

## Use of Low-Frequency Electrical Stimulation for the Treatment of Plantar Fasciitis

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**Background:** Recent research has discussed the use of low-frequency electrical stimulation to increase blood flow by eliciting muscular contraction in soft tissues. This randomized clinical trial examined the efficacy of low-frequency electrical stimulation combined with stretching exercises and foot orthoses in individuals diagnosed as having plantar fasciitis for less than 6 months.

**Methods:** Twenty-six participants aged 18 to 65 years diagnosed as having plantar fasciitis were randomly assigned to two treatment groups: a control group receiving only stretching and orthoses and a treatment group receiving low-frequency electrical stimulation in addition to stretching and orthoses. To assess treatment response, a visual analog scale was used to determine first-step morning pain, and changes in daily activity levels were monitored by using a validated outcome measure. All of the participants were assessed before starting treatment, after 4 weeks of treatment, and 3 months after the conclusion of treatment.

**Results:** Participants in the control and experimental groups demonstrated pain reduction and improvements in functional activity levels after 4 weeks and 3 months.

**Conclusions:** Regardless of whether low-frequency electrical stimulation was used as an intervention, the use of plantar fascia-specific stretching and prefabricated foot orthoses provided short-term (3-month) pain relief and improvement in functional activity levels. (*J Am Podiatr Med Assoc* 99(6): 481-488, 2009)

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Plantar fasciitis is a common cause of heel pain.<sup>1-6</sup> More than 2 million Americans receive treatment for plantar fasciitis annually.<sup>7</sup> Plantar fasciitis is an inflammation of the plantar muscular and fascial complex resulting from overuse, trauma, or mechanical or congenital dysfunction.<sup>8</sup> Although the exact etiology of plantar fasciitis is controversial, it is generally recognized to be associated with inflammation,<sup>3, 4, 9</sup> degeneration,<sup>1, 10-12</sup> or abnormal biomechanics.<sup>3, 5, 9, 13, 14</sup>

The plantar aponeurosis is a complex ligamentous structure that possesses neurovascular and muscular components.<sup>5, 9</sup> The plantar fascia originates and intertwines with the superficial layer of in-

trinsic muscles that includes the abductor hallucis, flexor digitorum brevis, and abductor digiti minimi.<sup>5, 9</sup> In the second layer of intrinsic foot muscles, the quadratus plantae also shares its two heads of origin with the plantar fascia on the inferior surface of the calcaneus.<sup>9</sup>

Some of the most common interventions used for the management of plantar fasciitis include calf muscle stretching, plantar fascia-specific stretching, and foot orthoses. DiGiovanni et al<sup>15</sup> investigated the effects of specific plantar fascia stretching compared with calf muscle stretching. All of the participants in their study improved in functional activity levels and had decreased pain. They concluded that patients with chronic plantar fasciitis symptoms significantly improved with the use of more tissue-specific plantar fascia stretching exercises compared with calf stretching. DiGiovanni et al,<sup>16</sup> in a second study, performed a 2-year reevaluation of patients who had participated

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in the initial 8-week study comparing calf stretching with plantar fascia-specific stretching. In this follow-up study, all of the patients completed a specific plantar fascia stretching protocol and demonstrated a significant improvement in pain and level of function. The improvements were also observed in patients who were originally treated with calf stretching and in those who performed plantar fascia-specific stretches.

Several studies have assessed the clinical effectiveness of custom and prefabricated foot orthoses. Lynch et al<sup>17</sup> investigated the effectiveness of foot orthoses and steroidal and nonsteroidal injections and reported that orthoses were the most beneficial treatment. Pfeffer et al<sup>7</sup> investigated five different orthotic interventions in 200 individuals diagnosed as having plantar fasciitis during an 8-week period. The interventions included a silicone heel insert, a rubber heel insert, a felt arch support, custom orthoses, and stretching. They concluded that patients using prefabricated foot orthoses had significantly better outcomes (reduced pain and improved foot function) than groups receiving custom orthoses. Martin et al<sup>18</sup> also reported no significant differences between custom orthoses and over-the-counter arch supports in 193 individuals followed-up during a 12-week period. They did note, however, that participant compliance was greatest with custom foot orthoses. In a more recent long-term study, Landorf et al<sup>19</sup> assessed the efficacy of prefabricated and custom foot orthoses in a randomized trial with more than 134 participants followed-up for 12 months. They reported short-term benefits from using either custom or prefabricated foot orthoses, but they did not find any significant long-term benefits in pain or improved functional levels using either type of foot orthosis compared with a sham device. They concluded that custom and prefabricated devices were equally effective in alleviating pain and improving functional levels in individuals with plantar fasciitis for a 3-month period.<sup>19</sup>

Therapeutic modalities, including phonophoresis, iontophoresis, and electrical stimulation, have also been suggested as treatment interventions for plantar fasciitis. Although phonophoresis and iontophoresis are used to deliver localized anti-inflammatory medications, electrical stimulation has been proposed to enhance circulation of the involved tissues to promote healing.<sup>20, 21</sup> Several studies<sup>22-26</sup> have suggested that low-frequency electrical stimulation at a rate ranging from 7 to 50 pulses per sec can be used to increase blood flow without irritating the involved tissues by eliciting muscular contractions. Nordenström<sup>27</sup> used electrical stimulation to study the relationship between blood flow and muscle tissue response by using an animal model to investigate neurovascular

pathways. He concluded that the vascular system may act as an alternate neuromotor pathway and is essential for muscular contraction, which increases blood flow to tissues. Randall et al,<sup>28</sup> using an animal model and various electrical stimulation parameters, found a significant increase in skeletal muscle blood flow. Electrical stimulation frequencies of 7 and 14 pulses per sec produced the greatest amount of blood flow, while tetany and surge settings increased blood flow volume for 9 min. Tracy et al<sup>22</sup> also reported similar results in human subjects. They found that blood flow was significantly increased with frequencies of 10, 20, and 50 pulses per sec. They concluded that electrical stimulation may be an effective treatment for vascular-related conditions. Cramp et al<sup>23</sup> investigated the effects of high- and low-frequency stimulation on 30 healthy participants. Although no significant temperature changes were observed, participants receiving low-frequency electrical stimulation had a significant increase in blood flow that peaked at 12 min. They concluded that low-frequency electrical stimulation increased blood circulation.

Because musculature is an integral component of the plantar fascial complex, it follows that optimal blood flow would be crucial in the healing of the plantar fascia and related soft-tissue structures. Low-frequency electrical stimulation has been shown to increase blood flow and enhance tissue healing in a noninvasive manner. However, no studies to date, to our knowledge, have examined the efficacy of low-frequency electrical stimulation as an adjunct treatment for plantar fascia symptoms. The purpose of this study was to examine the efficacy of low-frequency electrical stimulation combined with nonweightbearing plantar fascia-specific stretching exercises and prefabricated foot orthoses for the treatment of plantar fasciitis. We hypothesized that individuals who received low-frequency electrical stimulation would report lower levels of pain and higher levels of daily activity at the end of the 4-week treatment period and at a 3-month follow-up visit.

## Methods

### Patients

Twenty-six volunteers aged 18 to 65 years who had plantar fascia symptoms for at least 1 week but not longer than 6 months were recruited to participate in this clinical trial. Local physicians who had previously diagnosed the individual with plantar fasciitis referred all potential participants to the principal investigator (M.S.). A human subjects review board approved the protocol for the study, and all of the participants

provided written informed consent before their acceptance into the study.

Patients selected for the study met the following screening criteria: 1) no history of physical therapy for plantar fasciitis in the past month; 2) no history or diagnosis of circulatory conditions; 3) no foot abnormalities, including diabetes, gout, nerve impingement, tarsal tunnel syndrome, tumors, stress fracture, autoimmune disease, pitting edema, lower-extremity referred pain, previous plantar fascia surgical procedures, and corticosteroid injections in the past 12 months; and 4) participation in athletic activity 5 or more days per week for more than 90 min per day. Patients were also excluded if they had any orthopedic or neurologic impairment that prevented a symmetrical walking pattern, if they presented with an antalgic gait that was not attributed to plantar fascia pain, or if they were physically unable to perform the plantar fascia-specific stretches or to properly position the low-frequency electrical stimulation electrodes.

## Procedures

**Outcome Measures.** This study was an experimental randomized trial that required participants to complete self-administered outcome measures of pain and function. To assess pain levels associated with the first step out of bed each morning, all of the patients completed a visual analog scale scored from 0 (no pain) to 100 (worst possible pain) marked by the participant on a 10-cm (100-mm) line. This scale has been established as a reliable and valid instrument to measure acute and chronic pain.<sup>29,30</sup>

To assess functional activity levels, participants were asked to record their ability to perform daily activities using the Activities of Daily Living subscale of the Foot and Ankle Ability Measure (ADL/FAAM).<sup>31</sup> The ADL/FAAM has been shown to be a valid and reliable measure of function in individuals with leg, foot, and ankle musculoskeletal disorders. The ADL/FAAM identifies 20 daily activities, and participants rate their ability to complete each activity based on a scale ranging from no difficulty to inability to complete. Individual participant responses to the ADL/FAAM questions were converted to numerical scores using a 5-point scale, with 1 indicating no difficulty in performing the described task and 5 indicating inability to perform the task. Thus a lower ADL/FAAM score indicates a higher functional activity level. Each patient's responses were averaged to generate one numerical score for each ADL/FAAM assessment. The ADL/FAAM can be downloaded free of charge from <http://www.healthsciences.duq.edu/pdf/FAAM12-051.pdf>.

**Study Procedures.** Participants were required to attend four clinical visits consisting of 1) an initial visit for the baseline evaluation and therapy instructions, 2) a second visit to monitor compliance during the first week of treatment, 3) a third visit for an evaluation at the end of the fourth week of treatment, and 4) a follow-up evaluation 3 months after the end of the 4-week treatment period. To remunerate the patients for their participation in the study, each participant was paid \$100 at the completion of the study. All of the participants received a treatment log and instructions on how to complete it.

During the initial clinic visit, the Beighton Index<sup>32</sup> was used to screen each participant for excessive soft-tissue mobility. Tarsal tunnel syndrome was ruled out by using the dorsiflexion-eversion test as described by Kinoshita et al.<sup>33</sup> Once admitted to the study, participants were randomly assigned to the control or experimental group by an individual not involved with the study.

All of the participants were fitted with a pair of prefabricated foot orthoses (BFO model 6822; AliMed Inc, Dedham, Massachusetts) and were required to wear them for at least the first month of the study and were also encouraged to wear them for the remainder of the study. Any patient with prescribed or any other type of foot orthosis was required to use the study prefabricated foot orthosis for the first month instead of their own personal orthosis. Patients also were encouraged to continue using the prefabricated foot orthoses for the remainder of the study. Compliance with the use of the prefabricated foot orthoses was recorded in the treatment log and with a question on the ADL/FAAM.

All of the participants were also instructed in the plantar fascia-specific stretching protocol as described by DiGiovanni et al.<sup>15</sup> Each patient was provided with a demonstration of the stretching protocol (Fig. 1). Patients were instructed to hold each stretch for 10 sec before releasing it, and each stretch was repeated ten times. All of the participants were directed to complete the entire set of stretches three times daily and to note the time they completed each set of stretches in the treatment log.

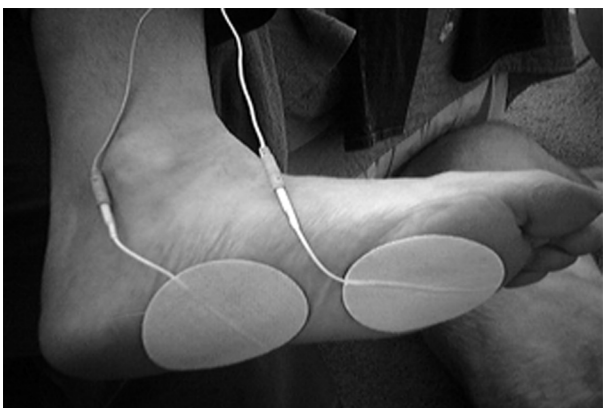
Participants who were assigned to the experimental group were also instructed in the application of low-frequency electrical stimulation. Before beginning low-frequency electrical stimulation treatment, experimental group participants were instructed to first clean the bottom of their foot with soap and water and then to dry the foot thoroughly with a clean towel. Self-adhesive electrodes were then positioned on the plantar surface of the foot just proximal to the metatarsal heads and immediately over the ori-



**Figure 1.** Position used for plantar fascia–specific stretching exercises.

gin of the plantar fascia (Fig. 2). After a demonstration of the low-frequency electrical stimulation unit (model NT2000 stimulators; Rehabicare, New Brighton, Minnesota), each participant was instructed to turn the unit on and to increase the intensity of the electrical stimulation until they felt a moderate contraction or pulsing action that was comfortable. The low-frequency electrical stimulation unit was preprogrammed by the principal investigator (M.S.) to provide a rate of contraction of 10 pulses per sec and to turn off automatically after 20 min of treatment. Patients were shown how to properly store the unit and electrodes and were asked to perform the low-frequency electrical stimulation treatment in the evening before performing their last set of stretches. They again were reminded to complete the treatment log after each low-frequency electrical stimulation treatment.

Within 1 week of the initial visit, all of the patients



**Figure 2.** Placement of the self-adhesive electrodes for low-frequency electrical stimulation treatment.

were required to return to the clinic to assess their ability to perform the stretching and low-frequency electrical stimulation protocol and to answer any questions. Each patient was also asked to demonstrate the stretching and, if necessary, the procedures for applying the low-frequency electrical stimulation. They also presented their treatment logs for review.

All of the patients returned to the clinic 4 weeks after their initial visit. At this time, they turned in their treatment log, and they were asked to complete the outcome measures. Patients returned for the final follow-up evaluation 3 months after the end of the 4-week treatment period, and they completed the outcome measures for the last time.

## Data Analysis

In addition to descriptive statistics, *t* tests were performed to determine whether differences existed in age or body weight between the control and experimental treatment groups. Pearson correlation coefficients were also calculated to assess whether age and body weight were associated with visual analog scale and ADL/FAAM scores. A 2-way mixed-model analysis of variance was conducted to determine differences between the control and experimental treatment groups for the variables visual analog scale and ADL/FAAM recorded at the time of the initial evaluation, after 4 weeks of treatment, and at 3-month follow-up. An  $\alpha = .05$  was used for all tests of significance.

## Results

Demographic data for all 26 participants are listed in Table 1. The control and experimental groups were each assigned 13 participants. The mean duration of symptoms for the control and experimental groups were 114 and 98 days, respectively. Based on the results of the *t* tests, neither age ( $P < .06$ ) nor body weight ( $P < .59$ ) was significantly different between the control and experimental groups. In addition, Pearson correlations between age or body weight and visual analog scale as well as ADL/FAAM scores were not statistically significant. Based on these results, patient age and body weight were not considered as covariates in further statistical analyses of the data.

No significant main effect differences were found between the control and experimental groups for visual analog scale scores (Table 2). The visual analog scale values after 4 weeks of treatment were significantly different compared with the initial evaluation values ( $P < .005$ ). Visual analog scale scores at the 3-month follow-up compared with the baseline scores were also significantly different ( $P < .0001$ ).

**Table 1. Demographic Data for the Control and Experimental Groups**

Group	Age (y)	Body Weight (pounds)	Duration of Symptoms (d)
Control (n = 13)	45.0 ± 10.8	185.0 ± 35.9	114.0 ± 44.0
Experimental (n = 13)	37.0 ± 10.8	203.3 ± 41.1	98.0 ± 63.0

Note: Data are given as mean (± SD).

**Table 2. Visual Analog Scale Scores for First-Step Morning Pain**

Group	Initial Visit	After 4 wk of Treatment	At 3-mo Follow-up
Control (n = 13)	48.6 ± 25.6	37.0 ± 26.0	22.3 ± 21.3
Experimental (n = 13)	54.0 ± 23.4	32.9 ± 27.7	17.3 ± 21.6

Note: Data are given as mean (± SD).

The ADL/FAAM scores were not significantly different between the experimental and control groups (Table 3). Although ADL/FAAM scores after 4 weeks of treatment were significantly different compared with initial evaluation values ( $P < .0001$ ), scores after 4 weeks of treatment compared with 3-month follow-up scores were not significantly different.

## Discussion

The intent of this study was to determine the efficacy of low-frequency electrical stimulation combined with plantar fascia-specific stretching and prefabricated foot orthoses in the treatment of plantar fasciitis. We hypothesized that individuals who received low-frequency electrical stimulation would report lower levels of pain and higher levels of daily activity at the end of the 4-week treatment period and at a 3-month follow-up visit.

There were no differences between the control and experimental groups in visual analog scale scores. Both groups, however, demonstrated significant reductions in visual analog scale pain levels from baseline to 3-month follow-up. There were also no differences between the control and experimental groups in ADL/FAAM scores. Both groups demonstrated a significant increase in daily activity levels after 4 weeks of treatment, but unlike the visual analog scale

results, a continued increase in daily activity levels was not observed from the end of the 4 weeks of treatment to the 3-month follow-up. These findings indicate that regardless of whether low-frequency electrical stimulation was used, plantar fascia-specific stretching and prefabricated foot orthoses provided short-term pain relief (up to 3 months) and improved levels of functional activity (up to 1 month) for all of the participants in this study. Based on these results, the efficacy of low-frequency electrical stimulation in the management of patients with plantar fasciitis is questionable.

The findings of this study are consistent with results previously reported that have suggested that treatment interventions for plantar fasciitis, in general, provide short-term symptom relief and function improvement. Gudeman et al<sup>2</sup> reported that iontophoresis significantly decreased pain and improved function on a short-term (2- to 4-week) basis. Similarly, Osborne and Allison<sup>34</sup> also reported short-term improvements (up to 4 weeks) in pain and function using iontophoresis for individuals diagnosed as having plantar fasciitis.

Pfeffer et al<sup>7</sup> reported that individuals diagnosed as having plantar fasciitis who were managed with prefabricated inserts and stretching had significantly decreased pain levels when followed during an 8-week period. More recently, Landorf et al<sup>19</sup> reported a signif-

**Table 3. Ratings for the Activities of Daily Living Subscale of the Foot and Ankle Ability Measure**

Group	Initial Visit	After 4 wk of Treatment	At 3-mo Follow-up
Control (n = 13)	52.3 ± 17.1	37.3 ± 12.1	32.3 ± 14.4
Experimental (n = 13)	52.2 ± 13.8	34.4 ± 13.3	32.3 ± 13.4

Note: Data are given as mean (± SD).

icant improvement in pain and function in individuals diagnosed as having plantar fasciitis after using either custom or prefabricated foot orthoses during a 3-month period. They also found that after 1 year, there was no significant improvement in pain and function with the use of either type of foot orthoses.

Specific plantar fascia stretching is one of the few interventions that has demonstrated short- and long-term treatment effectiveness. DiGiovanni et al<sup>15</sup> studied the short-term (2-month) use of plantar fascia-specific stretching and reported significant reductions in pain and improvements in levels of activity. In a 2-year follow-up study using the same patients who participated in their initial study, DiGiovanni et al<sup>16</sup> reported that patients who continued to perform plantar fascia-specific stretching continued to show improvement in pain and function.

Despite the fact that the present study could not demonstrate that the application of low-frequency electrical stimulation was no more effective in reducing morning pain and increasing daily levels of activity compared with stretching and foot orthoses alone, several factors could have affected the results. It is possible that the procedure used for washing and drying the involved foot before application of the low-frequency electrical stimulation electrodes did not sufficiently decrease skin resistance, and thus affected the conductance of the electrical current. Previous researchers studying the effects of low-frequency electrical stimulation have used frequencies of 7 to 50 Hz (pulses per second). As such, we selected a low-frequency electrical stimulation frequency of 10 Hz or pulses per second for all of the participants in this clinical trial because this frequency was at the lower end of the range of frequencies previously reported. It is possible that a higher frequency for the application of the low-frequency electrical stimulation might have produced different outcomes. In addition, although the instructions provided to participants using low-frequency electrical stimulation indicated that they should adjust the intensity of the electrical current until only a moderate contraction or pulsing motion was observed, it is possible that certain individuals either adjusted the intensity to be either too much or not enough, thus affecting the effectiveness of the low-frequency electrical stimulation to provide an increase in blood flow. Although this potential issue with the intensity of the low-frequency electrical stimulation could have been managed more effectively if all of the participants in the experimental group were given their daily treatment in the clinic under direct supervision, we believed it was critical that the study protocol require a minimum number of clinic visits and that the low-frequency electrical stimulation treat-

ment be completed at home or at work to optimize patient compliance.

As previously noted in the "Results" section, the age of the participants was not significantly different between the control and experimental groups. Thus patient age was not considered as a covariate in any further statistical analyses of the data in the present study. It is important to note, however, that age has been identified as a factor in the development of chronic plantar heel pain. Irving et al<sup>35</sup> reported in a systematic review of factors associated with chronic plantar heel pain that there is evidence to support an association between increased age and chronic plantar heel pain. They further note that the association between age and the symptoms of chronic plantar heel pain increases up to approximately 60 years of age and then declines with increasing age.<sup>35</sup>

An important factor for the success of this clinical trial was the compliance of the patients assigned to the control and experimental groups. To monitor compliance, all of the participants were asked to record the time and date when they completed daily treatments in a treatment log. Patients also recorded their compliance with use of the prefabricated foot orthoses in the treatment log. Throughout the study, the principal investigator (M.S.) maintained frequent communication with all of the patients. On the basis of the examination of patient treatment logs, we determined that patient compliance was acceptable. The high level of compliance in this study was expected because the treatment protocol was simple for patients to complete and the protocol could be completed at home, thereby preventing frequent clinic visits. Motivation was also enhanced with monetary remuneration that was provided to all of the participants who were determined to be compliant with the study protocol.

Further research on the efficacy of low-frequency electrical stimulation should address the issues of plantar skin resistance, higher frequencies of application, and standardization of the applied electrical stimulation intensity with larger patient populations. It is possible that the effectiveness of the stretching protocol and use of the prefabricated foot orthoses, in conjunction with the small number of participants assigned to each group, may have contributed to the difficulty in establishing whether low-frequency electrical stimulation was an effective treatment. In addition, future studies should consider a long-term study design that includes a greater number of participants and with only one treatment variable assigned to each experimental group.

The inclusion and exclusion criteria in this study were established to exclude individuals with chronic

plantar fasciitis. For this study, an individual with heel pain with a duration of longer than 6 months was defined as having chronic plantar fasciitis. As a result, the participants in this study may have presented with symptoms more amenable to treatment than the average patient with plantar fasciitis. In addition, the referring physicians for this study may have referred a more active, healthier, and more compliant patient group compared with the general population.

## Conclusions

This study theorized that patients diagnosed as having plantar fasciitis who received low-frequency electrical stimulation in conjunction with specific plantar fascia stretching and prefabricated basic foot orthoses would report lower levels of pain and higher levels of daily activity at the end of the 4-week treatment period and at a 3-month follow-up visit. The findings of this study suggest that regardless of whether low-frequency electrical stimulation was used in the treatment program, plantar fascia stretching and prefabricated basic foot orthoses provided short-term pain relief (up to 3 months) and improvements in functional activity levels (up to 1 month) for all of the participants in this study. Based on these results, the efficacy of using low-frequency electrical stimulation in the management of patients with plantar fasciitis is questionable.

**Financial Disclosure:** None reported.

**Conflict of Interest:** None reported.

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