Yamashita *et al.*
Innovations in Acupuncture and Medicine (2025) 18:1
https://doi.org/10.1186/s44424-025-00002-6

Journal of Acupuncture and Meridian Studies

RESEARCH **Open Access**

The Electroacupuncture Treatment Causes Earlier Recovery of Motor Nerve Dysfunction After Eccentric Exercise

Takashi Yamashita[1], Hisashi Ueda[2], Yosuke Tsuchiya[3], Yuta Kosuge[1], Shigeki Izumi[1,4], Koichi Nakazato[5] and Eisuke Ochi[1,6*]

Abstract

Purpose The purpose of this study was to investigate the effect of electroacupuncture (EA) on muscle and nerve function after eccentric exercise.

Methods Fifteen young subjects were included in this study. All participants performed 100 eccentric contractions (ECCs) on the flexor pollicis brevis muscle of both hands and EA or rest intervention was randomly conducted on each hand. Maximal voluntary contraction torque (MVC), delayed onset muscle soreness (DOMS), range of motion (ROM), muscle stiffness, thickness, echo intensity, and motor nerve conduction velocity (MCV) were measured before, immediately after ECCs (only for MVC), immediately after intervention, day 1, 2, and 5 after ECCs.

Results The results showed that MVC, DOMS, ROM, muscle stiffness, muscle thickness, and echo intensity did not differ between the groups. However, MCV in the control group demonstrated a significant decrease immediately after ECCs and continued until 2 days post-exercise compared to the EA group (immediately after; $p = 0.009$, day 1; $p < 0.001$, day 2; $p = 0.002$). In addition, no significant change in MCV was observed in the EA group (before exercise; 59.8 ± 10.1 m/s, immediately after EA; 63.0 ± 11.2 m/s, day 1; 64.0 ± 7.7 m/s, day 2; 64.1 ± 7.2 m/s, and day 5; 63.4 ± 9.8 m/s).

Conclusion EA intervention after strenuous exercise may cause earlier recovery from nerve dysfunction, although the detailed mechanisms need to be examined.

Keywords Nerve damage, Lengthening contractions, Eccentric exercise, Acupuncture, Motor conduction velocity

*Correspondence:
Eisuke Ochi
ochi@hosei.ac.jp
[1] Graduate School of Sports and Health Studies, Faculty of Bioscience and Applied Chemistry, Hosei University, 3-7-2, Kajino, Koganei, Tokyo 184-8584, Japan
[2] Faculty of Health Care and Medical Sports, Teikyo Heisei University, Chiba, Japan
[3] Laboratory of Health and Sports Sciences, Center for Liberal Arts, Meiji Gakuin University, Kanagawa, Japan
[4] Faculty of Sports and Health Studies, Hosei University, Tokyo, Japan
[5] Graduate School of Health and Sports Science, Nippon Sport Science University, Tokyo, Japan
[6] Faculty of Bioscience and Applied Chemistry, Hosei University, Tokyo, Japan

1 Introduction

When eccentric contractions (ECCs) are repeated at high intensity, the delayed-onset muscle soreness (DOMS) and the exercise-induced muscle damage (EIMD) such as muscle swelling, decrease of maximum voluntary contraction (MVC) and range of motion (ROM), and increase of creatine kinase occur [1–5]. Regarding neuromuscular function, muscle fiber conduction velocity and M-wave amplitude showed decreases after ECCs [6–8]. Previous studies showed that motor nerve conduction velocity (MCV) in the musculocutaneous nerve and median nerve (MN) decreases immediately after ECC and continues for more than 2 days [9–11]. These findings indicate that neuromuscular dysfunction could be caused by EIMD. To continue the strenuous exercise, including ECCs, to find the appropriate intervention to reduce EIMD and/or cause earlier recovery from EIMD is crucial.

Acupuncture is often used to stimulate the skeletal muscles before or after exercise. In addition, previous studies showed the clinical efficacies of needle insertion treatments; improvement of muscle strength, microcirculation of both muscle and tendon, and range of motion. Huang et al. [12] observed an improvement in muscle strength after 6-week interventions of both acupuncture and electroacupuncture (EA). Also, Hubscher et al. [13] confirmed that a single intervention of acupuncture for recreational athletes caused an improvement in isometric knee extension strength. In the microcirculation, it showed that both EA and manual acupuncture treatments increased the blood flow in skeletal muscle and tendons from immediately after to 20 or 40 min [14–17]. Then, range of motion, 4 weeks of needle intervention given a higher hip flexion and maintained until 2 months follow-up in elite soccer players [18]. Interestingly, several studies reported that motor and/or sensory nerve conduction velocity was recovered in peripheral nerve neuropathy patients after acupuncture treatment [19–21]. Also, acupuncture intervention to the acupoint, which is a specific inserting point located on the body surface or underneath that is related to the somatosensory nervous system [22, 23], had cross-transfer and remote effects. For the cross-transfer effect, the ipsilateral intervention of acupuncture improved blood circulation of the Achilles tendon and muscle strength in both legs [24–26]. For the remote effect, Maioli et al. [27] showed that a needle insertion of acupuncture to the upper limb induced motor evoked potential in the lower limb, which suggests that different muscles may be activated through somatic sensory afferent pathways. Thus, based on the above studies, acupuncture treatment may have the potential to contribute to the recovery of muscle and nerve dysfunction after exercise.

Regarding the EIMD to acupuncture intervention, several studies showed that acupuncture is effective in reducing DOMS. For example, in arm curl ECCs, DOMS reduced immediately after treatment and 3 days after exercise [28–30]. Another study in lower leg ECCs, DOMS reduced immediately and 24 h after exercise, with the occurrence of 1/2 to 1/3 decreasing from baseline [31]. In contrast, previous studies have not been able to fully establish the effect of acupuncture on the recovery of muscle strength [29, 30, 32]. Similarly, in a systematic review of the effects of acupuncture to exercise performance and post-exercise recovery, Urroz et al. [33] noted that acupuncture has only a minor effect on post-exercise recovery, likely due to the limited amount of literature. Since then, systematic review and meta-analysis by Ko et al. [34], Huang et al. [35], and Chang et al. [36] reported that acupuncture could be effective for decreasing DOMS and creatine kinase levels. However, most previous studies have focused on DOMS, and have been limited by weak methodological measurements, although acupuncture may contribute to the recovery of muscle and nerve function.

This study aimed to investigate the effects of EA on muscle and nerve functions after ECCs (Fig. 1). We hypothesized that EA would cause earlier recovery of muscle damage such as muscle strength, joint flexibility, muscle stiffness, muscle soreness, and nerve damage compared to the control conditions. This hypothesis is based on the evidence of the neurophysiological effect of acupuncture that could play a crucial role in mitigating the decline of nerve dysfunction typically observed after EIMD. However, no previous study has investigated the effect of acupuncture on nerve dysfunction after ECCs so far.

2 Methods

2.1 Study Design

This study was conducted as randomized within-subject controlled trial design. The target muscle and nerve were flexor pollicis brevis muscle (FPBM) and median nerve (MN). These anatomical structures were selected as frequently used in nerve conduction studies and allow for accessible, localized assessment of both muscle and nerve function [10, 37]. ECCs with rest intervention (CON) and ECCs with EA intervention (EA) were assigned randomly to either thumb using a pre-generated randomization table. All participants performed maximal ECC of the thumb flexion by using their FPBM, and the performance was executed in both thumbs. After the ECCs session, 15 min of intervention took place immediately. The assessment of EIMD included maximum voluntary contraction (MVC) torque and range of motion (ROM) of the thumb, muscle soreness using the visual analog scale (VAS), muscle thickness, stiffness, and echo intensity assessed by ultrasound imaging, and motor nerve conduction velocity (MCV) of the MN by electronic stimulation, which was done to both motor and sensory nerve. These assessments were taken before (PRE) and after intervention (POST), 24 h (DAY 1), 48 h (DAY 2), and 120 h (DAY 5) after ECC. MVC torque was also assessed immediately after ECCs session. These time points were selected based on previous studies [10, 35, 38].

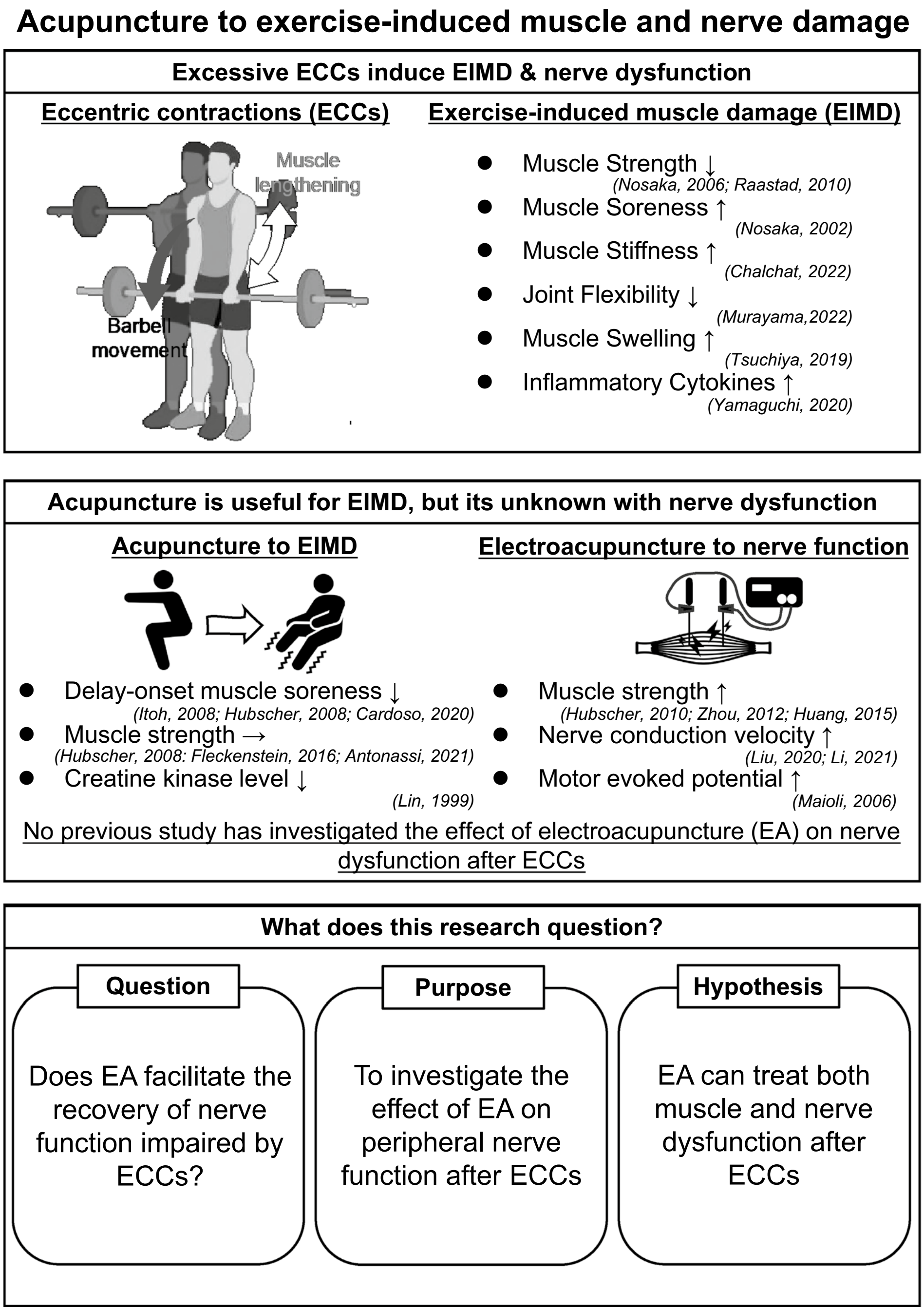

Fig. 1 Introduction figure for the research question

2.2 Participants

The sample size was calculated by using G*Power (Ver.3.1.9.6; Heinrich-Heine University), by setting the type of power analysis as A priori, effect size as 0.25, α level as 0.05, and power (1-β) as 0.8 for the repeated measures within factors, which required at least 11 participants. After recruitment, 15 young college students (13 male and 2 female, age: 23.2 ± 2.6 years, height: 168.3 ± 0.1 cm, weight: 66.5 ± 11.4 kg, BMI: 23.4 ± 3.3) were included in this study. All participants did not have any muscle disorders or thumb joint injuries. Before the study, they were informed of the purpose and methods of the study and that they would not be disadvantaged by participating or not participating by the declaration of Helsinki, and their informed consent was obtained in writing. This study was approved by the Ethics Committee of the Graduate School of Sports and Health Studies, Hosei University (ID: 2023–19).

2.3 Eccentric Exercise Intervention

ECCs were held in a custom-made torque dynamometer (S-14049; TAKEI KIKI, Niigata, Japan). The forearm was placed in an intermediate position, and the thumb was set to the dynamometer's lever with a joint angle of 90° extension. When the lever moved to 0°–90° extension, participants performed with maximal resistance strength. Participants completed 10 ×10 sets for a total of 100 ECCs with 60 deg/s. The resting time was 60 s in between sets. During ECCs, a workload was recorded in each set. These methods were based on previous studies [10, 11].

2.4 Electroacupuncture Intervention

EA intervention was held immediately to either assigned thumb after ECC. The stainless acupuncture needle (0.2 mm ×40 mm JSP-type; SEIRIN, Shizuoka, Japan) was inserted depth of 20 mm into "Yuji (LU10)", located at the muscle belly of FPBM, and "Hegu (LI4)", located at radial to the midpoint of the second metacarpal bone (Fig. 2). A reference electrode was attached to LU10, a ground electrode was attached to LI4, and electrical stimulation was delivered from the pulse generator (Ohm Pulser LFP-2000e; ZEN Iryouki, Fukuoka, Japan) and electrical stimulation was performed via acupuncture needles. In this study, the pulse frequency of 30 Hz, pulse duration of 250 μm, and the current value were set until muscle contraction occurred (0.06 ± 0.05 mA). The pulse frequency was chosen based on previous study [12, 26], although we adjusted a lower frequency due to operational limitations. The pulse duration was based on the default setting of the stimulator, and the current value was adjusted to a clinically acceptable level just below the pain threshold, as commonly used in clinical practice. All acupuncture handling was performed by one of the author (T.Y.) who is a licensed acupuncturist with 3 years of clinical experience.

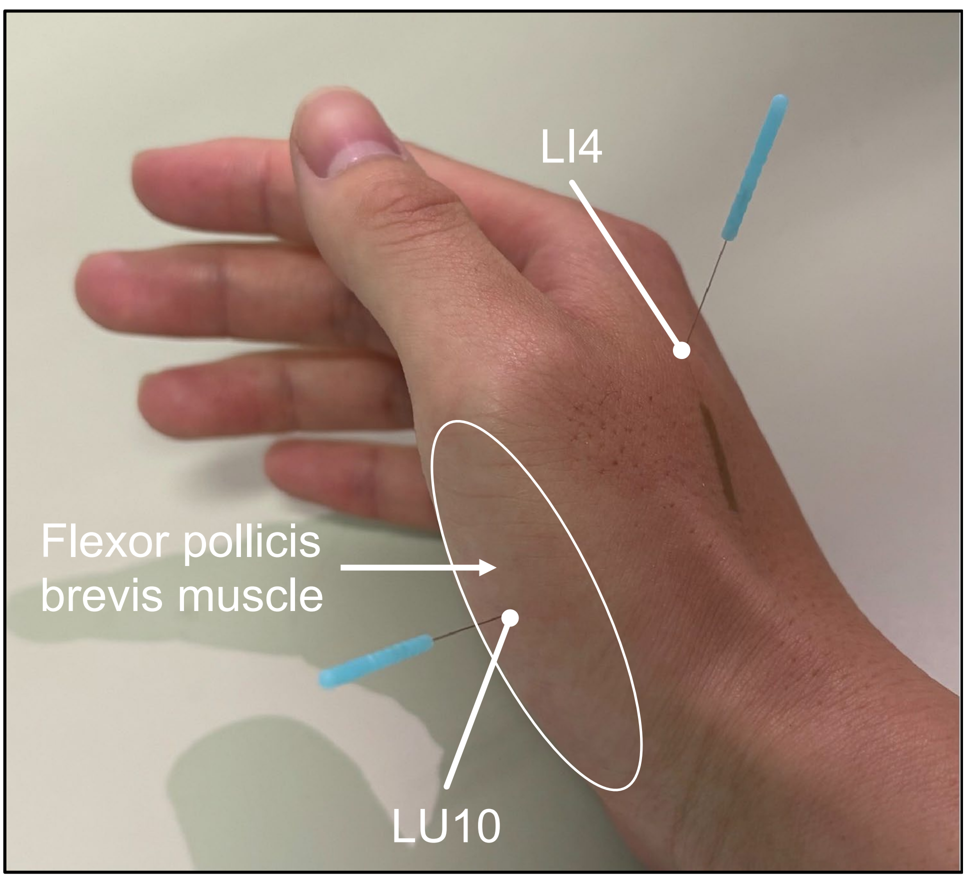

Fig. 2 The stainless needles were inserted into LU10 (reference electrode) and L14 (ground electrode)

2.5 Maximum Voluntary Contraction Torque

MVC was held in a custom-made torque dynamometer (S-14049; TAKEI KIKI, Niigata, Japan). Two 3 s of MVC at 90˚ extension were performed in each participant. 15 s of rest were set in between contractions. The set with a higher peak torque was used as MVC torque.

2.6 Muscle Soreness

The soreness of FPBM was assessed by using a 100 mm scale of visual analog scale (VAS). Participants draw a line for their subjective soreness, with the scale start point indicating "no pain" and the endpoint showing "worst imaginable pain." The investigator placed a hand-held pressure algometer (Neutone, TRY-ALL Y.K., Chiba, Japan) on the belly of FBPM, every 5 Nm pressure was given to each participant to cause the pressure pain.

2.7 Range of Motion

The range of thumb extension was measured using image analysis software (ImageJ ver. 2.14.0, National Institute of Health, Maryland, USA). The hand was placed on a table with a pronated position, starting full thumb extension from 0˚ joint angle as much as possible. While participant fully extended their thumb, the investigator took pictures from directly above each hand. Three measurements were taken from each participant.

2.8 Ultrasound Imaging

Muscle thickness, stiffness, and echo intensity were assessed by an ultrasonic scanner (Aixplorer Ver. 4.2; Supersonic Imagine, Aix-en-Provence, France) with a 4–15 MHz linear probe (SL15-4; Supersonic Imagine, Aix-en-Provence, France). Ultrasound settings were stabled in frequency 12 Hz, gain 36%, and dynamic range 67 dB. Both sagittal plane and coronally plane images of FBPM were collected from each participant. For thickness and echo intensity, B-mode ultrasound imaging was used for measurement. Scanned coronally plane images of FPBM were exported to a personal computer, and calculated manually by tracing FPBM using image analysis software (ImageJ ver. 2.14.0, National Institute of Health, Maryland, USA). To measure echo intensity, the average value within the ROI (3 mm diameter) was calculated by using the grayscale histogram function (0, black; 255, white). For muscle stiffness, shear wave elastography was used to assess muscle shear modulus (μ), a measure of normalized muscle stiffness, which was calculated using the following equation: $\mu = \rho \mathrm{Vs}^2$, where ρ is the density of muscle (assumed to be 1000 kg/m^3) and Vs is the velocity of shear wave propagation caused by focused ultrasound beam from the scanner. A 10 mm square map of the muscle shear modulus with a diameter of 3 mm was obtained with each ultrasound image.

2.9 Motor Nerve Conduction Velocity

MCV of the MN was measured by using surface electromyography (sEMG) to record M-wave latency and amplitude, according to our previous studies [10, 11]. For arrangement, the room temperature was set to 23–28 ℃. In addition, the skin was cleaned with cotton dipped in alcohol. A recording electrode was placed at the mid-belly of the FPBM long head, a reference electrode was placed on the tip of the second finger, and a ground electrode was attached to the wrist, which is between the stimulation and recording electrodes. The stimulation was given at two points, first at the medial side of the elbow with the distal of the biceps tendon, and second at the radial side of the wrist between the tendons of the flexor carpi radialis and the palmaris longus. The bipolar stimulation electrode with an inter-electrode distance of 30 mm and diameter of 0.8 mm (NM-430S, Nihon Kohden, Tokyo, Japan) was firmly pressed to each stimulation point. After the electrode was set on each point, a pulse duration of 10 ms stimulation was generated from an electrical stimulator (DS7 AH, Digimeter, Hertfordshire, UK), interfaced with an isolator (Model ML408, ADInstruments, New South Wales, Australia). The stimulation current was gradually increased to obtain a supramaximal *M*-wave, which confirmed that further increasing the current did not increase the *M*-wave amplitude.

2.10 Data Acquisition and Analysis of Nerve Conduction Velocity and Maximum Amplitude

Data acquisition and analysis were performed using physiological data analysis software (LabChart 8, ADInstruments, New South Wales, Australia). MCV was calculated as the value of dividing the forearm distance and time of two latencies as follows: MCV = distance/(proximal latency – distal latency). The latency was determined as the onset of electrical stimulation to the first negative peak of the *M*-wave. The onset of the *M*-wave induced by the electrical stimulus is defined as the first point at which the signal surpasses the mean baseline by two SDs, and this criterion is widely utilized to determine the start of electrical and mechanical muscle contraction over at least ten consecutive data points.

2.11 Statistical Analyses

All descriptive statics value is shown as mean ± SD. The data were normalized using the Shapiro–Wilk test to ensure that ANOVA could be used. The workload in each ECC set, changes in MVC, VAS, ROM, muscle stiffness, thickness, and echo intensity of each assessment time between CON and EA were compared by repeated measures of two-way ANOVA. When a significant interaction effect was observed, Bonferroni's post hoc test was conducted. The effect sizes were calculated, and eta-square

(η^2) values were reported with small ($\geq$ 0.01), medium ($\geq$ 0.07), and large ($\geq$ 0.14), respectively. A significant level was set at $p <$ 0.05. Statistical analysis was performed using statistical software (IBM SPSS statistics ver.29, IBM, New York, USA).

3 Results

3.1 Workload

Significant decrease was observed in the workload, with a 30.1% reduction for the CON and a 28.7% reduction for the EA by the 10 th set, compared to the 1 st set ($F=$ 33.884; $p<$ 0.001; $\eta^2=$ 0.723; 1 st: CON = 57080.7 ± 11556.3 W, EA = 55418.5 ± 11902.3 W; 10 th: CON = 39890.1 ± 11860.3 W, EA = 39525.3 ± 9349.9 W). No differences were observed between the groups.

3.2 Maximum Voluntary Contraction Torque

Figure 3 shows the changes in MVC torque from pre-exercise to day 5 after exercise in the groups. There was a significant time effect, with a decrease in torque from pre-exercise to day 2 in both groups ($F=$ 11.898; $p<$ 0.001; $\eta^2=$ 0.459). However, there was no significant interaction effect, indicating that no differences were observed between the groups at any time point ($F=$ 0.193; $p=$ 0.964; $\eta^2=$ 0.014).

3.3 Muscle Soreness

Figure 4 shows the changes in muscle soreness by VAS score from pre-exercise to day 5 after exercise in the groups. There was a significant time effect, with an increase in soreness from pre-exercise to day 2 in both

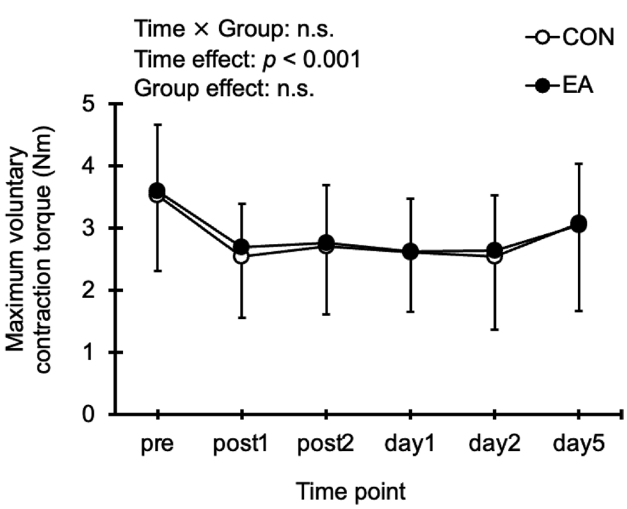

Fig. 3 Changes in the maximum voluntary contraction torque compared to before eccentric exercise (pre), immediately after eccentric exercise (post1), immediately after rest (CON) or electroacupuncture (EA) intervention (post2), and 1, 2, and 5 days after the eccentric exercise. Values are mean ± SD

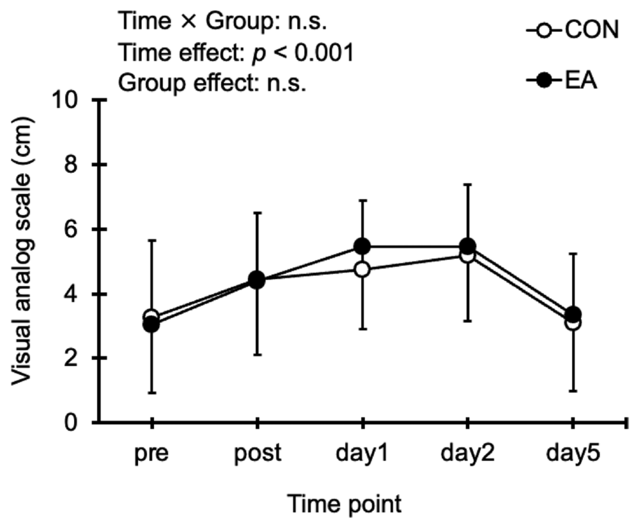

Fig. 4 Changes in the visual analog scale compared to before eccentric exercise (pre), immediately after rest (CON) or electroacupuncture (EA) intervention (post), and 1, 2, and 5 days after the eccentric exercise. Values are mean ± SD

groups ($F=$ 8.754; $p<$ 0.001; $\eta^2=$ 0.385). However, there was no significant interaction effect, indicating that no differences were observed between the groups at any time point ($F=$ 1.576; $p=$ 0.193; $\eta^2=$ 0.101).

3.4 Range of Motion

Figure 5 shows the changes in ROM from pre-exercise to day 5 after exercise in the groups. There was a significant time effect, with a decrease in ROM from pre-exercise to day 5 in both groups ($F=$ 8.606; $p<$ 0.001; $\eta^2=$ 0.381). However, there was no significant interaction effect, indicating that no differences were observed between the groups at any time point ($F=$ 2.017; $p=$ 0.104; $\eta^2=$ 0.126).

3.5 Motor Nerve Conduction Velocity

Figure 6 shows the changes in MCV from pre-exercise to day 5 after exercise in the groups. A significant interaction effect was found in MCV ($F=$ 3.344; $p=$ 0.016; $\eta^2=$ 0.205). MCV was delayed at CON, before exercise from immediately after intervention, day 1 and day 2, compared to the EA (post: CON = 51.9 ± 8.6 m/s, EA = 63.0 ± 11.2 m/s, $p=$ 0.009, day 1: CON = 50.6 ± 7.3 m/s, EA = 64.0 ± 7.7 m/s, $p<$ 0.001; day 2: CON = 55.4 ± 5.9 m/s, EA = 64.1 ± 7.2 m/s, $p=$ 0.002).

3.6 Muscle Stiffness, Thickness, and Echo Intensity

Table 1 shows the changes in muscle stiffness, thickness, and echo intensity from pre-exercise to day 5 after exercise in the groups. No significant interaction effects for the ultrasound imaging variables, indicating that no

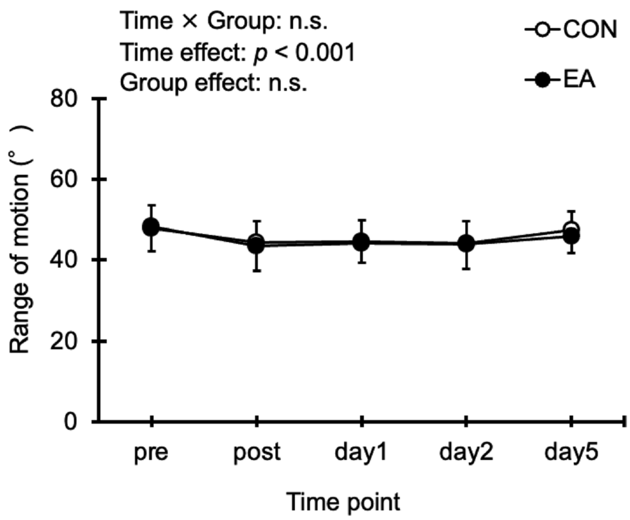

Fig. 5 Changes in the range of motion compared to before eccentric exercise (pre), immediately after rest (CON) or electroacupuncture (EA) intervention (post), and 1, 2, and 5 days after the eccentric exercise. Values are mean ± SD

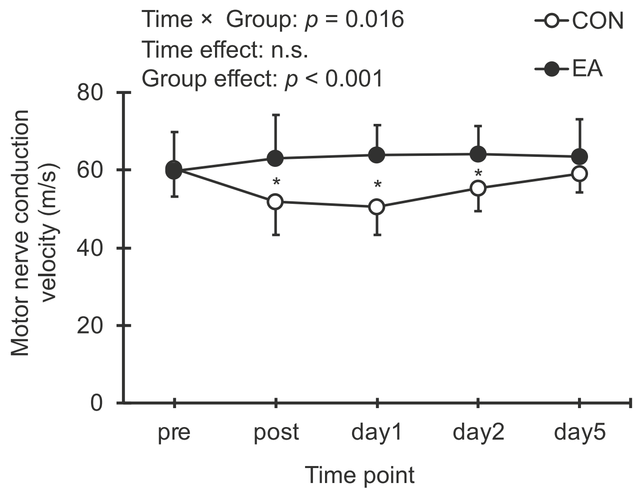

Fig. 6 Changes in the motor nerve conduction velocity compared to before eccentric exercise (pre), immediately after rest (CON) or electroacupuncture (EA) intervention (post), and 1, 2, and 5 days after the eccentric exercise. Values are mean ± SD. *Significant difference at each time point between CON and EA, $p < 0.001$

differences were observed between the groups at any time points.

4 Discussion

In the present study, we investigated the acute effect of acupuncture intervention on muscle damage following ECCs. Our findings indicate that the function of the motor nerve recovered in the EA-treated group immediately after the treatment, days 1 and 2 compared to the non-treatment group. However, we did not observe any differences in MVC, VAS, ROM, muscle stiffness, muscle thickness, and echo intensity between groups. This observation of motor nerve function supports our hypothesis.

In this study, all variables at baseline and changes after ECCs were consistent with our previous studies [10, 11]. We confirmed both muscle damage of the FBPM, with 10 × 10 ECCs exercise condition (MVC; − 32.9%, ROM; − 11.6%, VAS; 1.7 cm), which are similar to our previous studies (MVC; − 26.8%, ROM; − 5.3%, VAS; 1.1 cm). Additionally, the decrease in workload in the present study (− 30.1% and − 28.7% for CON and EA, respectively) was similar with a previous study (− 29.8%) [39]. Since these parameters are measured as the indicators of muscle damage [40], it is considered that this protocol has generated the EIMD. Thus, we believe that the exercise load to FBPM in the present study was reproducible and appropriate. However, we did not observe the differences in MVC, VAS, ROM, and ultrasound imaging variables between two groups, suggesting that these outcomes may not be enough to detect the effects of acupuncture intervention or no effects for them. Therefore, based on our results, we suggest that the acute effect of acupuncture on muscle dysfunction may be limited. Future research should explore the potential effects of acupuncture interventions, considering the settings of electrical stimulation, other muscles, exercise protocols, or pre-exercise intervention.

This study first demonstrated that acupuncture could cause earlier recovery to the MCV following ECCs. We found that the MCV in the EA group did not show significant changes in all time points (post: 107.8 ± 25.9%, day 1: 110.5 ± 24.0%, day 2: 110.0 ± 22.1%, day 5: 108.7 ± 27.1%), while MCV decreased from baseline after exercise and remained delayed until day 2 compared to the CON group (post: 86.4 ± 14.8%, day 1: 84.4 ± 14.0%, day 2: 93.0 ± 15.7%, day 5: 99.1 ± 14.4%). One possible mechanism to explain the observed recovery of nerve function in the EA group is that acupuncture stimulation modulated the motor nerve function, subsequently leading to an increase in MCV [19–21]. In addition, the systematic review conducted by Dimitrova et al. [37] shows that acupuncture treatment shows significant positive effects on MN compound muscle action potential amplitude and MCV compared with medication control. To summarize these results, previous studies support that in the treatment of neurological disorders, acupuncture has been found to facilitate the recovery of MCV. We also speculate that the neural activation through acupoint might be related to the present study. The acupoints are located close to or near the peripheral nerves, vessels,

Table 1. All ultrasound imaging variables of CON and EA

		Pre	Post	Day 1	Day 2	Day 5	Interaction	Group effect	Time effect
Stiffness (kPa)									
	CON	19.7 ± 21.1	18.3 ± 16.8	16.4 ± 16.5	19.3 ± 16	24.4 ± 11.7	F = 1.076 p = 0.377	F = 0.505 p = 0.489	F = 4.942 p = 0.002
	ACU	17.5 ± 17.3	16.2 ± 17.2	16.3 ± 16.2	14.4 ± 10.3	14.2 ± 15.5			
Thickness (cm)									
	CON	1.1 ± 0.2	1.2 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	F = 1.227 p = 0.310	F = 0.006 p = 0.937	F = 9.992 p < 0.001
	ACU	1.1 ± 0.2	1.2 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2			
Echo intensity (A.U.)									
	CON	53.8 ± 14.3	53.7 ± 13.7	45.8 ± 9.4	47.4 ± 11.8	49.7 ± 12.6	F = 0.280 p = 0.890	F = 4.844 p = 0.045	F = 2.468 p = 0.055
	ACU	56.1 ± 11.2	57.6 ± 13.5	48.3 ± 11	48.1 ± 7.8	54.1 ± 16.6			

Values are mean ± SD

and sensory receptors [41]. Moreover, the high density of nerve endings or receptors of both Aδ and C fibers is closely associated with acupoints [42]. From the animal experiments, manual acupuncture treatment to acupoints on the hindlimb, which are branches of the sciatic nerve that originate from L4–L6 activated group I, II, III, and IV nerve fibers [43]. 50 Hz of EA reduced the H/M ratio of motor nerve, which resulted in a partial improvement of motor performance and H-reflex responses [44]. In addition, EA showed recovery promotion of peripheral nerve pathways and somatosensory evoked potentials [45]. These factors may be explained by neurological mechanisms detailing how the insertion of acupuncture or EA at acupoints activates peripheral nerves, which could treat nerve dysfunction. However, these previous studies are conducted in clinical settings. As such, the protocols are based on long-term intervention, which differs from interventions for our short-term study. Therefore, the mechanism may not be fully consistent with previous studies, and the present results should be interpreted with caution.

Another possible mechanism of acupuncture was likely to be related to reducing intramuscular pressure. It showed that external compression to the MN in healthy individuals caused the decreases in MCV and the increases in amplitude with 30, 60, and 90 mmHg compression [46]. The stiffness of MN at the wrist with carpal tunnel syndrome showed twice as high values as the control group [47]. Another previous study showed that the acupuncture treatment of two sessions per week for 4 weeks increased nerve conduction velocity in carpal tunnel syndrome patients [48]. These results suggested that compression to MN reduced muscle and nerve conduction velocities. Interestingly, a previous study reported that the EA to tibialis anterior muscle showed significant increases in both skin and muscle blood flow [17]. Other studies have shown that manual acupuncture treatment to tendons and acupoints increased both skin and tendon blood flow during treatment and sustained for 40 min after treatment [15, 16, 24, 49]. From these results, it is clear that acupuncture improves intramuscular blood circulation and increases cardiovascular function. After strenuous exercise, it is widely known that intramuscular swelling occurs immediately, although we did not measure the muscle blood flow in this study or observe the changes in muscle thickness or echo intensity. However, we could speculate that the improved circulation may have affected the reduced post-exercise swelling, thereby we did observe the positive effect of MCV after acupuncture treatment. Future studies are required to establish the viability of considering muscle size and utilizing methods that can detect related changes in intramuscular pressure and blood flow.

There are three limitations in our study. First, the present study was limited by the absence of the order of acupuncture intervention was always before acupuncture. Previous studies have shown that unilateral intervention of manual acupuncture increased muscle blood flow and muscular strength on the contralateral side [24, 26]. Thus, the effect of intervention order on the efficacy of acupuncture and the bilateral effect of unilateral intervention remains unexplored in our research. Second, although previous studies reported that acupuncture treatment after strenuous exercise was mostly by traditional manual intervention, we conducted our intervention with the EA, which combined traditional manual acupuncture with electrical stimulation. Previously, the efficacy of acupuncture is widely known to the traditional acupuncture approach. This method is the input of sensory neurons, which demonstrated the opioid release and effect on analgesic and cellular regeneration by minimal tissue damage [50]. In this study, we thought that EA might be more effective in function recovery, but further research is needed to clarify the difference in muscle and nerve damage between acupuncture and EA. Finally, there was a gender imbalance among participants (13 males, 2 females), which may limit the generalizability of the findings.

5 Conclusion

In summary, our findings indicate that EA treats motor nerve dysfunction after strenuous eccentric exercise. While no significant positive effects were observed on muscle damage and soreness, the finding of recovery in MCV by the EA. Therefore we conclude that EA intervention was effective for exercise-induced nerve damage. Further research is needed to clarify the mechanisms by which EA promotes the recovery of muscle and nerve function and explore the long-term effect of repeated EA treatments.

Abbreviations

ANOVA	Analysis of variance
CON	Control condition (rest intervention)
DOMS	Delayed-onset muscle soreness
EA	Electroacupuncture
ECCs	Eccentric contractions
EIMD	Exercise-induced muscle damage
FPBM	Flexor pollicis brevis muscles
MCV	Motor nerve conduction velocity
MN	Median nerve
MVC	Maximal voluntary isometric contraction
ROM	Range of motion
sEMG	Surface electromyography
SD	Standard division
VAS	Visual analog scale

Acknowledgements

The authors appreciate the time and effort put in by all volunteer participants. Also, we would like to thank Dr. Takashi Shimizu and Mr. Gaku Murakami for their assistance with the measurements.

Author Contributions

T. Y. and E. O. conceptualized and designed the study; T. Y., Y. K., H. U., and Y. T. performed experiments; T. Y., H. U., and Y. K. analyzed data; E. O., H. U., Y. T., and K. N. interpreted the results of experiments; T. Y. prepared figures and table; T. Y. drafted the article; T. Y., S. I. and E. O. discussed and edited manuscript; All authors commented and approved the final version of the article.

Funding

No funds, grants, or other support was received.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest

The authors declare no competing interests.

Ethics Approval and Consent to Participate

All participants were informed of the purpose and methods of the study and that they would not be disadvantaged by participating or not participating by the declaration of Helsinki, and their informed consent was obtained in writing. This study was approved by the Ethics Committee of the Graduate School of Sports and Health Science, Hosei University (ID: 2023–19).

Consent for Publication

Not applicable.

Received: 22 January 2025 Accepted: 13 April 2025
Published online: 07 May 2025

References

1. Nosaka K, Newton M. Concentric or eccentric training effect on eccentric exercise-induced muscle damage. Med Sci Sports Exerc. 2002;34(1):63–9.
2. Ochi E, Tsuchiya Y, Nosaka K. Differences in post-exercise T2 relaxation time changes between eccentric and concentric contractions of the elbow flexors. Eur J Appl Physiol. 2016;116(11–12):2145–54.
3. Tsuchiya Y, Ueda H, Ochi E. Muscular recruitment is associated with muscular function and swelling following eccentric contractions of human elbow flexors. J Sports Med Phys Fitness. 2019;59(7):1097–101.
4. Yamaguchi S, Suzuki K, Inami T, Kanda K, Hanye Z, Okada J. Changes in urinary titin N-terminal fragment concentration after concentric and eccentric exercise. J Sports Sci Med. 2020;19(1):121–9.
5. Murayama M, Inami T, Shima N, Yoneda T, Nosaka K. Changes in biceps brachii muscle hardness assessed by a push-in meter and strain elastography after eccentric versus concentric contractions. Sci Rep. 2022;12(1):9214.
6. Piitulainen H, Bottas R, Komi P, Linnamo V, Avela J. Impaired action potential conduction at high force levels after eccentric exercise. J Electromyogr Kinesiol. 2010;20(5):879–87.
7. Piitulainen H, Botter A, Merletti R, Avela J. Muscle fiber conduction velocity is more affected after eccentric than concentric exercise. Eur J Appl Physiol. 2011;111(2):261–73.
8. Cabral HV, Meiburger KM, de Oliveira LF, Vieira TM. Changes in supramaximal M-wave amplitude at different regions of biceps brachii following eccentric exercise of the elbow flexors. Eur J Appl Physiol. 2021;121(1):307–18.
9. Kouzaki K, Nosaka K, Ochi E, Nakazato K. Increases in M-wave latency of biceps brachii after elbow flexor eccentric contractions in women. Eur J Appl Physiol. 2016;116(5):939–46.
10. Ochi E, Ueda H, Tsuchiya Y, Kouzaki K, Nakazato K. Eccentric contraction-induced muscle damage in human flexor pollicis brevis is accompanied by impairment of motor nerve. Scand J Med Sci Sports. 2020;30(3):462–71.
11. Ochi E, Ueda H, Tsuchiya Y, Nakazato K. Eccentric exercise causes delayed sensory nerve conduction velocity but no repeated bout effect in the flexor pollicis brevis muscles. Eur J Appl Physiol. 2021;121(11):3069–81.
12. Huang LP, Zhou S, Lu Z, Tian Q, Li X, Cao LJ, et al. Bilateral effect of unilateral electroacupuncture on muscle strength. J Altern Complement Med. 2007;13(5):539–46.
13. Hubscher M, Vogt L, Ziebart T, Banzer W. Immediate effects of acupuncture on strength performance: a randomized, controlled crossover trial. Eur J Appl Physiol. 2010;110(2):353–8.
14. Kubo K, Yajima H, Takayama M, Ikebukuro T, Mizoguchi H, Takakura N. Effects of acupuncture and heating on blood volume and oxygen saturation of human Achilles tendon in vivo. Eur J Appl Physiol. 2010;109(3):545–50.
15. Kubo K, Iizuka Y, Yajima H, Takayama M, Takakura N. Acupuncture- and intermittent compression-induced changes in blood circulation of tendon. J Altern Complement Med. 2020;26(3):231–8.
16. Kubo K, Yasuda A, Yajima H, Takayama M, Takakura N. Effects of acupuncture and acupressure of the acupoint compared to the tendon on the blood circulation of human tendon in vivo. Eur J Appl Physiol. 2024;124(1):269–79.
17. Kubota T, Mori H, Morisawa T, Hanyu K, Kuge H, Watanabe M, et al. Influence of electroacupuncture stimulation on skin temperature, skin blood flow, muscle blood volume and pupil diameter. Acupunct Med. 2020;38(2):86–92.
18. Haser C, Stoggl T, Kriner M, Mikoleit J, Wolfahrt B, Scherr J, et al. Effect of dry needling on thigh muscle strength and hip flexion in elite soccer players. Med Sci Sports Exerc. 2017;49(2):378–83.

19. Schroder S, Liepert J, Remppis A, Greten JH. Acupuncture treatment improves nerve conduction in peripheral neuropathy. Eur J Neurol. 2007;14(3):276–81.
20. He GH, Ruan JW, Zeng YS, Zhou X, Ding Y, Zhou GH. Improvement in acupoint selection for acupuncture of nerves surrounding the injury site: electro-acupuncture with Governor vessel with local meridian acupoints. Neural Regen Res. 2015;10(1):128–35.
21. Li H, Yu L, Ye D, Chang L, Zhao F, Wang H, et al. Rehabilitation training combined with jiaji electroacupuncture can promote the recovery of muscle group function and improve the quality of life in patients with upper limb peripheral nerve injury. J Healthc Eng. 2021;2021:3621568.
22. Li F, He T, Xu Q, Lin LT, Li H, Liu Y, et al. What is the Acupoint? A preliminary review of Acupoints. Pain Med. 2015;16(10):1905–15.
23. Liu S, Wang Z, Su Y, Qi L, Yang W, Fu M, et al. A neuroanatomical basis for electroacupuncture to drive the vagal–adrenal axis. Nature. 2021;598(7882):641–5.
24. Kubo K, Yajima H, Takayama M, Ikebukuro T, Mizoguchi H, Takakura N. Changes in blood circulation of the contralateral Achilles tendon during and after acupuncture and heating. Int J Sports Med. 2011;32(10):807–13.
25. Zhou S, Huang LP, Liu J, Yu JH, Tian Q, Cao LJ. Bilateral effects of 6 weeks' unilateral acupuncture and electroacupuncture on ankle dorsiflexors muscle strength: a pilot study. Arch Phys Med Rehabil. 2012;93(1):50–5.
26. Huang LP, Zhou S, Ao M, Zhao ML, Zhang LQ, Cao LJ. Unilateral intramuscular needling can improve ankle dorsiflexor strength and muscle activation in both legs. J Exerc Sci Fit. 2015;13(2):86–93.
27. Maioli C, Falciati L, Marangon M, Perini S, Losio A. Short- and long-term modulation of upper limb motor-evoked potentials induced by acupuncture. Eur J Neurosci. 2006;23(7):1931–8.
28. Itoh K, Ochi H, Kitakoji H. Effects of tender point acupuncture on delayed onset muscle soreness (DOMS)–a pragmatic trial. Chin Med. 2008;3(1):14.
29. Hubscher M, Vogt L, Bernhorster M, Rosenhagen A, Banzer W. Effects of acupuncture on symptoms and muscle function in delayed-onset muscle soreness. J Altern Complement Med. 2008;14(8):1011–6.
30. Antonassi DP, Rodacki CLN, Lodovico A, Ugrinowitsch C, Rodacki ALF. Immediate effects of acupuncture on force and delayed onset of muscle soreness. Med Acupunct. 2021;33(3):203–11.
31. Cardoso R, Lumini-Oliveira JA, Santos MJ, Ramos B, Matos LC, Machado J, et al. Acupuncture can be beneficial for exercise-induced muscle soreness: a randomised controlled trial. J Bodyw Mov Ther. 2020;24(1):8–14.
32. Fleckenstein J, Niederer D, Auerbach K, Bernhorster M, Hubscher M, Vogt L, et al. No effect of acupuncture in the relief of delayed-onset muscle soreness: results of a randomized controlled trial. Clin J Sport Med. 2016;26(6):471–7.
33. Urroz P, Colagiuri B, Smith CA, Cheema BS. Effect of acute acupuncture treatment on exercise performance and postexercise recovery: a systematic review. J Altern Complement Med. 2013;19(1):9–16.
34. Ko GWY, Clarkson C. The effectiveness of acupuncture for pain reduction in delayed-onset muscle soreness: a systematic review. Acupunct Med. 2020;38(2):63–74.
35. Huang C, Wang Z, Xu X, Hu S, Zhu R, Chen X. Does acupuncture benefit delayed-onset muscle soreness after strenuous exercise? A systematic review and meta-analysis. Front Physiol. 2020;11:666.
36. Chang WD, Chang NJ, Lin HY, Wu JH. Effects of acupuncture on delayed-onset muscle soreness: a systematic review and meta-analysis. Evid Based Complement Alternat Med. 2020;2020:5864057.
37. Dimitrova A, Murchison C, Oken B. Acupuncture for the treatment of peripheral neuropathy: a systematic review and meta-analysis. J Altern Complement Med. 2017;23(3):164–79.
38. Ochi E, Tsuchiya Y, Yanagimoto K. Effect of eicosapentaenoic acids-rich fish oil supplementation on motor nerve function after eccentric contractions. J Int Soc Sports Nutr. 2017;14(1):23.
39. Tsuchiya Y, Kikuchi N, Shirato M, Ochi E. Differences of activation pattern and damage in elbow flexor muscle after isokinetic eccentric contractions. Isokinet Exerc Sci. 2015;23(3):169–75.
40. Markus I, Constantini K, Hoffman JR, Bartolomei S, Gepner Y. Exercise-induced muscle damage: mechanism, assessment and nutritional factors to accelerate recovery. Eur J Appl Physiol. 2021;121(4):969–92.
41. Quiroz-Gonzalez S, Torres-Castillo S, Lopez-Gomez RE, Jimenez EI. Acupuncture points and their relationship with multireceptive fields of neurons. J Acupunct Meridian Stud. 2017;10(2):81–9.
42. Li P, Ayannusi O, Reid C, Longhurst JC. Inhibitory effect of electroacupuncture (EA) on the pressor response induced by exercise stress. Clin Auton Res. 2004;14(3):182–8.
43. Kagitani F, Uchida S, Hotta H, Aikawa Y. Manual acupuncture needle stimulation of the rat hindlimb activates groups I, II, III and IV single afferent nerve fibers in the dorsal spinal roots. Jpn J Physiol. 2005;55(3):149–55.
44. Escobar-Corona C, Torres-Castillo S, Rodriguez-Torres EE, Segura-Alegria B, Jimenez-Estrada I, Quiroz-Gonzalez S. Electroacupuncture improves gait locomotion, H-reflex and ventral root potentials of spinal compression injured rats. Brain Res Bull. 2017;131:7–17.
45. Meng S, Wu C, Junichi K, Seiichi O, Kensuke O. Electroacupuncture improves neuronal function by stimulation of ascending peripheral nerve conduction in rats with spinal cord injury. J Tradit Chin Med. 2019;39(4):509–15.
46. Lundborg G, Gelberman RH, Minteer-Convery M, Lee YF, Hargens AR. Median nerve compression in the carpal tunnel–functional response to experimentally induced controlled pressure. J Hand Surg Am. 1982;7(3):252–9.
47. Kantarci F, Ustabasioglu FE, Delil S, Olgun DC, Korkmazer B, Dikici AS, et al. Median nerve stiffness measurement by shear wave elastography: a potential sonographic method in the diagnosis of carpal tunnel syndrome. Eur Radiol. 2014;24(2):434–40.
48. Khosrawi S, Moghtaderi A, Haghighat S. Acupuncture in treatment of carpal tunnel syndrome: a randomized controlled trial study. J Res Med Sci. 2012;17(1):1–7.
49. Kubo K, Yajima H, Takayama M, Takakura N. Comparison of changes in blood circulation of patellar and Achilles tendons during and after acupuncture. Transl Sports Med. 2020;3(6):581–8.
50. Zhou Y, Dong X, Xing Y, Wang R, Yang S, Han Y, et al. Effects of electroacupuncture therapy on intractable facial paralysis: a systematic review and meta-analysis. PLoS One. 2023;18(7): e0288606.

Publisher's Note