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Open Access Original Article

Sequence of Acupuncture and Massage and the Immediate Effects on Muscle Hardness

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Review began 10/14/2026
Review ended 10/26/2026
Published 10/31/2026

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DOI: 10.7759/cureus.118914

Abstract

Introduction

To maintain muscle function and physical performance, acupuncture and massage are often used in combination. We investigated how the sequence of these treatments affects muscle hardness.

Methods

The study included the muscles of nine male participants (19-23 years old). Muscle hardness was measured at 10 points, spaced 10 mm apart, starting 20 mm distal to the lateral epicondyle of the humerus, during both relaxation and contraction, using a muscle hardness tester (PEK-1, Imoto Machinery Co., Kyoto, Japan). Acupuncture needles inserted into the extensor digitorum communis muscle at 2.5 cm and 10.5 cm distal to the lateral epicondyle of the humerus were energized to an intensity that caused mild muscle contraction. Massage consisted of pressure and kneading applied to points where hardness was measured. An envelope method was used to assign the order of acupuncture first and massage later (AM) on one side and massage first and acupuncture later (MA) on the opposite side. Results were statistically analyzed using two-way repeated-measures analysis of variance (RM-ANOVA) and multiple comparison tests.

Results

Muscle hardness during relaxation was significantly decreased before and after AM. A significant interaction ($F(1, 8) = 9.137$, $p = 0.0165$) was observed for muscle hardness during contraction. Massage significantly reduced muscle hardness during contraction, whereas subsequent acupuncture prevented this decline, demonstrating that the treatment sequence directly affects contractile responsiveness.

Conclusions

Massage reduced muscle hardness during both relaxation and contraction, whereas subsequent acupuncture counteracted this reduction. These findings suggest that the MA sequence may help preserve active contractile responsiveness and prevent pre-performance force decrement by maintaining contractile muscle hardness.

Categories: Sports Medicine, Physical Medicine & Rehabilitation, Integrative/Complementary Medicine
Keywords: acupuncture, combined therapy, immediate effects, massage, muscle hardness, muscle strength, treatment sequence

Introduction

Acupuncture reduces delayed-onset muscle soreness and improves muscle recovery [1,2]. Massage has also been reported to reduce delayed-onset muscle soreness and perceived fatigue [3]. Both acupuncture [4-6] and massage [7-9] reduce muscle hardness. Immediately after treatment, the effect on instantaneous muscle strength is predominantly positive, and several studies have reported an increase following acupuncture [10-14]. For massage, Hunter et al. reported a decrease in muscle strength that was independent of changes in neuromuscular recruitment [15]. Similarly, in a review, Mine et al. concluded that massage decreases muscle strength and therefore does not recommend massage as a pre-treatment [16]. Thus, acupuncture and massage have been reported to have both similar and different effects on muscles.

In Japan, acupuncture and shiatsu massage are routinely used in combination in clinical and sports settings. However, to the best of our knowledge, no studies have examined the combined effects of acupuncture and massage on the muscles. Muscle strength and muscle hardness during contraction are highly correlated [17,18], and muscle hardness measurements are more stable than muscle strength measurements because of the ease of multipoint measurements. In this study, we experimentally investigated the sequential effects of acupuncture and massage when used together, measuring muscle hardness during relaxation and muscle hardness during contraction.

How to cite this article
Arima Y, Oba M (October 31, 2026) Sequence of Acupuncture and Massage and the Immediate Effects on Muscle Hardness. Cureus 18(10): e118914. DOI 10.7759/cureus.118914

Materials And Methods

Nine healthy adult males (19-23 years old, mean age: 20.6 years) were included in this study. The experiment was approved by the Tokoha University Research Ethics Review Committee (2017-029H), and each participant provided informed consent prior to participation. This study was conducted between February 2018 and March 2018 at Tokoha University. This study employed a randomized, single-assessor, two-period crossover design to evaluate the sequence-dependent effects of combined acupuncture and massage interventions on muscle hardness during relaxation and contraction.

The extensor digitorum communis was selected for measurement based on the following conditions: finger pressure could be applied at a constant pressure, it was easy to maintain the muscle relaxation limb and the muscle contraction limb at the maximum joint movement angle in a constant state, and the stiffness measurement of the entire muscle belly could be completed in 10-15 seconds. The relaxed position was defined as placing the entire medial surface of the forearm and palm flat on a desk in a relaxed state. The contracted position was defined as performing maximal voluntary extension of the middle finger without wrist extension, while maintaining the forearm and palm flat on the desk to selectively isolate the extensor digitorum communis (Figure *1A*).

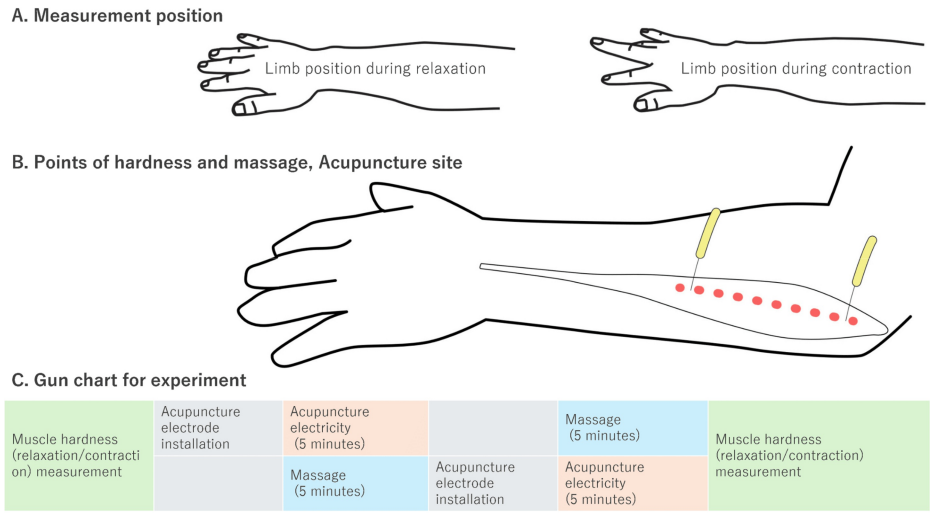


FIGURE 1: Schema of the experiment

(A) Schematic image showing the limb position during relaxation and contraction for muscle hardness measurements; (B) the muscle hardness measurement points (red circles) and acupuncture points; and (C) an experimental gun chart

Figure created by the first author specifically for this study. It is an original figure and has not been published previously

Direct exertion force was not monitored because force measurement during finger extension is methodologically difficult due to compensatory movements and variations in sensor contact angle. Instead, contracted muscle hardness was measured as a surrogate index for contractile force. Preliminary testing using a continuous displacement-monitoring system sharing the same mechanism as the PEK-1 demonstrated alignment between joint range of motion and contracted hardness values, as well as the ability to maintain a stable contracted state consistently for 10-15 seconds. The examiner visually verified position consistency during testing, and measurements across all 10 points were completed within 10-15 seconds.

Muscle hardness was measured using a muscle hardness tester (PEK-1, Imoto Machinery Co., Kyoto, Japan) at a measuring pressure of 4.9 N. Muscle hardness was measured during relaxation in the muscle-relaxed limb position and during contraction in the muscle-contracted limb position. The tip of PEK-1 consisted of a spindle and sub-shaft with different spring strengths, and the hardness value was 1/10 of the distance traveled by the spindle when the sub-shaft moved by 10 mm. In this study, the measured value was multiplied by 10, and the unit was treated as mm. Ten points were measured at 10 mm intervals from a position 20 mm distal to the lateral epicondyle of the humerus and from proximal to distal, and the average of the 10 points was used as the hardness measurement value (Figure *1B*).

Stainless steel needles (Seirin Nanshin, 0.20 x 50 mm, Shizuoka) were used, with an OhmPulser (LFP-4000A, Zen Iryoki Corp., Fukuoka) used as the energizer. Needle sites were 2.5 cm and 10.5 cm from the lateral epicondyle of the humerus (Figure *1B*). The acupuncture needles were stimulated at a frequency of 1 Hz for

five minutes at an intensity that caused mild muscle contractions. Massage was performed for five minutes in the area where muscle hardness was measured by pressing and kneading with the thumb (Figure *1B*). In the pressing method, pressure was applied in a direction perpendicular to the muscle, whereas in the kneading method, small circles were drawn while pressure was applied.

Prior to testing, the outline of the extensor digitorum communis muscle belly was palpated, and 10 measurement points were marked on the skin (Figure *1B*) by an experienced examiner whose palpation accuracy had been previously validated using ultrasonography. Bilateral forearms (extensor digitorum communis muscles) were assigned to either the AM (acupuncture first, massage second) or MA (massage first, acupuncture second) sequence using a sealed envelope randomization method, without stratification by hand dominance. A simultaneous bilateral within-subject design was employed to control for systemic physiological fluctuations (such as autonomic nervous activity and general fatigue), room environmental conditions, and natural time-course changes over the 10-minute window, thereby allowing a direct comparison of sequence-dependent effects within the same participant.

Both sequences were implemented simultaneously over a total 10-minute intervention window: during the first five minutes, electroacupuncture (1 Hz, 5 min) was applied to the AM side while thumb massage (pressing and kneading, five minutes) was performed on the MA side by a single practitioner who had undergone preliminary feedback training using a push-pull gauge to apply a consistent pressing force of 1.4-1.7 kgf at a constant rhythm (two seconds per press and two seconds per knead) along the marked EDC muscle belly; during the subsequent five minutes, massage was applied to the AM side while electroacupuncture was performed on the MA side (Figure *1C*). Muscle hardness was measured before and after the 10-minute intervention.

GraphPad PRISM 6J (Windows version, GraphPad Inc., Boston, MA) was used for statistical analysis, with the significance level set at $p < 0.05$. A two-way repeated-measures analysis of variance (RM-ANOVA) with matching across both factors (sequence (AM vs. MA) × time (before vs. after)) at the subject level ($n = 9$) was performed separately for muscle hardness during relaxation and contraction. Sidak's multiple comparison test was subsequently used to evaluate specific pre-to-post intervention changes within each sequence (AM and MA).

Results

Figure *2* shows the muscle hardness results during relaxation. The vertical axis indicates muscle hardness (mm), and the horizontal axis indicates values before and after the intervention. Repeated-measures two-way ANOVA revealed no significant main effect for intervention sequence ($F(1, 8) = 0.6241$, $p = 0.4523$) or sequence × time interaction ($F(1, 8) = 0.3071$, $p = 0.5946$). However, the main effect of time (pre- vs. post-intervention) was statistically significant ($F(1, 8) = 12.53$, $p = 0.0076$), indicating an overall reduction in resting tissue stiffness across interventions. Sidak's multiple comparisons test showed a statistically significant decrease in muscle hardness after the AM intervention ($p = 0.0196$), whereas the decrease after the MA intervention did not reach statistical significance ($p = 0.0638$).

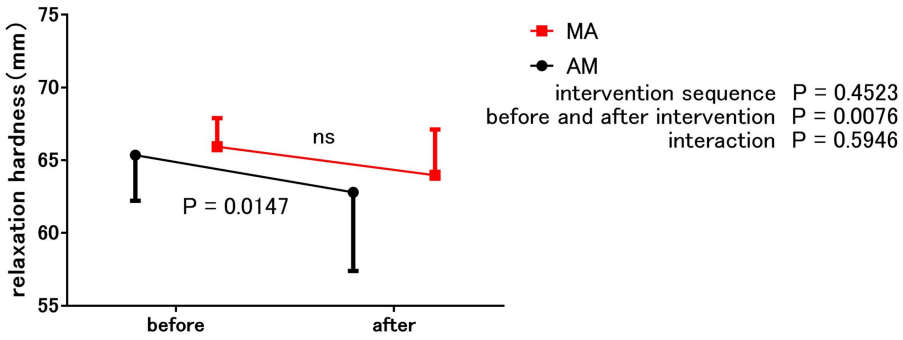


FIGURE 2: Muscle hardness results during relaxation

A significant decrease in muscle hardness is observed at relaxation after AM intervention. Data were analyzed using repeated-measures two-way ANOVA followed by Sidak's multiple comparisons test

AM: acupuncture first followed by massage; MA: massage first followed by acupuncture; NS: non-significant; ANOVA: analysis of variance

Figure *3* shows the muscle hardness results during contraction. The vertical axis indicates contractile muscle hardness (mm), and the horizontal axis indicates values before and after the intervention. Repeated-measures two-way ANOVA demonstrated a statistically significant interaction between intervention

sequence and time (F(1, 8) = 9.137, p = 0.0165), showing that the effect of treatment on contractile responsiveness depended directly on the sequence of administration. Main effects for time (F(1, 8) = 3.651, p = 0.0924) and intervention sequence (F(1, 8) = 0.01135, p = 0.9178) were not significant. Sidak's multiple comparisons test revealed a significant reduction in muscle hardness during contraction after the AM intervention (t(8) = 3.291, p = 0.0070), whereas contractile muscle hardness was fully maintained following the MA intervention (t(8) = 0.1489, p = 0.9798).

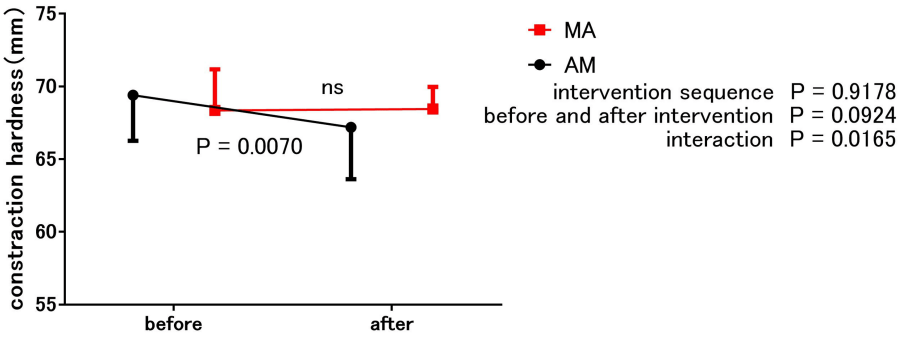


FIGURE 3: Muscle hardness results during contraction

A significant decrease in contractile hardness is observed after AM intervention. Data were analyzed using repeated-measures two-way ANOVA followed by Sidak's multiple comparisons test

AM: acupuncture first followed by massage; MA: massage first followed by acupuncture; NS: non-significant; ANOVA: analysis of variance

Discussion

There was a decreasing trend in muscle hardness during relaxation in both treatment groups, similar to the results of other studies. Significant differences were observed before and after AM treatment, suggesting that massage was more effective in reducing muscle hardness during relaxation immediately after the treatment. If acupuncture and massage are used together to relieve stiffness, acupuncture followed by massage is considered the better treatment sequence. However, there are two types of stiffness symptoms, subjective and objective, and the effect of this method on subjective stiffness needs to be studied separately.

The primary mechanisms underlying the decrease in muscle hardness during relaxation differ between acupuncture and massage. Hunter et al. considered that the decrease in muscle hardness with massage does not involve the mobilization of motor units and the conduction velocity of muscle fibers, but is due to the effect on muscle structure [15]. That is, the decrease in actin and myosin cross-linking due to muscle stretching. Muscle tension is regulated by the sympathetic nervous and gamma systems, and acupuncture is known to exert inhibitory effects on sympathetic nerve activity [19] and gamma motor neurons [5]. Due to the difference in the mechanism of action, massage is more effective in immediately decreasing muscle hardness during relaxation.

Contractile muscle hardness, evaluated as a surrogate index for contractile response, decreased significantly in the AM group while remaining maintained at pre-intervention levels in the MA group. Massage immediately reduced muscle hardness during both relaxation and contraction, which aligns with previous reports demonstrating that massage reduces muscle stiffness [4-8] and transiently decreases muscle strength [15,16]. Although muscle strength, electromyographic activity, and muscle structural parameters were not directly measured in the present study, our findings suggest a possible explanation: subsequent acupuncture in the MA sequence may have counteracted the massage-induced reduction in contracted muscle hardness. We hypothesize that acupuncture-induced recruitment of motor units might offset structural relaxation; however, as neural excitability and tissue structure were not directly evaluated under our specific stimulation conditions and target muscle, this mechanism remains a theoretical hypothesis requiring future physiological verification.

Previous literature suggests that acupuncture can induce motor nerve excitation, recruit motor units, and acutely affect muscle force production [11-13,20]. In the MA group, it is plausible that such acupuncture-induced motor unit recruitment modulated the structural relaxation caused by preceding massage, thereby contributing to the maintenance of contracted muscle hardness. However, even though previous studies reported increases in muscle strength following acupuncture, such effects cannot necessarily be assumed to occur identically under the specific stimulation parameters, target muscle (extensor digitorum communis), or measurement time point used in our protocol. Nevertheless, our observed preservation of contractile hardness in the MA sequence aligns broadly with findings by Wang et al. [6], supporting the concept that

treatment order can be strategically selected to preserve active muscle responsiveness.

Limitations

This study has several limitations. First, the sample size was relatively small (n = 9) and comprised young healthy male participants, which may limit the generalizability of the findings to females, older populations, or individuals with muscular disorders. Second, we evaluated only the extensor digitorum communis muscle; however, muscle hardness during contraction was deliberately selected as a surrogate measure because direct maximum voluntary contraction measurement in this muscle is highly susceptible to compensatory movements and large data variability, which compromises measurement sensitivity.

Third, because both intervention sequences involved combined treatments, standalone single-intervention conditions (acupuncture-only or massage-only) were not included; therefore, the isolated, independent contributions of each modality cannot be definitively established. Fourth, interventions were administered simultaneously to both upper limbs (one side AM and the contralateral side MA), which leaves open the possibility of interlimb cross-over or systemic reflex effects; however, the fact that distinct, sequence-dependent responses were observed between contralateral limbs within the same individual suggests that local sequence effects predominated. Fifth, outcome measures were evaluated only immediately post-intervention, and the long-term persistence or delayed time-course of the observed mechanical changes remains unknown.

Furthermore, although the extensor digitorum communis was localized using skin marking by an examiner with ultrasonography-validated palpation accuracy, contraction verification during acupuncture stimulation, and isolated finger extension without wrist movement, minor influence from adjacent forearm muscles (such as the extensor carpi radialis longus and brevis) cannot be entirely ruled out due to the nature of surface hardness measurement. Finally, while the intra-rater repeatability and measurement validity of this device have been previously established, an unblinded single-assessor design was used in this study, whereas a blinded protocol would have been preferable.

Conclusions

These findings indicate that the sequence of acupuncture and massage differentially affects muscle hardness, with the immediate treatment response being strongly influenced by the preceding intervention. Therefore, when combining these treatments, the sequence should be selected according to the intended therapeutic outcome: acupuncture followed by massage to relieve stiffness, and massage followed by acupuncture to maintain contractile muscle hardness and potentially preserve muscle force production.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Yoshitaka Arima, Miho Oba

Acquisition, analysis, or interpretation of data: Yoshitaka Arima, Miho Oba

Drafting of the manuscript: Yoshitaka Arima

Critical review of the manuscript for important intellectual content: Yoshitaka Arima, Miho Oba

Supervision: Yoshitaka Arima

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. The Tokoha University Research Ethics Review Committee issued approval 2017-029H. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number 18K10868. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

This work was supported by a Grant-in-Aid for Scientific Research (18K10868) from the JSPS. We would like

to thank Editage (www.editage.com) for English-language editing and journal submission support. No artificial intelligence (AI) tools or generative AI were used in the preparation, creation, or modification of Figure 1 (or any other figures in this manuscript)

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