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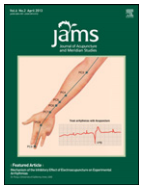

RESEARCH ARTICLE

Development and Evaluation of a Bio-ion Measurement System on Acupoints for Meridian Diagnosis

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Abstract
The aim of this study was to develop a new method of measuring the meridian energy potential (MEP) at an acupoint with bioelectrical impedance in order to establish an objective meridian diagnosis. To confirm the reflection of the changes in body composition at acupoints, the changes in the MEP on the bladder meridian before, during and after cupping were observed. Additionally, to evaluate the usefulness of diagnosis, the MEP on the stomach meridian before and after a meal was measured. Significant increases were found at every acupoint during cupping and after eating a meal. It was confirmed that the MEP data reflected changes in body composition at every acupoint and that these changes were associated with functioning of the associated internal organs. In conclusion, we propose the usefulness of this method, which can indicate the state of acupoints.

1. Introduction

In traditional Chinese medicine (TCM), diagnoses are based on meridian theory, which explains the relationship between meridians and life energy (Qi) [1,2]. Meridians reflect the pathophysiological state of the five viscera and the six entrails of the human body. The conditions of the viscera and entrails are represented by acupoints that are

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found along meridians and which are used to control Qi with techniques such as acupuncture, cupping and moxibustion [3—6]. However, the existence of meridians has not been proven and the correlation between acupoints and the conditions of internal organs has not been demonstrated objectively. Consequently, it has been difficult to demonstrate the concept of Qi circulation despite the research that has been conducted related to the therapeutic effects of TCM [7—9]. Therefore, it is important to establish a diagnostic index obtained by quantitative analysis of the interaction of the internal organs and meridians in TCM.

Several studies have reported the electrical properties of meridians with the intention of proposing the characteristics that may establish an objective diagnostic index. The first published study investigated the impedance properties of meridians using a two-electrode method with a direct current source. Consequently, the study revealed that both meridians and acupoints had a lower electrical impedance when compared to nonmeridian sites and nonacupoints [10,11]. It has also been reported that meridians and acupoints have a higher conductivity than nonmeridian sites and nonacupoints [12,13]. These reported findings correspond with the fact that the capillary and nervous systems are more closely distributed than the nonacupoints.

The state of bio-ions at acupoints was analyzed in another study to progress the objectification of the diagnosis. This study reported that there was a fair amount of evidence to support the existence of metallic cations, such as Ca^{2+}, Fe^{3+}, Cu^{2+}, and Zn^{2+}, at acupoints rather than non-acupoints [14]. The distribution of various bio-ions at acupoints indicates that acupoints are of particular importance in the transduction of an electromagnetic signal [15]. Interestingly, the anatomical locations of the acupoints are similar to locations of painful trigger points with a at high 93.3% agreement [16]. Thus, acupoints have been considered as the generation points of pain.

Several studies have demonstrated the diagnostic importance of bio-ions within acupoints. As results of these studies, bio-ions within acupoints have been shown to be influenced by the accumulation of metabolites and substrate depletion incurred from fatigue [17—19]. For example, sarcoplasmic Ca^{2+} release and the impairment of its reuptake as well as the disturbance of electrolyte concentrations have been observed at acupoints under the influence of fatigue [20—22]. Such phenomena in TCM have been referred to as the induration of acupoints. Moreover, electrical stimulation [23,24], magnetic stimulation [25,26] or traditional Chinese treatment such as acupuncture [1,7,8,27,28] have been shown to have a beneficial effect on bio-ion imbalance. This is surely an indication that bio-ion state should be observed as a significant factor in diagnosis and treatment. However, there is still a substantial lack of research regarding the state of bio-ions at acupoints. Most studies report skin impedance measured by a constant current and not by bioelectrical impedance, which might indicate the amount of bio-ions in the body.

Bioelectrical impedance analysis has been used as a method to assess body composition. Thus, the single frequency type method was used to measure bioelectrical impedance. There was a certain limit to reflection of bioelectrical impedance, which includes amount of bio-ions from extracellular or intracellular fluid. At a low frequency, an electrical current does not penetrate the cell membrane, which acts as an insulator, and thereby the current passes freely through the extracellular fluid. At a high frequency, the current passes through both intracellular and extracellular fluid because of the loss of cell membrane function [29,30]. However, it has a serious problem with low reproducibility. Moreover, surface electrodes require that a high electrical current (800 μA) must be used to decrease the instability of the injected current [31]. As such, this study proposes a nonstimulation method for detecting body composition with bioelectrical impedance at acupoints.

2. Materials and methods

2.1. Measurement principles

Fig. 1 illustrates the principle of body composition measurement with bioelectrical impedance at an acupoint. This system was designed based on the fact that bio-ion concentrations are more evenly distributed at an acupoint than at nonacupoints. In order to measure bioelectrical impedance in proportion to bio-ion concentration, the C_{system} as an external element had smaller capacitance than acupoints. The C_{system} indicates the electrical element in the system. The role of C_{system} is to find the peak electrical potential at an acupoint. The C_{system} is simply considered by peak detector. The C_{system} repeated the charge/discharge in order to detect the potential incurred from capacitance. This study termed the collected bioelectric potential data at an acupoint as the meridian energy potential (MEP).

The charge/discharge operation consisted of two sessions. In the first session, the C_{system} electric charges which were generated by the difference in potential between the capacitance of the selected acupoint and the capacitance of the C_{system} after the switch signal becomes a low level potential. In the second session, the C_{system} discharged electrical charges when the switch signal changed to a high level. Therefore, the potential of the C_{system} was observed with ascending and descending forms. The designed system operated six repetitions of charge/discharge for 1 second in one channel.

The system was designed to detect MEP data in 12 channels. Fig. 2 illustrates that this system consists of a power supply, a controller and an electrode connector. Considering participant safety, a safety device was composed of a protective component for overvoltage and current surge. The detected signal was amplified, ranging from 0 V to 5 V. The sampling frequency was 600 Hz with a 10 bit resolution.

2.2. Participants

The participants ($n = 30$, all male, age $= 23 \pm 2.8$ years) attended the three-part experiment. Self-report questionnaires about treatment experience related to general disorders were completed by all participants and we confirmed that they did not have a clinical medical history. Written informed consent was obtained from each participant after they were informed of the nature and requirements of this experiment. Skin lesions due to burns