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Using Extracorporeal Shockwave Therapy in Patients with Orthopedic Conditions

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Abstract

Background: Among other non-invasive procedures, Extracorporeal Shockwave Treatment (ESWT) has been used to resolve many musculoskeletal ailments. The authors completed a systematic review to study articles that reported the effectiveness of focused shockwave therapy in patients with orthopedic conditions. Methods: A comprehensive search was conducted across reputable databases including Pub Med, The Cochrane Library, Science Direct, PEDro, Clinicaltrials.gov, and Google Scholar, ensuring a thorough review of the literature until October 10, 2022. Original articles of any design reporting on the use of ESWT in orthopedic patients were meticulously selected. Information related to study design, sample size, participants, intervention, and key findings of the study were extracted. The PEDro classification scale, a recognized tool, was used to evaluate the quality of the studies, further enhancing the credibility of findings. Results: Nineteen research articles (including 1157 participants) were retrieved and included for qualitative analysis. The sample size ranged from twenty-one to one hundred fifteen subjects, and the articles were published between 2001 and 2022. Out of 19 studies published, five were conducted in China, three in Germany, two in Iran and Turkey, and one in the United States, Canada, Italy, Denmark, Spain, Taiwan, and Saudi Arabia. The risk of bias was either moderate or low among the included studies. In patients with various orthopedic conditions, considerable moderate evidence of ESWT's effectiveness and success in lowering pain levels, increasing treatment success rates, promoting patient-reported functional recovery, and raising performance-based functional outcomes was seen in the results. Conclusion: The systematic literature review provided compelling evidence of the successful application of ESWT in treating a wide range of musculoskeletal problems. These positive outcomes were achieved without severe complications and morbidities, offering a promising outlook for the future of orthopedic treatment.

Keywords: Extracorporeal shockwave therapy; Orthopedic conditions; Rehabilitation; Focused- extracorporeal shockwave therapy; physical therapy.

1. Introduction

Several methods are used to treat patients with orthopedic conditions. In mild to severe cases, a conservative method includes splinting, oral corticosteroids, nonsteroidal anti-inflammatory medications, or physical therapy. Steroid injections and surgery are additional alternatives for therapy [1]. Multiple studies have shown that surgical treatment, local corticosteroid injection, and wrist splinting have positive results. Surgery and steroid injection come with the risks of adverse consequences, such as infections or allergic responses[2]. Therefore, there is a need for a pragmatic, inexpensive, and complication-free treatment approach.

Extracorporeal shockwave therapy (ESWT) has extensively been implemented to treat various musculoskeletal problems. It is a non-invasive procedure that is highly safe [3]. ESWT have been employed to treat multiple medical conditions safely and successfully over the past 20 years. Numerous musculoskeletal conditions, including avascular necrosis of the femoral head, calcific tendinitis of the lateral, shoulder, and medial epicondylitis, chronic tendinopathies, Achilles tendinopathy, jumpers knee, calcaneal spur, and plantar fasciitis, have been effectively treated with ESWT [1, 4].

ESWT has gained popularity in the past ten years for treating a variety of soft tissue complications, like humeral epicondylitis, calcifying tendinopathy in the rotator cuff, and plantar fasciitis. ESWT was first used to treat renal stones. The FDA has approved it for treating plantar fasciitis, which is now used worldwide. The outcomes for calcifying tendinopathy in the humeral epicondylitis, rotator cuff, and plantar fasciitis have been contradictory [5], [6]. ESWT has received much attention lately. Many ailments can be resolved safely and effectively with no side effects [6].

ESWT is based on producing acoustic waves that interact with cells directly through mechano-transduction, boosting the metabolic rate and causing tissue remodeling [1], According to Holfeld, *et al.* [7] it has anti-inflammatory, proliferative, and analgesic actions. It also affects peripheral nerve reinnervation. According to animal studies, shock waves may activate osteoblast cells and encourage the production of new bone.

Radial Shockwave Therapy (R-SWT) and Focused Shockwave Therapy (F-SWT) are two distinct forms of shockwaves. A projectile is propelled, while radial shockwaves are produced by propelling using compressed air through a tube until it strikes the applicator that touches the skin. Inside the applicator, focused shockwaves are created, focused through a lens, and delivered into the tissue. The therapeutic benefits of F-SWT and R-SWT may vary due to differences in technology in the physical mechanism [8]. The highest energy by F-SWT is created deep in the body tissues at the focus. In contrast, R-SWT has a more surface-level impact, and its maximum power is developed on the skin's surface before getting radially dispersed within the tissue [9]. The present systematic review sought to determine the effectiveness of ESWT in reducing pain and enhancing the functional results in patients with orthopedic conditions.

2. Methods

2.1. Search Strategy

Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) checklist standards were followed [10]. A comprehensive literature search was conducted in appropriate peer-reviewed journals published between 1998 and the present in six databases (Pub Med, The Cochrane Library, Science Direct, Clinicaltrial.gov, Google Scholar, and PEDro). There were no constraints on the country, time, or language of publication during the literature search. The study did not include conference proceedings, case reports, protocols, practice guidelines, and letters to the editor. Manual searches of cited references for related retrieved articles were performed to identify additional publications (snowball referencing).

The searches used the PICO strategy (P- patient or problems; I- intervention; C- comparison of interventions; O- outcome measurement).

P: Physical therapy patients with orthopedic involvements who require rehabilitation.

I: Extracorporeal shockwave therapy

C: No treatment

O: Reduced rehabilitation times in return to function

The broad key terms used for database searches were Extracorporeal shockwave therapy OR Mechano-transduction OR Regeneration OR Physical medicine and rehabilitation OR Physical therapy AND Orthopedic conditions, and only research articles were retrieved and reviewed.

2.2. Study Selection

After deduplication, titles were screened, and potentially relevant articles were identified by analyzing associated abstracts. Abstracts and full-text papers of identified studies were independently reviewed. Study information was abstracted from full texts of articles included in the study.

2.3. Inclusion and Exclusion Criteria for Considering Studies

The inclusion criteria included (1) published studies of any design (in addition to retrospective and prospective cohort studies or randomized controlled trials (RCTs)) documenting the efficacy or effectiveness of shockwave therapy in orthopedic conditions (2) Studies with adequate detail to determine the critical information of the research studies (3) Patients enrolled had medically determined musculoskeletal issues, including orthopedic trauma, bone fracture, and acute ankle sprain (4) Reliable measurement tools have been used.

The exclusion criteria were: (1) studies irrelevant to the study, (2) studies not providing sufficient data or without results, (3) studies published in languages besides English or before 1998, (4) Commentaries, guidelines, editorials, book chapters, letters to editor, reviews, and metanalysis (5) animal studies (6) protocols (7) studies investigating intervention for involvements other than orthopedic and athletic injuries of the lower extremity (8) Subjects with other somatic pathologies, such as balance dysfunction, cerebral palsy, and cancer.

Previous systematic reviews/metanalysis reference lists were also screened for relevant studies.

2.4. Data Extraction and Synthesis

Two independent reviewers extracted data from selected articles. Any discrepancies were resolved through discussion. The data was extracted using a standard Excel spreadsheet. Table 1 provides an overview and the features of the included studies. Authors, publication year, sample size, age, study design, participants, primary endpoint, intervention, and significant study findings were collected for each included study. A metanalysis was not performed because of the variability of the interventions, demographics, and outcome measures.

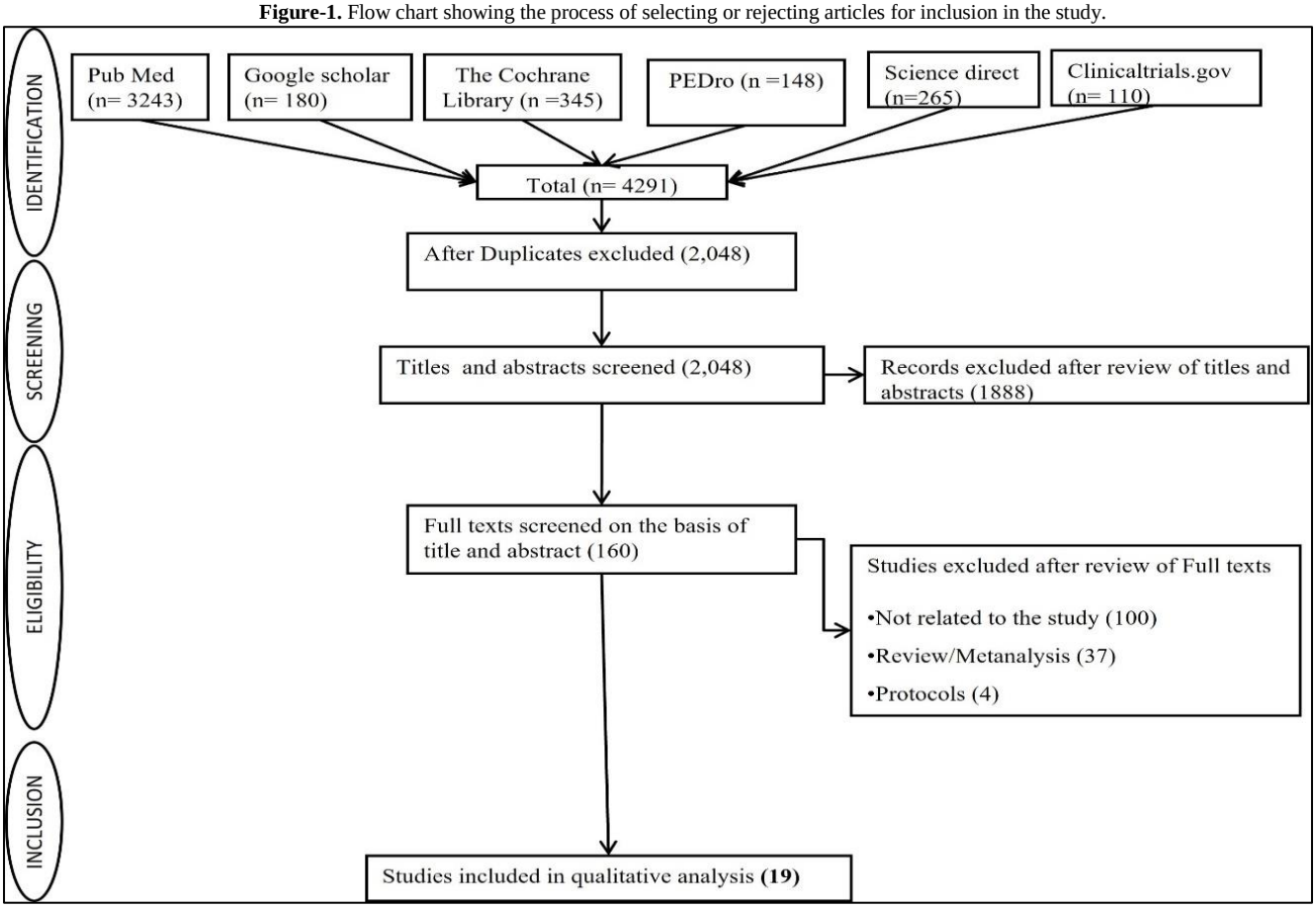
2.5. Assessment of Study Quality

The PEDro classification scale was used to evaluate the quality of the chosen studies. Two researchers used the PEDro classification scale to evaluate the quality of the methodologies of all included studies individually [10]. Deliberation and common consent between the two reviewers were used to solve disagreements.

One of the reliable indicators of the quality of the clinical trial methodologies is the PEDro classification scale [10]. For a score ranging from 0 to 10, the ten-item scores of the PEDro classification scale are added up. Based on

the PEDro score, each included study's methodological quality was assessed as low (≤3/10), medium (4–6/10), or high (≥7/10).

Figure-1. Flow chart showing the process of selecting or rejecting articles for inclusion in the study.



3. Results

3.1. Identification and Description of Included Studies

There were a total of 4291 citations, with 3243 from PubMed, 345 from The Cochrane Library, 265 from Science Direct, 362 from Google Scholar, 148 from PEDro, and 110 from Clinicaltrials.gov, and from these 2,243, duplicate studies were removed. A total of 1,888 studies were eliminated after the titles and abstracts of 2,048 articles were evaluated. The remaining 160 articles fulfilled the full-text review criteria. After applying exclusion criteria, 141 full texts were excluded, and the remaining 19 articles were included for final qualitative analysis. Figure 1 displays the approach of study selection. There were eight randomized control trials, six retrospective, and five prospective studies among the 19 articles.

3.2. Characteristics of the Included Studies

The key demographic and clinical features of each included study are summarized in Table 1. There were 1157 patients that participated in the studies. Among them, 667 (58%) were females, and 490 (42%) were males. The sample size ranged from twenty-one to one hundred fifteen subjects, and the articles were published between 2001 and 2022. Out of 19 studies published, five were conducted in China, three in Germany, two in Iran and Turkey, and one in the United States, Canada, Italy, Denmark, Spain, Taiwan, and Saudi Arabia.

3.3. Efficacy of Shockwave Therapy in Patients with Orthopedic Conditions

3.3.1. Chronic Tennis Elbow and Non-Calcific Rotator Cuff Tendinopathies

Typically, because of repetitive wrist and arm motions, the tendons in the elbow can be overloaded, causing tennis elbow (lateral epicondylitis). ESWT may be a successful conservative therapy for unilateral chronic tennis elbow, according to Rompe and colleagues [11]. To treat chronic tennis elbow, the authors compared the results of ESWT and ESWT combined with manual cervical spine treatment. Patients in Group I received manual treatment ten times on the cervical spine and ten times on the cervicothoracic junction, in addition to receiving 1,000 shockwave impulses at the lateral elbow with an energy flux density of 16mJ/mm2. Those patients who had received low-energy shockwave therapy during the previous three years in the same institution were initially included in Group II for conservative treatment. Before the trial, neither group showed a statistically significant difference; all patients received low ratings ($p > 0.05$). Even after a full year, there was still no discernible difference between the groups, with 56% in Group I and 60% in Group II reporting outstanding or satisfactory results ($p>0.05$). However, each group showed a substantial improvement ($p <0.0001$) over the pre-study assessment.

Razavipour and colleagues [12] conducted a prospective clinical trial to examine the benefits of ESWT in the treatment of tennis elbow. They found that for newly diagnosed patients, ESWT can lessen the intensity of pain and enhance daily activities. For a week, 40 patients received 2000 extracorporeal shock wave pulses daily. The Visual Analog Scale (VAS) was used for the assessment of the pain intensity; in contrast, a brief DASH questionnaire was used to assess the capacity to conduct daily activities (Disabilities of the Arm, Shoulder, and Hand). The average VAS pain score was observed to have decreased from 7.25±1.54 before therapy to 2.76±2.08 at 60 days after treatment ended (P<0.001).

Li and colleagues [8] evaluated the efficacy of Focused Extracorporeal Shock Wave (F-SWT) with Radial Extracorporeal Shock Wave (R-SWT) for treating non-calcific rotator cuff tendinopathies. Forty-six patients with non-calcific rotator cuff tendinopathies were divided into two groups, each comprising 23 people at random. Group A patients had four F-SWT therapy sessions, whereas group B patients underwent four R-SWT therapy sessions. The Constant-Murley Scale (CMS) and numerical rating scale (NRS) evaluated shoulder function and pain level. Within 24 weeks of the intervention, no discernible differences were there between the two groups concerning NRS pain score and CMS score (all $p > 0.05$). However, after 24 and 48 weeks following treatment, F-SWT significantly reduced NRS compared to R-SWT (2.7 ± 1.0 vs. 4.5 ± 1.2 and 1.4 ± 1.0 vs. 3.0 ± 0.8, respectively, with all p values < 0.001) [8]. Radiographic findings and CMS tweaks had similar effects. R-SWT and F-SWT are successful when treating individuals with non-calcific rotator cuff tendinopathy. At long-term follow-up, F-SWT was demonstrated to be noticeably more effective than R-SWT.

3.3.2. Chronic Plantar Fasciitis

Plantar fasciitis (PF) is a common reason for heel discomfort. ESWT is regarded as the standard therapy among several conservative choices. In an open-label randomized controlled clinical research study, Tognolo, *et al.* [13] assessed ESWT's efficacy on myofascial points in participants with PF. Randomly chosen PF patients were categorized into two treatment groups: the experimental group (EG), which underwent focused ESWT on myofascial sites, and the control group (CG), which underwent focused ESWT using the standard technique on the medial calcaneal tubercle. Every patient was provided a three-session program and follow-up visits at one and four months. The Italian Foot Functional Index and the Foot (17-IFFI) and Ankle Outcome Score (FAOS) were used as outcome measurements. Starting with the third treatment, both groups showed improvements in the FAOS scores and 17-IFFI, and these improvements were verified at the one-month and four-month follow-ups, along with the score values of earlier improvement demonstrated in the EG. For the conservative management of PF, it was shown that ESWT on myofascial sites might offer an intriguing option with superior results in terms of recovery time.

Hammer et al.Hammer, *et al.* [14] compared the efficacy of ESWT with traditional conservative therapy in individuals with chronically painful proximal plantar fasciitis. Forty-seven patients with conservative treatment for at least six months without results were randomly assigned to two groups. Three weekly ESWT sessions were the first step in Group 1's treatment. Patients in Group 2 (24 individuals) received therapy for an additional 12 weeks. Following this time, they received care following Group 1's procedure. After additional non-ESWT treatment for three months, there was no discernible change in discomfort or walking time. On the VAS, ESWT pain decreased by 64% to 88% six months later, and both groups' comfortable walking times increased.

Compared to a placebo, Kudo, *et al.* [15] found that ESWT was safe and effective at reducing the discomfort caused by persistent plantar fasciitis. One hundred fourteen adult patients with persistent plantar fasciitis who had resisted conservative treatments for at least six months were randomly assigned to one of the two groups. Three thousand eight hundred total shock waves constituted the therapy, which delivered 1,300 mJ/mm2 (ED+) of energy compared to the placebo in a single session. There was a statistically significant difference between the therapy groups in the primary effectiveness endpoint of discomfort in the first few minutes of walking as judged through a Visual Analog Scale between baseline and three months. Additionally, there was a statistically consequential difference between treatment groups in the number of participants whose Visual Analog Scale score changes at both six weeks and three months. Posttreatment met the study's definition of success, as well as in the difference between treatment groups in the Roles and Maudsley Score changes from baseline to three months after treatment. The outcomes of this study support the use of ESWT as a safe and productive therapy for persistent plantar fasciitis.

In a large group of people on active military duty, Purcell and colleagues [16] also evaluated the efficacy of ESWT for treating persistent plantar fasciitis. It was decided to evaluate 82 individuals with ESWT for chronic PF. The entire ESWT was conducted for 2000 shocks at 24 kV. Out of 82 patients 76 (93%) volunteered to participate, and 73.6% were serving members of the armed forces. At the most recent follow-up visit, the mean preoperative pain score, which was 7.8±2, decreased to 2.5± 2 ($p<0.0001$). Active-duty patients reported a mean improvement in pain of 4.8±3 than 6.8±3 for patients who were not on active duty ($p = 0.005$). Out of 76 patients, 75 (98%) went through 1 ESWT session, and 1 (2%) needed two sessions. Seventy-five (98%) of the patients underwent one ESWT session, with one patient (2%) requiring two. Seventy-four percent of patients gave their surgery either a high or outstanding rating, and 87% said ESWT worked. Ten patients (18%) could resume running. However, ten patients (18%) left the military due to persistent foot discomfort. These findings suggest that ESWT can treat chronic PF patients' pain in >85% of cases, with patients not in the military often reporting more significant pain reduction.

3.3.3. Chronic Achilles Tendinopathy

Chronic Achilles tendinopathy affects the foot often and makes walking and jogging difficult. It is a painful condition, and conservative therapy frequently yields disappointing results. Rasmussen and colleagues [18] examined the results of adding ESWT or a placebo to conventional treatment for chronic Achilles tendinopathy.

Active ESWT or sham ESWT was administered to patients assigned with non-operative chronic Achilles tendinopathy therapy for four weeks. Forty-eight patients (28 men) ranging from 19 to 80 years old participated. Pain and the American Orthopedic Foot and Ankle Society (AOFAS) scores were evaluated during, before, and after the four weeks of treatment. These evaluations were also performed at 4, 8, and 12-week check-ups. Throughout the therapy and follow-up phase, both groups made progress. In the intervention group, the mean AOFAS score went from 70±6.8 to 88±10, while in the placebo group, it increased from 74±12 to 81±16 ($p = 0.05$). During the follow-up period of 8 and 12 weeks, the intervention group had better outcomes ($p=0.01$ and $p=0.04$, respectively). ESWT seems like a possible adjunctive therapy for chronic Achilles tendinopathy management.

Yan, *et al.* [17] assessed ESWT's efficacy in curing chronic Achilles tendinopathy (CAT) with various disease courses. Data from 66 individuals having ESWT for CAT were analyzed. These patients were grouped into long-term (LT group, symptom duration >6 months) and short-term (ST group, symptom duration 3-6 months) groups based on the illness courses. Compared to their baseline scores after three months of the initial ESWT, both groups' AOFAS and VAS scores showed a substantial improvement ($p <0.01$). Additionally, the ST group's AOFAS was higher than the LT group (85.08 ± 9.83 vs 76.76 ± 9.85, $t = 76.76 \pm 9.85$, $p = 0.019$), and so was the Likert satisfaction rate at post-intervention month three (PIM3); though not reaching, it was close to a considerable level (70.6% vs. 47.1%). After ESWT, no statistically significant difference was present in the VAS ratings of the two groups (1.96 ± 0.98 vs 2.24 ± 1.29, t = 0:703, $p = 0.487$). Individuals with chronic Achilles tendinopathy may benefit from ESWT's efficient pain relief and restoration of hind foot function; more specifically, it may be more beneficial for patients who have recently developed CAT symptoms.

3.3.4. Frozen Shoulder

Idiopathic and progressive, frozen shoulder is recognized by discomfort, a reduced range of motion, and shoulder joint capsule fibrosis. Due to the increased regional blood flow, enzyme release, neovascular changes, inflammatory cytokine reduction, and increased flexibility of the tendons and collagen fibers in that area, shockwave therapy using low-energy waves and electromagnetic excitation may be effective in treating this condition. ESWT's efficacy in treating frozen shoulder was reported by Vahdatpour, *et al.* [18]. A total of 36 patients were separated into two groups. ESWT was administered to the intervention group once per week for four weeks, whereas sham shockwave treatment was administered to the control group. The Shoulder Pain and Impairment Index (SPADI) questionnaire and a goniometer were used to measure changes in the range of motion and the degree of pain and disability throughout the follow-up. The mean SPADI scores for pain and impairment were different between the two groups and the flexion, extension, and external rotation of the affected shoulder (P 0.05). The intervention group's improvement was more significant, but the two groups' mean internal rotations ($P > 0.05$) were not different. ESWT usage was found to benefit therapy, improve the quality of life in frozen shoulder sufferers, and a speedy return to normal activities.

Numerous short-term trials have shown that ESWT has proven to be a useful calcific tendinitis (CT) treatment, a temporary shoulder condition. In research involving 115 patients, Daecke, *et al.* [19] assessed the long-term consequences. Each patient received one (Group A, n=56) or two (Group B, n=59) high-energy shockwave treatment sessions. The results after six months revealed substantial variations in radiologic changes across the groups and energy-dependency of the degree of success in pain reduction and the Constant-Murley Shoulder Outcome Score (CMS). Four years after receiving shockwave treatment, 20% of all patients had undergone shoulder surgery. Out of the 115 original patients, the effects of ESWT were assessed without any other therapy within the first six months in 59% (n=68) of patients. Subjectively, 87% of Group B patients and 78% of Group A patients agreed that the shockwave therapy was effective. Before therapy, a mean of 45 was the CMS score; after treatment, it was 88 in Group A and 85 in Group B. In each group, 93% of patients had radiologic alterations. This study discovered that the therapy proved effective for 70% of patients, and long-term side effects were not presented.

3.3.5. Other Orthopedic Conditions

Kuo, *et al.* [20] examined the efficacy of ESWT and its application to the management of atrophic femoral non-union. Studies using ESWT demonstrated that, with a 9.2-month average union time, 14.6% of the 22 fractures achieved bone union (range 6-13 months). ESWT was conducted within 12 months following closed reamed nailing surgery, giving a union rate of 100% (8 out of 8 instances), as opposed to 42.9% (6 of 14 cases) when ESWT was not conducted after the first operation. Out of the 22 patients in the cohort, eight patients had bone grafting with augmentative plating surgery as a follow-up treatment, and all eight patients experienced bony union within five months of the intervention. ESWT may be an alternate and successful non-invasive therapy technique for individuals having atrophic non-unions of femoral shaft fractures.

Often, snapping scapula bursitis goes undiagnosed. Acar, *et al.* [21] evaluated and contrasted the results of corticosteroid injection with ESWT's efficacy in scapulothoracic bursitis treatment. Forty-three individuals with scapulothoracic bursitis were separated into two groups using randomized controlled trials. ESWT was administered three times to Group 1 (n=22). One local injection containing 80 mg of methylprednisolone was given to Group 2 (n=21). After one, two, and six months, the average VAS scores in Group 1 were 39, 30, 27, and 16, respectively. In contrast, the average VAS values in Group 2 were 46, 44, 35, and 36, respectively. The two groups displayed no statistically significant difference in the first and second months. With p-values of (0.012) and (0.001), respectively, Group 1 showed lower ratings of average VAS than the second group after 3 and 6 months. Concerning the roles and Maudsley criteria, the first set of patients had results that were 4% bad, 14% acceptable, 36% good, and 46%

excellent. Patients in the second group had outcomes that were 24% poor, 19% acceptable, 33% good, and 24% great. ESWT might be highly advised in excruciating scapulothoracic bursitis cases.

Osteonecrosis of the femoral head (ONFH), also known as ischemic necrosis of the hip, is a clinical disorder that worsens with time and causes considerable morbidity and permanent impairment. With varying degrees of effectiveness, several therapeutic techniques and surgical and nonsurgical alternatives have been tried. ESWT is a valuable therapeutic option for ONFH, especially in cases of early illness. Algarni and Al Moallem [22] evaluated ESWT's functional and radiological results in ONFH treatment. Before and after the intervention, clinical results using the Visual Analog Scale (VAS) and Harris Hip Score (HHS) and radiographic (using plain radiography and MRI) examinations were conducted. Pain and HHS ratings improved compared to pre-intervention scores at an average of 8 months following ESWT ($p<0.001$). The clinical results were overall better in 21 hips (63.3%), remained the same in 5 hips (15.15%), and deteriorated in 7 hips (21.2%). Despite not being clinically significant, there was a trend toward a shrinkage of the ONFH ($p=0.235$). Bone marrow edema has significantly resolved, according to MRI ($p=0.003$). Nine lesions (42.9%) showed regression, while one lesion (4.7%) showed advancement. There was no change in the remaining 23 lesions (52.4%). For early-stage ONFH, ESWT is a productive, non-invasive therapeutic option.

When patients having knee joint discomfort undergo MRI imaging, a reversible but excruciatingly painful result is identified as bone marrow edema (BME). In retrospective research, Kang, *et al.* [4] examined ESWT's effectiveness on painful BME in knee osteoarthritis. One hundred twenty-six patients underwent either alendronate treatment (Group B, n=44) or ESWT treatment (Group A, n=82). For at least 12 months, all patients underwent clinical and radiological follow-ups. Within three months of therapy, Group A experienced a more significant reduction in VAS and Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores than Group B ($P<0.01$). A higher incidence of an apparent decrease and complete BME regression of the afflicted knee in Group A compared to Group B at 6-month MRI follow-ups ($P<0.01$) was observed. ESWT is an efficient, dependable, and non-invasive therapy for patients with painful BME in knee osteoarthritis, followed by a quick return to normalcy in the MRI appearance. It could decelerate this disease's normal progression.

Zhang, *et al.* [23] assessed the effectiveness of the hip's painful bone marrow edema syndrome (BMES) with high-energy focused extracorporeal shock wave treatment (HFESWT). After the therapeutic intervention, the VAS was decreased at S1-S2 (1 and 3-months post-treatment), and the HHS was dramatically improved in comparison to pre-therapy ($P<.05$). The mean improvements between S0 (pre-therapy) and S1 and S1 and S2 were statistically very considerable ($P <.0001$), and between S2 and S3 (six months) they were less statistically significant ($P<.01$). There was no statistical significance in the mean improvement between the last follow-up at more than one year after the final follow-up at six months (S3). According to the MRI results, the diffuse BMES in the femoral head and neck entirely vanished. For patients having painful BMES of the hip, HF-ESWT is a safe, reliable, and non-invasive therapy that can hasten recovery, decrease the course of the illness and the length of treatment, and enhance patient quality of life and hip joint function.

Lateral hip discomfort is caused by greater trochanteric pain syndrome (GTPS) disorder. Its physiopathology is yet unclear, and there is no agreement on the best course of treatment. In patients with GTPS, Ramon, *et al.* [24] evaluated the efficacy of electromagnetic-focused extracorporeal shockwave therapy (F-ESWT). In this multi-center clinical experiment, 103 patients with chronic GTPS were randomly divided into two groups: those receiving electromagnetic F-ESWT plus a particular exercise regimen and those getting sham F-ESWT as a control. Patients were evaluated before therapy and one, two, three, and six months after that. At two months, the mean VAS score was 2.0 in the F-ESWT group and 4.7 in the control group, a significant difference between the groups (p 0.001). The mean VAS score reduced from 6.3 in both groups at baseline to 2.0 at two months. The F-ESWT group significantly outperformed the control group in every secondary outcome at every follow-up time point, except for the Lower Extremity Functional Scale (LEFS) one month after treatment ($p =0.25$). F-ESWT, in addition to a particular exercise regimen, is effective and safe for GTPS with a success rate of 86.8% at two months following treatment, which was maintained till the end of the follow-up.

Coccydynia is a condition that significantly impairs function while lowering quality of life. Thirty-four patients (29 female, 5 male) who underwent ESWT treatment because of chronic coccydynia between 2017 and 2018 had their medical records reviewed by Gönen, *et al.* [25]. Before the therapy, 9.6 (9–10) was the mean VAS score; after the treatment, it was 3.4 (0–2). In 79.4% of patients, the VAS levels dropped to ≤3. In 6% of individuals, the edema in the bone marrow subsided. Except for two metrics, every single The Short Form 36 Health Survey (SF-36) parameter showed a significant improvement. ESWT effectively reduced pain in this patient population.

Li et al. [8] examined the effect of ESWT on patients receiving therapy for lower limb spasms and discomfort brought on by lumbar degenerative diseases (LDD). Pain scores improved more in the ESWT group in contrast to the control group ($p< 0.001$ and $p< 0.001$, respectively). Reviewing the patients' lumbar multifidus atrophy (LMA) ratings revealed that while all patients had improved overall functional status following therapy, only patients in the ESWT group had moderate functional limits before treatment ($p< 0.001$). Patients with LDD benefit notably from the effectiveness of ESWT. Leg cramp relief and an improvement in overall functional status are significantly influenced over the long term by using ESWT.

3.4. Quality Assessment of Included Studies

Two reviewers independently evaluated the included studies. Twelve out of nineteen studies (63.2%) had medium methodological quality and thus moderate risk of bias, whereas seven were high-quality studies (36.8%) with low risk of bias (Table 3).

Table-1. Characteristics of included studies

Author	Year	Country	Sample size	Age	Design of study	Diagnosis	Primary objective	Randomization	Intervention	Outcome results
Rompe JD	2001	Germany	30 (14 M, 16 F)	37-68years	Prospective, matched single-blind control trial	Chronic tennis elbow	The Roles and Maudsley outcome scores at 12 months	Group I: Low-energy shockwave therapy and manual therapy Group II: Low-energy shockwave therapy	Extracorporeal shockwave therapy and Manual therapy of the cervical spine and cervicothoracic junction	With the result being excellent or good in 56% of the Group I participants and in 60% of the Group II participants after 12 months, there was still no discernible difference.
Daecke W	2002	Germany	115 (67 M, 48 F)	28-77 years	Prospective study	Chronic calcific tendinitis of shoulder	To examine the long-term effects and complications	One (Group A, n =56) or two (Group B, n= 59) sessions of high-energy shockwave therapy	Extracorporeal shockwave therapy	Subjectively, 87% of Group B patients and 78% of Group A patients agreed that the shockwave therapy had been effective.
Hammer DS	2002	Germany	47 (15 M, 32 F)	24-79 years	Prospective study	Chronically proximal plantar fasciitis	Compare the effect of ESWT with a conservative treatment	Group 1 (25 heels) with three ESWT sessions at weekly intervals Group 2 (24 heels) conservative treatment was continued for 12 weeks	Extracorporeal shockwave therapy	On a visual analog scale (VAS), ESWT discomfort decreased by 64% to 88% six months later, and both groups' comfortable walking times increased.
Kudo P	2006	Canada	114 (41 M, 73 F)	51.1±10.6 (A) 48.8 ± 9.8 (P)	Randomized, placebo-controlled, double-blind, clinical study	Plantar Fasciitis	Safety and efficacy of ESWT to treat the pain related to chronic plantar fasciitis	Active treatment group (n=58) or the Placebo control group (n=56)	Extracorporeal shockwave therapy	Recalcitrant plantar fasciitis can be treated with ESWT, which is both safe and effective.
Rasmussen S	2008	Denmark	48 (28M, 20F)	19-80	Randomized, placebo-controlled, double-blind, clinical study	Chronic Achilles tendinopathy	To compare the effect of adding conservative treatment of chronic Achilles tendinopathy with ESWT or placebo	Active ESWT or sham ESWT	Extracorporeal shockwave therapy	Throughout the therapy and follow-up phase, both groups made significant progress. At 8 and 12 weeks of follow-up, the intervention group showed better results ($p = 0.01$ and $p = 0.04$ respectively).
Vahdatpour B	2014	Iran	36 (11M, 25F	56.1 ± 10.6 (I) 60.3 ± 4.8 ©	Randomized clinical study	Frozen shoulder	ESWT's effect in treating patients with frozen shoulder	Intervention group (n=19) Control group (n=17)	Extracorporeal shockwave therapy	ESWT appears to have beneficial benefits on therapy, a quicker return to normal activities, and improvement in frozen shoulder sufferers' quality of life.
Kuo SJ	2015	Taiwan	22 (9M, 13F)	18-45years	Retrospective study	Atrophic non-unions of isthmic femoral shaft fractures	ESWT's efficacy in treating atrophic non-union of femurs.		Extracorporeal shockwave therapy	ESWT is an effective and alternative method of treatment.
Acar N	2017	Turkey	43 (19M, 24F)	43.2 ± 5.6 (I) 41.7 ± 2.3 (II)	Randomized clinical study	Scapulothoracic bursitis	To evaluate ESWT's effectiveness in treating scapulothoracic	Group I (n=22) Group II (n=21)	Extracorporeal shockwave therapy	In excruciating cases of scapulothoracic bursitis, ESWT is a helpful and reliable kind of therapy that can be strongly recommended.

							bursitis			
Algarni AD	2018	Saudi Arabia	21 (9M, 12F)	21-54	Prospective study	Osteonecrosis of the Femoral head (ONFH)	The functional and radiological results of ESWT in treating ONFH		Extracorporeal shockwave therapy	For early-stage ONFH, ESWT is a suitable noninvasive therapeutic approach that enhances clinical results and has the potential to slow or stop the disease's radiological development
Razavipour M	2018	Iran	40 (12M, 28F)	43.80±8.97	Prospective study	Tennis elbow	Effects of ESWT in Tennis elbow treatment		Extracorporeal shockwave therapy	ESWT reduce the severity of pain and improve daily activity.
Kang S	2018	China	126 (55M, 71F)	39-73	Historical cohort study	Knee osteoarthritis	ESWT's efficiency on painful BME in osteoarthritis of the knee.	ESWT treatment (Group A, n=82) or alendronate treatment (Group B, n=44)	Extracorporeal shockwave therapy	ESWT is an efficient, safe, and non-invasive therapy for painful BME in knee osteoarthritis patients.
Purcell RL	2018	USA	76 (41 M, 35F)	18-62	Prospective study	Chronic plantar fasciitis (PF)	Effectiveness in treating chronic PF in an active-duty population		Extracorporeal shockwave therapy	ESWT alleviated pain in more than 85% of individuals with chronic PF, with patients who are not in the military often reporting greater pain alleviation.
Yan B	2020	China	66 (31 M, 35F)	60:80 ± 8:74 (LT) 56:77 ± 8:68 ST)	Retrospective study	Chronic Achilles Tendinopathy	To evaluate ESWT's efficiency on chronic Achilles tendinopathy (CAT)	Long term (LT= 45) Short term (ST=21)	Extracorporeal shockwave therapy	ESWT might successfully treat chronic Achilles tendinopathy patients' discomfort and enhance hindfoot function.
Ramon S	2020	Spain	103 (29 M, 74 F)	57.1 ± 12.9 (FESWT) 55.6 ± 11 ©	Randomized controlled clinical study	Greater Trochanteric Pain Syndrome (GTPS)	F-ESWT's effectiveness in GTPS patients.	FESWT= 53 Control =50	Extracorporeal shockwave therapy	In addition to a particular exercise program, F-ESWT is safe and effective for GTPS
Gönen Aydın C	2020	Turkey	34 (5M, 29F)	16-62 years	Retrospective study	Chronic Coccydynia	Efficiency of ESWT in treating coccydynia.		Extracorporeal shockwave therapy	ESWT provided effective pain control.
Zhang L	2020	China	34 (23 M, 11F)	19-56 years	Retrospective study	Bone marrow edema syndrome (BMES)	Evaluate the efficiency of ESWT on painful BMES of the hip		Extracorporeal shockwave therapy	HF-ESWT is an effective and safe treatment in painful BMES of the hip patients.
Li C	2021	China	46 (19M, 25F)	50.6 ± 5.2 (F-ESWT) 53.4 ± 6.7 (R-ESWT)	Randomized controlled clinical study	Noncalcific rotator cuff tendinopathies	To compare the effectiveness of F-SWT and R-SWT for noncalcific rotator cuff tendinopathies management	FESWT= 23 RESWT =23	Extracorporeal shockwave therapy	When treating individuals with non-calcific rotator cuff tendinopathy, R-SWT and F-SWT are both successful. At long-term follow-up, F-SWT proven to be much better than R-SWT.

Li BZ	2021	China	126 (51 M, 75F)	34-84 years	Retrospective study	Lumbar degenerative disorders (LDD)	Assess the influence of ESWT in patients with LDD	ESWT= 78 Control =44	Extracorporeal shockwave therapy	ESWT usage significantly improves overall functional status over the long term by reducing pain, leg cramps, and other symptoms.
Tognolo L	2022	Italy	30 (9M, 21F)	23-82years	Open label randomized clinical trial	Plantar fasciitis (PF)	Effectiveness of the ESWT on myofascial points in cases with PF	Experimental treatment Group (EG)= Control Group (CG)=	Extracorporeal shockwave therapy	ESWT on myofascial points can be an effective alternative with better outcomes concerning recovery time.

Table-2. Type of wave characteristics, source of stimulation energy, application parameters, and the key findings

		Shock wave therapy							
Author	**Year**	**Energy generator**	**Rate (Hz)**	**EFD (mJ/mm2)**	**No. of impulses**	**Total treatment sessions**	**Treatment success rate**	**Pain score reduction**	**Overall patient improvement**
Rompe JD	2001	Focused	4	0.16	1000	3	40% patients in Group I, versus 50% patients in Group II, had an excellent or good result	Mean subjective improvement of the symptoms was 62% ± 27% in Group I and 60% ± 34% in Group II	The mean subjective improvement was 75% ± 23% in Group I and 72% ± 33% in Group II
Daecke W	2002	Focused		0.3	2000	Group A: 1 Group B: 2	Although Group B experienced more subjective successes than Group A, there was no statistical significance in the differences.	There was a considerable difference in the pain relief amount was there for all groups (P<0 .001)	The first three months had the highest rate of radiologic changes (67%) overall. In the next three months, 17% of patients showed changes, and in the following 3.5 years, 16% of patients experienced partial or total resorption.
Hammer DS	2002	Focused	16-20	0.2	3000	3	On the VAS scale, pain decreased by 64% to 88% six months following ESWT.	After a six-month follow-up, up to 80% of the patients reported having all their pain completely or almost completely relieved.	Both groups have experienced a considerable improvement in comfortable walking time.
Kudo P	2006	Focused		0.64	3800	1	There was a mean percentage improvement of 49.1% in the active treatment group than the mean improvement of 33.3% in the placebo group.	At three months, the mean pain score in the group receiving active therapy dropped from 7.5 to 3.9 (p<0.0001). The mean pain score dropped from 7.9 to 5.3 in the placebo group at three months (p<0.0001) and a mean improvement of 33.3%.	Only 23% (12 of 52) of the participants in the Placebo group matched the same criterion, compared to 47% (25 of 53) of

									the subjects in the Active group (p=0.0099).
Rasmussen S	2008	Focused	50	0.12-0.51	2000	4	The supplement ESWT seems to be used to treat chronic Achilles tendinopathy.	Although both groups had less pain, the statistical significance in their difference was nil.	Following treatment, AOFAS score of the intervention group grew over time more than the control groups did (p = 0.05).
Vahdatpour B	2014	Focused		0.1-0.3	1200	1	ESWT helps the frozen shoulder recovery process move forward more quickly.	The mean pain and disability scores of the two groups before and after the ESWT were different.	Although the mean internal rotation was similar in both groups, the improvement was more satisfying in the intervention group (P <0.05).
Kuo SJ	2015	Focused		0.58	3000		ESWT was conducted within 12 months following the closed reamed nailing surgery, and the union rate was 100% (8 out of 8 cases), contrary to 42.9% (6 out of 14 cases) when ESWT was conducted after the first operation.		Using ESWT, we demonstrated that, with an average union time of 9.2 months, 14.6% of the 22 fractures achieved bone union (range 6e13 months).
Acar N	2017	Focused		0.1-0.15	1500	3	Similar outcomes in terms of pain reduction and overall satisfaction rate were seen in the ESWT and corticosteroid injection groups.	Group 1 demonstrated lower average VAS scores at 3 and 6 months compared to the second group, with p-values of (0.012) and (0.001), respectively.	Maudsley criteria and roles revealed that the first patient group had results that were 4% poor, 14% acceptable, 36% good, and 46% excellent. Patients in the second group, however, had outcomes that were 24% poor, 19% acceptable, 33% good, and 24% great.
Algarni AD	2018	Focused			1500	1	Clinical outcomes were overall better in 21 hips (63.3%), remained the	Pain and HHS ratings improved compared to preintervention scores at an average of 8 months following ESWT (p 0.001).	The ONFH's size appeared to be

							same in 5 hips (15.15%), and deteriorated in 7 hips (21.2%).		shrinking after ESWT compared to before the intervention, although there was no statistical significance (p=0.23) in this tendency.
Razavipour M	2018	Focused			2000	1	After therapy, patients' daily activities improved (P <0.001).	At 60 days after the end of therapy, the mean VAS pain score decreased.	At 60 days after the therapy, the Quick Dash score had dramatically decreased (p<0.001)
Kang S	2018	Focused	2-3	0.44	3000-4000	2	Painful BME in osteoarthritis of the knee patients responded well to the noninvasive, effective therapy ESWT, which was followed by a quick return to normalcy in the MRI appearance.	Within three months of therapy, Group A saw a greater reduction in VAS and WOMAC scores than did Group B (P< .01).	There was a larger incidence of a clear decrease and full BME regression of the afflicted knee in Group A than in Group B at 6-month MRI follow-ups (P<.01).
Purcell RL	2018	Focused			2000	1	74% of patients thought the results of their surgeries were "good" or "excellent," and 87% said that the ESWT was effective.	In contrast to non-active-duty patients, active-duty patients reported in pain improvement (p =.005).	Study supports the statistically significant and clinical effectiveness of ESWT in treating chronic PF in a primarily active-duty population.
Yan B	2020	Focused	4 or 8	0.096-1.37	2000	3-5	Chronic Achilles tendonitis might enhance function and successfully reduce discomfort with ESWT.	When compared to their baseline scores 3 months after the first ESWT, both groups' AOFAS and VAS scores show a substantial improvement (p <0.01).	The satisfaction rating of the ST group was 70.6% (12/17), which is greater than that of the LT group (47.1%, 8/17), three months after the first ESWT session.
Ramon S	2020	Focused	5	0.2	2000		Success rate of 86.8% at 2 months after treatment	At 2 months, the mean VAS score in the F-ESWT group was 2.0 and 4.7 in the control group which is a significant difference (p<0.001). The mean VAS score reduced from 6.3 to 2.0 in both groups at baseline at 2 months.	No complications were observed
Gönen Aydın C	2020	Focused		0.2	3000	6-8	ESWT is an effective treatment with	In 79.4% of patients, the VAS score decreased to ≤3.	6% of individuals saw a

							low complication rates		decrease in bone marrow edema. All SF-36 metrics showed a significant improvement.
Zhang L	2020	Focused		0.5	2500-4000	2	It is a valid, reliable, safe, effective, non-invasive treatment for people with painful BMES of the hip that has a low risk of complications and can hasten BMES of the hip recovery.	After therapeutic intervention, the VAS was decreased at S1-2 (1- and 3-months post-treatment) and the HHS was dramatically improved in comparison to pretherapy (P<0.05)	The hip joint's recovery from BMES is sped up by HF-ESWT, which also reduces treatment duration and disease progression and enhances patient quality of life and hip joint function.
Li C	2021	Focused-ESWT Radial-ESWT	5.1 ± 0.5 (F-ESWT)	0.09 ± 0.018 (F-ESWT)	3000 (F-ESWT) 3000 (R-ESWT)	4 (F-ESWT) 4 (R-ESWT)	At 24 and 48 weeks, focused shockwaves proved to be noticeably better to radial shockwaves.	At 24- and 48-weeks following treatment, F-SWT had a lower NRS than R-SWT.	F-SWT is advised for treating non-calcific rotator cuff tendinopathies.
Li BZ	2021	Focused	8		2000	once every two days for four weeks		Improvements in pain and cramp frequency and duration were statistically significant for the ESWT group's patients.	ESWT group patients experienced a complete improvement in their overall functional level (p<0.001).
Tognolo L	2022	Focused	5	0.05-0.167	1500			When compared to the usual treatment, the myofascial group showed better benefits in terms of pain relief and recovery time.	By applying the conventional technique to the myofascial points and the medial calcaneal insertion of the plantar fascia, ESWT was proven to be a successful therapy option for the pathology.

Author	**Year**	**Random Allocation**	**Concealed Allocation**	**Similarity at the baseline**	**Subject blinding**	**Therapist blinding**	**Assessor blinding**	**More than 85% follow-up for at least one key outcome**	**Intention-to-treat analysis**	**Between-group statistical comparison for at least one key outcome**	**Point and variability measures for at least one key outcome**	**Overall Score**	**Quality of studies**
Rompe JD	2001	Y	Y	Y	Y	N	N	Y	Y	Y	Y	8/10	High

Daecke W	2002	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	Medium
Hammer DS	2002	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	Medium
Kudo P	2006	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9/10	High
Rasmussen S	2008	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9/10	High
Vahdatpour B	2014	Y	Y	Y	Y	N	N	Y	Y	Y	Y	8/10	High
Kuo SJ	2015	N	N	Y	N	N	N	Y	Y	N	Y	4/10	Medium
Acar N	2017	Y	Y	Y	N	N	N	Y	Y	Y	Y	7/10	High
Algarni AD	2018	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Razavipour M	2018	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Kang S	2018	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	Medium
Purcell RL	2018	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Yan B	2020	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	Medium
Ramon S	2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10/10	High
Gönen Aydın C	2020	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Zhang L	2020	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Li C	2021	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	9/10	High
Li BZ	2021	N	N	Y	N	N	N	Y	Y	Y	Y	5/10	Medium
Tognolo L	2022	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	Medium

4. Discussion

Early systematic reviews support the commonly held opinion that ESWT is risk-free, technically simple to conduct, and beneficial in some cases. This systematic review used a comprehensive search to choose previous clinical studies investigating ESWT's clinical effectiveness in patients with orthopedic conditions. In patients with various orthopedic disorders, the results showed considerable moderate proof of the efficacy and safety of general ESWT in raising treatment success rates, lowering pain levels, promoting functional recovery reported by patients, and boosting the functional outcomes of performances.

ESWT has been utilized extensively in recent years to treat different musculoskeletal conditions, including plantar fasciitis, chronic heel pain, lateral epicondylitis of the elbow, and calcific rotator cuff tendinopathies [1]. The therapeutic benefits of ESWT are mediated by various mechanisms, including mechanical stimulation, increased expression of several growth factors, and regional blood flow. ESWT has a more protracted therapeutic impact. Conflicting findings were found in two systematic reviews. The first prospective controlled trial on the efficiency of ESWT for chronic tennis elbow treatment was released in 1996, according to a literature review by Heller and Niethard [26].

Although ESWT is often used, the FDA has only approved it for managing plantar fasciitis. There is still controversy around the use of ESWT in treating musculoskeletal issues worldwide. The most frequent cause of a stabbing sensation at the enthesis of the fascia in the medial plantar region of the heel (medial calcaneal tuberculum region) is plantar fasciitis (PF), a chronic musculoskeletal ailment [14]. Rest, weight loss, NSAIDs, physical therapy (ultrasound therapy, low-energy, and high-energy laser therapy), and stretching exercises for calf muscles and the plantar fascia are all considered conservative treatments for PF. Local corticosteroid injections are frequently used as a backup therapy if symptoms continue. Corticosteroids have been shown to damage the fascial tissue, increasing the likelihood of additional degeneration and, ultimately, rupture despite having a positive impact on pain relief [13].

Controlled investigations on ESWT's efficacy in chronically sore heel management have shown success rates ranging from 48% to 77%. In patients who had previously had ineffective nonsurgical therapy for proximal plantar fasciitis, Hammer, *et al.* [14] found that ESWT considerably reduced discomfort and extended the time that patients could walk comfortably. After a six-month follow-up, up to 80% of the patients reported having all their pain entirely or almost completely relieved. The findings of the Purcell, *et al.* [16], studies contribute to the growing body of research that shows ESWT's efficiency in treating chronic PF in a mostly active-duty group in both a clinically and statistically meaningful way.

Patients with chronic PF resistant to standard conservative therapies are advised to have ESWT. Compared to placebo, previous studies have shown varying efficacy rates for pain reduction, ranging from 55% to 88%, over short or medium lengths of time [16]. According to Tognolo, *et al.* [13], ESWT applied to the myofascial points in patients with plantar fasciitis may be a successful therapy.

ESWT is a helpful treatment for tennis elbow in well-designed randomized controlled trials, according to Rompe, *et al.* [27]. However, in another study by Stasinopoulos and Johnson, who looked at seven clinical studies, they found no evidence of this treatment's effectiveness. ESWT's analgesic effects in patients having intractable medial or lateral epicondylitis were compared prospectively by Krischek, *et al.* [28]. Using the Verhaar, *et al.* [29] scoring system, they found that 62% of tennis elbow patients had good or outstanding results after a year, compared

to 28% of golfer's elbow patients. Regarding the Roles and Maudsley scores, at 6-month follow-up, 48% of the treatment group had good or outstanding results, compared to 6% in the control group; at 12-month follow-up, there were 52% against 6% good or excellent cases [5]. Sixty people with chronic tennis elbow had ESWT and surgery, and Perlick et al. [30] prospectively compared the results. They reported good or outstanding improvements in the Roles and Maudsley scores at a 12-month follow-up in 43% of ESWT patients and 73% of surgery patients. No improvement was reported by 10% of surgery patients and 23% of EWST patients. Rompe, *et al.* [11] also validate earlier findings, with 56% and 60% of patients seeing satisfactory or outstanding outcomes at a one-year follow-up.

Chronic Achilles tendinopathy (CAT) is a prevalent pain condition that affects athletes, middle-aged male runners, and the sedentary population [17]. Traditional non-operative treatments include stretching exercises, non-steroid anti-inflammatory medicines, tailored heel lifts and shoes, relative rest, eccentric calf muscle training, and avoiding unpleasant aggravating activities. However, these therapies provide frequently subpar outcomes. Due to the potential for tendon weakening, corticosteroid injection at the lesion site has not been advised. ESWT is a therapeutically useful addition to traditional tendinopathy therapy. At this time, there is not enough evidence to endorse ESWT [31]. According to the therapeutic mechanism, ESWT could, through mechanical stimulation, encourage the expression of inflammatory factors, boost tenocyte proliferation, and increase collagen synthesis, all of which would help to heal damaged tendinous tissue and enhance the Achilles tendon's functionality. Additionally, the shock wave may reduce local substance P levels, destroy unmyelinated nerve fibers, and, as a result, lessen CAT-related pain [17].

According to one meta-analysis, the success rate of ESWT application for long bone fractures depends on the kind of non-union, with a 29% success rate for atrophic non-unions and a 76% success rate for hypertrophic non-unions [32]. In contrast, [20] found that the treatment of atrophic non-unions had an overall union rate of 63.6%. Additionally, when ESWT was used within 12 months of the first fracture therapy, the union rate was 100% and fell to 42.6% when ESWT was applied more than a year after the initial operation. According to findings from earlier research, the effectiveness of the ESWT therapy of the atrophic non-unions can be associated with the promotion of neovascularization and the decrease of the inflammatory response of local tissues due to shockwaves [33].

Numerous studies have suggested that F-SWT has positive effects. At 24 weeks and 48 weeks, focused shockwaves seemed to be noticeably superior to radial shockwaves, according to Li, *et al.* [8]. Additionally, they discovered that F-SWT patients improved more radiologically than R-SWT patients.

5. Conclusion

ESWT has successfully resolved various musculoskeletal problems without significant side effects or complications. How ESWT improves pain and function is still being determined, and this subject requires more research. Prospective randomized studies with extended follow-up timeframes are needed to compare ESWT with various therapeutic modalities and energy doses.

5.1. Competing Interests

The authors have no competing interests.

5.2. Authors' Contributions

JM is the principal investigator and conceived and designed the study. GT assisted the design of the study. JM and GT analyzed the data and interpreted the results, prepared and critically reviewed the manuscript. Both authors have read and approved the manuscript.

References

[1] Wang, C. J. and Chang Gung Med, J., 2003. "An overview of shock wave therapy in musculoskeletal disorders." *26*, vol. 4, pp. 220-232.

[2] Gesslbauer, C., Mickel, M., Schuhfried, O., Huber, D., Keilani, M., and Crevenna, R., 2021. "Effectiveness of focused extracorporeal shock wave therapy in the treatment of carpal tunnel syndrome : A randomized, placebo-controlled pilot study." *Wien Klin Wochenschr*, vol. 133, pp. 568-577.

[3] Lo, W. S., Sheen, J. M., and Chen, Y. C., 2022. "The Application of focused medium-energy extracorporeal shockwave therapy in hemophilic a arthropathy." *Healthc Basel Switz*, vol. 10, p. 352.

[4] Kang, S., Gao, F., and Han J, 2018. "Extracorporeal shock wave treatment can normalize painful bone marrow edema in knee osteoarthritis: A comparative historical cohort study." *Medicine Baltimore*, vol. 5, p. e9796.

[5] Rompe, J. D., Hope, C., Küllmer, K., Heine, J., and Bürger, R., 1996. "Analgesic effect of extracorporeal shock-wave therapy on chronic tennis elbow." *J. Bone Joint Surg Br.*, vol. 78, pp. 233-237.

[6] Schmitz, C., Császár, N. B. M., and Milz, S., 2015. "Efficacy and safety of extracorporeal shock wave therapy for orthopedic conditions: A systematic review on studies listed in the PEDro database." *Br Med Bull*, vol. 116, pp. 115-138.

[7] Holfeld, J., Tepeköylü, C., and Kozaryn, R., 2014. "Shockwave therapy differentially stimulates endothelial cells: implications on the control of inflammation via toll-Like receptor 3." *Inflammation*, vol. 37, pp. 65-70.

[8] Li, B. Z., Li, H. F., Zhang, Z. W., Li, Y., Wang, W., and Xiong, Y., 2021. "Effectiveness of extracorporeal shock wave therapy reduces leg cramps in patients of lumbar degenerative disorders: A retrospective study." *BioMed Res Int.*, Available: 10.1155/2021/3554397

[9] Ke, M. J., Chen, L. C., and Chou, Y. C., 2016. "The dose-dependent efficiency of radial shock wave therapy for patients with carpal tunnel syndrome: A prospective, randomized, single-blind, placebo-controlled trial." *Sci Rep.*, vol. 6, p. 38344.

[10] de Morton, N. A., 2009. "The PEDro scale is a valid measure of the methodological quality of clinical trials: A demographic study." *Aust J Physiother*, vol. 55, pp. 129-133.

[11] Rompe, J. D., Riedel, C., Betz, U., and Fink, C., 2001. "Chronic lateral epicondylitis of the elbow: A prospective study of low-energy shockwave therapy and low-energy shockwave therapy plus manual therapy of the cervical spine." *Arch Phys Med Rehabil*, vol. 82, pp. 578-582.

[12] Razavipour, M., Azar, M. S., Kariminasab, M. H., Gaffari, S., and Fazli, M., 2018. "The short term effects of shock-wave therapy for tennis elbow: A clinical trial study." *Acta Inform Medica AIM J Soc Med Inform Bosnia Herzeg Cas Drustva Za Med Inform BiH*, vol. 26, pp. 54-56.

[13] Tognolo, L., Giordani, F., and Biz, C., 2022. "Myofascial points treatment with focused extracorporeal shock wave therapy (f-ESWT) for plantar fasciitis: an open label randomized clinical trial." *Eur. J. Phys. Rehabil Med.*, vol. 58, pp. 85-93.

[14] Hammer, D. S., Adam, F., Kreutz, A., Rupp, S., Kohn, D., and R., S., 2005. "Ultrasonographic evaluation at 6-month follow-up of plantar fasciitis after extracorporeal shock wave therapy." *Arch Orthop Trauma Surg*, vol. 125, pp. 6-9.

[15] Kudo, P., Dainty, K., Clarfield, M., Coughlin, L., Lavoie, P., Lebrun, C., and Randomized, J., 2006. "Placebo-controlled, double-blind clinical trial evaluating the treatment of plantar fasciitis with an extracoporeal shockwave therapy (ESWT) device: A North American confirmatory study." *Orthop Res Off Publ Orthop Res Soc.*, vol. 24, pp. 115-123.

[16] Purcell, R. L., Schroeder, I. G., Keeling, L. E., Formby, P. M., Eckel, T. T., and Shawen, S. B., 2018. "Clinical outcomes after extracorporeal shock wave therapy for chronic plantar fasciitis in a predominantly active duty population." *J. Foot Ankle Surg Off Publ Am Coll Foot Ankle Surg*, vol. 57, pp. 654-657.

[17] Yan, B., Wan, Y., Zhang, H., Pan, M., and Zhou, C., 2020. "Extracorporeal shockwave therapy for patients with chronic achilles tendinopathy in long or short course." *BioMed Res Int.*, p. 7525096. Available: 10.1155/2020/7525096

[18] Vahdatpour, B., Taheri, P., Zade, A. Z., and Moradian, S., 2014. "Efficacy of extracorporeal shockwave therapy in frozen shoulder." *Int. J. Prev. Med.*, vol. 5, pp. 875-881.

[19] Daecke, W., Kusnierczak, D., and Loew, M., 2002. "Long-term effects of extracorporeal shockwave therapy in chronic calcific tendinitis of the shoulder." *J Shoulder Elbow Surg.*, vol. 11, pp. 476-480.

[20] Kuo, S. J., Su, I. C., Wang, C. J., and Ko, J. Y., 2015. "Extracorporeal shockwave therapy (ESWT) in the treatment of atrophic non-unions of femoral shaft fractures." *Int J Surg Lond Engl*, vol. 24, pp. 131-134.

[21] Acar, N., Karaarslan, A. A., and Karakasli, A., 2017. "The effectiveness of extracorporeal shock wave therapy in snapping scapula." *J Orthop Surg Hong Kong*, vol. 25, Available: 10.1177/2309499016684723

[22] Algarni, A. D. and Al Moallem, H. M., 2018. "Clinical and radiological outcomes of extracorporeal shock wave therapy in early-stage femoral head osteonecrosis." *Adv. Orthop.*, Available: 10.1155/2018/7410246

[23] Zhang, J., Li, Y., and Wang, H., 2017. "Musculoskeletal ultrasound-guided physical therapy in hemiplegic shoulder pain." *Medicine (Baltimore)*, vol. 96, p. e9188.

[24] Ramon, S., Russo, S., and Santoboni, F., 2020. "Focused shockwave treatment for greater trochanteric pain syndrome: A multicenter, randomized, controlled clinical trial." *J. Bone Joint Surg Am.*, vol. 102, pp. 1305-1311.

[25] Gönen, A. C., Örsçelik, A., Gök, M. C., and Akman, Y. E., 2020. "The efficacy of extracorporeal shock wave therapy for chronic coccydynia." *Med Princ Pract Int J Kuwait Univ Health Sci Cent*, vol. 29, pp. 444-450.

[26] Heller, K. D. and Niethard, F. U., 1998. "Using extracorporeal shockwave therapy in orthopedics: A meta-analysis." *Z Orthop Ihre Grenzgeb*, vol. 136, pp. 390-401.

[27] Rompe, J. D., Theis, C., and Maffulli, N., 2005. "Shock wave treatment for tennis elbow." *Orthopade*, vol. 200, pp. 567-570.

[28] Krischek, O., Hopf, C., Nafe, B., and Rompe, J. D., 1999. "Shock-wave therapy for tennis and golfer's elbow: 1 year follow-up." *Arch Orthop Trauma Surg*, vol. 119, pp. 62-66.

[29] Verhaar, J., Walenkamp, G., Kester, A., van Mameren, H., and van der Linden, T., 1993. "Lateral extensor release for tennis elbow. A prospective long-term follow-up study." *J Bone Joint Surg Am.*, vol. 75, pp. 1034-1043.

[30] Perlick, L., Gassel, F., Zander, D., Schmitt, O., and Wallny, T., 1999. "Comparison of results of results of medium energy ESWT and Mittelmeier surgical therapy in therapy refractory epicondylitis humeri radialis." *Z Orthop Ihre Grenzgeb*, vol. 137, pp. 316-321.

[31] Rasmussen, S., Christensen, M., Mathiesen, I., and Simonson, O., 2008. "Shockwave therapy for chronic Achilles tendinopathy: a double-blind, randomized clinical trial of efficacy." *Acta Orthop*, vol. 79, pp. 249-256.

[32] Zelle, B. A., Gollwitzer, H., Zlowodzki, M., and Bühren, V., 2010. "Extracorporeal shock wave therapy: current evidence." *J. Orthop Trauma*, Available: 10.1097/BOT.0b013e3181cad510

[33] Davis, T. A., Stojadinovic, A., and Anam, K., 2009. "Extracorporeal shock wave therapy suppresses the early proinflammatory immune response to a severe cutaneous burn injury." *Int Wound J.,* Available: 10.1111/j.1742-481X.2008.00540.x