Abstract. [Purpose] We investigated the occurrence of delayed-onset muscle soreness and the suppression of muscle rigidity by ultrasound irradiation before high-load exercise. [Participants and Methods] The study was a randomized crossover controlled trial. The participants were 28 healthy university students (12 males, 16 females). Delayed-onset muscle soreness was induced in the biceps brachii muscle; ultrasound (3 MHz, 1.5 W/cm², 10 min) was applied before high-load exercise. Pain during elbow motion was evaluated on a visual analog scale. Muscle rigidity was evaluated using a muscle rigidity meter. [Results] After exercise on the second day, the ultrasound group showed significantly less muscle rigidity. [Conclusion] The heat stimulus of ultrasound therapy before high-load exercise reduces muscle rigidity.

Key words: Delayed onset muscle soreness (DOMS), Ultrasound therapy, Muscle rigidity meter

INTRODUCTION

Muscle pain following high-load exercise is termed “delayed onset muscle soreness” (DOMS). DOMS is an inflammatory reaction to tears in muscular fibers and accompanies the repair process, and the pain or discomfort lasts 2 to 3 days after exercise. DOMS can discourage further exercise and decrease exercise performance.

In addition, muscle rigidity increases after high-load physical exercise. The rigidity is due to increased vascular permeability for the export of intramuscular metabolites such as carbon dioxide and lactic acid, produced during exercise, from the muscle fibers. Increased muscle rigidity also decreases performance. Among elderly people, it may limit activities of daily living.

Ultrasound can promote the metabolic rate, suppress pain and spasticity, improve nerve conduction rate, improve blood circulation, and increase soft tissue compliance. Increases in muscle temperature were similar following ultrasound and warm-up exercise. We thought that ultrasound might reduce DOMS when used in place of a warm-up, but its effects on DOMS and on muscle rigidity before high-load exercise have been hardly investigated so far. It was shown that effect of the ultrasound in some investigations, but it was only a subjective index. If shown to be effective, it could be used to prevent DOMS in persons who have difficulty warming up. Here, we measured muscle rigidity for an objective index, and investigated the effect of warming by ultrasound irradiation before exercise on DOMS prevention and muscle rigidity.
PARTICIPANTS AND METHODS

The participants were 28 healthy university students (12 males, 16 females; mean age 22.1 ± 2.0 years). Before the study started, we obtained the participants’ consent and agreement to participate. We explained that they could choose to withdraw from the study, that they would not be identified, and that any personal details associated with the study would be known only to members of the research group. This study was approved by the Committee of Medical Ethics of Hirosaki University School of Health Sciences, Hirosaki, Japan (approval number; HS 2016-048).

The study used a randomized crossover controlled trial. We tested ultrasound irradiation and sham ultrasound treatment in random order for each person, with a 5-day rest so that no intervention effect would remain between treatment conditions.

We applied ultrasound irradiation to 5.0 cm² of the belly of the biceps brachii muscle of the non-dominant arm with an L-type ultrasound probe (beam unevenness rate 2.4) connected to an ultrasound therapy device (UST-770, Ito Co., Ltd., Tokyo, Japan). The ultrasound was applied at a speed of 1 cm/s in strokes parallel to the muscle through ultrasound gel over a distance of 10 cm. The device operated at 3 MHz and 1.5 W/cm², with constant exposure for 10 min. We applied the probe at a slight pressure to push the skin in. These ultrasonic irradiation conditions are the setting that is effective for enough warm-up to the belly of the biceps brachii muscle ⁹. We applied sham treatment the same way except at 0.0 W/cm². The participants did not know which treatment they received.

This study induced DOMS in reference to preliminary researches ⁹, ¹¹. As heating by ultrasound lasts for around 20 min, we directed the participants to induce DOMS of the biceps brachii muscle within 5 min after treatment by repetitive lifting of a 5-kg dumbbell while sitting on a chair, with the elbow on a desk and the forearm supine. The participants were asked to repeatedly lift the weight until stopped by muscle fatigue in four sets separated by 30-s breaks.

We used a visual analog scale (VAS) to investigate the participants’ perception of pain during concentric contraction (curvature movement) and eccentric contraction (extension movement). The VAS used a 100-mm line with “No pain” written at one end and “Worst possible, unbearable, excruciating pain” at the other end. Participants placed a mark in the position that they felt reflected the current level of their perceived pain. The distance from the “No pain” end to the mark in mm was used as a percentage. We measured muscle rigidity with a muscle rigidity meter (Newtone TDM-Z1 (RB); Try-All, Chiba, Japan). The participant sat on a chair with the upper arm lying on a desk, and we measured muscle rigidity with the shoulder joint 90° abducted, elbow joint extended, and forearm supine, having marked the belly of the biceps brachii muscle long head with a pen to ensure consistency of measurement. We tested muscle rigidity five times at each assessment and analyzed the means as a percentage of the value before movement (assumed to be 100%). We measured muscle rigidity on five occasions: immediately before treatment, immediately after movement under DOMS, and 2, 5, and 8 days later. We directed participants not to stretch or massage their muscles as much as possible during an experiment period.

We used Friedman’s test to investigate time-course changes of measurements, followed by multiple comparison using Scheffé’s method. We compared treatment means using the Wilcoxon Rank Sum test to confirm an effect of the ultrasound. All tests were performed in SPSS Statistics 19.0 for Windows (SPSS Japan), with a significance of p<0.05.

RESULTS

There were no significant differences in pain or muscle rigidity between the first and second sessions or between treatment conditions (Table 1). The 5-day rest period was effective.

In both conditions, the VAS rating was significantly greater after exercise on days 0 and 2 than before (p<0.05; Table 2). There was no significant difference between conditions. Following ultrasound, muscle rigidity was significantly greater after exercise on day 0 than before (p<0.05). Following sham treatment, muscle rigidity was marginally greater after exercise on day 0 and 2 than before (p<0.05), it was significantly greater on day 2 (p<0.01), and it was significantly greater than following ultrasound on day 2 (p<0.01).

Table 1. Comparison of pain and muscle rigidity during exercise between first and second sessions

|                        | First session (n=28) | Second session (n=28) |
|------------------------|---------------------|-----------------------|
| VAS pain of concentric contraction (%) | 0.6 ± 0.5           | 0.8 ± 2.5             |
| VAS pain of eccentric contraction (%)   | 1.2 ± 2.1           | 1.3 ± 4.2             |
| Muscle rigidity (N)         | 24.7 ± 7.6          | 23.6 ± 7.6            |

Values are mean ± SD.
Wilcoxon Rank Sum test: no significant differences.
VAS: Visual Analog Scale.
DISCUSSION

Both warm-up and heat treatment before exercise are commonly thought to reduce DOMS following high-load exercise\(^8\). To confirm this effect, we investigated muscle rigidity.

There was no difference in VAS rating in either contraction or extension of the elbow between ultrasound irradiation and sham treatment. We assessed pain on both movements to guide the setting of exercise loads in future research, as DOMS is strong in eccentric contraction\(^11\).

On day 2 after exercise, muscle rigidity increased following sham treatment. A preliminary study found that the degree of DOMS is not necessarily associated with muscle rigidity\(^6\). Our results support this finding. By vibrating deep tissues, ultrasound stimulation produces frictional heat\(^{10}\). When tissue temperature rises by 1°C, metabolic activity is accelerated; by 2°C, myotonia is inhibited and pain is suppressed; and by 3–4°C, the extensibility of collagen fibers increases\(^{12}\). Ultrasound irradiation (3 MHz, 2.0 W/cm\(^2\), 10 min) of the triceps surae muscle increased muscle temperature by ≥4°C at 0.89°C/min over 6 min\(^{13}\).

This study used an exposure time of 10 min to ensure complete warm-up. We speculate that the temperature in the belly of the biceps brachii muscle rose by 3–4°C in our study, and so we hypothesize that the rise in muscle rigidity was suppressed by the improved metabolic activity of the myocytes and by the increased discharge of metabolites by the increased vascular flow.

Our results show that ultrasound irradiation before high-load exercise was effective at inhibiting increased muscle rigidity. Such treatment could be used to prevent DOMS.

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Conflict of interest

None.

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