IOSR Journal of Nursing and Health Science (IOSR-JNHS)
e-ISSN: 2320–1959.p- ISSN: 2320–1940 Volume 8, Issue 3 Ser. II. (May. - June .2019), PP 48-54
www.iosrjournals.org

Efficacy of Extracorporeal Shock wave and Ultrasound on plantar fasciitis pain

[1]Abeer Mahmoud Yousef,Shaimaa ElGhareb[2]

1 Cairo Universitiy, Physical Therapy Faculty, Department of Basic Science, Cairo,Egypt.

2 Cairo Universitiy, Physical Therapy Faculty, Department of Basic Science, Cairo,Egypt.

Correspondence Author:Abeer Mahmoud Yousef

E-mail:abeer.mahmoud28@yahoo.com

Abstract:*The objective of this study is to compare between shock wave and ultrasound on plantar fasciitis pain. In this study, we determined the effects of both physical modalities as shock wave and ultrasound in treatment of plantar fasciitis pain. There is lack in the literature review to establish the effectiveness of shock wave and ultrasound therapy when compared to each other in treatment of plantar fasciitis. Forty subjects with plantar fasciitis (PF) were randomly assigned into two equal groups with twenty subjects in each group. Group A: twenty female subjects with plantar fasciitis received ultrasound and Stretching and strengthening Exercises. Group B: twenty female with plantar fasciitis received shock wave and Stretching and strengthening Exercises. Paired t-test was used, pretest and posttest within groups. Unpaired t-test pretest and posttest between both groups.Ultrasonographic evaluation for Planter fascia thickness was carried out before and after the therapy. Pain intensity was assessed using visual analogue scale, and then patients were asked to consider the following questions of foot ankle disability index two times before and after treatment.The results indicated that both extracorporeal shock wave and ultrasound are effective in decreasing the plantar fasciitis pain (decreasing the values of visual analogue scale and Planter fascia thickness and increasing the values of foot ankle disability index). However, no statistical differences were found between both groups.The finding revealed that both ultrasound and extracorporeal Shock wave are effective in decreasing the PF pain, Shock wave therapy is more advantageous over ultrasound therapy. As it allows to obtain a similar analgesic effect by using less treatments sessions, which decreases the overall cost of the therapy.*

Key Words: *Ultrasound, Shockwave, Planter fasciitis. Visual analogue scale, Foot Ankle Disability Index*

Date of Submission: 08-05-2019Date of acceptance: 23-05-2019

I. Introduction

Plantar fasciitis is a disorder that results in pain in the heel and bottom of the foot (1). It involves frequent load on the plantar fascia that results in micro traumas that can eventually lead to inflammation and degeneration of the connective tissue in the fascia (2). Its incidence occur most common in middle-aged obese females and young male athletes (4) and is usually seen as an overuse injury in athletes, runners in particular (accounting for nearly 10% of running injuries), but is also seen in the general population. (7). A retrospective study with 2002 runners, showed that plantar fasciitis (PF) was the third most common injury in runners (3). Plantar fasciitis is a common cause of heel pain (5, 6).

Long-lasting pain might impair walking and cause spinal pain. It may reduce the patient's mobility and make everyday and free time activities as well as professional work almost impossible to be performed. Patients are not able to do their professional work activities. In the most extreme cases they are not able to function properly. Hence, fast and effective therapy, such as prevention of obesity and musculoskeletal overload of the feet, is crucial. Hence, fast and effective treatment, accompanied by education of the patient is essential (8).

Extracorporeal shock wave therapy (ESWT) is a noninvasive procedure used in rehabilitation therapy that is recently being applied in the treatment of tendinopathies and also PF (9).In ESWT, shock waves are generated by means of electrohydraulic, piezoelectric, and electromagnetic methods. There are some possible mechanisms mentioned for the efficacy of shock wave therapy. The transmitted waves may have effects on physiology of pain receptor(10), and also, through microtrauma, they may initiate healing processes by the release of molecular agents and growth factors leading to neovascularization(11).

Entering mechanical impact of these waves in target area causes to increase the permeability in cell membrane and neovascularization in created small cavities by pulses in the tissue. The result of this process is the reduction in sensitivity of pain receivers and improvement of dying tissues. In the form of focused shock wave, the waves have short wavelength and high penetration depth and energy. Generated waves concentrate in a focal point away from the applicator's surface and import the highest energy in that point, therefore, it is used to treat different areas in the body (deep and superficial) such as pains of lateral epicondylitis and classifying tendons (12).

One of the most widely used electrical devices among physical therapists worldwide is therapeutic ultrasound (13). Therapeutic ultrasound raises tissue temperature and metabolism, softens the tissues, increases blood circulation, increases the chemical activity of the tissues, increases the permeability of the cell membranes, and modulates the molecular structures and the rate of pulsation and protein production—all potentially affecting the speed of tissue recovery (14).

Therapeutic ultrasound is used routinely by podiatrist's physiotherapists, and is prescribed by physicians in their treatment of plantar fasciitis and plantar heel pain (15). There is lack in the literature review to establish the effectiveness of extracorporeal shock wave and ultrasound therapy when compared to each other in treatment of PF.

II. Materials And Methods

2.1Participants:

Forty female subjects participated in the study. Their ages ranged from 40-50 years, their weights ranged from 50 - 80 and their heights ranged from 155 - 170 cm(16). This study was done in Buraidah Central Hospital. .The subjects were randomly divided into two equal groups. Group I received USandStretching and strengthening Exercises, group II received Extracorporeal Shock waveandStretching and strengthening Exercises. All participants met the inclusion criteria.

2.2Inclusion criteria:

Patients complaining from pain at the bottom of the heel, with the following clinical features: (1) a gradual development of pain (with no trauma), (2) pain generated by carrying weight or by local pressure, (3) an increase in pain in the morning upon taking a few steps or after prolonged non–weight bearing, and (4) symptoms decreasing with slight levels of activity, such as walking. Additional criteria were a visual Analogue scale (VAS) score for morning pain of greater than 3 (to prevent the floor effect), sensitivity or swelling in the proximal planetary region of the fascia, or medial plantar tuberosity of the calcaneal bone(14).

2.3Exclusion criteria:

Patients with diabetes, additional foot or ankle pathology (including instability, arthritis, generalized polyarthritis, diffuse heel pad tenderness), local dermatological problems, neurological abnormalities, history of recent trauma or foot surgery, connective tissue or infectious diseases, malignancy, or vasculitis and pregnant patients or those who received anticoagulant therapy in the preceding six months were not included(9).

2.4Evaluation procedure:

1-Initial assessment for height, weight was done, then calculate body mass index according to the formula, BMI= weight in Kg/ height^2 in m^2 (16).

2-Ultrasonographic evaluation was carried out before and after the therapy. Ultrasound was performed by the same radiologist, using a 10 MHz linear array transducer. Both heels of the participants were scanned in two-dimensional (2D) real-time B mode. We took care to obtain comparable views of the contralateral sides. Sagittal imaging of the plantar fascia was performed with the transducer aligned along the longitudinal axis of the aponeurosis. Quantitative evaluation of plantar fasciitis was achieved by measurement of its thickness about 2 cm distal of the medial calcaneal tuberosity. In addition, qualitative assessment including echogenic appearance of plantar fascia and its fibrillary pattern was done (9, 16).

3- Pain intensity was assessed using Visual analog scale (VAS) (17). Then patients asked to consider the following questions FADI (Foot Ankle Disability Index) two times before and after treatment. The Foot and Ankle Disability Index is a 34-item questionnaire divided into two subscales: the Foot and Ankle Disability Index and the Foot and Ankle Disability Index Sport. The FADI has twenty-six items, and the FADI Sport has eight. The FADI contains four pain related items and twenty-two activity related items. The FADI Sport contains eight activity related items. It assesses more difficult tasks that are essential to sport. The FADI Sport is unique in that it is a population-specific subscale designed for athletes. It is designed to address this need by detecting deficits in higher functioning subjects (18, 19).

2.5Allocation:

The allocation of patients to group A and group B was performed using a 10-patient block randomization software program (mahmoodsaghaei.tripod.com/Softwares/randalloc.html). The results of the randomization were recorded, placed in sealed envelopes, After signing an informed-consent form and meeting the inclusion criteria, patients were assigned to a specific group (14).

2.6Treatment procedure:

After the initial assessment, the patients were randomly divided into two groups:

Group A- Ultrasound: Twenty patients were treated with 8 minutes of therapeutic ultrasound using EME ULTRASONIC 1500 MI11030712N with at a frequency of 1 MHz and continuous current at a pulse intensity of 1.8 W/cm2 (when the sensitivity level was too high and the procedure hurt the patient, the therapist reduced the intensity),they received 8 treatments(14). The selection of the parameters was based on the recommendations of the ultrasound dose calculations website

(http://www.electrotherapy.org/modality/ultrasound-dose-calculation). The authors also used an online calculator for ultrasound dosage (http://www.sonodose.dk/SONODOSE-lite/SONODOSE-lite.htm) (14). The patients were positioned in prone lying position, with the dorsum of the foot supported on the edge of the bed, circular motion on insertion of the plantar fascia in thecalcaneus, and a gel was used to maintain contact with the skin.

Group B- Shock wave: Twenty patients were treated with Extracorporeal Shock wave device using EME SHOCK MED EM06120618, focus method with the energy of 0.25 mj/mm21000 shockwaves/ sessions were applied at an intensity of 2.5 bars, 15 Hz, the applicator was 9 mm in diameter, each session was of 15 minutes with weekly intervals of three sessions (9,12). Patients were positioned in prone, with the dorsum of the foot supported on the edge of the bed. The applicator was placed perpendicular to the insertion of the plantar fascia into the calcaneus, and a gel was used to maintain contact with the skin (20).

2.6.1Stretching and strengthening Exercises:

All patients performed exercises after US & ESWT application to stretch all posterior leg muscles and strengthen the tibialis anterior, and to maintain the normal longitudinal arch of the foot and were advised to perform active stretching of the gastrocnemius and plantar fascia at home (9,14).

In all patients, pain intensity was assessed two times: before and after treatment using Visual analog scale (VAS); patients marked a point, which corresponded to the current pain sensations. Then patients asked to consider the following questions FADI (Foot Ankle Disability Index).

III. Result

3.1 Demographic Data of the investigated subjects of both groups:

As observed in table (1), and illustrated in fig (1), the mean values of age for subjects of first and second group were (50.6±10.1 and 48.1±8.8 years) respectively. While the mean values of body mass index for subjects of first and second group were (28.8±4.1 and 29.4±4.2 Kg/m2) respectively.

Table no(1): The mean and standard deviation of age, BMI of subjects in both groups.

Parameter	Groups	X ±SD	p-value	Significance
Age±SD (years)	**A**	50.6±10.1	0.403	NS
	B	48.1±8.8		
BMI±SD (Kg/m^2)	**A**	28.8±4.1	0.812	NS
	B	29.4±4.2		

X: Mean, SD: Standard Deviation,P value: Probability value and NS: Non-significant.

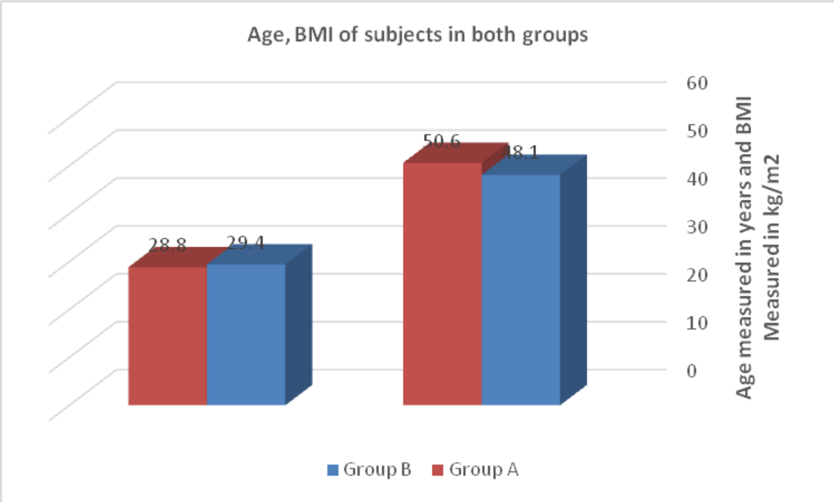

Figure no 1: age, body mass index of subjects in both groups:

3.2The Data of the investigated subjects of group A (US):

The mean values of Planter fascia thickness for subjects of first group before treatment were (4.1±1.1), While after treatment the mean values of Planter fascia thickness were (3.7±1.4). Application of paired t-test revealed significant difference where p value =0.001.

The mean values of pain for subjects of first group before treatment according to VAS were (6.6±1.14) & according to FADI the mean were (62 ±5.43).

While after treatment the mean values of pain according to VAS were (4.8±0.83) & according to FADI the mean were (83.2±9.09). Application of paired t-test revealed significant difference where p value =0.0008 & according to FADI p value=0.001 that< 0.05 which means that there is significant different before and after US as shown in Table no2 and figno2.

Table no 2: Statistical analysis of thickness of PF before and after, pain assessmentbefore/aftertreatment for Group A(US):

Group A	X	SD	P-value	Significance
Planter fascia thickness before	4.1	±1.1	0.001	S
Planter fascia thickness after	3.7	±1.4		
VAS before	6.6	±1.14	0.000844	S
VAS after	4.8	±0.83		
FADI before	62	±5.43	0.001190	S
FADI after	83.2	±9.09		

X: Mean, SD: Standard Deviation, P value: Probability value and NS: Non-significant.

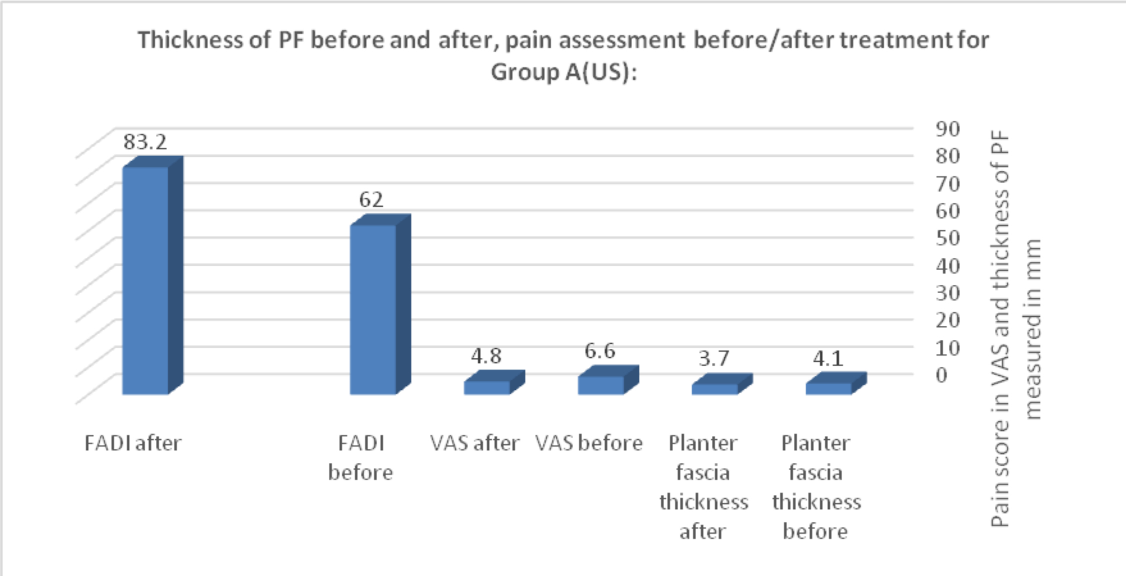

Figure no2: statistical analysis of thickness of PF before and after, pain assessment before/after treatment for group A (US):

3.3The Data of the investigated subjects of group B (Shockwave):

The mean values of Planter fascia thickness for subjects of second group before treatment were (4.0±1.3), While after treatment the mean values of Planter fascia thickness were (3.6±1.2). Application of paired t-test revealed significant difference where p value =0.001.

The mean values of pain for subjects of second group before treatment according to VAS were (6.8±0.83) & according to FADI the mean were (67.8±10.63). After treatment, the mean values of pain according to VAS were (3.8±1.09), & according to FADI the mean were (84.8±6.34).

Application of Paired t-test revealed significant difference where p value =0.005408 & according to FADI t test was 2.265 and p value=0.086140 that < 0.05 which means that there is significant different before and after Shock wave as shown in Table no 3 and fig no 3.

Table no3: Statistical analysis of thickness of PF before and after, pain assessment before/after treatment for Group B (Shock wave):

Group B	X	SD	P-value	Significance
Planter fascia thickness before	4.0	±1.3	0.001	Significant
Planter fascia thickness after	3.6	±1.2		
VAS before	6.8	±0.83	0.005408	Significant
VAS after	3.8	±1.09		
FADI before	67.8	±10.63	0.086140	Significant
FADI after	84.8	±6.34		

X: Mean, SD: Standard Deviation, P value: Probability value and NS: Non-significant.

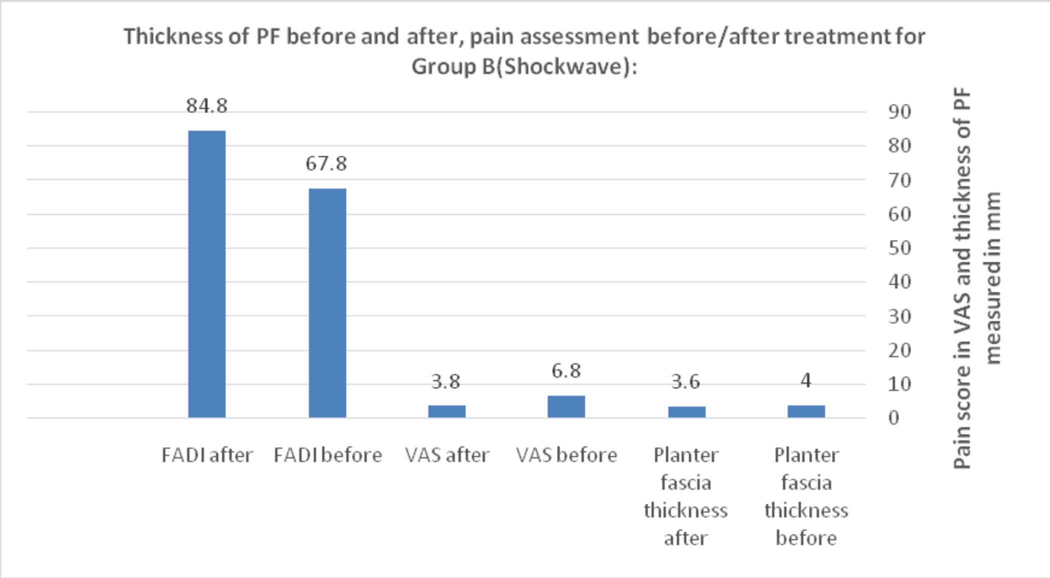

Figure no3:statistical analysis of thickness of PF before and after, pain assessment before/after treatment for group B(Shock wave):

3.4The results of the investigated subjects of group A (US) & group B (Shock wave):

After treatment for group A, the mean values of Planter fascia thickness of US group were (3.7±1.4). After treatment for group B, the mean values of Planter fascia thickness of Shock wave group were (3.6±1.2).Application of dependent t-test revealed no significant difference where p value =0.9532 that> 0.05 which mean there is no significant differences between US & Shock wave.

The mean values of pain of US according to VAS were (4.8±0.83), & according to FADI the mean were (83.2±9.09). After treatment for group B, the mean values of pain of Shock wave according to VAS were (3.8±1.09) & according to FADI the mean were (84.8±6.34). Application of dependent t-test revealed no significant difference where t value according to VAS was 3.162278 and p value =0.034109 & according to FADI, t value was 0.262825 and p value =0.805667 that > 0.05 which mean there is no significant differences between US & Shock wave as shown in Table no 4 and fig no 4.

Table no4: Statistical analysis of thickness of PF after and pain assessment after treatment for Group A&B

Variable	Group A X±SD	Group B X±SD	p-value	Significance
Planter fascia thickness after	3.7±1.4	3.6±1.2	0.9532	NS
VAS after	4.8 ±0.83	3.8±1.09	0.34109	NS
FADI after	83.2±9.09	84.8±6.34	0.805667	NS

X: Mean, SD: Standard Deviation, P value: Probability value and NS: Non-significant.

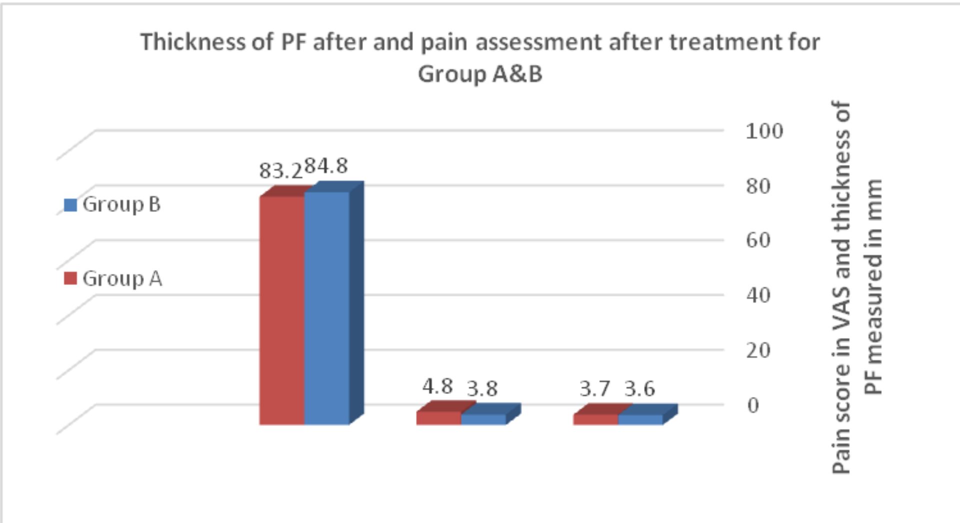

Figure4:statistical analysis of thickness of PF after and pain assessment after treatment for group A&B

IV. Discussion

Within the limitations of this study, the application of both types of treatment produced significant increment ($P < 0.0001$) decrease in plantar fasciitis pain while comparing the degreeof pain with that of before treatment. However comparing the effect of both treatment among each other's, no statistical significant differences were found between both types of treatment on plantar fasciitis pain.

After treatment, the mean plantar fascia thickness was significantly decreased in both groups ($P < 0.001$),there were no significant differences between the mean plantar fascia thickness of the two groups ($P = 0.95$).

In addition, FADI had a significant increase in both groups ($P < 0.001$),there were no significant differences between the mean FADL of the two groups ($P = 0.8$).

A beneficial effect of shock wave in treating overload is associated with micro destruction. The impact is likely to cause micro-tears of non-vascularized or scantily vascularized tissues, and thus stimulate revascularization by the release of local growth factors and mobilization of appropriate stem cells (21).

Additionally, as the exact mechanism of action of the shock wave has not yet been fully explained, it might be that the increase of pressure in the focal point of the shock wave causes cavitation in the area of ischemic calcification and its fragmentation, which leads to the disorganization and disintegration of concernments. Calcium concernments can be dissolved as a result of the molecular mechanism of absorption depending on the blood flow, which intensifies after treatment (22).

Ultrasound is a mechanical wave with constant amplitude, width and pulse interval. Its effect on tissue is dependent on the intensity, frequency, pulse shape, duration of action and method of application. Mechanical vibration bundles induced by the action of longitudinal waves create variations in shape and intracellular pressure which act as an "internal tissue massage". They induce a number of regulatory phenomena resulting in significant reductions in swelling and pain, an increase of the repair processes and standardization of immunological reactions. These phenomena occur due to improved perfusion and oxygenation of tissues, faster operation of the prosthetic group of enzymes, the release of mediators, and increased cell and intercellular membrane penetrability (23).

An acoustic wave (mechanical) is a stimulus in the treatment with shock waves and ultrasound. The analgesic effect in the treatment with shock waves involves blocking the trigger (activation) and transmission of pain signals by non-invasive stimulation of cell membranes and nerve endings. The increase in the pressure at the focus of the shock wave causes a cavitation in the area of calcifications and its fragmentation, which leads to disorganization and decomposition of deposits (24). Treatment with ultrasound induces changeable intracellular pressure, which acts as an "internal tissue massage", causes changes in the nervous conductivity, raises the threshold of pain, contributes to muscle relaxation. Greater enzymatic activity is also observed. It accelerates metabolism and regenerative processes (25).

The purpose of the comparative analysis of the analgesic efficacy of the two selected treatments was to assess pain insensitivity by the FADI and the VAS scale. The degree of pain intensity was assessed before and after treatment therapy. InGroupA, where ultrasound was used, it was observed that the subjects experienced pain with an average value of 6.6 points before treatment whereas this was 1.8 points lower after treatments according to VAS. The average ADL intensity in FADL was 62 before treatment and 83.2 after treatment. In Group B, which used shock wave therapy, a similar trend in pain reduction was also observed. According to the VAS, 6.8 points were noted before therapy and 3.8 points were noted after therapy. Similarly, according to the

FADL, 67.8 points was the average value before therapy and 84.8 points after therapy. The analysis of the results in the test intervals in both groups confirms the analgesic efficacy of the applied physical treatments. However, the lack of statistical significance between the groups' results indicate that both treatments have comparable analgesic efficacy.

Extracorporeal Shock wave is preferable to ultrasound due to the number of applied treatments. It allows to achieve a similar analgesic effect but in this method, we apply fewer treatment sessions, Less time spent in a clinic by the patient, less frequent visits to the clinic, possibility of treating more patients at the same time (due to the fact that procedures can be performed every second or third day) reduces the overall cost of the therapy (8).

V. Conclusion

Within the limitation of this study, the following conclusions are warranted.Ultrasound and shock wave therapy demonstrate significant pain reduction in patients with planter fasciitis.The fewer number of treatment sessions required by shock wave therapy compared to ultrasound suggests that shock wave therapy has better analgesic efficacy.Shock wave therapy is more advantageous over ultrasound therapy. It allows to obtain a similar analgesic effect by using less treatments, which decreases the overall cost of the therapy

References

[1]. James D. Goff, DO, and Robert Crawford MD, Summa Health System, Akron, Ohio *Am Fam Physician,84(6),* 2011, 676-682.
[2]. Daniel L, Riddle DL, Pulisic M, Pidcoe P, Johnson RE, Risk factors for plantar fasciitis, A matched case-control study. *J Bone Joint Surg Am, 85*, 2003, 872-77.
[3]. Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR. Plantar fasciitis, A retrospective analysis of 267 cases. Phys Ther Sports, 3, 2002, 57–65.
[4]. Hossain M, Makawana N. “Not Plantar Fasciitis”: The differential diagnosis and management of heel pain syndrome. Orthopaedics and Trauma. 2011; 25(3):198-206**.**
[5]. Sanzo. The Effects of Extracorporeal Shockwave Therapy on Pain, Function, Range of Motion and Strength in Patients with Plantar Fasciitis 2013.
[6]. Rompe, “Plantar fasciopathy,” *Sports Med Arthrosc Rev, vol. 17, no. 2*, 2009, pp. 100-104.
[7]. Buchbinder R. Clinical practice. Plantar fasciitis,*NEngl J Med,350, 2004,* 2159-66.
[8]. Krukowska J, Wrona J, Sienkiewicz M, Czernicki J,A comparative analysis of analgesic efficacy of ultrasound and shock wave therapy in the treatment of patients with inflammation of the attachment of the plantar fascia in the course of calcaneal spurs,*Archives of Orthopaedic and Trauma Surgery,vol. 136*,2016, pp. 1289–1296.
[9]. Vahdatpour B, Sajadieh S, Bateni V, Karami M and Sajjadieh H: Extracorporeal shock wave therapy in patients with plantar fasciitis. A randomized, placebo-controlled trial with ultrasonographic and subjective outcome assessments, *Journal of Research in Medical Sciences, 17(9)*, 2012, 834–838.
[10]. Wu YH, Lun JJ, Chen WS, Chong FC. The electrophysiological and functional effect of shock wave on peripheral nerves. *Conf Proc IEEE Eng Med Biol Soc.* 2007;2007:2369–72.
[11]. Mariotto S, de Prati AC, Cavalieri E, Amelio E, Marlinghaus E, Suzuki H, Extracorporeal shock wave therapy in inflammatory diseases: Molecular mechanism that triggers anti-inflammatory action, *Curr Med Chem;16*, 2009, 2366–72.
[12]. Taheri P, Emadi M and Poorghasemian J: Comparison the Effect of Extra Corporeal Shockwave Therapy with Low Dosage Versus High Dosage in Treatment of the Patients with Lateral Epicondylitis, *Adv Biomed Res, 6*, 2017, 61
[13]. Stuber K, Kristmanson K: Conservative therapy for plantar fasciitis: a narrative review of randomized controlled trials. J Can Chiropr Assoc. 2006; 50: 118– 133.
[14]. Katzap Y, Haidukov M, Berland OM, Itzhak RB and Kalichman L: Additive Effect of Therapeutic Ultrasound in the Treatment of Plantar Fasciitis: A Randomized Controlled Trial,*JOSPT,48(11)*, 2018, 847-855.
[15]. Whiting M F. The treatment of painful conditions affecting the heel and plantar fascia. Chiropodist 1996; 30: 247-63.
[16]. Tas S, Bek N, Onur MR and Korkusuz F: Effects of Body Mass Index on Mechanical Properties of the Plantar Fascia and Heel Pad in Asymptomatic Participants, *Foot and Ankle International, 38 (7)*, 2017, 779-784
[17]. Jollant F, Voegeli G, Kordsmeier NC, Carbajal JM, Richard S, Turecki G and Caceda R: visual analog scale to measure psychological and physical pain:ApreliminaryvalidationofthePPP-VAS in two independent samples of depressed patients, *Progress in Neuropsychopharmacology& Biological Psychiatry, 90*, 2019, 55-61.
[18]. Sheri A. Hale and Jay Hertel: Reliability and Sensitivity of the Foot and Ankle Disability Index in Subjects With Chronic Ankle Instability. *Journal of Athletic Training, 40(1)*, 2005, 35–40.
[19]. Garg M, Khan SA, Quddus N: Correlation between the Foot and Ankle Disability Index (FADI) Score and Strength of HIP and Knee Muscles in Subjects with Unilateral Chronic Ankle Instability, *IJSR, 6 (19)*, 2017, 1489-1492.
[20]. Roxas M: Plantar Fasciitis: diagnosis and therapeutic considerations. Alt Med Rev,10,2005, 83–93.
[21]. Król P, Franek A, Zinka W, Kubacki J, Polak A, Franek E, Focused and radial shock wave in orthopedics and physiotherapy. *Fizjoter Pol, 1(4*), 2009, 1–20.
[22]. Speed CA, Extracorporeal shock-wave therapy in the management ofChronic soft-tissue conditions. *J Bone Joint Surg, 86-B (2), 2004,* 165–171.
[23]. Straburzyńska-Lupa A, Kornacka A: Ultrasound therapy in the treatment of calcar pedis—own experiences. *OrtopTraumatolRehabil, 7(1),* 2005, 79–86.
[24]. Sabeti-Aschraf M, Dorotka R, Goll A, Trieb K, Extracorporeal shock wave therapy in the treatment of calcific tendinitis of the rotator cuff. *Am J Sports Med, 33(9), 2005,* 1365–1368.
[25]. Boerner E, Toruń-Kotarska E, Kusiciel-Lewandowska J: The comparison of the efficiency of ultrasounds therapy of calcanean spur depending on therapeutic dose. *Acta Bio-Optica Inform Med, 15(3), 2009,* 230–233.