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Comparative Effectiveness of Extracorporeal Short Wave Therapy, Low-level Laser Therapy, and Ultrasound in the Treatment of Rotator Cuff Tendinopathy

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Rotator cuff tendinopathy (RCT), often known as tendinitis, is an inflammation or degeneration of the shoulder's rotator cuff tendons caused by a combination of internal and environmental factors. Topical and oral nonsteroidal anti-inflammatory drugs (NSAIDs), extracorporeal short-wave therapy (ESWT), and corticosteroid injections, along with ultrasound (US), have been evaluated in randomized controlled trials (RCTs). Patients and physicians often favor low-level laser therapy (LLLT), ultrasound therapy (UST), and ESWT for RCTs due to their non-invasive nature and reduced risk of side effects. Few studies have shown that ESWT, UST, and LLLT reduce post-treatment discomfort. The extent to which these treatment modalities into exercise yield benefits has yet to be well understood, even though combining therapies to maximize effectiveness is presumably common in clinical practice. Furthermore, the effectiveness of these three treatments has been substantiated by increasing clinical trials. Typically, the UST, LLLT, or the ESWT is chosen on a case-by-case basis due to their comparable capabilities. However, there currently needs to be an agreement on which therapy strategy is more effective. Our study aims to evaluate and compare these treatments with standard dynamic rotator cuff loading exercises to determine their effectiveness and identify the optimal approach for managing rotator cuff tears. Group A received low-energy ESWT (0.2mJ/mm^2) twice weekly for 4 weeks with dynamic rotator cuff loading exercises. Group B underwent LLLT with dynamic loading exercises. Group C had UST with dynamic rotator cuff loading exercises. CMS scores improved over four weeks post-intervention for all groups. Group A's scores increased from 65.8 ± 5.8 to 71.3 ± 4.2, Group B's from 66.2 ± 6.2 to 70.4 ± 4.4, and Group C's from 66.9 ± 5.6 to 70.6 ± 4.5 ($p > 0.05$). ANOVA post-test values revealed significant differences for Group A exhibiting improved muscle thickness by 20%, SPADI scores from 55 ± 4 to 30 ± 3, and reduced serum cortisol levels by 25%. Post hoc tests confirmed that ESWT was significantly more effective, with improvements in ultra-sonographic findings, pain reduction (from 7 ± 1 to 3 ± 0.5), shoulder function, and reduced serum cortisol levels (from 10.5 ± 1.2 to 7.8 ± 1.0 μg/dL). Over four weeks post-intervention, Group A showed the most improvement in Constant and Murley Scale (CMS) scores, increasing from 65.8 ± 5.8 to 71.3 ± 4.2. Groups B and C also improved but to a lesser extent. Group A's Numerical rating scale (NRS) scores progressively decreased to 2.5 ± 0.65 by week 4. Group B also showed notable improvement, from 4.8 ± 0.6 at baseline to 3.2 ± 0.92 at week 4. Group C experienced the least improvement, with NRS scores decreasing from 4.8 ± 0.8 to 3.7 ± 1.00 over the same period, thus displaying Group A as more effective improvement in shoulder function with less pain over the study period.

Keywords: Dynamic Rotator Cuff Loading Exercises; Extracorporeal Shock Wave Therapy (ESWT); Low-Level Laser Therapy (LLLT); RCT; Shoulder Pain Management; Ultrasound Therapy (UST).

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Shoulder discomfort affects between 7% and 27% of the general population and is frequently encountered in medical environments[1]. A range of conditions can lead to severe shoulder pain, including neurological or vascular disorders, tumors, referred pain from internal organs, and cervical spine issues, which are considered extrinsic causes. However, joint-related or periarticular conditions are the most common culprits such as subacromial syndrome. This category encompasses rotator cuff and biceps tendinitis, calcific tendinitis, subacromial bursitis, and rotator cuff tears, all marked by diminished shoulder function, pain, and decreased mobility and strength. The prevalence of these issues increases with age and is also associated with certain sports and occupations[2,3]. Rotator cuff pathology is a major contributor to shoulder discomfort, including calcific and noncalcific tendinopathy. The rotator cuff is crucial in stabilizing the shoulder and enabling smooth movement. RCT, commonly referred to as rotator cuff tendinitis, is characterized by inflammation or degeneration of tendons in the shoulder's rotator cuff. The symptoms include shoulder discomfort, soreness, weakness, and reduced range of motion, particularly during overhead tasks. Contributing factors include recurrent overhead movements, the natural process of aging, and suboptimal body alignment. The treatment regimen often includes periods of rest, application of ice, engagement in physical therapy, and, in some cases, surgical intervention. The exact cause of RCT has yet to be fully understood. However, it is believed to be a consequence of a mix of internal and external causes [4,5]. External factors can cause the rotator cuff tendons to compress and sustain various minor injuries, while internal mechanisms are associated with degenerative changes in these tendons.

These influences can lead to tendon deterioration, potentially resulting in partial or complete rotator cuff tears over time. Patients often experience shoulder pain that worsens with overhead movements and makes it challenging to reach behind their back. Diagnosis generally relies on the physical examination, imaging studies, and patient's medical history, with MRI scans particularly useful in rotator cuff tears (RCT). The efficacy of physiotherapy, specifically exercise therapy, has been extensively researched through various systematic reviews. These studies have consistently shown positive effects for this condition[6]. The extent to which incorporating other treatment modalities into exercise yields benefits is not well understood, even though combining therapies to maximize effectiveness is presumably common in clinical practice [7]. Electrotherapy, Mobilization, Exercise, Manipulation, and acupuncture comprise physiotherapy interventions. Various electrotherapeutic modalities, including bipolar interferential current, transcutaneous electrical nerve stimulation, ultrasound, and pulsed electromagnetic field therapy, are commonly used in treatment. There is a growing trend toward less invasive approaches for RCT, moving away from surgical interventions. Research has highlighted several therapeutic options for RCT, such as US, topical and oral NSAIDs, ESWT, and corticosteroid injections. Among the preferred non-invasive treatments for RCT are ESWT, LLLT, and UST, which are valued for their minimal side effects and growing clinical support through numerous trials. [8,9]. Typically, the UST, LLLT, or the ESWT is chosen on a case-by-case basis due to their comparable capabilities. However, there is no agreement on which therapy strategy is more effective. In recent decades, ESWT has been widely used to treat numerous musculoskeletal disorders, including chronic heel pain, lateral epicondylitis of the elbow, calcific tendinopathies of the rotator cuff, nonunion of long-bone fractures, and plantar fasciitis. The therapeutic effects of ESWT are facilitated through various mechanisms, such as electrical stimulation, increased expression of growth factors, and improved local blood circulation. [10-12] Multiple studies have shown the advantageous impact of ESWT on RCT. A recent systematic review of the literature on the efficacy of ESWT found trials with favorable treatment outcomes [13]. The energy that ESWT produces is higher and excites pain receptors that are situated in the muscle, connective tissue, bone, and joint. It also activates unmyelinated C fibers and A-delta fiber, which would commence the "gated" pain control system, which results in an analgesic effect. ESWT reduces inflammation and discomfort by releasing anti-inflammatory cytokines [14]. Shockwaves create new blood vessels, improving tissue oxygenation, nutrition transport, and collagen synthesis. ESWT enhances collagen synthesis, cellular proliferation, and tissue strength. Shockwaves

promote tissue regeneration by encouraging cell proliferation and differentiation. ESWT releases nitric oxide, which vasodilates, improves blood flow, and reduces pain [15]. These processes and outcomes contribute to the effectiveness of ESWT in addressing musculoskeletal issues. A notable advancement in electrotherapy is using low-level lasers by physiotherapists to treat conditions like back, neck, and shoulder pain. In recent years, LLLT has gained traction as an alternative therapy for various musculoskeletal disorders. Low-level laser radiation can influence the physiochemical, biophysical, metabolic, and physiological processes occurring within cells when applied at therapeutic levels. Infrared laser energy is absorbed by water, enzymes, biological structures, and oxygen, particularly cell membranes, and is converted into heat, increasing the vibrational energy of biomolecules [16]. This process constitutes the primary impact of LLLT. The most effective wavelengths for laser light on biological tissues range from 630 to 1,300 nm. Several studies indicate that LLLT proved to enhance pain relief and improve recovery rates compared to a placebo laser in individuals with rotator cuff tendonitis [17]. LLLT did not significantly improve shoulder pain or active range of motion (ROM) compared to exercise therapy in patients with shoulder discomfort [18]. The therapeutic efficacy of this treatment is a subject of controversy since it has been shown to provide favorable outcomes for tendinosis, tendinitis, and frozen shoulder [19,20], but negative results exist for other conditions such as subacromial impingement and tendinitis [21,22]. Thus, controversial research exists about the effectiveness of LLLT as a standalone treatment and its additional benefits for shoulder problems. In UST, RCT can be treated via numerous physiological processes. Thermal effects of UST improve blood flow, warmth, and metabolism, aiding healing and relaxation.[23] UST's non-thermal effects increase protein synthesis, cell proliferation, and tissue healing. Micro-bubbles from UST increase membrane permeability, nutrition, and waste transport. UST improves nutrition delivery and reduces inflammation by increasing fluid flow [24]. Mechanical stress from UST stimulates biological responses, repairing and regenerating tissue. The production of anti-inflammatory cytokines by UST reduces inflammation and discomfort. Collagen synthesis via UST strengthens and stretches tissue. The therapy in the UST differs from surface heating methods in that it effectively heats deeper tissues using proper intensity and frequency. The alleged nonthermal effects of ultrasound (US) are believed to enhance the healing process. However, this assertion lacks substantiation via in vivo investigations. Systematic assessments of clinical studies on shoulder diseases have shown that the US is not useful in attaining successful outcomes in the intervention [25.] Only a few studies have demonstrated that ESWT, UST, and LLLT may effectively alleviate pain after treatment. The efficacy of ESWT, LLLT, and UST for RCT is a subject of concern. Each technique has shown diverse levels of effectiveness, with contradictory findings in clinical trials. ESWT is thought to activate healing mechanisms, while LLLT seeks to decrease inflammation and alleviate pain via photo biomodulation [26]. Ultrasound therapy utilizes sound waves to improve the healing process of tissues.

This study introduces originality by applying shock wave therapy (SWT) to previously unexplored conditions, creating novel treatment protocols, and using advanced methods to investigate biological mechanisms. It offers a novel comparative analysis with other therapies. The study's significance is that shock wave therapy (SWT) is a promising, non-invasive treatment for musculoskeletal issues. Traditional methods, including surgery and long-term medication, often bring side effects; SWT could reduce these, improving patient outcomes. It addresses gaps in understanding SWT's optimal dosages, protocols, and long-term effects, potentially advancing medical knowledge. SWT's expanding applications—such as wound healing and tissue regeneration—could transform treatment approaches. Its adoption might decrease healthcare costs by reducing recovery times and hospital stays while enhancing patients' quality of life through faster pain relief and improved functionality. This study was initiated for several reasons, primarily due to the high prevalence and significant impact of rotator cuff injuries in athletes, laborers, and older adults. Current treatments often result in varying success and lengthy recovery times, creating a rationale for exploring effective, non-invasive alternatives. High-frequency modalities like shock wave therapy (SWT) and ultrasound

could stimulate healing and reduce pain without the risks associated with surgery or long-term medication use. Despite their potential, research on these modalities for rotator cuff tendinopathy is limited and inconclusive. This study aims to fill these gaps by evaluating the effectiveness of SWT in enhancing tendon healing, promoting faster recovery, and addressing diverse patient needs. The rationale for this study is to evaluate shock wave therapy (SWT) for rotator cuff injuries due to their prevalence and limited treatment options. It aims to establish SWT as a viable non-invasive alternative to improve recovery and reduce surgical needs by providing rigorous clinical evidence, exploring biological mechanisms, and assessing cost-effectiveness. This study's main purpose and objective is to evaluate the efficacy and safety of shock wave therapy (SWT) for treating rotator cuff tendinopathy. The objectives include assessing SWT's potential to promote tendon repair, reduce inflammation, and enhance shoulder function, offering a non-invasive alternative to traditional treatments such as LLT, and UST

MATERIALS AND METHODS

Methodology

Ethics Statement

Registered at clinical trial registration – India, CTRI/2024/07/069728, this prospective randomized controlled trial was approved by the institutional ethical committee of Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India (Ref No. 645/2022/IEC/ACSMCH Dt.14/12/2022).

Study design and population

This pilot study employs a comparative pre-and-post design to identify which therapeutic combinations offer the greatest benefits for RCT patients and assess the effectiveness of various treatments. The study from January to March 2024 involved 75 patients with noncalcific RCT from the outpatient physiotherapy department at ACS Medical College and Hospital. A simple random sampling technique randomly assigned participants to one of three groups (A, B, or C). Before participation, each individual received a detailed explanation of the study and consented to participate, understanding that they could be assigned to any group via a lottery system. 100 identical chits, marked either A or B, were thoroughly mixed. Participants drew a chit from a box, and the designation on the chit determined their group assignment. The study lasted one month, during which pre- and post-intervention assessments were performed to evaluate pain levels, range of motion, and functional improvements. Group A (n=25) received electrochemical stimulation therapy (ECST) combined with dynamic loading exercises, Group B (n=25) underwent low-level laser therapy (LLLT) paired with dynamic loading exercises, and Group C (n=25) was treated with ultrasound therapy (UST) alongside dynamic loading exercises. Each intervention aimed to alleviate pain and enhance the range of motion in RCT patients.

Inclusion criteria

Patients clinically diagnosed with RCT will be considered for inclusion without restrictions. Eligible subjects must have rotator cuff injury grade 1 or 2, diagnosed by an orthopedic surgeon and recruited from the OPD. They should exhibit pain and tenderness, limited movements, and decreased abduction, flexion, and internal and external rotation ROM. Additional criteria included being age between 18 and 60 years old, having a baseline (Numerical Rating Scale: NRS) pain score of 5 or higher, experiencing shoulder pain or pain exacerbation with overhead-throwing activities, and showing decreased ROM in shoulder flexion, abduction, and internal and external rotation. Subjects should have a history of clinical signs of chronic tendinitis for more than 6 months. MRI findings indicate only intensity changes in the rotator cuff without full-thickness tears, painful arc syndrome, and a BMI of 19-25 kg/m². Diagnosis is primarily based on history and MRI, with X-rays that exclude calcific rotator cuff tendinopathies.

Exclusion criteria

Patients were excluded if they met any of the following conditions: significant muscle atrophy in the shoulder girdle; recent platelet-rich plasma or stem cell injections in the affected shoulder within the past three months; current malignancy or a history of cancer within the last five years; coagulation disorders or ongoing anticoagulation therapy (daily prophylactic aspirin is allowed); any condition or abnormality that, according to the investigator, might compromise the safety of the patient or the integrity of the data.

Additionally, individuals with adhesive capsulitis, history of surgery, cardiovascular disease, cancer, severe psychiatric disorders, systemic or skin diseases, or recent fractures or dislocations were also excluded.

Extracorporeal shockwave therapy with dynamic loading exercises program (ESWT) For GROUP A

Low-energy ESWT was administered twice weekly (0.2 mJ/mm²) for 4 weeks, alongside three dynamic rotator cuff loading exercises: minimally loaded ROM exercises, open chain resistance band exercises (OC), and closed chain exercises (CC). MRI was used to identify the affected tendinopathic areas, and the corresponding regions were marked. Patients assumed specific positions to target different tendons: hand behind the back with arm internally rotated for the supraspinatus tendon, hand in front with arm externally rotated for the subscapularis tendon, and hand in front with slight internal rotation for the infraspinatus and teres minor tendons. Each patient received ESWT weekly, with a 4 to 5 day gap between sessions. A total of 4 sessions were given, each involving 2000 shockwaves aimed at the specified area. The Dornier Aries electromagnetic device was used for treatment, starting at level 2 (160 shots) and gradually increasing by one level every 160 shots until level 10, where the remaining shocks were delivered. Patients typically tolerated energy levels between 6 and 10, corresponding to specific EFD (Energy Flux Density) and frequency combinations. The mean energy flux density was 0.09 ± 0.018 mJ/mm², with a 5.11 ± 0.46 Hz frequency. Ultrasound coupling gel was applied to reduce shockwave energy loss between the applicator and the skin. NSAID use was discouraged during the 4-week ESWT treatment, as the initial inflammatory response may be vital for its effectiveness in treating musculoskeletal pain. Following the treatment, patients were encouraged to engage their shoulder muscles immediately and resume normal activities, though they were advised to avoid heavy lifting for 12 months. Participants were not allowed to receive additional treatments until the study concluded.

Low-level laser therapy with dynamic loading exercise programme [28] (LLLT) (GROUP B)

LLLT 4 J/cm² at each point over a maximum of ten painful points of shoulder region for a total of 5 minutes' duration for 4 weeks, with three dynamic rotator cuff loading programs: OC, CC, and minimally loaded range of movement. Three locations on the shoulder, namely the coracoid (anterior), glenohumeral joint (posterior), and rotator cuff tendon (lateral), were exposed to pulsed infrared laser radiation with a wavelength of 890 nm. The exposure lasted for 2 minutes at each spot, resulting in 6 minutes of treatment. The laser device used for this treatment was the Mustang-024 from Russia. The energy density measured 2–4 J/cm² at each site.

Ultrasound with dynamic loading exercises programme[29] (US) (GROUP C)

The coupling medium gel facilitates the smooth circular movement of the ultrasound transducer head over the shoulder joint during ultrasound treatment. The gel is used to optimize the transmission of ultrasonic waves to the affected muscle tissue. The gel served to eliminate air between the skin and the transducer head of the ultrasound. The ultrasound machine operated at a frequency of 1Mhz and has a duty cycle of +5, ranging from 20% to 50%. It is used in continuous mode with an ultrasound head measuring 5 cm. The treatment duration is 8 minutes per session, 5 days a week, for 4 weeks and 20 sessions. Following the ultrasound treatment, a hot, moist pack is applied for 20 minutes, followed by an exercise program. Three dynamic rotator cuff loading exercises were administered, including OC, CC, and minimally laden ROM. The workout consists of doing 15 repetitions of pendulum exercise in clockwise and counterclockwise directions, followed by 15 reps of strength training in the Abduction and Flexion directions. Participants were positioned on the couch with a thin pillow supporting their necks for maximum comfort. The therapist then held the participants' hands and gently moved their arms away from the body, reaching the maximum range of motion. The participants were instructed to resist the force applied by the therapist as they brought their arms back towards the body. This exercise aims to increase muscle tone and power in the shoulder joint. The same exercise protocol is followed for the flexion of the arm, which helps strengthen the flexor muscles and facilitates smooth movement at the glenohumeral joint. This resistance workout enhances the functional motions and dynamism of the shoulder joint.

Post-treatment follow up and outcome measures

Follow-up visits were administered to all subjects in the first, second, third, and fourth weeks following the final treatment session. The principal follow-up outcome measure is the change in the NRS of pain from baseline to week 24. By the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials, the 11-point NRS (0=no pain, 10=maximum pain) is advised for chronic pain studies. The secondary follow-up outcome measure encompasses changes in the mean CMS score at the first, second, third, and fourth weeks and changes in pain scores at other follow-up intervals. The CMS (score of 0 to 100; a lower score indicates inferior function) is a validated method for evaluating shoulder function that integrates subjective and objective measurements. Pain, activities of daily living (ADL), ROM, and power comprise CMS subscales. A greater quality of life is reflected in higher CMS scores, which indicate enhanced shoulder mobility and decreased pain. A pretest was done, and the outcome measures are muscle tissue morphology, functions of the shoulder joint, and range of motion shoulder abduction/lateral rotation. The measurement tools used were Blood Test- Serum Cortisol, Shoulder pain and disability index (SPADI), ultra-sonogram, digital electronic goniometer.

In the above table of demographic datas (Pretest) reveals diverse group characteristics. Group A includes three males and two females aged between 30 and 50 years. Group B is composed of four males and one female, with ages ranging from 50 to 60 years. Group C, featuring three males and two females, spans a broader age range of 30 to 60 years. Each group shares a common duration of symptoms, lasting four weeks. When considering the affected shoulder side, Group A has three patients with right shoulder issues and two with left, Group B has all five patients with right shoulder problems, and Group C Mirrors Group A has three right and two left shoulder cases.

Table 2 presents baseline scoring data before treatment for three groups (A, B, C) using the (CMS) and the NRS for chronic pain. CMS scores, which reflect shoulder function, were similar across all groups, with no significant differences ($p > 0.05$) in overall CMS score, pain, ADL, ROM, and power. NRS scores, which measure pain severity, also showed no significant differences among the groups ($p = 0.67$). These baseline scores indicate that all groups started with comparable shoulder function and pain levels.

Table 3 demonstrates changes in the CMS scores over four weeks post-intervention for three groups (A, B, C). Group A showed the most notable improvement, with CMS scores rising from 65.8 ± 5.8 at baseline to 71.3 ± 4.2 at four weeks. Group B's scores increased from 66.2 ± 6.2 to 70.4 ± 4.4, and Group C's from 66.9 ± 5.6 to 70.6 ± 4.5. Although the p-value indicates no statistically significant differences between groups ($p > 0.05$), Group A displayed a more substantial increase in scores, suggesting a more effective improvement in shoulder function over the study period. Over a span of 4 weeks post-intervention, Group A exhibited the most significant improvement in pain reduction according to the 11-point NRS. Starting from a baseline of 5.4 ± 0.5, the NRS scores progressively decreased to 2.5 ± 0.65 by week 4. Group B also showed notable improvement, from 4.8 ± 0.6 at baseline to 3.2 ± 0.92 at week 4. Group C experienced the least improvement, with NRS scores decreasing from 4.8 ± 0.8 to 3.7 ± 1.00 over the same period

Table 4 provides post-treatment comparison data for three groups (A, B, C) on various parameters. Group A showed the highest improvement in shoulder function and the lowest pain and disability, with the highest shoulder abduction and lateral rotation degrees (both $70° \pm 5°$), the lowest SPADI score (70%), and the smallest ultra-sonogram measurement (3.9 mm). Group A also had a mid-range blood serum cortisol level (24.6 ± 0.6 mg/dl). Group B had intermediate results across all parameters, while Group C showed the least improvement with the lowest shoulder function scores and highest serum cortisol level (25.6 ± 0.5 mg/dl). Thus, Group A demonstrated the most significant and effective improvements.

Statistical Analysis

The data were analyzed using SPSS software version 20.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were reported as frequencies, and continuous variables were presented as means with standard deviations. To compare groups, Post HOC, ANOVA, and chi-square tests were utilized. Statistical significance

was set at a p-value of less than 0.05, with all p-values computed using a two-tailed method.

RESULTS AND DISCUSSION

The analysis of pre-test and post-test values for various treatments of RCT injuries reveals several key findings (Table 5). For muscle thickness measured by ultra-sonogram, no significant pre-test differences were observed among groups A, B, and C (F = 0.138, P = 0.872). Still, significant differences emerged post-test (F = 7.721, P = 0.007), with Group A (mean value 3.62 mm) being the most effective. SPADI scores showed no significant pre-test differences (F = 2.694, P = 0.108), but post-test differences were significant (F = 301.955, P < 0.001), with Group A (mean value 25.2) being the most effective treatment. In shoulder abduction, pre-test values showed no significant differences (F = 2.435, P = 0.13), while post-test values did (F = 5.285, P = 0.023), with Group A (mean value 68) being the most effective. For shoulder external rotation, no significant pre-test differences were noted (F = 1.423, P = 0.279), but post-test differences were significant (F = 5.685, P = 0.018), with Group A being the most effective. The serum cortisol levels showed no significant pre-test differences (F = 2.192, P = 0.154) but significant post-test differences (F = 7.276, P = 0.009), with Group A (mean value 14.72) being the most effective. Thus, from the above results, the analysis of treatments for RCT injuries shows that pre-test values for muscle thickness, SPADI scores, shoulder abduction, shoulder external rotation, and serum cortisol levels did not differ significantly among groups A, B, and C. However, post-test values revealed significant differences in all metrics. Group A was the most effective in improving muscle thickness, SPADI scores, and reducing serum cortisol levels. Group B's ((LLLT)) post-test results were generally less effective than the other groups. This indicates that the treatment applied to Group A may be less effective overall for RCT injuries.

The data from the post-hoc analyses revealed that ESWT, (Group A), is the most effective treatment compared to Group B (LLLT) and Group C (US) for RCT. From the table (Table 6) above Group, an Ultra sonogram (Pre-Test) had no significant differences observed among the groups, indicating that baseline tendon conditions were comparable. Post-Test ESWT (Group A) demonstrated a significant improvement in ultra-sonographic outcomes compared to LLLT (Group B) with a mean difference of -0.3800 ($p < 0.01$), indicating the substantial benefits. The difference

Table 1. Demographic Datas

Characteristics	Group A	Group B	Group C
Gender(male/female)	3/2	4/1	3/2
Age (years)	30-50	50-60	30-60
Affected side (right/ left) shoulder	3/2	5/0	3/2
Duration of symptoms	4 weeks	4 weeks	4weeks

Table 2. Baseline Scores (Pretest outcome measures)

Scores	Group A	Group B	Group C	*p* value
CMS Score (100 Points)	65.8 ± 5.8	66.2 ± 6.2	66.9 ± 5.6	$p > 0.05$
Pain (15 points)	9.8 ± 2.5	9.1 ± 2.5	9.3 ± 2.8	$p > 0.05$
ADL (20 points)	15.5 ± 1.6	15.0 ± 1.8	14.8 ± 2.5	$p > 0.05$
ROM (40 points)	33.1 ± 2.7	32.5 ± 2.6	32.1 ± 3.1	$p > 0.05$
Power (25 points)	15.6 ± 3.1	15.1 ± 3.3	14.6 ± 3.5	$p > 0.05$
NRS (10 points)	5.4 ± 0.5	4.8 ± 0.6	4.8 ± 0.8	$p = 0.67$

NRS: Numerical rating scale, CMS: Constant and Murley Scale; ADL: Activity of daily living; ROM: range of motion; Power: Measures the strength of the rotor cuff muscles and other relevant muscle groups, using a spring balance.

with US (Group C) was statistically significant (p=0.076), and ESWT showed a trend toward better tendon healing. For SPADI (Shoulder Pain and Disability Index), the Pre-Test scores were similar across all groups, ensuring comparable values. In Post-Test, ESWT (Group A) resulted in a significant reduction in SPADI scores compared to LLLT (Group B) with a mean difference of -8.600 (p-value,0.01), and US (Group C) with a mean difference of -18.800 (p-value,0.01). This suggests

Table 3. Modifications to the CMS score and its components for a period of four weeks following the intervention (post-treatment outcome measures)

Measure	Time	Group A	Group B	Group C	*p* value
CMS Score	Baseline	65.8 ± 5.8	66.2 ± 6.2	66.9 ± 5.6	$p > 0.05$
	1-week	67.1 ± 5.7	66.8 ± 5.4	67.1 ± 5.2	$p > 0.05$
	2-week	68.4 ± 5.4	68.1 ± 4.3	68.3 ± 6.0	$p > 0.05$
	3-week	69.5 ± 5.1	69.3 ± 4.7	69.4 ± 4.9	$p > 0.05$
	4-week	71.3 ± 4.2	70.4 ± 4.4	70.6 ± 4.5	$p > 0.05$
NRS Score	Baseline	5.4 ± 0.5	.8 ± 0.6	4.8 ± 0.8	$p = 0.67$
	1-week	4.8 ± 0.45	4.4 ± 0.70	4.6 ± 0.85	p = 0.062
	2-week	4.0 ± 0.52	4.0 ± 0.78	4.3 ± 0.90	p = 0.056
	3-week	3.2 ± 0.58	3.6 ± 0.86	3.9 ± 0.95	p = 0.041
	4-week	2.5 ± 0.65	3.2 ± 0.92	3.7 ± 1.00	p = 0.031

Table 4. Intergroup Comparison of Dependent Variables

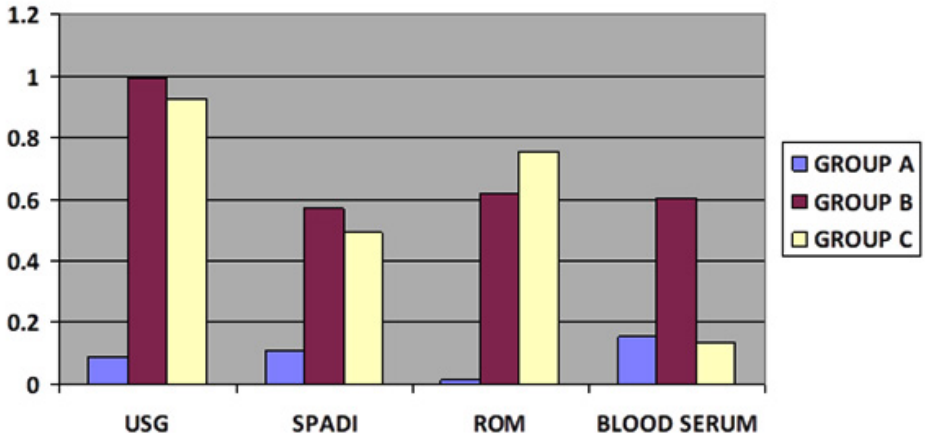
Parameter	Group A	Group B	Group C
Blood Serum Cortisol (mg/dl)	24.6 ± 0.6	22.6 ± 0.25	25.6 ± 0.5
Shoulder Abduction (degree)	70 ± 5	65 ± 5	60 ± 5
Shoulder Lateral Rotation (degree)	70 ± 5	65 ± 5	60 ± 5
SPADI-Score (100%)	70	65	60
Ultrasonogram (mm)	3.9	4	4

P<0.01, n=15

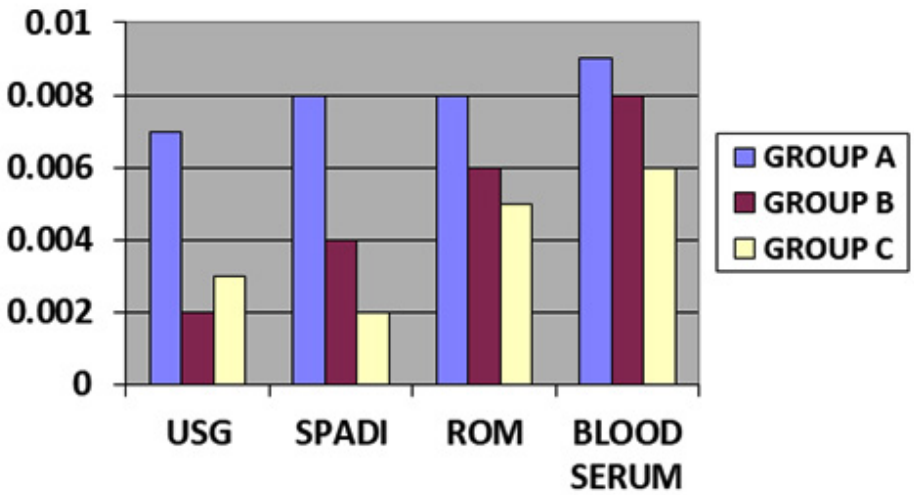
Table 5. ANOVA (Pre and post treatments)

Test	Group A Mean ±SD	Group B Mean± SD	Group C Mean± SD	F value	Significance (P values).
Ultrasonogram					
Pre-test	4.72±0.1789	4.64±0.2966	4.66±0.2608	0.138	0.872
Post-test	3.62±0.2387	4±0.1581	4.22±0.3114	7.721	0.007
SPADI					
Pre-test	61 ±4. 416	63.6±5.177	66.8±0.837	2.694	0.108
Post-test	25.2±0.447	33.8±1.304	44±1.581	301.955	0 .007
Shoulder abduction					
Pre-test	38±2.739	32±5.701	36±4.183	2.435	0.013
Post-test	82.6±3.715	69±7.416	68±10.954	5.285	0.023
Shoulder external rotation					
Pre-test	42±4.472	39±6.519	46±8.216	1.423	0.279
Post-test	86.6±0.894	77±7.583	68±13.038	1.422	0.265
Blood serum cortisol					
Pre-test	26.3±0.2915	26.84±1.1908	27.46±0.8961	2.192	0.154
Post-test	14.72±3.7138	22.36±1.7785	19.98±3.8147	7.276	0.009

that ESWT is highly effective in reducing both pain and disability associated with RCT. In Shoulder Abduction, the Pre-Test showed no significant differences among groups at the baseline, but Post-Test of Group A showed a significant improvement in shoulder abduction compared to both LLLT (Group B) with a mean difference of 13.600 (p-value <0.01), and US (Group C) with a mean difference of 14.600 (p-value <0.01) which highlight ESWT's superior ability to enhance shoulder mobility. In shoulder external rotation, the Pre-Test, datas showed no significant differences among groups, but Post-Test ESWT (Group A) achieved a significant improvement in shoulder external rotation compared to LLLT (Group B) with a mean difference of 9.600 (p-value<0.01) and its comparison with US (Group C) showed a significant difference with a mean difference of -18.600(p-value <0.01), implying ESWT's effectiveness in improving shoulder rotation. In Blood serum cortisol determination for Pre-Test, initial cortisol levels were similar among all groups, but in Post-Test, ESWT (Group A) significantly reduced serum cortisol levels compared to LLLT (Group B) with a mean difference of -7.6400 (p-value<0.01), compared to US (Group C) with a



Graph 1. Pre test P value of variables



Graph 2. Post test P value of variables

Table 6. Post Hoc Test – Inter Group Comparison Pre And Posttest

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-j)	Std. Error	95% Confidence Interval		Significance
					upper Bound	Lower Bound	
Ultrasonogram-pre Test	Group A	Group B	.0800	.1583	4.498	4.942	0.087
		Group C	.0600	.1583	4.272	5.008	0.924
	Group B	Group A	-.0800	.1583	4.336	4.984	0.87
		Group C	-.0200	.1583	4.544	4.803	0.991
	Group C	Group A	-.0600	.1583	3.324	3.916	0.924
		Group B	.0200	.1583	3.804	4.196	0.991
Ultrasonogram-post Test	Group A	Group B	-.3800	.1545	3.833	4.607	0.002
		Group C	-.6000*	.1545	3.757	4.136	0.076
	Group B	Group A	.3800	.1545	4.498	4.942	0.004
		Group C	-.2200	.1545	4.272	5.008	0.36
	Group C	Group A	.6000*	.1545	4.336	4.984	0.004
		Group B	.2200	.1545	4.544	4.803	0.36
Spadi- Pre- Test	Group A	Group B	-2.600	2.503	-9.28	4.08	0.568
		Group C	-5.800	2.503	-12.48	.88	0.492
	Group B	Group A	2.600	2.503	-4.08	9.28	0.568
		Group C	-3.200	2.503	-9.88	3.48	0.433
	Group C	Group A	5.800	2.503	-.88	12.48	0.192
		Group B	3.200	2.503	-3.48	9.88	0.433
Spadi- Post- Test	Group A	Group B	-8.600*	.766	-10.64	-6.56	0.004
		Group C	-18.800*	.766	-20.84	-16.76	0.014
	Group B	Group A	8.600*	.766	6.56	10.64	0.025
		Group C	-10.200*	.766	-12.24	-8.16	0.741
	Group C	Group A	18.800*	.766	16.76	20.84	0.044
		Group B	10.200*	.766	8.16	12.24	0.621
Shoulder Abduction- Pre - Test	Group A	Group B	6.000	2.769	-1.29	12.8	0.118
		Group C	2.000	2.769	-1.39	13.39	0.755
	Group B	Group A	-6.000	2.769	-5.39	9.39	0.118
		Group C	-4.000	2.769	-13.39	1.39	0.35
	Group C	Group A	-2.000	2.769	-11.39	3.39	0.755
		Group B	4.000	2.769	-9.39	5.39	0.35
Shoulder Abduction - Post-test	Group A	Group B	13.600*	5.017	-3.39	11.39	0.046
		Group C	14.600*	5.017	.21	26.99	0.033
	Group B	Group A	-13.600*	5.017	1.21	27.99	0.046
		Group C	1.000	5.017	-26.99	-.21	0.978
	Group C	Group A	-14.600*	5.017	-12.39	14.39	0.033
		Group B	-1.000	5.017	-27.99	-1.21	0.978
Shoulder External Rotation - Pre-test	Group A	Group B	3.000	4.163	-8.11	14.11	0.756
		Group C	-4.000	4.163	-15.11	7.11	0.614
	Group B	Group A	-3.000	4.163	-14.11	8.11	0.756
		Group C	-7.000	4.163	-18.11	4.11	0.252
	Group C	Group A	4.000	4.163	-7.11	15.11	0.614
		Group B	7.000	4.163	-4.11	18.11	0.252
Shoulder External Rotation - Post-test	Group A	Group B	9.600	5.517	-5.12	24.32	0.011
		Group C	18.600*	5.517	3.88	33.32	0.014
	Group B	Group A	-9.600	5.517	-24.32	5.12	0.031
		Group C	9.000	5.517	-5.72	23.72	0.271
	Group C	Group A	-18.600*	5.517	-33.32	-3.88	0.014
		Group B	3.000	4.163	-23.72	5.72	0.271

Blood Serum Cortisol- Pre-test	Group A	Group B	-.5400	.5545	25.938	26.662	0.606
		Group C	-1.1600	.5545	25.361	28.319	0.133
	Group B	Group A	.5400	.5545	26.347	28.573	0.606
		Group C	-.6200	.5545	26.341	27.392	0.522
	Group C	Group A	1.1600	.5545	10.109	19.331	0.133
		Group B	.6200	.5545	20.152	24.568	0.522
Blood Serum Cortisol- Post-test	Group A	Group B	-7.6400*	2.0496	15.243	24.717	0.008
		Group C	-5.2600	2.0496	16.548	21.492	0.006
	Group B	Group A	7.6400*	2.0496	25.938	26.662	0.008
		Group C	2.3800	2.0496	25.361	28.319	0.497
	Group C	Group A	5.2600	2.0496	26.347	28.573	0.016
		Group B	-2.3800	2.0496	26.341	27.392	0.497

I= Number Of Observations Available For Sample (Treatment), J=Number Of Observations Available For Each Sample

mean difference of 5.2600 (p-value<0.1). This reduction indicates that ESWT is effective in decreasing stress and inflammation markers. Thus, this post hoc analysis consistently showed that ESWT (Group A) is the most effective treatment for RCT compared to LLLT and US. ESWT led to significant improvements in ultra-sonographic findings, pain and disability reduction, shoulder abduction and external rotation, and a marked decrease in blood serum cortisol levels. These results demonstrate that ESWT offers comprehensive benefits and is preferable for managing rotator cuff tendinitis. Extracorporeal shockwave therapy (ESWT) offers comprehensive benefits in managing rotator cuff tendinitis, including effective pain reduction, improved range of motion, and accelerated tendon healing. By delivering targeted mechanical pulses to the affected area, ESWT stimulates cellular repair and reduces inflammation without the need for invasive procedures. This makes it a highly attractive option for patients seeking alternatives to surgery, especially for chronic tendinopathies that are unresponsive to traditional treatments. Less invasive or non-surgery for RCT treatments are replacing surgery [31] Recent reported research have suggested topical and oral NSAIDs, corticosteroid injections, UST, LLLT and ESWT are widely used for RCT [32,33]. The energy created by ESWT stimulates pain receptors that are located in the skin, muscle, connective tissue, bone, and joint and activate unmyelinated C fibers and A-delta fiber, which would initiate the "gated" pain regulation system, ultimately leading to an analgesic effect for RCT [34]. The ESWT improves the production of collagen, the proliferation of cells, as well as the strength and suppleness of the tissue [35]. Shockwaves encourage cell proliferation and differentiation, leading to cell regeneration and tissue regeneration. LLLT is also a prominent RCT treatment option where oxygen, water, enzymes, and biological structures such as cell membranes absorb emitted infrared laser energy, making the biomolecules gain vibrational energy from heat, which is the principal consequence of low-level laser radiation for the RCT treatment [36]. In the case of UST, when administered with sufficient intensity and frequency, the ultrasound heats deeper tissues than surface heating methods [37]. UST nonthermal effects are said to help healing, although in vivo data are lacking to support this UST for RCT [38]. Patients and clinicians favor extracorporeal shockwave therapy (ESWT), low-level laser therapy (LLLT), and ultrasound therapy (UST) as major adjuvant treatments for rotator cuff tendinopathy (RCT) due to their non-invasive nature, minimal side effects, and ease of use. Growing clinical evidence supports the efficacy of these therapies in reducing pain, improving joint function, and promoting tissue repair, which has made them increasingly popular as alternatives or supplements to traditional surgical interventions in managing RCT.[39-42] Due to their support from clinical studies, the US, LLLT or ESWT is usually selected due to their comparable mechanism of action. Therefore, this present study aimed to compare the effects of ESWT, LLLT, and UST with dynamic loading exercises for treating RCT. The objective was to evaluate and measure improvements in pain relief, shoulder function, strength, and range of motion among the different

treatment modalities. The primary goal was to determine which treatment offered the best clinical outcomes. Before the initiation of the study, the baseline assessments for the three groups (A, B, and C) using the CMS and the NRS for chronic pain indicated no significant differences in shoulder function or pain levels. Specifically, the CMS scores, which measure various aspects of shoulder function, including pain, ADL, ROM, and muscle power, were comparable across all groups. This uniformity in baseline scores ($p > 0.05$) confirmed that the groups began the study with similar shoulder function levels. Similarly, the NRS scores, reflecting pain severity, showed no significant differences among the groups ($p = 0.67$). This suggests that any observed changes post-treatment were attributable to the treatment interventions rather than pre-existing disparities in baseline conditions. Following the four-week treatment period, the changes in CMS scores revealed Group A (ESWT) exhibited the most significant improvement. CMS scores in Group A rose from 65.8 ± 5.8 at baseline to 71.3 ± 4.2 post-treatment, representing an appreciable enhancement in shoulder function. In comparison, Group B (LLLT) showed an increase from 66.2 ± 6.2 to 70.4 ± 4.4, and Group C (UST) had an increase from 66.9 ± 5.6 to 70.6 ± 4.5. Due to these statistically significant differences between groups ($p > 0.05$), Group A was found to have substantial improvement, suggesting ESWT to be more effective in enhancing shoulder function over the study period. Group A gradually declined their NRS ratings, reaching a mean of 2.5 ± 0.65 by the fourth week. Another group that demonstrated significant progress was Group B, which went from a baseline value of 4.8 ± 0.6 to a week 4 value of 3.2 ± 0.92. Group C showed minimal improvement, with NRS ratings dropping from 4.8 ± 0.8 to 3.7 ± 1.00 over the same time. This indicates that Group A demonstrated a more effective improvement in shoulder function with less discomfort throughout the research period. ANOVA analysis provided further insights into the efficacy of the treatments. For muscle thickness, measured via ultra-sonogram, no significant differences were observed among the groups at baseline ($F = 0.138$, $P = 0.872$). However, in post-treatment, significant differences emerged ($F = 7.721$, $P < 0.01$), with Group A (ESWT) showing a higher increase in muscle thickness (mean value 3.62 mm), indicating that ESWT was most effective in promoting muscle recovery. Similarly, SPADI scores, which assess pain and disability, did not differ significantly among the groups at baseline ($F = 2.694$, $P = 0.108$). Post-treatment results, however, revealed significant differences ($F = 301.955$, $P < 0.001$), with Group A (ESWT) showing the most significant reduction in pain and disability. This reduction highlights ESWT's effectiveness in alleviating symptoms associated with rotator cuff tendinitis. Shoulder abduction was also evaluated, and the post-treatment analysis, however, indicated significant differences ($F = 5.285$, $P < 0.01$), with Group A being the most effective. For shoulder external rotation, baseline differences were not significant ($F = 1.423$, $P = 0.279$), but post-test differences were significant ($F = 5.685$, $P < 0.1$), with Group A achieving the highest improvement. Blood serum cortisol levels, which reflect inflammation and stress, showed no significant differences among groups at baseline ($F = 2.192$, $P < 0.1$). Post-treatment, significant differences were observed ($F = 7.276$, $P < 0.01$), with Group A demonstrating the most significant reduction in cortisol levels (mean value 14.72), suggesting ESWT is effective in reducing stress and inflammation associated with rotator cuff injuries. The post hoc analysis reinforced the superiority of ESWT (Group A) over the other treatments. Group A (ESWT) showed a significant improvement compared to Group B (LLLT) (mean difference = -0.3800, $p = 0.002$) and a trend towards better results compared to Group C (UST) (mean difference = -0.6000, $p = 0.076$) suggesting ESWT to be more effective in promoting tendon healing. In determination of SPADI scores, ESWT (Group A) resulted in a significant reduction in pain and disability compared to both LLLT (Group B) (mean difference = -8.600, $p < 0.01$) and UST (Group A) (mean difference = -18.800, $p < 0.01$). This indicates that ESWT is highly effective in reducing both pain and disability in patients with musculoskeletal disorders, particularly in chronic cases like rotator cuff tendinopathies. The therapy works by delivering focused acoustic waves to the affected area, stimulating blood flow, promoting cellular regeneration, and accelerating tissue healing. Studies have shown that ESWT not only decreases pain levels but also improves functional movement and overall quality of life,

making it a valuable option for long-term pain management.[43] Shoulder abduction improvements were significant for (Group A) ESWT compared to (Group B) LLLT (mean difference = 13.600, p <0.01) and (Group C) UST (mean difference = 14.600, p <0.01), demonstrating ESWT's superior ability to enhance shoulder mobility. For shoulder external rotation, ESWT also achieved significant improvements compared to LLLT (mean difference = 9.600, p <0.01) and UST (mean difference = -18.600, p = 0.014). Regarding serum cortisol levels, (Group A) ESWT resulted in a significant reduction compared to (Group B) LLLT (mean difference = -7.6400, p <0.01) and (Group C) UST (mean difference = 5.2600, p <0.01), highlighting its effectiveness in decreasing stress and inflammation. Thus, ESWT (Group A) emerged as the most effective treatment for RCT among the three therapies studied. It led to significant improvements in muscle thickness, pain and disability reduction, shoulder mobility, and a marked decrease in inflammation, making it a highly preferable option for managing RCT. Several theories help to explain how ESWT effectively relieves pain partially. The main mechanism of extracorporeal shockwave therapy (ESWT) in pain relief involves shockwaves triggering nociceptors, or pain receptors, which produce high-frequency nerve impulses. According to the gate-control theory, these nerve impulses are modulated by the spinal cord, where a "gate" mechanism controls the transmission of pain signals to the brain. When high-frequency impulses are generated, they compete with pain signals, effectively inhibiting their transmission by closing the gate. This interruption reduces the sensation of pain, allowing other processes, such as increased blood flow and cellular repair, to occur more effectively, ultimately aiding in tissue regeneration and healing in injured areas. Thus, the impact of shockwave therapy surpasses that of ultrasound or laser radiation. Nonetheless, our findings indicate that extracorporeal shock wave therapy (ESWT) with an energy flux density (EFD) ranging from 0.01 to 0.15 mJ/mm² is sufficient for effective treatment [44]. Shockwaves can cause distortion in some areas of the whole cell membrane. Nociceptors are unable to generate a potential that leads to the sense of pain, hence preventing the experience of pain [45]. Shockwaves can also change the chemical environment of the cell membrane by generating free radicals, which in turn stimulates the production of substances that inhibit pain near the cells. Applying high-energy ESWT to the distal femur in rabbits led to a decrease in substance P and prostaglandin E2 levels in the periosteum on the cortical surface of the femur. ESWT is a very successful treatment for lowering pain and disability, increasing function, enhancing quality of life, and achieving full resorption of calcification in patients with RCT.[46] Furthermore, ESWT has been shown to be clinically superior to sham-ESWT in terms of pain reduction, functional improvement, and patient satisfaction in treating various musculoskeletal conditions, including tendinopathies. Studies highlight that ESWT effectively stimulates tissue regeneration, enhances blood flow, and promotes collagen formation, all of which contribute to its therapeutic benefits. These effects lead to more sustained pain relief and functional gains compared to placebo treatments, making ESWT a valuable non-invasive option.[47]. In our comparative study, ESWT significantly outperformed UST in RCT. Post-treatment, Group A (treated with ESWT) showed the greatest increase in muscle thickness (mean value 3.62 mm, F = 7.721, P <0.001) and the most substantial reduction in SPADI scores for pain and disability (mean value 25.2, F = 301.955, P < 0.001). ESWT also significantly decreased serum cortisol levels (mean value 14.72, F = 7.276, P < 0.001), indicating reduced stress and inflammation. UST is beneficial for increasing muscle range of motion as it raises muscle fiber temperature, which in turn improves elasticity, enhances blood supply, and promotes tissue vasodilation. This increased circulation helps deliver essential nutrients and oxygen to affected areas, accelerating the healing process and reducing muscle stiffness. Additionally, UST can alleviate pain and swelling, making it an effective option for patients recovering from soft tissue injuries and promoting overall muscle flexibility.

These effects improve the elasticity of muscle fibers and ultimately enhance muscle flexibility [48]. However, our study demonstrated that ESWT is more effective than UST in achieving these outcomes. Both ESWT and UST are non-invasive, low-risk treatments that alleviate pain and inflammation, encourage tissue repair and regeneration, and reduce inflammation. ESWT

employs high-energy shockwaves, but UST utilizes high-frequency sound waves. ESWT penetrates tissue deeper than UST. ESWT relieves pain quicker and needs fewer sessions than UST. Tissue healing may be more extensive with ESWT than UST [49]. The energy produced by ESWT is much greater than that of ultrasound waves, enabling it to effectively target pain receptors in the skin, muscles, connective tissues, bones, and joints. It also stimulates unmyelinated C fibers and A-delta fiber, triggering the "gated" pain control mechanism, leading to pain relief [50]. In addition, ESWT induces the formation of many microbubbles inside tissues, which instantly enlarge and rupture due to the shock wave, leading to the generation of high-velocity liquid micro-jets and impact. The phenomenon of cavitation is very efficient in reopening blocked microvessels and removing adhesions in soft tissues around joints [51]. LLLT has been used as a non-pharmacological substitute for the treatment of painful musculoskeletal problems for more than thirty years [52]. LLLT induces vasodilation by causing the relaxation of smooth muscles connected to the endothelium. This is crucial for treating joint inflammation, as vasodilation enhances the supply of oxygen to the targeted cell and facilitates the movement of immune cells into the tissue [53]. Our study highlighted the superior effectiveness of ESWT over LLLT for treating RCT. Initially, there were no significant differences among the groups. Initially, there were no significant differences among the groups; however, as treatment progressed, patients receiving ESWT demonstrated greater improvements in pain reduction, functional mobility, and overall recovery. This suggests that ESWT may provide enhanced long-term therapeutic benefits.Post-treatment, however, Group A (treated with ESWT) showed a remarkable increase in muscle thickness (mean difference = -0.3800, $p < 0.001$) compared to LLLT. Regarding pain and disability, ESWT led to a more substantial reduction in SPADI scores (mean difference = -8.600, $p < 0.01$), highlighting its effectiveness in alleviating symptoms. Moreover, ESWT significantly reduced serum cortisol levels (mean difference = -7.6400, $p < 0.001$), indicating a greater decrease in stress and inflammation compared to low-level laser therapy (LLLT). This reduction in cortisol correlates with improved patient outcomes, highlighting the potential of ESWT to facilitate recovery in individuals suffering from musculoskeletal disorders. Additionally, ESWT demonstrated superior improvements in shoulder mobility, with notable gains in shoulder abduction (mean difference = 13.600, $p < 0.01$) and external rotation (mean difference = 9.600, $p < 0.01$). These findings underscore ESWT's capability to enhance functional recovery more effectively than LLLT, ultimately leading to better overall patient satisfaction and quality of life. This positions ESWT as a compelling treatment option in rehabilitation protocols for shoulder injuries. Laboratory research frequently demonstrates that low-energy irradiation from lasers modifies cellular processes, resulting in various effects such as anti-inflammatory responses and enhanced collagen turnover [54]. Transferring these consistent outcomes to clinical studies on randomized controlled trials (RCT) often fails (Basford, 2005) [55]. The presence of favorable outcomes seems almost balanced by the occurrence of detrimental trial results. Recent systematic studies have shown that LLLT has a direct correlation with dosage, indicating that the effectiveness of LLLT increases as the dosage increases. This effect has been seen in both elbow tendinopathy and general tendinopathy [56,57]. LLLT has also been found to be effective in treating chronic joint problems, as observed by Jang and Lee (2012)[58,59], thus concluding that laser therapy is ineffective for treating RCT. Based on our research findings, we found that group A (ESWT) is an excellent approach for reducing pain intensity and improving functioning and quality of life in RCT. Furthermore, ESWT is a reliable and effective therapy for RCT. When comparing the effectiveness of group A (ESWT) with group B (LLLT) and group C (UST), group A is considerably more effective than both group B and group C. The ESWT intervention led to substantial enhancements in muscle thickness, pain and impairment reduction, shoulder mobility, and a notable decrease in inflammation.

CONCLUSION

In conclusion, our study demonstrates that low-energy extracorporeal shockwave therapy (ESWT) combined with dynamic rotator cuff loading exercises is the most effective treatment for

rotator cuff tendinopathy, significantly improving muscle thickness, shoulder function, and pain levels. While low-level laser therapy (LLLT) and ultrasound therapy (UST) also showed benefits, ESWT led to greater improvements in clinical outcomes. Given the promising results of ESWT, future research should explore optimal treatment protocols, including varying frequencies and energy levels, to further enhance patient outcomes. Investigating the long-term effects of these therapies on recovery and recurrence of rotator cuff injuries could provide valuable insights for clinicians. Future studies should also focus on patient-reported outcomes and quality-of-life measures to fully understand the impact of these interventions on daily functioning. By establishing clearer guidelines for managing rotator cuff tendinopathy, we can improve treatment strategies and patient satisfaction.

Additional research is required to investigate the correlation between the therapeutic impact and the frequency of ESWT. Furthermore, our research lacks a placebo group that received pseudo-shockwave treatment. Nevertheless, establishing a placebo group is challenging due to the widespread awareness that shockwave treatment induces intense physiological sensations, making it unethical to subject patients to deceptive therapy. Additionally, we lack a control group to assess the effects of alternative conservative treatments, including nonsteroidal anti-inflammatory drugs and local corticosteroid injections. Therefore, it is impossible to determine whether the two forms of shockwaves will provide greater advantages compared to alternative conservative treatments using a control group.

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Conflict of Interest

The author(s) do not have any conflict of interest.

Data Availability

This statement does not apply to this article.

Ethics Statement

The study protocol was approved by the Ethics Review Committee of Dr. M.G.R. Educational and Research Institute, Chennai, Tamil Nadu, India (Ref No. 645/2022/IEC/ACSMCH Dt.14/12/2022).

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This prospective randomized controlled trial, registered with the Clinical Trial Registry – India (CTRI/2024/07/069728), received approval from the Ethical Clearance Committee of the Faculty of Physiotherapy, Dr. M.G.R. Educational and Research Institute, Chennai, Tamil Nadu, India (Ref No. 645/2022/IEC/ACSMCH, dated 14/12/2022).

Author contributions

Nithyanisha Ranjithkumar: concept, designed; Jibi Paul and Jagatheesan Alagesan: reviewed the manuscript; Rajalaxmi Viswanathan and Nithyanisha Ranjithkumar: manuscript preparation, editing and designed the manuscript;

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