



Original Article

The effects of pre-exercise vibration stimulation on the exercise-induced muscle damage

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Abstract. [Purpose] To investigate the effects of pre-induced muscle damage vibration stimulation on the pressure-pain threshold and muscle-fatigue-related metabolites of exercise-induced muscle damage. [Subjects and Methods] Thirty healthy, adult male subjects were randomly assigned to the pre-induced muscle damage vibration stimulation group, post-induced muscle damage vibration stimulation group, or control group (n=10 per group). To investigate the effects of pre-induced muscle damage vibration stimulation, changes in the pressure-pain threshold (lb), creatine kinase level (U/L), and lactate dehydrogenase level (U/L) were measured and analyzed at baseline and at 24 hours, 48 hours, and 72 hours after exercise. [Results] The pressure-pain thresholds and concentrations of creatine kinase and lactate dehydrogenase varied significantly in each group and during each measurement period. There were interactions between the measurement periods and groups, and results of the post-hoc test showed that the pre-induced muscle damage vibration stimulation group had the highest efficacy among the groups. [Conclusion] Pre-induced muscle damage vibration stimulation is more effective than post-induced muscle damage vibration stimulation for preventing muscle damage.

Key words: Muscle damage, Muscle fatigue, Pressure-pain threshold

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INTRODUCTION

Exercise-induced muscle damage (EIMD) is caused by eccentric contraction or excessive overload, which requires large changes in muscle length¹⁾. EIMD secretes the intracellular proteins of muscle cells such as creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin into the blood. In addition, metabolites such as lactic acid and potassium are temporarily produced in the contracted muscle, which can cause fatigue, pain, and a decrease or loss in muscular performance and exercise regulation ability due to inappropriate blood and oxygen supply to the muscles^{2, 3)}. Delayed onset muscle soreness is first felt 24 hours after exercise, and it peaks within 24–72 hours after exercise. The soreness gradually decreases and disappears after 5–7 days³⁾.

Physical therapy interventions such as stretching⁴⁾, ultrasound treatment⁵⁾, and micro-current treatment⁶⁾ are used to treat symptoms of EIMD. Recently, vibration stimulation, which is a type of mechanical stimulation, has emerged as a new treatment method⁷⁾. Lebedev and Peliakov have suggested the possibility that vibrations may elicit excitatory inflow through muscle spindle-motoneurons connections in the overall motoneuron inflow⁸⁾. Koh et al. reported that a significant change in the pressure-pain threshold (PPT) was observed when 10 minutes of a 20-Hz vibration stimulus was applied after the onset of delayed muscle soreness⁹⁾. Song et al. reported that a significant decrease in muscular pain was observed when 10 minutes of a 20-Hz vibration stimulus was applied on biceps with muscle damage for 4 days¹⁰⁾. In addition, Kim reported that the levels of CK and LDH in the quadriceps and biceps femoris decreased in the group that received 1-minute long vibration stimula-

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tion at 30 Hz after exercise compared to the control group¹¹). As shown in previous studies, the positive effects of vibration stimulation have mostly been investigated for improving the symptoms after EIMD. However, there is a lack of studies on using pre-induced muscle damage vibration stimulation to prevent EIMD. Therefore, the present study aimed to investigate the effects of local pre-induced muscle damage vibration stimulation for preventing muscle damage.

SUBJECTS AND METHODS

All 30 participants in this study were healthy, male adults in their 20s with an average weight of 66.6 kg and an average height of 174.5 cm. Participants were all right hand dominant with no recent or previous history of a neck disorder requiring medical intervention, and absent signs of physical dysfunction in a clinical examination of the neck. Participants were excluded from the study if they reported any current shoulder disorders. This study received approval from the Cheongju University's Research and Ethics Committee. All participants received verbal and written information about the study and signed a consent form. Participants were randomly assigned to the pre-induced muscle damage vibration stimulation group (group I), post-induced muscle damage vibration stimulation group (group II), or non-intervention group (control group) (n=10 per group). The PPT and blood muscle-related fatigue metabolite levels were measured before EIMD. These variables were measured again at 24 hours, 48 hours, and 72 hours after a vibration stimulus was applied in the same conditions used in the control group. EIMD was measured by using weight equivalent to 60% of one repetition maximum, which was lifted and lowered in the 0–135° range of motion of the elbow joint while participants' bodies and shoulders were in a fixed position. The weight-bearing arms were slowly lowered at the same pace (8 seconds according to a metronome), and an assistant helped lift them. Five sets of 15 repetitions were performed with a 60-second break in between sets¹²). A 60-Hz vibrator (AT-1000, AT System, Seongnam-si, Korea) was used to apply the vibration stimulus to the middle of the biceps muscle for 5 minutes during a relaxed state by the same therapist¹³). To determine the PPT before and after EIMD, we used a digital pressure algometer (Algometer TM Commander, J-TECH Medical, Salt Lake City, UT, USA). The measuring electrodes were vertically placed 5, 9, and 13 cm from the muscular body, and then force was applied. The amount of applied pressure increased linearly, and participants were instructed to notify the therapist when they felt pain. The amount of pressure exerted when pain was felt was measured. The measurements were repeated three times, and an average value was calculated. The measurement locations were clearly marked with an oil-based marker. The measurements were assessed again at pre-exercise and at 24 hours, 48 hours, and 72 hours after vibration stimulation was applied. High measurement values indicated a low PPT¹⁴).

Participants' blood samples were collected at pre-exercise and at 24 hours, 48 hours, and 72 hours after vibration stimulation was applied to determine the CK and LDH levels. Blood samples were obtained after fasting, and participants were instructed to have their blood drawn at their designated time with an error margin of ± 1 hour¹⁰).

Windows SPSS 18.0 (SPSS, Inc., Chicago, IL, USA) was used for data analysis, and one-way analysis of variance (ANOVA) was conducted to test for homogeneity. Differences in the variables among each group were tested using repeated-measure ANOVA. The Tukey method was used to perform the post-hoc test, and the statistical significance was set to $p < 0.05$.

RESULTS

Changes in the PPT with vibration stimulation before or after EIMD showed significant differences ($p < 0.001$) and significant interactions ($p < 0.01$) between the application times and groups. Results of the post-hoc test showed that the pre-induced muscle damage vibration stimulation group had the highest PPT (Table 1).

Changes in the CK levels with vibration stimulation before or after EIMD showed significant differences between the application times and groups ($p < 0.01$), and significant interactions between the application times and groups ($p < 0.001$). Results of the post-hoc test showed that the pre-induced muscle damage vibration stimulation group had the lowest CK level (Table 2).

Changes in the LDH levels with vibration stimulation before or after EIMD showed significant differences ($p < 0.001$) and significant interactions ($p < 0.001$) between the application times and groups. Results of the post-hoc test showed that the pre-induced muscle damage vibration stimulation group had the lowest LDH level (Table 3).

DISCUSSION

Vibration stimulation is a treatment method that directly stimulates the human body and induces exercise-like effects on desired locations¹⁵). Bakhtiary et al.¹⁶) reported that vibration stimulation was very effective for muscle damage recovery, and it could be used in athletes and the public who require a fast recovery. Aminian-Far reported that 5 minutes of pre-induced muscle damage vibration stimulation of the lower limbs significantly reduced the delayed muscle soreness-pain threshold in healthy adults compared to those in the control group¹⁷). In the present study, the pre-induced muscle damage vibration stimulation group showed a relatively higher PPT than the other groups, which coincided with the results from previous studies. Saijo et al.¹⁸) reported that vibration stimulation induced pain relief and topical anesthesia based on gate control

Table 1. Comparison of changes in the pressure-pain threshold among the groups (n=10)

	M ± SD (lb)			
	Pre	Post-24h	Post-48h	Post-72h
CON	35.0 ± 2.6	16.8 ± 2.6	15.5 ± 2.1	15.6 ± 3.1
Exp-I†	31.3 ± 6.3	20.4 ± 7.5	27.6 ± 6.8	27.6 ± 5.1
Exp-II	36.4 ± 9.9	19.0 ± 7.8	17.4 ± 5.0	12.8 ± 6.7

†p<0.01, Comparison among the groups.

Exp-I: Vibration stimulus before EIMD of biceps brachii

Exp-II: Vibration stimulus after EIMD of biceps brachii

Table 2. Comparison of changes in the creatine kinase level among the groups (n=10)

	M ± SD (U/L)			
	Pre	Post-24h	Post-48h	Post-72h
CON	147.6 ± 12.1	140.5 ± 8.2	433.3 ± 8.0	131.6 ± 7.3
Exp-I†	141.0 ± 4.2	131.7 ± 3.9	130.7 ± 4.6	128.1 ± 3.7
Exp-II	139.0 ± 5.0	136.8 ± 3.1	135.4 ± 2.0	133.1 ± 1.7

†p<0.001, Comparison among the groups

Table 3. Comparison of changes in the lactate dehydrogenase level among the groups (n=10)

	M ± SD (U/L)			
	Pre	Post-24h	Post-48h	Post-72h
CON	392.3 ± 41.4	609.0 ± 56.7	890.0 ± 51.4	2,034.1 ± 207.4
Exp-I†	383.7 ± 113.0	417.2 ± 65.9	365.1 ± 54.9	345.3 ± 54.5
Exp-II	377.4 ± 37.1	384.9 ± 99.6	360.1 ± 43.1	430.5 ± 65.1

†p<0.001, Comparison among the groups

theory. Additionally, McHugh¹⁹⁾ reported that vibration stimulation increased the activity and tension of the muscle, which helped prevent damage caused by injuries or contraction. Therefore, it can be inferred that vibration stimulation of the muscle decreases muscle injuries, EIMD, and pain.

The CK and LDH levels are used as indicators of cell membrane damage, tissue necrosis, and muscle cell damage caused by high-intensity exercise. In addition, CK and LDH are enzymes that aid in regulating the balance between catabolism and anabolism of carbohydrates, which means they represent energy metabolism^{20, 21)}. Changes in the CK and LDH levels in the current study showed that the pre-induced muscle damage vibration stimulation group displayed the lowest CK level, whereas LDH levels in the pre-induced muscle damage vibration stimulation group and post-induced muscle damage vibration stimulation group were lower than those in the control group. Bakhtiary et al.¹⁶⁾ studied 25 non-athletes who ran on a treadmill after 50 Hz of vibration stimulation was applied to the lower limbs, and they reported that the CK level was relatively lower in the experimental group than in the control group. Imtiyaz et al.⁷⁾ conducted a study in which 5 minutes of 50 Hz of vibration stimulation was applied to healthy women after EIMD was induced; they also reported that the CK and LDH levels were significantly reduced after 48 hours of stimulation.

Based on these results, we infer that vibration stimulation improved muscle recovery from fatigue by quickly removing lactic acid in the blood²²⁾. Hazell et al. reported that arterial pressure, blood flow, and the superficial skin temperature significantly increase around the location of vibration stimulation²³⁾. Similarly, Butterfield et al. reported that the increased blood flow improved permeability of the cell membrane and removed inflammatory agents such as prostaglandin, bradykinin, and histamine²⁴⁾, which improved exercise-induced fatigue and muscle damage²⁵⁾. These results indicate that vibration stimulation on the biceps after EIMD affects the PPT and CK and LDH levels. We determined that pre-induced muscle damage vibration stimulation is more effective than post-EIMD vibration stimulation for preventing muscle damage.

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