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Original Article

Radial versus focused extracorporeal shockwave therapy in lateral epicondylitis: Acute effects on pain, muscle strength, upper extremity function, and quality of life

Bihter Akınoğlu[1], Aydan Örsçelik[2], Ayfer Ezgi Yılmaz[3], Salman Usman Shehu[1], Şeyma Özal[1], Hüseyin Günaydın[4], Tuğba Kocahan[2]

[1]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Ankara Yıldırım Beyazıt University, Ankara, Türkiye
[2]Department of Sports Medicine, Gülhane Medical Faculty, Health Sciences University, Ankara, Türkiye
[3]Department of Statistics, Hacettepe University, Beytepe, Ankara, Türkiye
[4]Department of Sports Medicine, Gülhane Training and Research Hospital, Ankara, Türkiye

ABSTRACT

Objectives: This study aimed to compare the acute effects of radial extracorporeal shockwave therapy (r-ESWT) and focused extracorporeal shockwave therapy (f-ESWT) on pain, muscle strength, and function in patients with lateral epicondylitis (LE).

Patients and methods: Fifty-six patients (31 males, 25 females; mean age: 44.6±8.4 years; range, 19 to 60 years) who were diagnosed with LE participated in the randomized study between August 2023 and October 2023. The patients were stratified by pain level to have four r-ESWT or f-ESWT treatments once a week. Patients were evaluated on the first day of treatment and one week after the last treatment. The outcome measures used were the Visual Analog Scale for pain, isokinetic dynamometer for wrist muscle strength measurement, the DASH (Disabilities of the Arm, Shoulder, and Hand) score for functional status, and the 36-item Short-Form Health Survey (SF-36) for health-related quality of life.

Results: After the treatment, the pain at rest and during activity decreased in both groups ($p=0.018$, $p=0.001$, $p=0.003$, and $p<0.001$). Nocturnal pain was found to be lower in the f-ESWT group ($p=0.028$). The isokinetic muscle strength of the wrist extensors was higher in the r-ESWT group compared to the f-ESWT group ($p=0.002$ and $p=0.017$). The DASH performance score of the r-ESWT group was higher compared to the f-ESWT group ($p=0.009$). Both groups showed improvements in SF-36 scores ($p<0.05$).

Conclusion: Both groups showed a decrease in pain levels, but the effects were superior in the f-ESWT group. However, r-ESWT was found to present better results in terms of its effect on isokinetic muscle strength. While f-ESWT may be more effective in reducing pain, r-ESWT may be more effective in increasing muscle strength.

Keywords: Elbow, extracorporeal shockwave therapy, lateral epicondylitis, pain, strength.

Lateral epicondylitis (LE) is among the prevalent causes of elbow pain, affecting 1 to 3% of the population.[1] It is mostly attributed to repetitive microtrauma from excessively moving the wrist or extreme gripping motions. Extensor group muscles and extensor carpi radialis brevis are the most frequently affected muscles.[2]

Patients diagnosed with LE often complain of pain at the extra-articular lateral elbow, which is accompanied by reduced grip strength. Symptoms may last for several weeks or persist for months. Pain intensity varies from minimal to severe. It can affect a patient's daily activities and sleep quality. Symptoms are usually more apparent after moving the wrist and elbow in a repetitive manner.[3] Some of the risk factors for LE include female sex, dominant side involvement, manual work involving the hand and wrist, and rotator cuff tear.[4]

Despite numerous studies, LE is still not fully understood and has no clear treatment guidelines.[5] Physiotherapy is the main treatment and includes muscle strengthening, mobilization, stretching, and deep friction massage.[6] Other physiotherapy tools used in the treatment of LE

Corresponding author: Bihter Akınoğlu, PhD. Yıldırım Beyazıt Üniversitesi, Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü, 06010 Keçiören, Ankara, Türkiye.
E-mail: rgkardelen@yahoo.com

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include extracorporeal shockwave therapy (ESWT), cryotherapy, electrotherapy, ultrasound therapy, and application of tape or orthosis.[7] Nonsteroidal anti-inflammatory drugs are used to control pain and improve function temporarily. More recently, other types of therapies, such as corticosteroid injection, autologous blood, and platelet-rich plasma have been utilized in the treatment of LE.[8] Surgery is another treatment option for patients who do not respond to conservative treatment. Open release and arthroscopic release are the two main options for LE surgery.[9]

Extracorporeal shockwave therapy is a noninvasive treatment method that involves the transmission of shockwaves to the musculoskeletal tissues of the body.[10] Generally, two distinct types of ESWT are available: radial ESWT (r-ESWT) and focused ESWT (f-ESWT).[11] Radial ESWT uses low energy density and slow pulse to treat a large surface area of superficial indications, while f-ESWT uses high energy density and fast pulse to treat smaller focal points with greater accuracy and depth. Radial ESWT is commonly used in the treatment of most musculoskeletal injuries.[12] This is mostly due to its applicability and lower cost.[13]

In recent literature, the effects of ESWT together with other therapies have been compared. In a study by Rogoveanu et al.,[14] ESWT in LE was found to provide superior results in reducing pain compared to classical physical therapies. Yao et al.[15] found that ESWT effectively alleviated pain and functional impairment in LE and provided an overall edge in safety than several other methods, particularly corticosteroid injections. Dedes et al.[16] found r-ESWT to be significantly better than ultrasound therapy in patients with LE. There is no complete consensus in studies comparing the effects of r-ESWT and f-ESWT in tendinopathies. Yoon et al.[17] found that r-ESWT showed greater pain relief than f-ESWT in LE, but the difference was not clinically significant. Li et al.[18] found f-ESWT to show more long-term radiological improvements than r-ESWT in patients with rotator cuff tendinopathy.

In light of this information, we hypothesized that ESWT would be effective in managing pain and muscle weakness in patients diagnosed with LE. However, due to the limited number of studies comparing the two types of ESWT, there is no clear evidence as to which type of ESWT should be preferred over the other. Therefore, the primary aim of this study was to examine the acute effects of r-ESWT and f-ESWT on pain and muscle strength in LE.

PATIENTS AND METHODS

Fifty-six individuals (31 males, 25 females; mean age: 44.6±8.4 years; range, 19 to 60 years) who were diagnosed with LE at the sports medicine outpatient clinic of the Gülhane Training and Research Hospital between August 2023 and October 2023 were included in this randomized study. The inclusion criteria were being able to read and write, not having any known systemic conditions, not having undergone any surgical operation related to the upper extremity, not having any orthopedic injury to the upper extremity within the past three months, and not having received any treatment for the diagnosis of LE in the last six months. Pregnancy, having a pacemaker, local dermatological and neurological conditions, wrist joint limitation, and incomplete follow-up were determined as exclusion criteria. Ethical approval was obtained from the Gülhane Training and Research Hospital Clinical Ethics Committee dated September 29, 2021, with the decision number 2021/64. Written informed consent was obtained from all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Focused ESWT and r-ESWT were randomly applied to the patients in a total of four sessions once a week. At the beginning of the study, descriptive data about paticipants' age, weight, height, body mass index, dominant hand, affected arm, and duration of complaints were recorded. The participants' pain, isokinetic muscle strength, and joint movements were evaluated on the first day of treatment and one week after the last treatment by a physiotherapist with 10 years of experience. The 36-item Short-Form Health Survey (SF-36) and The DASH (Disabilities of the Arm, Shoulder, and Hand) questionnaire were read and answered by the participants.

The patients had complaints of pain and tenderness on and around the lateral epicondyle persisting for at least three months and increased pain with resisted elbow extension, wrist extension, gripping, and supination. Patients were instructed not to use any analgesic or anti-inflammatory drugs and not to participate in any other intervention during the study period to avoid affecting the results.

The Visual Analog Scale (VAS) was used to measure the pain severity of the patients before and after treatment and for the purpose of stratified randomization. Patients were told to label the severity of their pain at rest, during activity, and at night on a 10-cm scale. A value of 0 corresponded to no pain, while 10 corresponded to the most severe pain.[19]

The participants' physical activity levels were categorized as sedentary if they engaged in less than 150 min of moderate to vigorous aerobic activity per week, less active if it was 150 to 300 min, and active when it was over 300 min.

The device used for r-ESWT and f-ESWT was DUOLITH SD-1 (Storz Medical, Tagerwilen, Sweden). Radial ESWT was applied with a transmitter head 15 mm in diameter. During the treatment, ultrasound gel was used to ensure conductivity between the transmitter head and the skin. Focused ESWT was applied with the focus transmitter head. A silicone cap was used to ensure conductivity during treatment. In the r-ESWT group, a total of 2,000 pulses at 8 Hz and 1.8 bar were applied to the painful points. In the f-ESWT group, a total of 2,000 pulses at 8 Hz and 0.28 mJ/mm^2 were applied.

The treatments were performed with the patient in sitting position, shoulder at 45° abduction, with the elbow flexed, and the forearm, wrist, and hand supported. The treatment was applied to the pain points around the lateral epicondyle and the surrounding areas, as well as the forearm extensor group muscles using the clinical focus technique. Before the treatment, the most painful points were assessed and marked with a pen, and the shocks were made to these points. Both groups were given an exercise program in addition to the treatment.

For the exercise program, patients were given an exercise program consisting of stretching exercises, with eccentric and concentric strengthening exercises. The exercise program was performed once a day for four weeks. The exercise program was supervised once a week when the participants presented for the treatment session, and they were enquired whether they performed the exercise on other days. Individuals who stated that they did not perform the exercise program were excluded from the study. The stretching exercise was performed for 30 sec with the aid of the contralateral hand, the shoulder placed in 90° flexion, the elbow in full extension, the forearm in pronation, and the wrist in flexion and ulnar deviation. As for the strengthening exercise, the elbow was placed in extension, the forearm was pronated, the arm was supported, and the wrist and hand were allowed to hang off the table while holding a 0.5 L water bottle. Wrist extension and flexion movements were done slowly and performed in three sets and 10 repetitions, with a 1-min break between sets. The same exercise was repeated with the forearm in supination.

The Biodex System 4 (Biodex Corp., Shirley, NY, USA) was used to assess the isokinetic strength of the wrist extensor muscles. Measurements were made in the morning and at room temperature. The concentric strength of the affected wrist extensor muscles was taken at angular velocities of 60°/sec and 180°/sec in a series of five and 15 repetitions, respectively. Before the measurement at each angular velocity, three repetitive movements at the same angular velocity and a warm-up exercise were performed. Measurements were taken in a sitting position, with the wrist open and forearm stabilized with belts. The fulcrum of the dynamometer was aligned to the ulnar styloid process as the anatomical reference. The maximum concentric strength of the wrist extensors was evaluated with concentric-concentric movements of the wrist joint at the range of motion of 90° extension and 70° flexion. The force-related peak torque of the wrist extensors was used in the analyses.

The participants' upper extremity functional status and symptoms were evaluated using the DASH questionnaire. The questionnaire, filled by the participants, and consists of three parts: the functional/symptom, the work model, and the sports/musicians model. The work model and the sports/musicians model were filled optionally. The first part consists of 30 questions, with 21 questions measuring the person's difficulties during activities of daily living, five assessing symptoms (pain, stiffness, tingling, and weakness), and four measuring work, sleep, social function, and self-confidence. The work model shows the patient's disability in work life and consists of four questions. The sports/musicians model shows the disability of individuals who play sports or are musicians and also consists of four questions. The questions were answered according to a 5-point Likert scale (1=no difficulty, 2=mild difficulty, 3=moderate difficulty, 4=extreme difficulty, and 5=inability). A score between 0 and 100 is obtained from each section, with highers score indicating greater disability.[20] In our study, the first 30 questions of the DASH questionnaire were applied.

The Turkish adaptation of the SF-36 was used to evaluate health-related quality of life (QoL), which was demonstrated to be reliable and valid for patients with chronic physical conditions.[21] The SF-36 is used as a self-assessment tool that consists of 36 items measuring different aspects of physical function, social function, limitations, mental health, vitality, pain, and overall health perception. A total score from different subscores is collected, with the scores ranging from

TABLE 1
Participants' general characteristics (n=56)

	r-ESWT (n=27)					f-ESWT (n=29)					
Variables	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Age (year)			44.0±9.1	45.0	19.0-60.0			45.1±7.9	46.0	28.0-58.0	0.630a
Sex											0.977a
Female	12	44.4				13	44.8				
Male	15	55.6				16	55.2				
Affected side											0.945a
Left	17	63.0				18	62.1				
Right	10	37.0				11	37.9				
Dominant side											0.731b
Left	23	85.2				23	79.3				
Right	4	14.8				6	20.7				
Physical activity level											0.052b
Sedentary	18	66.7				26	89.7				
Less active	5	18.5				1	3.4				
Active	4	14.8				2	6.9				
Body weight (kg)			80.93±15.96	84.00	52.00-110.00			75.14±10.47	74.00	60.00-103.00	0.118c
Height (cm)			168.33±10.32	167.00	150.00-187.00			167.97±8.15	168.00	154.00-179.00	0.909d
BMI (kg/m^2)			28.42±4.46	28.40	21.37-40.15			26.60±2.79	26.40	21.26-33.25	0.071c
Duration of complaint (month)			11.74±12.50	7.00	3.00-36.00			11.00±12.20	3.00	3.00-36.00	0.442d

SD: Standard deviation; r-ESWT: Radial extracorporeal shockwave therapy; f-ESWT: Focused extracorporeal shockwave therapy; a: Pearson chi-square test; b: Exact chi-square test results; c: Independent samples t-test; d: Mann-Whitney U test results.

0 to 100. An overall score of 100 indicates good health, while 0 indicates poor health condition.

Statistical analysis

The required sample size was calculated using the G*Power version 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). To compare two independent samples, the section of G*Power relating to the difference between two independent means was used. For the pre- and posttreatment measurements, the section relating to the difference between two dependent means was used. The power of the study was set at 80%, the margin of error at 5%, and the effect size at 0.80 (large) in accordance with Cohen,[22] and the total sample size was estimated to be a minimum of 52 participants.

Data were analyzed using IBM SPSS version 23.0 software (IBM Corp., Armonk, NY, USA). Mean, standard deviation (SD), median, minimum, and maximum values were calculated for quantitative variables, whereas frequency and percentage were used to present qualitative variables. General characteristics comparison according to groups was conducted with Pearson's chi-square test, and in cases where the chi-square assumption was not met, Fisher exact test was used. The Shapiro-Wilk test was used to determine whether the data showed normal distribution. Comparisons of the two independent groups were examined using the independent sample t-test in groups that showed normal distribution and the Mann-Whitney U test in groups that showed nonnormal distribution. Pre- and posttreatment comparisons were investigated using the paired sample t-test in groups that showed normal distribution and the Wilcoxon signed-rank test in groups showing nonnormal distribution. A p-value <0.05 was considered statistically significant.

RESULTS

There was no difference between the groups in terms of sex, affected side, dominant side, and physical activity level (p=0.977, p=0.945, p=0.731, and p=0.052, respectively; Table 1). Additionally, there was no difference in terms of age, body weight, height, body mass index, and duration of complaints (p=0.630, p=0.118, p=0.909, p=0.071, and p=0.442, respectively; Table 1).

A decrease was observed in pain during rest (p=0.018 and p=0.001) and activity (p=0.003 and p<0.001) after treatment in both groups. However, decrease in night pain was observed only in the f-ESWT group after the treatment (p=0.002). No statistically significant change was observed in night pain in the r-ESWT group before and after treatment (p=0.083). There was no significant difference in the decrease found in pain during rest and activity between the two groups before and after treatment (p>0.05 for all). Moreover, while there was no difference between the groups in terms of night pain before treatment (p=0.733), night pain was found to be lower in the f-ESWT group after treatment (p=0.028; Table 2).

TABLE 2
Comparison of groups and treatment effect in terms of pain

	Preoperative			Postoperative			Difference	
Variables	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
Resting pain								
r-ESWT	3.25±2.56	4.00	0.00-7.00	1.55±2.27	0.00	0.00-7.08	1.70±3.01	0.018c
f-ESWT	3.21±3.22	3.00	0.00-9.00	0.50±0.88	0.00	0.00-3.00	2.71±2.94	0.001c
p		0.866d			0.154d			
Activity pain								
r-ESWT	6.75±2.42	7.00	0.00-10.00	4.07±2.99	3.75	0.00-10.00	2.68±3.91	0.003a
f-ESWT	7.63±1.64	8.00	4.00-10.00	4.92±2.17	4.00	2.00-9.00	2.71±2.33	<0.001a
p		0.149b			0.233d			
Night pain								
r-ESWT	3.96±3.64	4.00	0.00-10.00	2.31±3.02	0.00	0.00-8.00	1.65±4.53	0.083c
f-ESWT	3.58±3.69	3.00	0.00-10.00	0.50±1.38	0.00	0.00-6.00	3.08±3.75	0.002c
p		0.733d			0.028d			

SD: Standard deviation; r-ESWT: Radial extracorporeal shockwave therapy; f-ESWT: Focused extracorporeal shockwave therapy; a: Paired sample t-test; b: Independent sample t-test; c: Wilcoxon signed-rank test; d: Mann-Whitney U test result.

TABLE 3
Comparison of groups and treatment effect in terms of isokinetic strength

	Preoperative			Postoperative			Difference	
Variables	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
Affected side isokinetic 60 ext.								
r-ESWT	5.97±3.00	5.60	2.40-11.10	7.91±2.25	7.60	4.50-12.30	-1.94±1.94	<0.001
f-ESWT	4.81±2.15	4.10	2.30-9.10	5.96±1.62	5.75	2.80-9.10	-1.15±2.16	0.021
p		0.180c			0.002b			
Affected side isokinetic 180 ext.								
r-ESWT	5.52±2.01	5.50	2.90-9.40	7.11±1.79	7.30	4.20-11.20	1.59±1.41	<0.001
f-ESWT	5.39±2.32	4.90	2.70-12.20	5.89±1.41	5.90	2.90-8.40	-0.50±2.06	0.265
p		0.609c			0.017b			

SD: Standard deviation; r-ESWT: Radial extracorporeal shockwave therapy; f-ESWT: Focused extracorporeal shockwave therapy; a: Paired sample t-test; b: Independent sample t-test; c: Mann-Whitney U test result.

TABLE 4
Comparison of groups and treatment effect in terms of DASH scores

	Preoperative			Postoperative			Difference	
Variables	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*pa*
DASH								
r-ESWT	43.71±21.31	48.15	5.83-98.00	28.85±15.89	28.48	17.72-60.00	14.86±20.14	0.001
f-ESWT	36.33±16.09	39.58	5.00-60.00	30.71±12.33	33.70	13.30-54.16	5.62±18.64	0.154
pb		0.182			0.652			

DASH: Dash-Arm-Shoulder-Hand; SD: Standard deviation; r-ESWT: Radial extracorporeal shockwave therapy; f-ESWT: Focused extracorporeal shockwave therapy; a: Paired sample t-test; b: Independent samples t-test result.

The results indicated that isokinetic muscle strength of the wrist extensors was significantly different between the groups after treatment at angular velocities of 60°/sec and 180°/sec (p=0.002 and p=0.017, respectively), with higher values in the r-ESWT group. Nevertheless, in both groups, isokinetic muscle strength of wrist extensors at an angular velocity of 60°/sec increased after the treatment (p<0.001 and p=0.021; Table 3).

It was determined that there was no difference between the groups in terms of DASH scores before and after the treatment (p=0.182 and p=0.652). However, DASH scores decreased in the r-ESWT group after treatment (p=0.001), while no significant difference was found between pre- and posttreatment measurements in the f-ESWT group (p=0.154; Table 4).

Finally, it was determined that there was no significant difference between the two groups in terms of all variables included in the SF-36 (all p>0.05). However, in the r-ESWT group, there was an increase in physical function and physical health after treatment (p=0.031 and p=0.005, respectively), and an increase in health change after treatment (p=0.017). In the f-ESWT group, there was an increase in energy/fatigue, social function, and pain after treatment (p=0.022, p=0.039, and p=0.047; Table 5).

DISCUSSION

This study investigated the effects of r-ESWT and f-ESWT on pain, isokinetic muscle strength, upper extremity function, and health-related QoL in patients with LE. Despite differing opinions in the current literature, ESWT is one of the commonly used physical therapy modalities to treat LE. The mechanism of ESWT has not been fully elucidated but has been associated with possible stimulation of healing, neovascularization, suppressive effects on nociceptors, and a hyperstimulation mechanism that blocks gate control.[12]

Our results show that both r-ESWT and f-ESWT play an important role in reducing elbow pain. Both groups showed improvements after treatment in pain during rest and activity. However, in night pains, only f-ESWT was found to have an effect. Overall, our findings indicate that f-ESWT outperformed r-ESWT in reducing pain. We believe that this can

TABLE 5
Comparison of groups and treatment effect in terms of SF-36 scores

	Preoperative			Postoperative			Difference	
Variables	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	Mean±SD	*p*
Physical function								
r-ESWT	68.33±20.62	72.50	20.00-100.00	76.25±17.34	82.50	30.00-100.00	–7.92±16.87	0.031a
f-ESWT	70.00±20.43	75.00	35.00-95.00	72.00±18.48	80.00	35.00-95.00	–2.00±18.26	0.597a
p		0.648d			0.394d			
Physical health								
r-ESWT	30.21±32.95	25.00	0.00-100.00	51.04±38.64	25.00	0.00-100.00	–20.83±32.69	0.005c
f-ESWT	41.66±42.78	50.00	0.00-100.00	42.71±39.34	50.00	0.00-100.00	–1.05±20.16	0.803c
p		0.503d			0.378d			
Emotional problem								
r-ESWT	38.89±40.13	33.30	0.00-100.00	45.83±43.75	33.30	0.00-100.00	–6.94±27.77	0.287c
f-ESWT	44.44±44.69	33.30	0.00-100.00	47.67±40.72	50.00	0.00-100.00	–3.23±45.33	0.730a
p		0.696d			0.906d			
Energy/fatigue								
r-ESWT	51.67±21.85	52.50	10.00-90.00	55.21±25.26	57.50	5.00-95.00	–3.54-14.85	0.255a
f-ESWT	48.33±21.45	50.00	5.00-85.00	50.83±20.52	50.00	5.00-85.00	–2.50±19.17	0.022a
p		0.596b			0.513b			
Emotional well-being								
r-ESWT	58.17±22.69	60.00	16.00-96.00	65.67±17.85	64.00	28.00-100.00	–7.50±14.98	0.529a
f-ESWT	60.67±20.08	58.00	16.00-92.00	58.38±22.90	58.00	20.00-100.00	2.29±22.43	0.622a
p		0.688b			0.225b			
Social function								
r-ESWT	64.58±22.92	62.50	25.00-100.00	71.87±22.19	68.75	25.00-100.00	–7.29±20.16	0.090a
f-ESWT	64.58±26.50	62.50	0.00-100.00	68.48±23.15	75.00	12.50-100.00	–3.90±27.10	0.039a
p		0.999b			0.606b			
Pain								
r-ESWT	46.77±22.62	45.00	10.00-100.00	56.56±19.52	57.50	10.00-90.00	–9.79±21.93	0.488a
f-ESWT	43.37±21.54	45.00	0.00-90.00	54.89±21.31	55.00	12.50-100.00	–11.52±26.21	0.047a
p		0.647b			0.780b			
General health								
r-ESWT	60.21±19.08	60.00	25.00-100.00	62.71±22.94	65.00	10.00-95.00	–2.50±16.94	0.477a
f-ESWT	51.09±22.10	50.00	0.00-80.00	56.30±19.96	55.00	15.00-90.00	–5.21±22.03	0.268a
p		0.155b			0.313b			
Health change								
r-ESWT	37.50±23.31	37.50	0.00-100.00	55.21±28.53	50.00	0.00-100.00	17.71±31.69	0.017c
f-ESWT	38.04±24.85	50.00	0.00-100.00	47.83±27.09	50.00	0.00-100.00	9.78±26.90	0.104c
p		0.939d			0.320d			

SF-36: 36-item Short-Form Health Survey; SD: Standard deviation; r-ESWT: Radial extracorporeal shockwave therapy; f-ESWT: Focused extracorporeal shockwave therapy; a: Paired sample t-test; b: Independent sample t-test; c: Wilcoxon signed-rank test; d: Mann-Whitney U test result.

be attributed to differences in the wave propagation patterns; f-ESWT has a wider reach and can focus energy deeper into the target area than r-ESWT.[23] Furthermore, f-ESWT is associated with cavitation release of nitric oxide, which increases cell metabolism, neovascularization, and anti-inflammatory effects. This has been demonstrated in a study by BrañEs et al.[24] where f-ESWT was associated with increased neovascularization in rotator cuff tendinopathies. However, the method of shock application to the painful points, which we applied to ensure the similarity between the two modalities in our study, may also have affected the effectiveness of r-ESWT. However, there is a need for studies that will be designed using not only clinical focus on painful areas but also anatomical focus.

Our results are mostly in agreement with the current literature on the effectiveness of both r-ESWT and f-ESWT in reducing pain and the superiority of f-ESWT. In a randomized controlled trial by

Rogoveanu et al.[14] on 50 patients with LE, pain relief measured on the VAS scale was found to be higher in ESWT patients (59.89%) compared to patients treated with drugs and standard treatments (37.01%). Aldajah et al.[25] also reported that participants treated with ESWT performed better in VAS, DASH, and grip strength than those in the conventional physical therapy group. Ko et al.[12] reported similar outcomes in a randomized controlled study of 42 patients with knee osteoarthritis. Despite both groups displaying improvements in VAS scores after treatment, f-ESWT was found to be superior to r-ESWT. However, our results were in odds with one study in which the effectiveness of ESWT in pain reduction was challenged. This is evident in a meta-analysis by Yoon et al.,[17] which revealed that ESWT did not show clinical significance in pain reduction and grip strength but found that r-ESWT provides better effects than f-ESWT. As can be observed, there is no total agreement in the literature about which type of ESWT is superior. However, in our study, the comparison of the methods and the application of both r-ESWT and f-ESWT to painful points with clinical focus under the same conditions suggests the application of f-ESWT to be more effective in reducing pain.

In terms of isokinetic strength of the wrist extensor muscles, both groups displayed overall improvements after treatment. Both groups showed improvements in isokinetic muscle strength of the wrist extensors at angular velocities of 60°/sec and 180°/sec. However, these improvements were better in the r-ESWT group. There is evidence to support the positive effects of ESWT on grip strength. In a meta-analysis by Yao et al.,[15] LE patients treated with ESWT showed a significant increase in grip strength (mean difference =3:36, 95% confidence interval 2:39 to 4:33, $p<0.00001$). Stania et al.[26] also found that grip strength, as well as strengths of the flexors and extensors in LE patients, was significantly higher at week 12 of treatment compared to preintervention values in both groups. The studies we could find in the literature appear to be in agreement with our findings on the superiority of r-ESWT in muscle strength. The advantage of r-ESWT can be explained by its higher peak force in superficial structures and energy attenuation at greater depths.[27] Liao et al.[28] also found r-ESWT to have more effects on superficial muscles.

The r-ESWT group showed improvement after treatment in DASH scores, while the f-ESWT group showed no improvement after treatment. A few studies have found that ESWT improves function in LE patients. Ibrahim et al.[29] found that r-ESWT significantly improved QuickDASH scores in acute and chronic LE. Maffulli et al.[30] also found that r-ESWT produced significant positive effects in reducing pain and improving functional ability. Both of these studies appear to agree with our results on the effectiveness of r-ESWT in improving function. However, we could not find a study comparing functional outcomes between the two ESWT types. From our understanding, the increase in function in r-ESWT may be attributed to the increase in muscle strength.

In the evaluation of health-related QoL using the SF-36 survey, no significant changes were detected in both groups in all variables. It should be noted that while r-ESWT performed better in physical function, physical health, and health-related changes, f-ESWT was superior in energy/fatigue, social function, and pain scores. However, we could not find any studies in the literature to compare with our findings.

This study had some limitations. First, the study lacked a true control group that received placebo or no treatment. However, previous studies have demonstrated that both r-ESWT and f-ESWT offer significant benefits over placebo in reducing pain and restoring upper limb function in LE patients.[15] Second, the parameters used in ESWT were based on prior studies due to the lack of established treatment protocols. Therefore, it is unclear whether changing the number of sessions, intensity, or frequency would have produced different outcomes. Third, it was not possible to verify exercise compliance, monitor participants' activities of daily living, or assess their physical activity levels at home.

In conclusion, both f-ESWT and r-ESWT are effective and safe to be utilized in LE. This study provided further insight into the impact of ESWT types in pain relief, muscle strength, upper extremity function, and health related QoL. However, more studies comparing ESWT types regarding the number sessions, intensity, or frequency are needed to help provide a clear picture of their effects and differences, which will facilitate the development of definitive treatment protocols or guidelines.

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