program. The force and EMG data were at a sampling rate of 2 kHz and filtered with a band-pass filter of 20-450 Hz. Four movement contractions were edited separately, and pre-test and post-test data were calculated with the mean values.

Measurement of peak torque

The isokinetic dynamometer was used to assess the concentric and eccentric peak torques. The positioning of the isokinetic device was based on the positioning of a previous single- group study that examined the acute effects of local Achilles tendon vibration on peak plantar flexor torque, twitch contractile properties, plantar flexor muscle activity, and brain activity [39]. An isokinetic dynamometer (HUMAC, NORM 770; Computer Sports Medicine Inc., Stoughton, MA, USA) was calibrated prior to the start of the study according to the operating manual's instructions. No gravity correction was used for all measurements. The software installed on the computer was similar (HUMAC 2009, v.9.7.1). An isokinetic device was individually adjusted with the participants lying in prone position with hip, knee, and ankle joints in neutral position (180°, 180°, and 90°, respectively) [39]. To evoke a more pronounced muscle twitch of the plantar flexor muscle, the muscles around the knee were fully extended (i.e., 180°) (i.e., the foot, specifically the heel of the right leg). The leg was firmly attached to the lever arm of the dynamometer with its rotational axis at the level of the malleoli. To limit upper body contributions to torque pro-

duction, straps were applied at the hip and knee level. This fixed position on the dynamometer was maintained throughout the entire procedure during the familiarization and experimental sessions. The trial was implemented for 4 times, and completion of 4 repetitions was recorded for analysis. This was followed by four concentric and eccentric measurements that were performed at an angular velocity of 60°/s with participants in a comfortable position, from 10° dorsiflexion to 20° plantarflexion set in range of motion with a resting period of 60 seconds with each repetition. The maximum concentric and eccentric torque values were used for subsequent analysis, which was normalized to the pre-exercise value. During the measurement of each peak torque, verbal encouragement was provided by a similar examiner by verbally instructing the participants to do the following: “contract as forceful and as fast as you can.”

Data analysis

Regarding the statistical analysis, to determine a significant difference after applying local vibration, pre and post-muscle performance and concentric and eccentric values were calculated and assessed using the paired t-test. To obtain a statistical result, all the four-time experiment mean values were used. All statistical analysis was calculated

Table 1. The general characteristics of participants (N=36)

Variable	Participants
Sex (male/female)	16/20
Age (y)	22.25 (4.32)
Height (cm)	167.86 (7.95)
Weight (kg)	62.56 (11.97)

Values are presented as number only or mean (SD).

Table 2. Comparison of muscle activity between pre and post-test (N=36)

Variable	Participants
EMG mean (μ V)	
Before	314.09 (157.97)
After	363.21 (200.85)
Difference	-49.12 (141.72)
t (p)	-2.080 (0.045)
EMG peak (μ V)	
Before	117.54 (71.43)
After	429.22 (224.52)
Difference	-311.68 (184.50)
t (p)	-10.136 (<0.001)

Values are presented as mean (SD).
EMG: surface electromyography.

IBM SPSS Statistics ver. 22.0 software (IBM Co., Armonk, NY, USA). A significance level was set at a *p*-value of <0.05.

Results

General characteristics of the participants

Thirty-six participants in this study. The participants' demographic characteristics are shown in Table 1.

Comparison of muscle activity

The s-EMG results showed significant differences in both mean and peak values (*p*<0.05). A significant increase in muscle activity was observed in the pre and post-test (Table 2, Figure 1).

Comparison of peak torques

Descriptive data for the peak torque of concentric and eccentric contractions are presented in Table 3. Our analysis

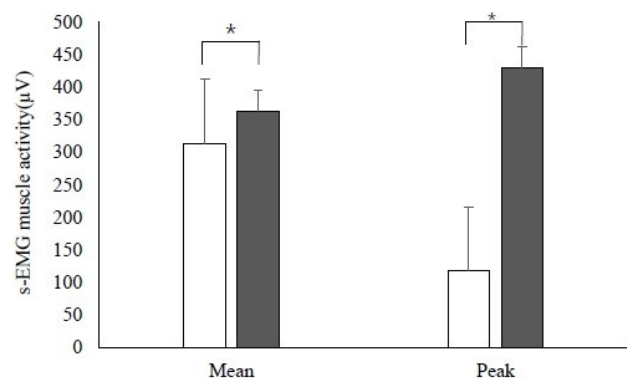


Figure 1. Comparison of muscle activity between pre and post-test. s-EMG: surface electromyography, white box: pre-test, gray box: post-test. **p*<0.05.

Table 3. Comparison of peak torque between pre and post-test (N=36)

Variable	Participants
Concentric peak torque (Nm)	
Before	23.71 (17.42)
After	31.05 (27.77)
Difference	-7.33 (25.61)
t (p)	-1.718 (0.095)
Eccentric peak torque (Nm)	
Before	42.38 (32.02)
After	51.97 (35.26)
Difference	-9.59 (22.00)
t (p)	-2.616 (0.013)

Values are presented as mean (SD).

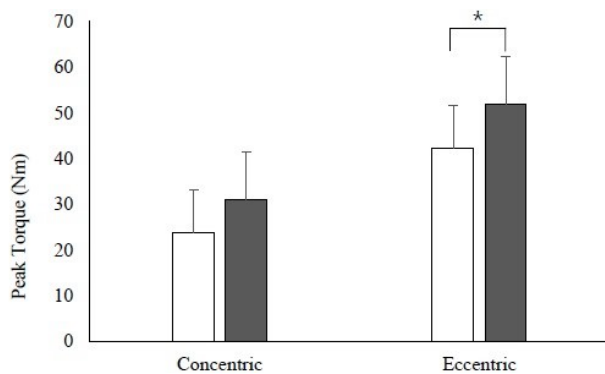


Figure 2. Comparison of peak torque between pre and post-test. White box: pre-test; gray box: post-test. * $p < 0.05$.

revealed that a significant difference was observed in eccentric contraction ($p < 0.05$). However, no significant difference was observed in concentric contraction ($p > 0.05$) (Table 3, Figure 2).

Discussion

This study aimed to investigate the immediate effects of local vibration on ankle plantar flexor muscle activation and peak torque. The results from this study clearly demonstrate that use of an intermittent mode of local vibration can increase muscle activation and eccentric peak torque. Vibratory stimuli potentially enhance neural and/or muscular (re)conditioning [15]. Local vibration could be an alternative form of vibration training. Local vibration requires the use of a small and portable device that applies vibration directly over the muscle or the tendon [40]. On the contrary, WBV energy from vibration is reduced by the ankle joint, knee joint, and calf musculature, which may influence the magnitude of the vibration stimulus applied to the proximal structures. This reduction in energy from the vibration signal could be lessened if vibrations were applied directly to the muscle of interest via local vibration rather than WBV [36].

First, the present study clearly showed the result of increased muscle activity in both peak value and mean value. This result is consistent with the results of previous several studies. However, each previous study applied various durations. According to a previous study, when vibration was applied to the biceps brachii (frequency range, 0-170 Hz) with concentric dynamic biceps curls after 10 minutes in master hockey players, significant increases in power output were observed [5], suggesting that short-term local vibration may have contributed to muscle performance enhancements

with contractile properties. Vibration stimulates muscle spindles and activates the α -motoneurons [41] and sends a nerve impulse to initiate muscle contractions through a tonic vibration reflex [29].

Second, the findings in this study showed that once the direct pulsing mode vibration was applied on the gastrocnemius lateralis muscle, the eccentric peak torque value showed a significant difference. On the contrary, the concentric peak torque value showed an insignificant difference. Based on a previous study, local vibration was applied for 30 seconds and 300 seconds to the plantar flexor local tendon with a frequency of 80 Hz and an amplitude of 1 mm. Both durations have not shown any significant difference but showed medium-sized effects of condition with the peak plantar flexor torque [39]. A previous study has focused on the individual's characteristics based on a previous study conducted in athletes [42]. These findings indicate that participants who showed a significant increase in contractile properties are not necessarily those showing the most significant performance improvements following acute exercise [39]. The present study used an isokinetic device set with an angular velocity of 60°/s, from 10° ankle dorsiflexion to 20° plantar flexion based on a previous study to measure both the concentric and eccentric peak torque values. This means a single task should be ideally performed in 0.5 seconds, significantly fast to perform. Hence, it was considered to be a difficult task even for healthy nonathletic adults. The result of the present study was inconsistent with the results of the previous studies, specifically differences in placement and types of vibratory devices. Based on a previous study, the vibratory device was placed over the mid-belly of the biceps brachii, and considering its flexible design with the strap and device itself, the muscles applied with vibration can be enclosed. The vibratory panels of the device were placed lateral, medial, superior, and inferior to the center of the muscle [42].

To the best of our knowledge, this is the first study showing a significantly different result regarding the immediate effects of direct pulsing mode vibration on the gastrocnemius lateralis muscle in healthy adults. The result of the present study is consistent with the results of a previous study [5], with increasing peak torque in the elbow flexors. Consistent with the previous studies, the present study used s-EMG and an isokinetic device to determine the muscle activity and peak torque, resulting in unchanged muscle activities after applying vibration to the plantar flexor tendon with different durations such as 30 seconds and 300 seconds

with a frequency of 80 Hz [39]. This is possibly attributed to the different methods, vibration types, devices and durations used in the previous studies. Hence, further studies determining the best parameters for local vibration stimuli (e.g., exposure times) in every muscle to create a protocol with acute performance gains are required.

With an increased eccentric peak torque, the s-EMG activity by local vibration on the gastrocnemius lateralis muscle has proven the clear immediate effects of a new portable vibration device. However, this study has the following limitations: The participants were limited to healthy young students, measurement using an isokinetic device may potentially lead to fatigue for the participants, although a 60-second rest period between every trial was provided, the present study has a limited angular velocity of 60°/s to determine the peak torque, and the measurement of pre and post-test data was conducted within the same group and the s-EMG electrodes were not detached during the experiment. Therefore, this study did not use normalization procedures, which has been recommended for inter-individual comparisons [43,44]. Lastly, the present study only showed the results of the immediate effects. Hence, further studies investigating the sustainability of the local vibration effects are required.

In conclusion, vibration device is one of the most commonly used warm-up devices not only for healthy athletes but also for healthy individuals. Therefore, this study was designed to demonstrate the use of local vibration using an intermittent mode to determine its immediate effects on the plantar flexor muscle activation and torque. Devices used in local vibration are portable, powered by batteries, and are easy to use. Based on these results, it can be suggested that local vibration can be possibly considered as one of the effective ways to increase muscle activity and muscle torque, specifically the eccentric peak torque.

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Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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