J Acupunct Meridian Stud 2014;7(5):250–257

Available online at www.sciencedirect.com

Journal of Acupuncture and Meridian Studies

journal homepage: www.jams-kpi.com

RESEARCH ARTICLE

Electromagnetic Acupuncture to Enhance the Effects of Manual Acupuncture on Recovery from Muscle Fatigue of the Quadriceps

Soo-Byeong Kim [1], Na-Ra Lee [2], Sun-Woo Park [3], Soon-Jae Ahn [3], Hyun Heo [4], Young-Ho Kim [3], Yong-Heum Lee [2,*]

[1] *Wellness Technology R&D Center, Human and Culture Convergence Technology R&D Group, Korea Institute of Industrial Technology, Ansan, South Korea*
[2] *Eastern & Western Biomedical System Laboratory, Department of Biomedical Engineering, Yonsei University, Wonju, South Korea*
[3] *Yonsei Biomechanics Research Laboratory, Department of Biomedical Engineering, Yonsei University, Wonju, South Korea*
[4] *Medical Computer System Laboratory, Department of Biomedical Engineering, Yonsei University, Wonju, South Korea*

Available online 18 September 2014

Received: Jun 11, 2013
Revised: Dec 27, 2013
Accepted: Jan 7, 2014

KEYWORDS
acupuncture point;
electromagnetic acupuncture;
muscle fatigue;
pulsed electromagnetic fields

Abstract
The aim of this study was to investigate a new method of manual acupuncture that used a magnetic field to stimulate only one acupoint vertically. We developed an eight-channel electromagnetic acupuncture (EMA) system that uses a solenoid-type electrode to insert the manual acupuncture needle into a hole in an electrode. We used a manual acupuncture needle for magnetic induction in order to penetrate vertically and deeply into tissues. In order to confirm the usefulness of EMA, we investigated the effects of treatment on muscle fatigue after strenuous knee extension/flexion exercises that had been performed by three groups: the nonstimulation, the manual acupuncture, and the EMA groups. Electromyograms showed that the median frequency (MF) in the EMA group

* Corresponding author. Eastern & Western Biomedical System Laboratory, Department of Biomedical Engineering, College of Health Science, Yonsei University, Wonju, Gangwon-Do 220-710, South Korea.
E-mail: koaim@yonsei.ac.kr (Y.H. Lee).

pISSN 2005-2901 eISSN 2093-8152
http://dx.doi.org/10.1016/j.jams.2014.01.005

had rapidly recovered after 4 minutes ($p = 0.608$), but that the peak torque had not recovered to the normal state ($p < 0.05$). Thus, we confirmed that compared with manual acupuncture, EMA resulted in better recovery from muscle fatigue.

1. Introduction

In recent years, there has been increasing interest in clinical research on Traditional Korean Medicine (TKM) [1]. An expanding number of papers reported the treatment effects of manual acupuncture techniques for certain conditions [2]. In order to suggest an objective treatment mechanism for manual acupuncture, many studies were conducted. Effects of manual acupuncture including activation of nerves, internal secretion, and effects on the cerebrospinal fluid were reported [3,4]. Moreover, studies on many different ailments including osteoporosis [5], hyperlipidemia [6], and pain relief [7] have reported on the treatment benefits of manual acupuncture.

To enhance the treatment effects of manual acupuncture, this study suggested a new method using magnetic fields. After a magnetic field penetrates an electric conductor such as the living body, bioelectric currents can generate an eddy current that has an impact on various tissues, such as nerve or muscular tissue, etc. Previous research on magnetic fields reported various treatment effects for fracture, pain relief, arteriosclerosis, Parkinson's disease, and neurological disease [8–12]. In addition, on the basis of the results of proven treatment effects, many studies applied the magnetic fields to the acupoints and also verified the treatment effect [11,12]. The majority of papers used a noninvasive method by applying an electrode that can generate magnetic flux density at the location of an acupoint. Because the generated magnetic flux density decreases geometrically according to the distance from the electrode, the noninvasive method cannot deliver enough stimulation to an acupoint located in the inner part under the subcutaneous tissue. However, it is possible to stimulate only one acupoint, if the manual acupuncture needle inserted into the body or an acupoint can generate magnetic flux density. Therefore, we selected electromagnetic acupuncture (EMA), which uses a solenoid-type electrode that enables insertion of the manual acupuncture needle into a hole as a new stimulus in order to generate the bioelectric current without any external potential interference and to penetrate vertically into the tissues. In order to conduct fundamental research for observing the usefulness of EMA in comparison to manual acupuncture, we developed an eight-channel EMA system and performed a muscle fatigue recovery experiment. We then analyzed the electromyography (EMG) signal.

We selected pulsed electromagnetic fields (PEMFs) to generate the magnetic flux density; this method was reported as an effective treatment for musculoskeletal disorders [13,14]. PEMFs have demonstrated their various treatment effects in many different ways, including microcirculatory effects, skin temperature, motor function recovery, and synthase activity [15–18]. Moreover, various researchers reported that extremely low frequency (ELF) PEMFs ($\leq$300 Hz) induced analgesia. A magnetic flux density of 0.1–0.3 millitesla (mT; 1–3 gauss) within the frequency range from 1 Hz to 4 Hz was widely used to treat acute orthopedics [19].

To compare the treatment effects under identical conditions, we selected vertical insertion of the manual acupuncture needle. The manual acupuncture applied at the acupoints of the Liver (LR) meridian had a treatment effect on muscular skeletal disorders [20]. Considering the inconvenience of applying the electrode and inserting the manual acupuncture needle, we selected the rectus femoris, which is close to the LR meridian, as the induction location for generating muscle fatigue. We selected LR9 which is 12.12 cm from the medial lateral epicondyle of the femur, because of the EMG noise induced by the interference between the EMG measurement electrode and the EMA electrode.

The aim of our study was to suggest EMA as a treatment option and observe its usefulness in comparison with manual acupuncture.

2. Material and methods

2.1. Eight-channel EMA system design and stimulation method

Figs. 1 and 2 show the eight-channel EMA system and the solenoid coil, which was 15 mm in diameter and 20 mm in length. The core was 5 mm in diameter and 16 mm in length and was made of the material SM45C. The diameter of the hole was 2 mm in the center of the core for inserting the manual acupuncture needle. The coil used a wire, which

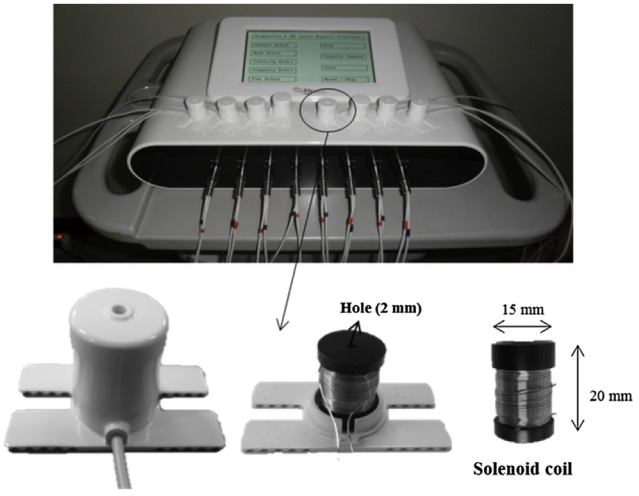

Figure 1 The solenoid coil for magnetizing acupuncture needles and the eight-channel pulsed electromagnetic field (PEMF) stimulator.