J Acupunct Meridian Stud 2009;2(1):49–55

RESEARCH ARTICLE

Investigation of Electrical Responses to Acupuncture Stimulation: The Effect of Electrical Grounding and Insulation Conditions

Yong-Heum Lee[1,2], Yeon-Hang Ryu[1], Byungjo Jung[1,2]*

[1]*Department of Biomedical Engineering, Yonsei University, Korea*
[2]*Institute of Medical Engineering, Yonsei University, Korea*

Received: Dec 15, 2008
Accepted: Jan 14, 2009

KEY WORDS:
acupuncture;
electric response;
meridian;
Oriental medicine

Abstract
Acupuncture in Oriental medicine has been widely used as a core therapeutic method due to its minimal side-effects and therapeutic efficacy. However, the electrical response to acupuncture stimulation (ERAS) has not been clearly studied under acupuncture conditions that might affect the efficacy of acupuncture therapy. In this study, the ERAS was objectively investigated by measuring meridian electric potentials (MEPs) when the electrical grounding conditions of the operator and subject were varied, and when the insulation conditions of acupuncture needle were varied. MEPs between Sang-geoheo (ST37) and Ha-geoheo (ST39) of the Stomach Meridian (ST) were measured by stimulating Jok-samni (ST36) with an acupuncture needle. For non-insulated acupuncture stimulation (NIAS), the average MEP peak was 148.6±20.6 when neither the operator nor the subject were electrically grounded, 23.1±8.8 when the subject only was electrically grounded, 348±76.8 when the operator only was electrically grounded, and 19.9±4.7 when both the operator and the subject were electrically grounded. The MEPs presented various magnitudes and patterns depending on the electrical grounding conditions. The MEP pattern was very similar to that of the charge and discharge of a capacitor. For insulated acupuncture stimulation (IAS), the average MEP peak was 20±4 in all electrical grounding conditions, which is not a significant electric response for acupuncture stimulation. In terms of electricity, this study verified that acupuncture therapy might be affected by acupuncture conditions such as (1) the electrical grounding condition of the operator and the subject and (2) the insulation condition of the acupuncture needle.

1. Introduction

External biological stimulations cause electrical and chemical reactions that affect important biological activities in human life. In Oriental medicine, acupuncture is also considered to cause such reactions, thereby allowing unbalanced physiological conditions to recover to normal balanced physiological conditions. In Western medicine, the physiological principle of acupuncture has been explained as a nerve and endocrine cell regulation process based on cytology [1,2]. In addition, the principles of acupuncture are also supported by the following studies: the effect of acupuncture anesthesia is delivered through cerebrospinal fluid [3] and sensory system is activated by neural complex sensory or nerve

*Corresponding author. Department of Biomedical Engineering, Yonsei University, 234 Maeji-Ri, Heungup-Myeon, Wonju-Si, Gangwon-Do, 220-710, Korea.
E-mail: bjung@yonsei.ac.kr

receptor [4,5]. The study done by Cho et al was remarkable in that it uncovered the acupuncture principle [6]. However, even though acupuncture stimulation results in brain responses, it might not be true that all acupuncture responses occur only through the nervous system, because the biological response to external stimulation is much faster than possible through the nervous system [7]. This means that biological pathways other than the nervous system might be involved in acupuncture responses. As a result, acupuncture might be considered a transfer of electric energy through nervous or connective tissue [8,9].

It has been reported that acupuncture stimulation seems to generate ion-electric-charge [10], which is transferred through various biological pathways [11]. In addition, it is well known that the effect of acupuncture therapy depends on the amount of electric charge or the acupuncture stimulation frequency [12,13]. In terms of electricity, acupuncture stimulation of the Meridian circuit amplifies small currents and voltages generated by this circuit [8,14]. This electricity may result from electric potential due to the current generated by stimulation of acupuncture points by an acupuncture needle or the chemical reaction between the acupuncture needle and the hypodermis [15,16]. The chemical reaction can be considered to have the same effect as the electric reaction because it affects ion distribution and bioelectrical charge.

Meridians can be considered ion-electric-charge pathways. Blocking the ion-electric-charge in a meridian results in unbalanced negative and positive charge and therefore pain and the development of various diseases. Acupuncture alters the excessive or deficient condition of the ion-electric-charge to allow normal health to be restored. This implies that acupuncture is closely related to the transfer of bioelectrical charge. However, acupuncture based on meridian theory does not always result in positive therapeutic outcomes but results in various therapeutic outcomes even when identical methods are used. Various acupuncture methods have been developed for different therapeutic purposes. However, current studies do not provide quantitative methods that can objectively evaluate the effect of acupuncture.

At present, acupuncture as a treatment modality has poor significance and reliability due to its low reproducible outcomes even under identical experimental conditions. To partially address this issue, the aim of this study was to objectively investigate the effects of electric grounding and insulation conditions in acupuncture stimulation by measuring meridian electric potentials (MEPs) between operator and subjects. The MEPs were measured in four different electrical grounding conditions of the operator and the subject for the non-insulated and insulated acupuncture stimulation (NIAS and IAS).

2. Materials and Methods

Figure 1 shows the experimental setup. Ten male subjects (24 ± 2.3 years old) without a medical history related to ST participated in the experiment. Acupuncture was performed by a professional acupuncture operator to minimize the operator-dependent errors. Jok-samni (ST36) was selected as an acupuncture point for the stimulation and Sang-geoheo (ST37) and Ha-geoheo (ST39) as the acupuncture points for the MEP measurement. Three ST acupuncture points were selected because they are established as the standard acupuncture points by the WHO (World Health Organization).

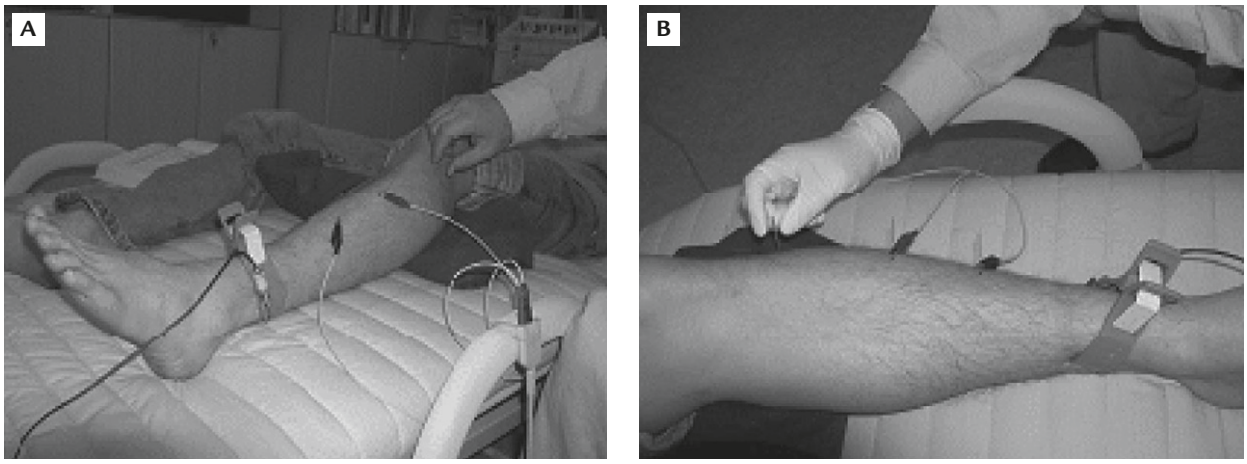

Figure 1 Experimental set-up to measure MEP for acupuncture stimulation: (a) non-insulated and (b) insulated acupuncture stimulation.

The MEPs were measured for NIAS and IAS in four different electric grounding (earth) conditions between the operator and the subjects: (1) no electrical grounding for either operator or subject; (2) electrical grounding for the subject only; (3) electrical grounding for the operator only; and (4) electric grounding for both operator and subject. The IAS and NIAS were implemented by wearing a surgical glove and using a bare hand, respectively.

The electrical grounding conditions are thought to address the problem of grounding, which becomes a base point when an electric circuit between the operator and subject is formed. The electric ground wire was connected to the grounding wire of a power line directly connected to earth, and its resistance was 0.4 Ω. In addition, the grounding terminal was always connected to the subject's ankle and switched by another person so that the operator and subjects were not aware of the electrical grounding conditions during the acupuncture procedure. The MEP was measured by randomly selecting the electrical grounding conditions.

The subjects were placed on an electrically insulated bed and took a rest for 20 min. The acupuncture needles were inserted into ST36, ST37, and ST39 at a depth of 3 cm. Positive and negative electric terminals were connected to ST37 and ST39, respectively. Acupuncture stimulation was implemented by hitting and periodically holding and releasing the acupuncture needle for approximately 20 seconds at 0.5–1 Hz. The MEPs were measured and analyzed with a signal amplifier, PowerLab (ADInstruments, USA) equipped with a 16bit A/D converter. To minimize noise signals not related to the acupuncture stimulation frequency, the cut-off frequency of the digital low pass filter was set to 30 Hz because the frequency of the MEP signal observed was less than 20 Hz. The MEP signals were sampled at 4 kHz.

3. Results

3.1. MEP change for NIAS when neither operator nor subject is electrically grounded

Figure 2A shows the MEP change when neither operator nor subject is electrically grounded. The average MEP peak was 148.6 $\pm$ 20.7, which can be considered a significant electrical response for the acupuncture stimulation. No MEP change was observed before the acupuncture stimulation of 10 seconds. However, whenever the acupuncture needle was held and released, we observed a fast and strong MEP peak similar to an impulse wave. The MEP peak was observed in both positive and negative directions or only in the positive direction depending on the subject. The MEP peak gradually decreased as a function of the number of holding and releasing events. In most cases, the MEPs similar to a square wave were observed in the positive direction when the acupuncture needle was held. These results may indicate that the bioelectrical charge from acupuncture stimulation is transferred from ST36 through ST37 and ST39 and from operator to subject, thereby reinforcing Qi.

3.2. MEP change for NIAS when the subject only is electrically grounded

Figure 2B shows the MEP change when the subject only is electrically grounded. The average MEP peak was 23.1 $\pm$ 8.8. When compared to the MEP (17.3) before acupuncture stimulation, this small MEP change does not appear to be a significant response to acupuncture stimulation. It might be a contact electric potential or electromyogram (EMG) generated by the acupuncture stimulation. This tiny MEP change was observed for the first acupuncture stimulation only, and no MEP change upon further stimulation was observed. This result indicates that bioelectrical charge is transferred only through the meridian and cannot be bypassed through other pathways with better electro-conductivity and lower impedance compared to the two measurement acupuncture points (ST37 and ST39).

3.3. MEP change for NIAS when the operator only is electrically grounded

Figure 2C shows the MEP change when the operator only is electrically grounded. The average MEP peak was 348 $\pm$ 76.8, which indicates a high and significant electrical response to acupuncture stimulation (ERAS). When compared to the MEP response when neither the operator nor subject was electrically grounded, this MEP was very high, though its pattern was similar. However, the MEP signals periodically presented bidirectional peaks in all subjects. Because the MEPs have very similar patterns to the charge and discharge of a capacitor, the acupuncture procedure might be considered to charge and discharge bioelectrical charge through the acupuncture needle. Therefore, if it is assumed that the MEP's peak magnitude and pattern can greatly affect the acupuncture procedure, the electrical grounding condition for the operator only might be the most effective one.

3.4. MEP change for NIAS when both operator and subject are electrically grounded

Figure 2D shows the MEP change when both operator and subject are electrically grounded. The average

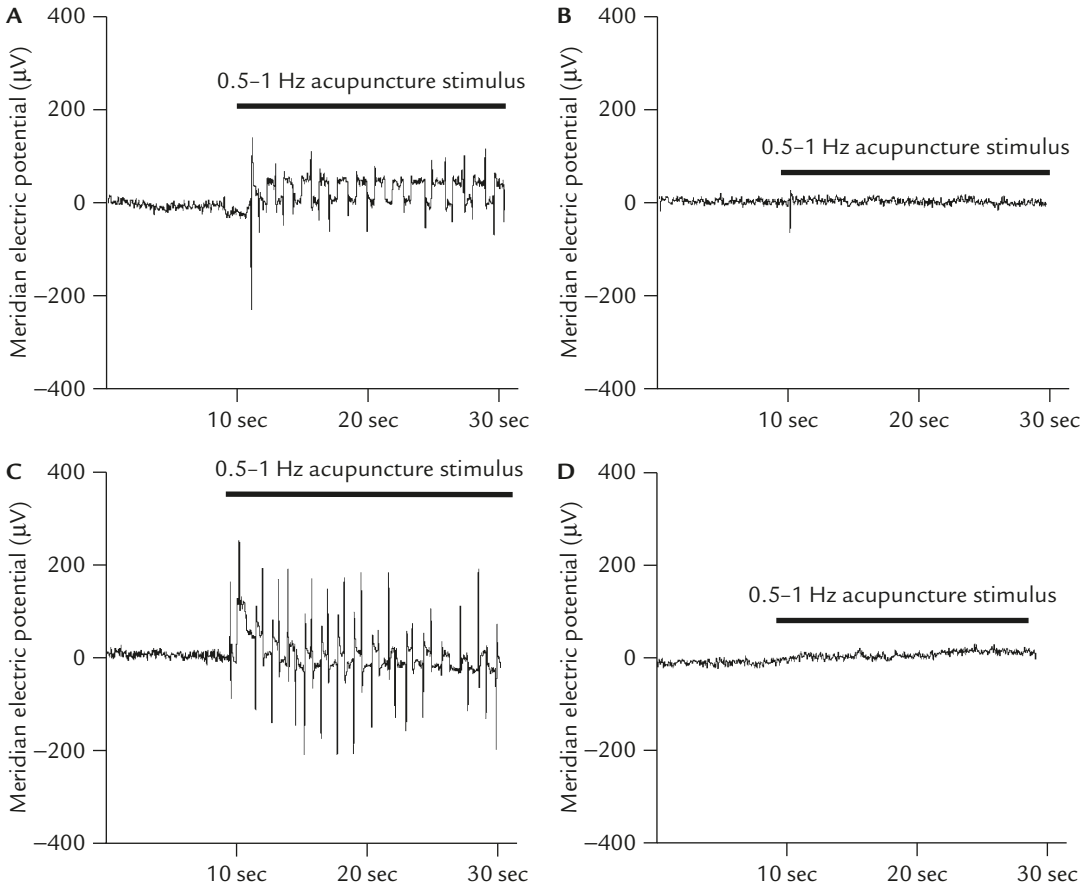

Figure 2 MEP changes for non-insulated acupuncture stimulations under the following conditions: (a) neither operator nor subject electrically grounded; (b) subject only electrically grounded; (c) operator only electrically grounded; and (d) both operator and subject electrically grounded.

MEP peak had the lowest value of 19.9±4.7, which is similar to that when the subject only was grounded. In addition, no MEP changes were observed during the first or subsequent acupuncture stimulations. This result implies that bioelectrical charge is not transferred through the meridian but through some other pathway, or MEP cannot be generated when both operator and subject are grounded.

3.5. MEP changes for IAS

To verify that acupuncture stimulation is closely related to the transfer of bioelectrical charge between operator and subject via the acupuncture needle, acupuncture stimulations were performed with the operator wearing a surgical rubber glove under the same experimental conditions as those for the NIAS. As shown in Figure 3, MEPs for all electric grounding conditions were very low, which is similar to the case when both operator and subject were electrically grounded for the NIAS. These results suggest that the MEP cannot be generated with an insulated acupuncture needle and as a result, the transfer of bioelectrical charge cannot occur. Therefore, the use of acupuncture needles insulated with plastic or other insulation materials might be avoided to maximize the efficacy of acupuncture therapy. The experimental results of this study verify that acupuncture stimulation is closely related to the conductivity of the acupuncture needle, which affects the transfer of bioelectrical charge.

3.6. Statistics of clinical trials

Figure 4 shows the average MEPs of 10 subjects in four different electrical grounding conditions for the NIAS and the IAS. The IAS did not show significant MEP in any electrical grounding condition. However, the NIAS resulted in the most significant MEP when the operator only was electrically grounded and can therefore be considered the most effective acupuncture procedure.

4. Discussion

Various studies have been performed to prove the principle of acupuncture. However, most acupuncture

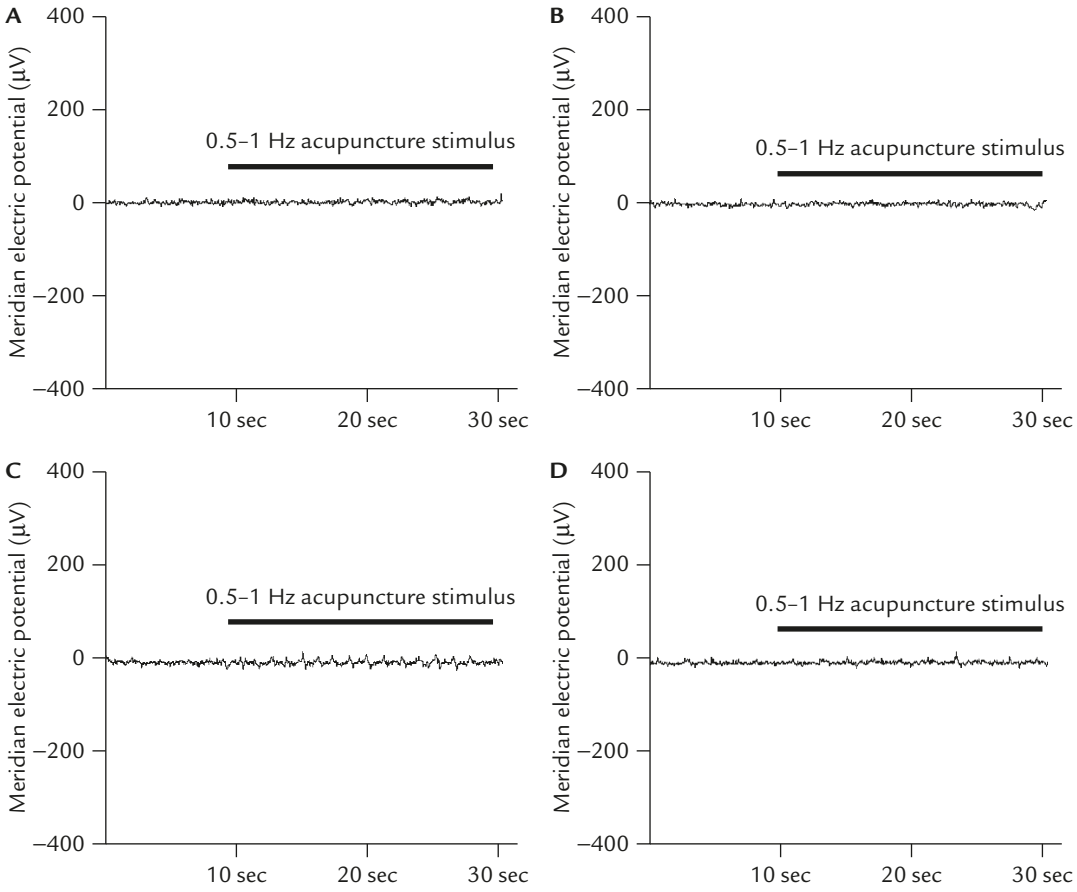

Figure 3 MEP changes for insulated acupuncture stimulations under the following conditions: (a) neither operator nor subject electrically grounded; (b) subject only electrically grounded; (c) operator only electrically grounded; and (d) both operator and subject electrically grounded.

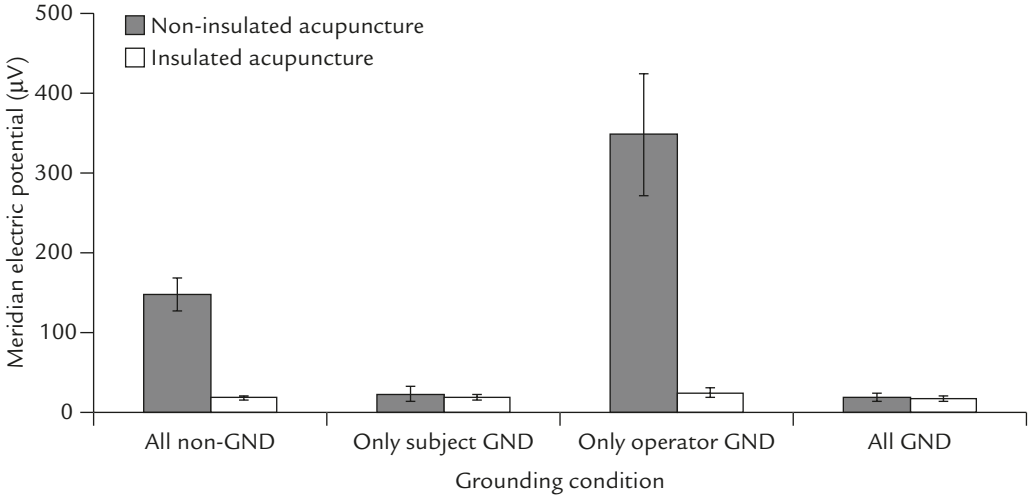

Figure 4 Comparison of average MEPs (n=10) for non-insulated and insulated acupuncture stimulation under various electrical grounding conditions. GND=electrical ground.

studies have focused on investigating the efficacy of acupuncture rather than the acupuncture procedure or stimulation method, both of which may affect the efficacy of acupuncture. A study by Cho et al, in which brain responses to acupuncture stimulation were observed by using fMRI, provided a breakthrough in the investigation of the principle of acupuncture. However, the study results were analyzed in terms of neurology rather than the acupuncture meridian theory and did not considered electrical

grounding and insulation conditions of the operator and subject during the acupuncture procedure.

The electric signals generated in the human body are transferred to all body parts, cause electric interference, and finally, form electric potentials at specific body parts. Analogously, the principle of acupuncture, in terms of electricity, might be explained by the interaction of bioelectrical charges between the operator and subject via an acupuncture needle inserted into the acupuncture points of a subject. Therefore, this study investigated the ERAS by measuring the MEP when the electrical grounding and insulation conditions were varied between different acupuncture procedures (Figures 2 and 3).

As illustrated in Figure 5, the principle of acupuncture might be explained as bioelectric charge transfer between operator and subject to allow recovery from an unbalanced capacitance ($C1 \neq C2$) to a balanced capacitance ($C1 = C2$). The bioelectric charge might be charged or discharged by an operator through an acupuncture needle depending on the capacitance at the acupuncture points of the subject. The charge or discharge of bioelectrical charge by the operator might result in different MEPs depending on the subject. This means that the meridian (C1, R1) property is subject-dependent, and this determines the amount of bioelectrical charge that will be charged or discharged as well as the transfer direction of the bioelectric charge.

The MEPs were observed in positive, negative, and both directions, depending on the electrical grounding conditions. A positive MEP may indicate stimulation transfer from ST37 to ST39, and be considered as a transfer of bioelectric charge from the operator (C2) to the subject (C1), thereby reinforcing (charging) Qi. The negative MEP may indicate stimulation transfer from ST39 to ST37 and be explained as bioelectric charge transfer from subject (C1) to operator (C2), thereby reducing (discharging) Qi. Bidirectional MEP can be explained as the charge and discharge of bioelectric charge between the operator and subject. This indicates that the efficacy of the acupuncture procedure may be determined by the formation of an electrical circuit whose characteristics are determined by the electrical grounding condition of the operator and subject and by the transfer of bioelectrical charge. In clinical trials of ten subjects, high reproducible MEP values for NIAS and IAS were observed depending on the electrical grounding condition used (Figure 4). When the operator only was electrically grounded, the highest MEP was obtained, which might indicate that the most effective acupuncture stimulation occurred. In terms of clinical efficacy, we verified that electrical grounding conditions are an important factor, which must be considered when performing an acupuncture procedure.

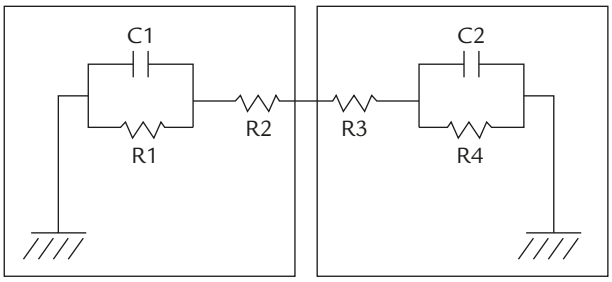

Figure 5 Equivalent electric circuit model between the operator and subject: C1 is the capacitance at an acupuncture point of the subject; R1 is the resistance at an acupuncture point of the subject; R2 is the skin resistance at an acupuncture point of the subject; C2 is the subcutaneous capacitance at an acupuncture point of the operator; R4 is the subcutaneous resistance at an acupuncture point of the operator; and R3 is the skin resistance at an acupuncture point of the operator.

In the IAS, no significant MEP was observed for any of the electrical grounding conditions as shown in Figure 4. That result indicates that wearing a surgical rubber glove opens the electric circuit resulting in no bioelectrical charge transfer from the operator (C2) to the subject (C1) via the acupuncture needle. Therefore, even though the conductivity of the acupuncture needle is excellent, bioelectric charge cannot be effectively transferred in an insulation condition. Therefore, insulated acupuncture needles might be avoided in acupuncture procedures. In addition, no significant electrical signals for the IAS (Figure 3) compared to the NIAS might present that the MEP is not the EMG but the electrical response due to acupuncture stimulation.

5. Conclusions

The electrical grounding condition of the operator and subject, and the conductivity of the acupuncture needle determine the amount and transfer direction of bioelectrical charges at the contact point between the acupuncture point and the needle. Therefore, The MEP might be generated by the strong induction of bioelectric responses to acupuncture stimulation at meridians. As a result, this study suggests that:

1. The electrical grounding and insulation conditions contribute to the formation of an electric circuit and therefore have to be considered during an acupuncture procedure.
2. The electrical grounding and insulation conditions determine the generation and pattern of the MEP, which might affect the efficacy of acupuncture.
3. In terms of electricity, the principle of acupuncture might be considered a transfer of bioelectric

charge from the operator to the subject via the acupuncture needle.
4. The NIAS compared to the IAS induces more complex bioelectrical charge phenomena.

In conclusion, this study proposes a new objective method to evaluate the principles of acupuncture in terms of electricity.

Acknowledgments

This research was supported by a grant from the Next Generation New Technology Development Program (10028424) funded by the Ministry of Commerce, Industry and Energy of the Korean Government.

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