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Original Research

Effect of Extracorporeal Shockwave Therapy on Passive Ankle Stiffness in Patients With Plantar Fasciopathy

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A B S T R A C T

Plantar fasciopathy (PF) is the most common cause of heel pain. Extracorporeal shockwave therapy (ESWT) improves the gait pattern in patients with PF. However, the effects of ESWT on the biomechanics of the ankle in these patients remains unclear. Sixteen participants were included in the present study. Of the 16 participants, 8 patients with PF were assigned to receive extracorporeal shockwave therapy, and 8 healthy participants served as an external control group. ESWT was applied to the PF group for 1500 pulses at an energy flux of 0.26 mJ/mm^2 every 3 weeks for 3 sessions. The biomechanics of the ankle joints were then assessed using an isokinetic dynamometer, and a health-related quality of life questionnaire was administered at baseline and at the final follow-up session 12 weeks after the initial treatment. Passive stiffness was calculated and compared between the foot affected with PF, the opposite foot, and both feet of those in the healthy control group. The Kruskal-Wallis 1-way analysis of variance with repeated measures was performed, and statistical significance was considered present at the 5% ($p \leq .05$) level. Ankle dorsiflexion in the affected limb increased from 14° ± 3° to 17° ± 2° after ESWT ($p < .05$). No statistically significant differences were noted in the strength of dorsiflexion or plantarflexion at baseline and after ESWT. However, a statistically significant increase in the ratio of strength in ankle dorsiflexion versus plantarflexion was found after ESWT ($p < .05$). No differences in the passive stiffness of the ankle joint were demonstrated. Patients reported an improved physical function score after ESWT ($p < .05$). An increased dorsiflexion/plantarflexion torque ratio and maximal dorsiflexion associated with decreased pain might contribute to the improved physical function after ESWT for PF.

Plantar fasciopathy (PF), a chronic debilitating disorder usually seen in middle-age adults, affects the insertion of the plantar fascia over the heel (1). Tightness of the calf muscles and Achilles tendons, a poor landing strategy, and excessive foot pronation have all been associated with PF (2–7). The plantar fascia exerts simultaneously with the calf muscle, which functions in a manner analogous to a “windlass” mechanism, elevating the arch of the foot (8). A windlass tightens a cable or rope, and the plantar fascia simulates a cable attached to the calcaneus and the metatarsophalangeal joints. During the propulsive phase of gait, dorsiflexion winds the plantar fascia around the head of the metatarsal, shortening the distance between the calcaneus and the metatarsals and raising the medial longitudinal arch.

Passive stiffness in the ankle joint reflects the elasticity of the soft tissue (9). A stiff ankle joint resulting from spasticity or limited range of motion can interfere with normal activity (10–12). Specifically, myofascial restrictions in the muscles of the calf can interfere with the extensibility of the muscles or the fascia and result in increased stiffness (13). Stretching the gastrocnemius muscles and the plantar fascia has been effective in decreasing stiffness and is useful for short-term management of plantar heel pain (14–16).

Apparently pain and restricted range of motion in the joint have reciprocal roles. In 1 study, long-term sole pain in PF patients was associated with a shift in the center of body weight toward the asymptomatic foot, which might have resulted in decreased movement and range of motion in the ankle (17).

Extracorporeal shockwave therapy (ESWT) is a treatment alternative for patients with recalcitrant PF (18,19). ESWT has been reported to

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improve health-related quality of life (QoL) in PF patients (18,20). In addition, as we have previously shown, ESWT improves the gait parameters of the symptomatic foot in PF patients (18,21). However, little information has been available about the passive stiffness and kinematics of the ankle joint after ESWT. We designed a study to investigate the effects of ESWT on patients with recalcitrant PF, specifically by evaluating the effects on ankle muscle strength and stiffness on patients' quality of life. We believed that ESWT would result in improved ankle function and better QoL in patients with recalcitrant PF.

Patients and Methods

From January 2011 to December 2013, a series of 8 consecutive patients with recalcitrant unilateral PF from orthopedic clinics in Chang Gung Memorial Hospital, Chia Yi, and 8 age- and sex-matched healthy individuals from the community around the hospital were enrolled in the present study. The patients rated their pain on a visual analog scale (VAS), with 0 cm denoting no pain and 10 cm indicating maximum pain (22–24).

The inclusion criteria were localized tenderness near the insertion of the plantar fascia over the medial calcaneal tuberosity, with exacerbation of symptoms after a period of non-weightbearing; and symptoms lasting >6 months. The exclusion criteria were bilateral PF; comorbid conditions interfering with foot sensation, such as diabetes mellitus and peripheral arterial occlusive disease; and previous surgery involving the spine, hip, knee, or ankle. The control group included age- and sex-matched participants recruited from the neighborhood community around hospital.

Our institutional review board approved the present study (approval no. 98–1746B), and all study participants provided informed consent to be involved in the study. All patients underwent ankle muscle strength, stiffness, and QoL and pain VAS assessments before the first ESWT session and 12 weeks after the initial treatment. The pain VAS and QoL assessments were performed by 1 of us (C.-H.F.). Isokinetic muscle strength testing was performed by another author (P.-A.Y.). The stiffness was calculated by another 1 of us (L.-T.K.). Data processing and statistical analysis were performed by 2 of us (C.-L.C., L.-J.L.). Finally, ESWT was performed by the first author (W.-H.H.).

ESWT Protocol

ESWT was administered in 3 sessions, scheduled 3 weeks apart (25). A total of 1500 shock waves were delivered per session using a Dornier Epos Ultra system (Dornier MedTech GmbH, Wessling, Germany) at an energy flux density of 0.26 mJ/mm^2 and a rate of 1 Hz, without any local anesthesia. Before the intervention, the point of maximum tenderness over the calcaneal medial tubercle was located by applying thumb pressure over the hindfoot of each patient, moving medially to laterally and then distally to proximally. The maximal area of tenderness was usually located at the medial calcaneal tubercle and was where ESWT was subsequently applied.

QoL Assessment

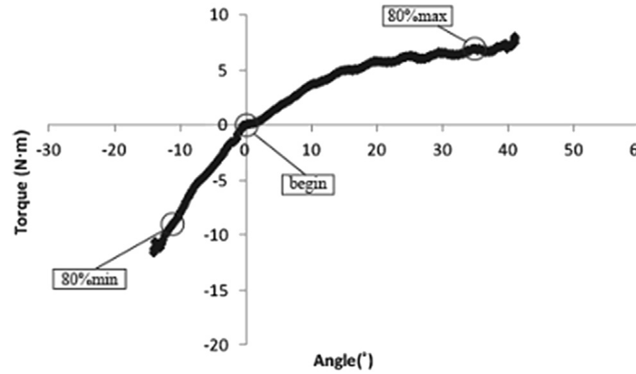
QoL was assessed using the Short-Form 36-item Health Survey (Taiwan version) (26). The Short-Form 36-item Health Survey is a multipurpose questionnaire that is commonly used in clinical practice to evaluate patients' QoL. A total of 8 domains are evaluated, including physical functioning, role limitation due to physical problems, bodily pain, general health, vitality, social functioning, role limitation due to emotional problems, and mental health. Additionally, the 8 health domains can be used to provide a physical component summary score and mental component summary score.

Muscle Strength and Stiffness Assessments

For the muscle strength measurement, the subjects were placed supine with their ankle joint strapped to a HUMAC® NORM™ Testing and Rehabilitation System (Computer Sports Medicine, Inc., Stoughton, MA). Ankle dorsiflexion and plantarflexion function was tested with the patient supine. Initially, the ankle joint was placed in a neutral position (0° dorsiflexion) and the subject's knee was supported in 90° of flexion. After 5 conditioning cycles were completed, the maximal range of motion and the corresponding measurement of torque by load cell were recorded. Passive stiffness was calculated as the change in torque divided by the change in angles as the HUMAC® NORM™ Testing and Rehabilitation System (Computer Sports Medicine, Inc.) moved the ankle joint from the neutral position to 80% of the maximum range of plantarflexion and dorsiflexion. This was performed at a constant angular velocity of 25°/s (27) (Fig); 25°/s is the speed typically recorded at the ankle joint during the stance phase of normal relaxed gait (28). The isokinetic torque of the ankle dorsiflexors and plantarflexors were measured with the mode of concentric/concentric contraction at the angular velocity of 60°/s (29,30). The measurements were performed by the same observer (C.-H. F.).

Statistical Analysis

Kruskal-Wallis 1-way analysis of variance with repeated measures was performed to compare the differences between the initial measurements and final follow-up measurements after ESWT for both feet of the PF patients and those in the control group. Multiple comparisons were performed using Dunn's test. A Mann-Whitney *U* test was used to compare the sound foot and affected foot among the patients in the PF group. The statistical software SPSS Statistics for Windows, version 17.0 (IBM Corp., Armonk, NY) was used for analysis. Statistical significance was assumed at $p < .05$. All values are presented as mean ± standard deviation. The sample size calculation was based on the model of stochastic superiority within the Kruskal-Wallis 1-way analysis for the primary outcome measure of the ankle isokinetic muscle strength ratio, with an α (2-sided) of 0.05 and a power of 80%. A relevant Kruskal-Wallis effect size of 6.38 was calculated.



$$\text{stiffness}_{\text{plantar flexion}} = \frac{\Delta\,\text{Torque}}{\Delta\,\text{Angle}} = \frac{\text{Torque}_{80\%\text{max}} - \text{Torque}_{\text{begin}}}{\text{Angle}_{80\%\text{max}} - \text{Angle}_{\text{begin}}}$$

$$\text{stiffness}_{\text{dorsi flexion}} = \frac{\Delta\,\text{Torque}}{\Delta\,\text{Angle}} = \frac{\text{Torque}_{\text{begin}} - \text{Torque}_{80\%\text{min}}}{\text{Angle}_{\text{begin}} - \text{Angle}_{80\%\text{min}}}$$

Fig. Schematic representation of the passive stiffness of ankle in continuous passive mode.

Results

A total of 16 participants were enrolled in the present study: 8 patients with PF and 8 healthy controls. Those in the patient group reported having had symptoms for a mean of 9.3 (range 6 to 15) months. The demographic characteristics were similar in both groups (Table 1). The PF group had a mean age of 54 (range 43 to 65) years and a mean body mass index of 28 ± 5 kg/m^2. The control group had a mean age of 53 (range 49 to 57) years and a mean body mass index of 27 ± 1 kg/m^2 (Table 1). The mean VAS score in the PF group had decreased significantly from 6 ± 2 at baseline to 3 ± 2 at the final follow-up after ESWT ($p = .41$; Table 2).

Dorsiflexion of the ankle of the affected limb was significantly more limited in the PF patients than that in the control group (14° ± 3° versus 17°± 3°, respectively; $p = .03$; Table 3). After ESWT, the dorsiflexion of the ankle had increased to 17° ± 2° among the PF group ($p = .04$), similar to that in the control group ($p = .937$). A similar trend was observed for plantarflexion of the ankle in the sound limbs. However, passive stiffness in the patient group was similar at baseline and after ESWT and in the control group (Table 3).

During the isokinetic muscle strength assessment, no statistically significant differences were detected between the baseline and after ESWT values in plantarflexor and dorsiflexor torque. When the strength of ankle dorsiflexion/plantarflexion ratio was calculated and compared, a significant increase was revealed after ESWT (Table 4).

In the QoL assessment, the bodily pain score had increased from 46 ± 12 to 56 ± 6 ($p = .01$) after ESWT, indicating less pain, but was still not as high as the 92 ± 15 measured in the control group ($p < .001$; Table 5). Similar findings were demonstrated in the physical component summary score, which increased from 42 ± 6 to 46 ± 4 ($p = .04$) after ESWT but was still less than the 55 ± 5 reported in the control group ($p = .03$). No significant differences between the 2 groups were found in the mental component summary score.