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Impact of Muscle Contraction and Acupuncture on the Electrical Impedance of the Heart Meridian Points in Healthy Young Adults

Kelly Zhang
Gustavo Henrique de Mello Rosa
Isabela Mayumi Pupo Nogueira d'Àvila
Manoela Gallon Pitta
João Eduardo de Araujo

Department of Health Sciences, Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, Brazil

Acupuncture involves stimulating points with lower electrical impedance (EI). Understanding EI changes with needle and exercise stimuli can elucidate acupuncture mechanisms. This study included 60 subjects, divided into control (C) and acupuncture (A) groups. EI was assessed at four points: 0 (before procedures), I (after handgrip protocol [HGP]), II (after 20 minutes of rest), and III (after 20 minutes of rest in C or stimulation in A, followed by HGP in both groups). Statistical significance was set at $p < 0.05$. In the A group, EI was significantly reduced at HT3, shown by increased % microampere when comparing assessments I, II, and III with assessment 0 ($p < 0.005$). Intergroup comparisons revealed a reduced % microampere when comparing assessments II ($p < 0.02$) and III ($p < 0.0001$). Furthermore, the stimulation of an acupoint over a motor nerve branch changes the EI.

Keywords: Acupuncture; Acupuncture points; Electric impedance; Muscle contraction; Striated muscles

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Corresponding author: João Eduardo de Araujo
Department of Health Sciences, Ribeirão Preto Medical School, University of São Paulo, Av. dos Bandeirantes, 3900, Ribeirão Preto 14049-900, São Paulo, Brazil
E-mail: araujoje@fmrp.usp.br

INTRODUCTION

Acupuncture is one of the therapeutic methods used in traditional Chinese medicine. Its first theoretical and practical description dates back to 2697 BC during the reign of the Yellow Emperor, as documented in *Huang Di Nei Jing* (*The Yellow Emperor's Classic on Internal Medicine*) [1]. This method involves the insertion of needles into specific acupoints, which are typically located in areas with depressions on the skin surface [2].

Acupoints are distributed throughout the body along a system of channels known as meridians. From a physiological perspective, several studies have shown that the regions where the acupoints are located tend to have higher concentrations of nerve fibers, blood vessels, and sweat glands as well as a higher density of gap junctions [2]. In addition to the anatomical characteristics, the acupoints exhibit distinct electrical properties, including increased conductance, capacitance, and electrical potential, as well as low electrical impedance (EI), compared with the adjacent non-acupuncture areas [3]. These electrical properties indicate that acupoints are areas of higher permeability to the flow of electrical current through the skin, which comprises different layers with varying characteristics that affect the impedance.

The dermis, which is the outermost layer of the skin, is characterized by a rich density of ions due to the presence of collagen, elastic fibers, blood vessels, lymphatic vessels, and nerve branches, resulting in a relatively lower impedance [4]. In contrast, the stratum corneum, the outermost layer of the dermis, can significantly increase its conductance when externally stimulated, thereby decreasing the local impedance [5]. A recent study suggested an association between the motor branches and acupoints [6], indicating a reflex relationship that influences various functions and organic responses [7].

Acupuncture activates complex neurophysiological mechanisms, such as the release of endorphins, inhibition of pain transmission in the spinal cord, and activation of brain areas related to controlling different systems in the body [8]. More specifically, with regard to the musculoskeletal system, neuroimaging studies have shown that stimulation at specific acupuncture points activates the brain areas involved in processing motor responses [9].

Motor branches are extensions of the motor nerve that branch out to the muscle belly [10,11]. These branches enable the functional characteristics by transmitting nerve impulses or responding to external electrical stimulations. Such electrical currents can penetrate the skin barrier and effectively stimulate the target muscle, thereby promoting functional responses [5]. When properly applied, electrical stimulation at a point with higher current permeability can evoke various functional responses similar to acupoints, which also exhibit different electrical properties [6]. Therefore, stimulating a point with lower EI yields a more significant response to the offered stimuli, which triggers the excitation of the target muscle where there is a higher release of acetylcholine and subsequent muscle contractions [6].

In this study, we hypothesized that acupuncture needle stimulation and muscle contraction will lead to measurable changes in the EI of acupuncture points along the heart meridian. Specifically, we speculated that acupuncture needle stimulation would reduce impedance, indicating increased electrical permeability and conductivity at the targeted acupoints. Conversely, muscle contractions may lead to variable impedance changes depending on the proximity to the motor nerve branches, suggesting a localized response pattern.

MATERIALS AND METHODS

This single-blinded, randomized controlled trial was conducted at Ribeirão Preto Medical School, University of São Paulo, São Paulo, Brazil. This study involving human subjects adhered to all pertinent national regulations and institutional policies in accordance with the principles of the Declaration of Helsinki and received approval from the Research Ethics Committee at Hospital das Clínicas, Ribeirão Preto Medical School of the University of São Paulo (CAAE number 58267422.9.0000.5440). Moreover, we followed the internationally recognized Consolidated Standards of Reporting Trials (CONSORT) statement [12] for proper study design reporting.

1. Participants

We recruited 60 participants using the posters displayed in classrooms. The posters provided details regarding the study, participation, and contact details.

The eligibility criteria included participants of both sexes, aged between 18 and 30 years, and availability for the study's required duration. The exclusion criteria included fear of needles, orthopedic alterations that could hinder handgrip movement, and the inability to understand the written and spoken Portuguese language. Moreover, all participants provided written informed consent before participating in this study.

Randomization was conducted using Random.org, which generates simple, non-sequential random numbers using computerized block randomization. The allocation was concealed using sealed opaque envelopes, while all participants were randomly assigned into two groups: the control (C) or acupuncture (A) treatment groups. Given the nature of the intervention, the therapist or patient could not be blinded.

2. Anatomic and electric identification

The participants were instructed to avoid hot baths, topical agents, vigorous exercise, and stimulating substances for two hours before the assessment. The room temperature was maintained at 23 ± 1°C, and fluorescent lamps were used to ensure experimental standardization.

For the assessment, the participants were positioned in a chair with adjustable height and posterior trunk support with their arms flexed and supine. After positioning, anatomical localization was performed. We used the finger-cun measurement method to locate the points accurately. This method uses a proportional approach based on the size of the finger of the volunteer, wherein the distance between the distal and proximal interphalangeal joints determines one cun or anatomical inch. In addition to the application of the finger-cun measurement method, we used the proportional bone (skeletal) measurement method (B-cun) to determine the location of the acupuncture point to ensure an accurate and precise placement in each examined subject [13].

The HT3 (ShaoHai) acupoint is located on the anteromedial aspect of the elbow, anterior to the medial epicondyle of the humerus, at the same level as the cubital crease, whereas the HT7 (ShenMen) acupoint is located on the anteromedial aspect of the wrist, radial to the flexor carpi ulnaris tendon, on the palmar wrist crease. Electrical identification was performed using the Acuspointer device (Medichina), which was calibrated at 200 μA by touching the electrode ends to ensure measurement precision and point location accuracy. This device consisted of a pair of electrodes with a 12 V direct current. Moreover, the passive electrode was positioned on the patient's hand, while the active electrode contacted the skin surface to detect the EI of the skin. The current may vary between 0 and 200 μA, with higher values indicating better current permeability through the region, corresponding to lower EI of the skin [3].

3. Handgrip protocol

To evaluate the isometric handgrip strength, we ensured that the participants' trunks remained straight and well-supported, with their feet on the ground in a neutral ankle position and knees and hips flexed at 90°. The upper limb holding the dynamometer was positioned with the shoulder on the side of the body in a neutral position and the elbow at a 90° angle. After positioning, with verbal encouragement from the therapist, the participants executed three maximal handgrip contractions sustained for 6 seconds with a 9-second interval between the contractions of the right upper limb. Moreover, this was followed by a 60-second rest period, which was then repeated with the left upper limb.

4. Acupuncture stimulation

In the A treatment group, the participants received four needles (bilateral points) perpendicular to the skin surface in HT3 and HT7 in a 20-minute session using sterile, disposable filiform acupuncture needles (0.20 × 15 mm, Dongbang).

5. Experimental design

After anatomic and electrical identification, four different assessments of EI were performed using the Ryodoraku device (RDK©; NKL Produtos Eletrônicos Ltda) as follows: assessment 0, initial assessment before any procedures; assessment I, immediately after the HGP; assessment II, after 20 minutes of rest in the C group or after 20 minutes of stimulation followed by needle removal in the A group; and assessment III, after 20 minutes of rest or after 20 minutes of stimulation followed by the HGP in both groups (Fig. 1). All data were recorded for subsequent analyses.

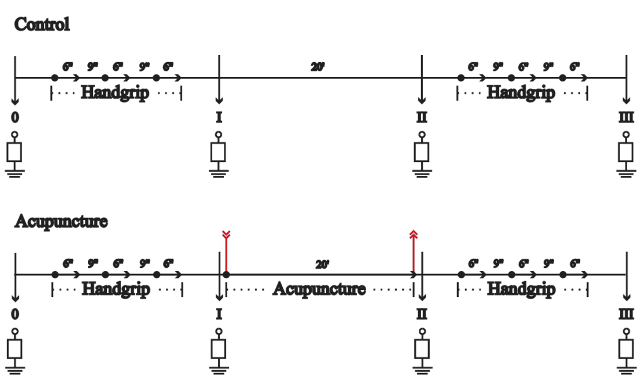

Fig. 1. Experimental design. Four different assessments of EI at the HT3 and HT7 acupoints in the following assessments: 0, initial assessment before any procedures; I, immediately after the HGP; II, after 20 minutes of rest in the C group or after 20 minutes of stimulation followed by needle removal in the A group; and III, after 20 minutes of rest in the C group or after 20 minutes of stimulation in the A group followed by the HGP. EI, electrical impedance; HGP, handgrip protocol; C, control; A, acupuncture.

Table 1. Demographic characteristics of study groups

Variable	Control group (n = 30)	Acupuncture group (n = 30)	*p*-value
Age (y)	21.87 ± 3.08	22.88 ± 2.58	0.09
Weight (kg)	68.54 ± 13.31	69.77 ± 16.43	0.57
Height (cm)	167.97 ± 8.11	168.81 ± 10.00	0.34
Male	9	11	0.58
Female	21	19	0.58

Values are presented as mean ± standard deviation or number only.

Table 2. Intergroup EI analyses at HT3 and HT7

Point	Assessment	Control group (n = 30)	Acupuncture group (n = 30)	Intergroup analyses
HT3	I	$p = 0.9999$	$p = 0.9999$	$p = 0.9999$
	II	$p = 0.9907$	$p = 0.3439$	$p = 0.0230$
	III	$p = 0.9985$	$p < 0.0001$	$p < 0.0001$
HT7	I	$p = 0.9999$	$p = 0.9998$	$p = 0.9999$
	II	$p = 0.9999$	$p = 0.8892$	$p = 0.7939$
	III	$p = 0.9999$	$p = 0.3433$	$p = 0.6621$

EI, electrical impedance.

6. Data analysis

The data were collected, normalized in percentages, and analyzed using appropriate statistical techniques to ensure the reliability and objectivity of the results. Multivariate analysis of variance (MANOVA) was used to compare the electric impedances with or without handgrip and with or without needle stimulation. Statistically significant differences were determined using Tukey's post hoc test. Statistical significance was set at a *p*-value of < 0.05.

RESULTS

Table 1 shows the demographic characteristics of the groups, which encompass sex distribution, height, weight, and age. Student's t-test was performed, revealing no statistically significant differences in age (p = 0.09), weight (p = 0.57), or height (p = 0.34) among the C and A groups. The results of the chi-square test also revealed no significant sex-related differences (p = 0.58).

The data analysis for the acupuncture group revealed a statistically significant increase in electrical current permeability (expressed as a percentage of microamperes). This increase is inversely proportional to EI, indicating a reduction in EI at the HT3 point. This was observed when comparing assessments I (immediately after the HGP), II (after 20 minutes of stimulation followed by needle removal in the acupuncture group), and III (after 20 minutes of stimulation followed by the HGP) with assessment 0 (initial assessment before any procedures) (p < 0.005).

The intergroup comparisons between the C and A groups showed a statistically significant reduction in current permeability. This reduction was observed when comparing assessments II (after 20 minutes of rest in the C group or after 20 minutes of stimulation followed by needle removal in the A group) (p < 0.02) and III (after 20 minutes of rest in the C group or after 20 minutes of stimulation in the A group followed by the HGP) (p < 0.0001). At HT7, the statistical analysis did not reveal any statistically significant differences in the intragroup or intergroup EI between the different assessments (p > 0.05) (Table 2, Fig. 2).

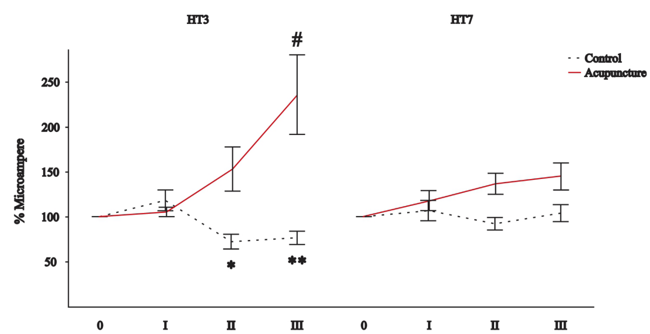

Fig. 2. Current permeability in the percentage of microamperes in assessments 0, I, II, and III. The lines indicate the control and acupuncture groups. The vertical bars represent the standard error of the mean. #Significance relative to 0 (p < 0.005). *Significance relative to II (p < 0.02). **Significance relative to III (p < 0.0001).

DISCUSSION

Our study investigated the correlation between skin EI at the two acupuncture points, before and after a muscle fatigue protocol, using a handheld dynamometer. The results emphasized the significant changes in EI at HT3, which is related to the branches of the ulnar nerve in the elbow region, both before and after stimulation by acupuncture needles in conjunction with the fatigue protocol. These findings are crucial for enhancing our understanding of the acupuncture point-stimulation mechanisms.

A significant difference in the outcomes between the HT3 and HT7 acupoints was observed. HT3, which is located near the motor branches of the ulnar nerve [11], showed significant changes in EI both before and after acupuncture needle stimulation and muscle contraction. This suggests a higher electrical permeability and conductivity at HT3, facilitating the passage of electrical current through the skin [14,15]. In contrast, HT7 did not exhibit as pronounced changes, likely due to its distinct anatomical features and lower concentration of nerve fibers and blood vessels. Moreover, the selection of HT3 and HT7 was based on their proximity to the ulnar nerve and their location on the same meridian [16]. The acupuncture points have distinctive electrical properties compared with non-acupuncture points, and the proximity of HT3 to free nerve endings and motor end plates likely explains the significant change in EI, unlike HT7, which lacks these structures nearby. These findings emphasize the importance of the anatomical and physiological context of each acupoint, indicating that the effectiveness and mechanisms of acupuncture may vary significantly depending on the specific point being stimulated.

The findings on the stimulation with filiform acupuncture needles at specific locations, where different nerve fibers play essential roles in converting mechanical information into bioelectrical and biochemical signals, are consistent with those of previous research [17]. Needle insertion into the skin excites afferent innervation at points of lower EI, creating a biomechanical phenomenon known as “needle grasp”. This phenomenon disturbs the surrounding tissues and cells, triggering a controlled inflammatory response [2,17]. This process increases blood flow and releases substances that alter tissue permeability, thereby altering the electrical characteristics of the skin [2,7]. Our results are consistent with this concept, as 20 minutes of stimulation at the HT3 acupoint increased skin permeability to electrical current, corresponding to a reduced EI at the HT3 acupoint.

The HT3 acupoint is located above the motor branch that innervates the deep finger flexor muscle belly [11]. Similar to the acupuncture points, the motor and muscle branches possess physiological and electrical properties that are conducive to conducting bioelectrical signals in response to external stimulation. Moreover, cellular studies have shown a higher concentration of gap junctions and dense network of nerve endings at these points, which may explain the increased conductivity and potential neural modulation triggered by point-stimulation [6].

Furthermore, our findings revealed that muscle contraction plays a significant role in modulating electrical activity. When muscles contract, a temporary increase in the demand for blood flow and metabolic activity is observed, which can lead to changes in the electrical properties of the tissues. This is evidenced by the HGP used in our study, which resulted in increased skin permeability to electrical current and a corresponding reduction in EI at the HT3 point. Muscle contraction during handgrip exercise likely enhances local blood flow and metabolic activity, facilitating the passage of electrical current through the skin [18].

The activation of these points also influences the autonomic nervous system, temporarily stimulating parasympathetic activities. This results in local cutaneous responses, such as increased peripheral blood flow and the accumulation of metabolites and inflammatory products, which further facilitates the passage of electrical current [19]. The combined effect of acupuncture stimulation and muscle contraction emphasizes the complex interaction between the mechanical and bioelectrical processes in modulating the EI at specific points.

Our study provides valuable insights and opens new avenues for research and clinical acupuncture. This study revealed that the stimulation of acupuncture and motor points significantly influences the electrical characteristics of the skin, such as EI. These findings improve our understanding of acupuncture mechanisms and suggest promising directions for future investigation that could determine the impact of acupuncture on different acupoints, non-acupoints, and meridians.

Daily physical activity and therapeutic techniques often involve muscle contractions, which can influence the activity of the acupuncture points. Understanding this interaction is crucial because it may affect the functional responses of these points. By investigating the changes in EI after muscle contractions, we can gain better insights into how these activities impact the acupuncture points. This knowledge could enhance the integration of acupuncture into other therapeutic modalities, leading to more effective treatments

One of the limitations of this study is its exclusive focus on two specific acupoints of the heart meridian. Consequently, the outcomes may differ when other acupoints, meridians, or anatomical locations are considered. Moreover, the EI of HT3 and HT7 were not assessed individually, which could have yielded more detailed insights into the distinct responses of each acupoint. Moreover, the effects observed in the other meridians were not investigated, which may limit the generalizability of the findings to the broader context of meridian-based therapies.

CONCLUSION

The findings of this study revealed that stimulating the HT3 acupoint, which is located over a motor nerve branch, significantly decreases the skin's EI. The combined effects of needle stimulation and muscle contraction suggest that acupoint needling can prevent the increase in skin EI. Furthermore, these findings emphasize the potential mechanisms underlying the therapeutic effects of acupuncture and the role of muscle contractions in modulating the electrical properties of the skin.

AUTHOR CONTRIBUTIONS

Conceptualization: JEA. Data curation: KZ, GHMR, IMPNA, MGP. Formal analysis: JEA. Funding acquisition: JEA. Investigation: KZ. Methodology: KZ, JEA. Validation: JEA. Writing – original draft: KZ, GHMR. Writing – review & editing: JEA.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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ETHICAL STATEMENT

This study involving human subjects adhered to all pertinent national regulations and institutional policies followed the principles of the Declaration of Helsinki and received approval from the Research Ethics Committee at Hospital das Clínicas, Ribeirão Preto Medical School of the University of São Paulo. All participants provided voluntary written informed consent after fully discussing potential benefits and risks before participating.

ORCID

Kelly Zhang, https://orcid.org/0000-0003-4321-3762
Gustavo Henrique de Mello Rosa, https://orcid.org/0000-0003-0648-5283
Isabela Mayumi Pupo Nogueira d'Àvila, https://orcid.org/0009-0008-2757-3489
Manoela Gallon Pitta, https://orcid.org/0000-0001-5582-2034
João Eduardo de Araujo, https://orcid.org/0000-0001-8709-318X

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