

# The Effect of Microcurrent-Inducing Shoes on Fatigue and Pain in Middle-Aged People with Plantar Fasciitis

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**Abstract.** When a muscle is used repeatedly for a long time, it often leads to muscular fatigue and muscle soreness. In middle-aged and elderly populations, muscular fatigue and pain during the performance of activities of daily living is a common problem caused by physiological changes in the musculoskeletal system due to the aging process. Microcurrent therapy has been shown to be effective at reducing pain and muscle soreness. For activities such as standing or walking, specially developed shoes (G-man, Busan, South Korea) which are capable of providing microcurrent therapy during the performance of these activities are an advantage as the treatment becomes integrated with the activity being performed. These therapeutic shoes or microcurrent induction shoes could be potentially useful for providing treatment if they were worn during normal activities. The purpose of this study, therefore, was to investigate the effect of these microcurrent induction shoes on pain and muscle fatigue in middle-aged people with plantar fasciitis. Subjects were asked to wear their normal shoes and instructed to walk on a treadmill at 2 and 3 km/hr for 10 minutes each. Subjects were then asked to wear the specially designed microcurrent induction shoes for six weeks for at least 4 hours per day during ADL activities such as standing and walking. During the initial evaluation and at the end of the 6 weeks intervention, the electromyographic (EMG) activity of their right tibialis anterior and soleus muscles were recorded, together with their perceived level of foot pain using a Visual Analogue Scale (VAS). The results showed a significant reduction in their VAS scores ( $p < 0.01$ ), and the change in median power frequency of their tibialis anterior EMG recording ( $p < 0.05$ ). In conclusion, this study demonstrated that microcurrent induction shoes were effective in relieving foot pain and muscle fatigue in subjects with plantar fasciitis.

**Key words:** Microcurrent, Plantar Fasciitis, ADL

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## INTRODUCTION

The application of electrical energy for medical treatment purposes is not new. Since early times, it has been observed that electrical stimulation can promote physiological and pathological changes in the tissues. Galvani, an Italian anatomist, demonstrated the effects of electrical currents on a

frog in 1789, and since then there have been numerous studies investigating the effects of faradic and sinusoidal currents in animals and human beings<sup>1)</sup>.

Microcurrent therapy has been regarded as having a limited therapeutic value because the intensity of the current is significantly less than that of other forms of electrical stimulation such as

transcutaneous electrical nerve stimulation<sup>2</sup>). Becker<sup>3</sup>) hypothesized that there was a measurable electrical microcurrent around normal healthy tissue, and that injury to the tissues would result in a disruption of this electrical field. Treatment with microcurrent therapy would stimulate the recovery and regeneration of the wounded tissues by restoring the normal electrical field. Illingworth and Barker<sup>4</sup>) reported that the electrical microcurrent around a child's cut fingernail was within the range of 10 to 30  $\mu\text{Acm}^{-2}$ . Since then, there have been many studies investigating the effects of microcurrent therapy. Cheng<sup>5</sup>) examined the physiological effects of varying the microcurrent intensities on ATP production, protein synthesis and membrane transport. Other studies have reported the effects of microcurrent therapy on nonunion of fractures<sup>6</sup>), chronic low back pain and myofascial pain<sup>7</sup>), and chronic Achilles tendinopathy<sup>2</sup>), among others. In addition, publications related to the effects of microcurrent on delayed onset muscle soreness<sup>8</sup>), tension of sympathetic nerves<sup>9</sup>), wound healing<sup>10</sup>), the recovery and re-growth of periodontal tissues<sup>11</sup>), beta-endorphin and cutaneous pain threshold<sup>12, 13</sup>), and the inhibition of bacterial growth<sup>14</sup>) have been reported in various Korean language journals. These studies<sup>8-14</sup>) show that microcurrent therapy has therapeutic effects on wounds, the inhibition of bacterial growth, and increased blood flow rate by mitigating the effects of sympathetic nerves.

When a muscle is used repeatedly for a long time, it often leads to decreased muscular power and efficiency. Muscular fatigue can be defined as a decrease in the muscle strength, or a loss in the ability to maintain muscle strength at a steady force 15. In the middle-aged population, muscular fatigue during the performance of activities of daily living is a common problem caused by physiological changes in the musculoskeletal system due to the aging process. While there has been one study<sup>16</sup>) which investigated the effects of transcutaneous electrical nerve stimulation on muscle fatigue, the effects of microcurrent therapy on muscle fatigue have yet to be investigated. For activities such as standing or walking, specially developed shoes (G-man, Busan, South Korea) which are capable of providing microcurrent therapy during the performance of these activities are an advantage as the treatment becomes integrated with the activity being performed. These

**Table 1.** Characteristics of subjects

	Males	Females	Total
No. of subjects	5	5	10
Age (years)	54.8 $\pm$ 2.6	53.4 $\pm$ 4.0	54.0 $\pm$ 3.1
Height (cm)	167.4 $\pm$ 3.1	154.0 $\pm$ 3.3	160.7 $\pm$ 7.7
Weight (kg)	64.4 $\pm$ 5.7	56.8 $\pm$ 3.5	60.6 $\pm$ 6.0

Mean  $\pm$  SD.

therapeutic shoes or microcurrent induction shoes could be potentially useful for providing treatment if they were worn during normal activities. The purpose of this study, therefore, was to investigate the effect of these microcurrent induction shoes on pain and muscle fatigue in middle-aged people with plantar fasciitis.

## MATERIALS AND METHODS

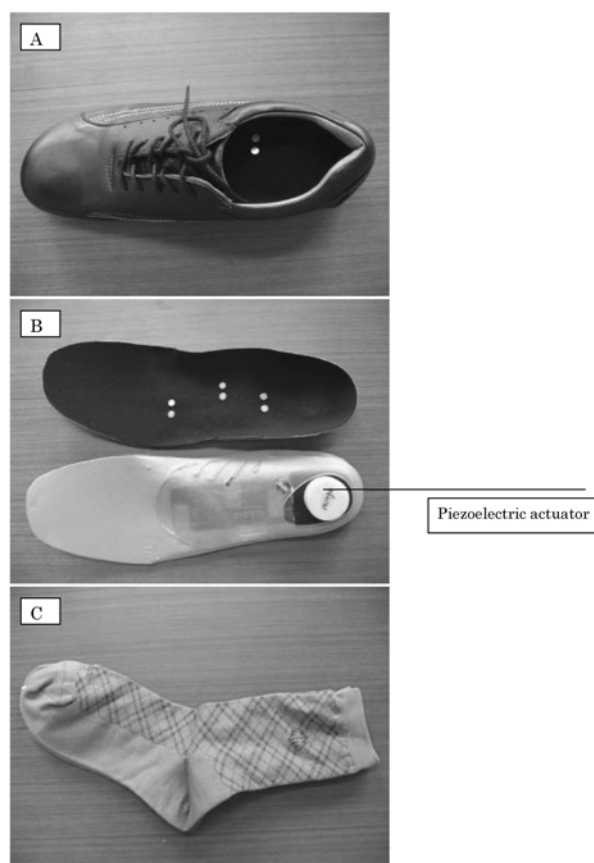
### Subjects

Five females and five males, who were over 50 years old and diagnosed with plantar fasciitis, participated in this study. The males were all office workers, and the females were all housewives. The study lasted a total of 6 weeks, and the participants gave their informed consent prior to the study. Information about the general characteristics of the participants is shown in Table 1.

### Instrumentation

For this study, specially constructed microcurrent shoes (Fig. 1a) were manufactured by G-man company (377-3 Young-ho 3 dong, Nam-gu, Busan, South Korea). The insoles of the shoes were constructed of a specially made piezoelectric material which is capable of generating a microcurrent field when mechanically compressed at the heel (for example, during heel strike of gait, or during standing) (Fig. 1b). The magnitude of the generated microcurrent is proportional to the loading during heel strike, and is transmitted from the insole to the sole of the foot by the subject wearing socks made of silver threads (Fig. 1c). When the piezoelectric actuator is loaded with a weight of 75 kg, a microcurrent intensity of 60 to 160  $\mu\text{A}$  is generated (Fig. 2).

Electromyographic (EMG) measurements were performed with a Biopac MP 150 remote monitoring system, TEL 100 (Biopac Systems Inc. California, USA), using Ag-AgCl electrodes. The



**Fig. 1.** Microcurrent induction shoes. (a) Shoe; (b) insole with piezoelectric actuator at the heel; (c) and silver-threaded socks.

diameter of the electrodes was 2 cm, with an inter-electrode distance of 2 cm. Electrode placements for the tibialis anterior and soleus muscles were as described by Tirosh and Sparrow<sup>17</sup>). In brief, the electrodes were placed in the middle of the muscle belly, and in parallel to the muscle fibers. To minimize the effects of skin impedance, the electrodes were attached on dried skin surface areas after shaving and cleaning with alcohol. The sampling rate was set at 1,000 Hz, with a band-pass filter of 20 to 500 Hz<sup>18</sup>).

#### *Procedure*

At the beginning of the study, all subjects were asked to wear their normal shoes and walked on a treadmill at 2 km/hr for 10 minutes. Following this, the speed was increased to 3 km/hr and the subjects were asked to walk for another 10 minutes. EMG activity of their right tibialis anterior and soleus

muscles were recorded during the first 10 seconds and last 10 seconds while the subjects walked at 3 km/hr. Immediately after the subjects had completed their walk on the treadmill, their perceived level of foot pain was measured using a Visual Analogue Scale (VAS)<sup>19</sup>).

Following the initial evaluation, the subjects were asked to wear the specially designed microcurrent induction shoes with the silver-threaded socks for six weeks. They were instructed to wear the shoes for at least 4 hours per day during ADL activities such as standing and walking. All subjects were also instructed not to do any form of vigorous exercise during the six-week period. At the end of the six weeks, their EMG activity of the right tibialis anterior and soleus muscles were recorded, as well as their perceived level of foot pain, similar to the procedure during initial testing.

#### *Data analysis*

Statistical analysis was carried out using the SPSS Version 12.0 for Windows (SPSS Inc. Chicago, Illinois, USA). For the EMG analysis of muscle fatigue, the MP 150 Acknowledge Software (Biopac Systems Inc. California, USA) was used. While the subjects were walking on the treadmill at 3 km/hr, the first and last 10 s of EMG signals were sampled and processed using a Fast Fourier Transformation, and the median peak frequencies (MDF) was recorded. To analyze for differences in muscle fatigue before and after wearing the shoes, the delta MDF (the MDF of the first 10 s–MDF of last 10 s) was calculated. The delta MDF as well as the VAS scores for foot pain, pre- and post-testing were then analyzed for significant differences using a Wilcoxon matched-pairs signed-ranked test. The level of statistical significance was chosen as 0.05.

## **RESULTS**

The means and SDs for the VAS and the MDF pre- and post-intervention is shown in Table 2. After the six-week period, the VAS scores for foot pain were found to be significantly reduced ( $p < 0.01$ ). The delta MDF pre- and post-testing was also significantly reduced ( $p < 0.05$ ), indicating a significant reduction in muscle fatigue for the tibialis anterior muscle (Fig. 3). In comparison, the delta MDF for the soleus muscle pre- and post-testing was not significantly different ( $p > 0.05$ ) (Fig. 3).

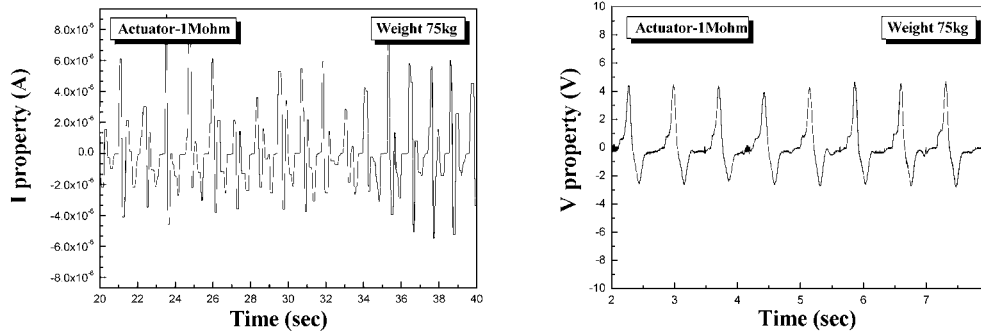


Fig. 2. Electric current and voltage produced by a 75 kg load.

Table 2. VAS and the MDF pre and post intervention

	Pre-intervention	Post-intervention
VAS	4.6 ± 2.2	2.0 ± 2.0
MDF(Hz)		
Tibialis Anterior (1st 10 sec)	28.9 ± 1.2	26.8 ± 2.1
Tibialis Anterior (Last 10 sec)	25.9 ± 1.5	25.9 ± 2.2
Soleus (1st 10 sec)	25.5 ± 3.9	28.5 ± 2.5
Soleus (Last 10 sec)	23.6 ± 3.4	27.0 ± 1.7
Delta MDF (Hz)		
Tibialis Anterior	-	-
Soleus	-	-

Mean ± SD.

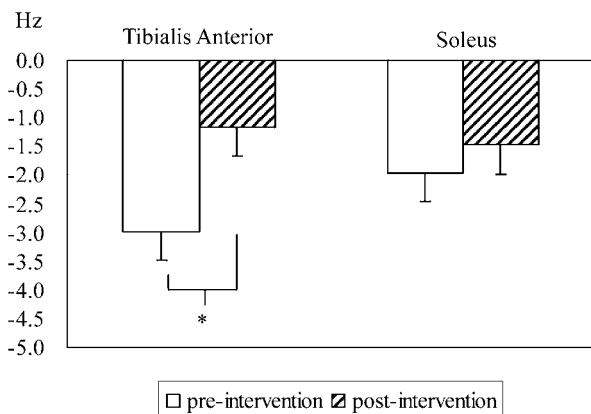


Fig. 3. Comparison of delta MDF scores pre- and post-intervention for tibialis anterior and soleus muscles.

### DISCUSSION

Plantar fasciitis, a common soft tissue lesion, is an inflammatory condition that occurs due to overuse. This is a particularly bothersome condition that creates pain in the sole of the foot and often limits its movement. Two types of treatment have been

used for plantar fasciitis: (1) pharmacological treatment such as non-steroidal anti-inflammatory drugs (NSAIDs) and a cortisone injection; and (2) physical therapy treatment such as stretching, massage, ultrasound therapy, cryotherapy, contrast bath and insertion of heel pads.

Clinical applications of microcurrents for pain management has been used in many studies and it has been demonstrated that microcurrents facilitate the production of beta-endorphin, relieve delayed onset muscle soreness and facilitate wound recovery<sup>20, 21</sup>). Although the mechanism of microcurrent in the human body is not clearly understood, it is known that microcurrent is closely related to Ca homeostasis among cells. The application of microcurrent facilitates pain relief and wound recovery by stimulating cells with electrical energy<sup>21</sup>).

In this study, 10 patients who were diagnosed with plantar fasciitis and who were all more than 50 years old were asked to wear specially constructed microcurrent induction shoes for six weeks, for more than four hours per day. After the six-week period, the degree of muscle pain was significantly

decreased. This result corresponds with the study by Smith<sup>22)</sup> who reported that the application of microcurrent on arteries and veins around the foot facilitated the relief of physiological stress and pain.

Muscle fatigue is a neuromuscular condition caused by excessively repetitive muscular action. To analyze for muscle fatigue using EMG, the MDFs were calculated using a frequency spectrum analysis. The MDF is proportional to the speed of the muscular action potential and the Type II muscle fiber activation rate<sup>23)</sup>. As the muscles become fatigued, the power of the muscles is reduced and the MDF of the frequency spectrum shifts from the high frequency band to the low frequency band. The decreased conduction speed of the muscle fibers caused by the muscle fatigue results in a reduction in Type II muscle fiber activation, with an increase Type I muscle fiber activation. This results in the MDF shifting to the low frequency band<sup>24–29)</sup>. Traditionally, frequency spectrum analysis has been carried out by recording the EMG signals during isometric contractions. However, Masuda et al.<sup>30)</sup> and Shin et al.<sup>31)</sup> have demonstrated that it is also possible to perform frequency spectrum analysis during isotonic contractions. Masuda et al.<sup>30)</sup> investigated the effect of contraction types on muscle fiber conduction velocity (MFCV), median frequency (MDF) and mean amplitude (AMP) of surface EMG in the vastus lateralis of 19 healthy male adults. Their results showed that MDF decreased during both isometric and isotonic contractions<sup>30)</sup>. Similarly, Shin et al.<sup>31)</sup> hypothesized that surface EMG data from both isometric and isotonic exercise can detect changes in the integrated EMG (iEMG) and the MDF of the elbow flexors and knee extensors following a 12-week strength training program. They concluded/suggested that the EMG data (iEMG and MDF) obtained during isometric and isotonic contractions of the muscles are similar<sup>31)</sup>. Frequency spectrum analysis under dynamic conditions have also been investigated during repeated eccentric-concentric muscle contractions of plantar flexors in patients with stroke<sup>32)</sup>, in the upper esophageal sphincter-opening muscles during head lift exercise<sup>33)</sup> in healthy elderly subjects, and in the biceps brachii of normal young male subjects<sup>34)</sup>. Therefore, in our study the frequency spectrum analysis for muscle fatigue was also performed under dynamic conditions during walking.

The results of this study show that there was a significant reduction in fatigue in the tibialis anterior muscle but not in the soleus muscle between the initial testing and at six weeks later. During initial contact (heel strike) of normal gait, the tibialis anterior muscle is activated, while the soleus muscle is not. At heel strike, the piezoelectric material located in the heel of the shoe is compressed, generating a certain microcurrent which is transmitted to the entire sole of the foot via the silver-threaded socks. During pre-swing and initial swing (push-off) of normal gait, the soleus muscle is activated; however, no microcurrent is generated since the piezoelectric material in the heel of the shoe is not compressed. Therefore, it is possible that the microcurrent has an effect on the tibialis anterior muscle because the design of the shoe limits stimulation to the tibialis anterior muscle only during gait activities. The results of our study clearly demonstrate that the microcurrent shoe, when it is activated in heel strike, has a significant effect in reducing fatigue in the tibialis anterior muscle. It is possible that if the design of the shoe was modified to include a piezoelectric material in the forefoot area and that this was activated during the push-off phase of the gait cycle, fatigue in the soleus muscles might also be significantly reduced. However, further testing and modification of the shoe will be necessary to evaluate this hypothesis.

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