

doi: 10.63360/ipmm.v1.e15

Systematic Review

Comparative Effectiveness of Extracorporeal Shockwave Therapy, Platelet-Rich Plasma, and Corticosteroid Injections in Greater Trochanteric Pain Syndrome: A Systematic Review of Randomized Controlled Trials

Mohammed Ashkanani¹   0009-0000-5899-0770

Ali Ashkanani¹  0009-0005-9834-9036

Mohammad Husain¹  0009-0002-5212-100X

Mahdi Garashi¹  0009-0005-2780-9138

Zaid Al Boloushi²  0000-0002-0842-1104

¹Ministry of Health Mubarak Hospital, State of Kuwait.

²Ministry of Health Jaber Hospital, State of Kuwait.

ABSTRACT

Background and Objectives: Greater Trochanteric Pain Syndrome (GTPS) is a common condition characterized by chronic lateral hip pain, particularly among females aged 40 to 60. Various non-surgical options, corticosteroid injections (CSI), platelet-rich plasma (PRP) injections, and extracorporeal shockwave therapy (ESWT), are used, but their comparative effectiveness remains uncertain. This systematic review aimed to evaluate the effectiveness of ESWT compared to PRP and CSI in managing GTPS.

Methods: A systematic literature search was conducted in March 2025 across PubMed, OVID Medline, and Embase, following PRISMA guidelines. Randomized controlled trials (RCTs) evaluating ESWT, PRP and CSI for GTPS were included. A total of 16 RCTs met the criteria: 6 on ESWT, 6 on PRP, and 4 on CSI. Methodological quality was assessed using the PEDro scale and Cochrane Risk of Bias Tool. Visual Analogue Scale (VAS) scores were extracted to compare pain outcomes at baseline, 3, 6, and 12 months. The most used tools for function and quality of life were the Harris Hip Score (HHS) and the Modified Harris Hip Score (mHHS).

Results: All three treatments ESWT, PRP, and CSI showed reductions in pain and improvements in function and quality of life, as measured by VAS and other functional scores. 1,275 patients were grouped across 16 RCTs, enhancing consistency and comparability. ESWT showed the greatest pain relief at 3 months (VAS 3.14), compared to PRP (3.39) and CSI (3.78). At 12 months, ESWT and CSI had similar outcomes (VAS 3.71), while PRP had a higher score (4.52). However, variability in treatment protocols and baseline characteristics across study populations limits direct comparison and generalizability.

Discussion and Conclusion: ESWT appears to offer rapid and sustained pain relief and functional benefit in GTPS. CSI offers similar long-term benefits, while PRP shows moderate mid-term promises. GRADE assessment

indicates that the overall evidence is of moderate certainty in supporting all three non-surgical interventions for pain reduction in GTPS. However, further high-quality research is warranted.

Keywords: greater trochanteric pain syndrome (GTPS), corticosteroid injections (CSI), platelet-rich plasma (PRP), extracorporeal shockwave therapy (ESWT), Systematic Review, non-surgical conservative therapies.

1. Introduction

Greater trochanteric pain syndrome (GTPS) is a musculoskeletal condition characterized by chronic pain in the lateral thigh and buttock region. It is most commonly seen in females between the ages of 40 and 60. GTPS accounts for approximately 20% of hip pain cases among patients seeking primary care. Recent studies report an annual incidence ranging from 1.8 to 5.6 cases per 1000 people, with a prevalence of approximately 17.6% in community-dwelling adults aged 50–79. These figures highlight the considerable global burden of this condition. Although GTPS was traditionally attributed to trochanteric bursitis, recent studies have demonstrated the involvement of tendinopathies of the gluteal muscles and other peri-trochanteric structures⁽¹⁾. GTPS is considered a challenging condition to evaluate due to the complex anatomy of the peritrochanteric structures⁽²⁾. This introduction provides a comprehensive overview of GTPS, encompassing its etiology, pathophysiology, clinical presentation, diagnostic evaluation, and non-surgical management strategies, with a particular focus on Extracorporeal Shockwave Therapy (ESWT).

1.1 Etiology and Pathophysiology

The etiology of GTPS is multifactorial, involving both intrinsic and extrinsic factors. Intrinsic factors include gluteal muscle weakness, altered hip biomechanics, and leg length discrepancies, which lead to increased tensile and compressive forces on the peri-trochanteric structures. Extrinsic factors encompass overuse injuries, direct trauma, and repetitive friction from the iliotibial band over the greater trochanter⁽¹⁾. While some patients may present with trochanteric bursitis, histopathological studies suggest that GTPS is primarily due to tendinopathy of the gluteus medius and minimus muscles. Bursal inflammation often develops secondarily due to repeated friction between the greater trochanter and the iliotibial band (ITB)⁽⁴⁾. Evolving insights into GTPS pathophysiology indicate a multifactorial basis. From a biomechanical perspective, the chronic overload and friction caused by altered gait patterns or ITB tension can contribute to degenerative changes in the gluteal tendons⁽²⁾. Additionally, there is evidence of neurophysiological involvement, as patients with GTPS may experience central and peripheral sensitization wherein pain processing is amplified. This leads to persistent symptoms even after the initial tissue injury resolves. For example, elevated levels of pain-related neuropeptides such as calcitonin gene-related peptide (CGRP) have been implicated in chronic lateral hip pain, and ESWT may exert analgesic effects in part by reducing the release of such mediators⁽³⁾.

1.2 Clinical Presentation

Patients with GTPS typically present with lateral hip pain that may radiate down the leg, often accompanied by paresthesia and difficulty lying on the affected side⁽¹⁾. The pain is often described as aching and can intensify during activities such as walking, climbing stairs, or prolonged sitting. Physical examination commonly reveals tenderness over the greater trochanter, and pain may be elicited with passive, active, and resisted hip abduction and external rotation. This is commonly assessed using clinical tests such as the Single Leg Stance (SLS) test, the resisted external de-rotation test (ADD-R), and the Flexion–Adduction–External Rotation with Resistance (FADER-R) test, which are helpful in provoking pain and supporting the diagnosis. The jump sign, where palpation of the greater trochanter causes the patient to nearly jump off the bed, is a characteristic finding^(1,4).

1.3 Diagnostic Evaluation

A thorough history and physical examination are essential for diagnosing lateral hip pain. Diagnosis is primarily clinical, supported by imaging modalities such as ultrasound and magnetic resonance imaging (MRI), which aid in excluding other pathologies. Ultrasound may reveal gluteal tendon thickening or bursal distension, whereas MRI can detect tendinopathy, tendon tears, or bursitis. Additionally, MRI can assist in ruling out alternative causes such as avascular necrosis, femoroacetabular impingement, labral pathology, snapping hip syndrome, and ischiofemoral impingement, which may mimic or coexist with GTPS^(2,4). Early and accurate diagnosis of GTPS is crucial, as delays and mismanagement can worsen the prognosis due to the development of persistent symptoms. Differential diagnoses include hip osteoarthritis, lumbar radiculopathy, and referred pain from the sacroiliac joint, necessitating a thorough clinical assessment⁽²⁾.

1.4 Management options

The majority of cases of GTPS can be effectively managed within a primary care setting using conservative treatments. These initial interventions include avoiding activities that exacerbate symptoms and performing physiotherapy or home-based exercises to strengthen and stretch the hip muscles. Pharmaceutical treatments mainly involve utilizing nonsteroidal anti-inflammatory drugs (NSAIDs) for pain relief and inflammation reduction. NSAIDs can be beneficial for acute tendinopathy; however, their use should be avoided in chronic cases^(2,5). Administration of corticosteroid injections is another common management strategy used to reduce inflammation and provide short-term pain relief. These injections deliver a targeted dose of cortisone, often in combination with a local anesthetic such as lidocaine⁽⁵⁾. Despite these interventions, some patients may still experience persistent symptoms, prompting exploration of alternative advanced therapies such as platelet-rich plasma (PRP) injections and extracorporeal shock wave therapy (ESWT)⁽⁴⁾. PRP is a concentration of platelets derived from a patient's own blood, containing growth factors that promote healing. When injected into injured tissues, PRP releases these growth factors, stimulating cell proliferation and tissue regeneration⁽⁶⁾. ESWT will be discussed in detail in the section below. Surgical intervention is considered only as a last resort for cases that do not respond to conservative management⁽⁴⁾.

1.5 Extracorporeal Shockwave Therapy (ESWT)

ESWT has emerged as a non-invasive treatment modality for various musculoskeletal disorders, including GTPS. It involves the application of shockwaves to the affected tissues to promote healing and alleviate pain. Understanding its mechanisms of action and the different types of ESWT is crucial for optimizing therapeutic outcomes⁽⁵⁾.

1.5.1 Mechanisms of Action

ESWT involves the application of acoustic waves that transmit energy through tissues, inducing a range of biological responses. The primary mechanism is mechanotransduction, wherein mechanical stimuli are converted into biochemical signals, promoting tissue regeneration and repair. This process enhances angiogenesis, the formation of new blood vessels, which improves blood supply to the affected area and facilitates healing^(4,7). Additionally, ESWT modulates inflammation by influencing the production of nitric oxide and other anti-inflammatory mediators, thereby reducing pain and swelling. Furthermore, ESWT has been shown to induce selective loss of unmyelinated sensory nerve fibers, leading to long-term analgesia without affecting motor function^(3,7).

1.5.2 Types of ESWT

There are two main types of ESWT: focused and radial, each differing in their generation methods and tissue penetration characteristics. Focused ESWT (F-ESWT) delivers shockwaves to a specific focal point, allowing precise targeting of tissues. F-ESWT is generated using electrohydraulic, electromagnetic, or piezoelectric sources, delivering high-energy shockwaves that aid tissue penetration. The electrohydraulic technique uses a high-voltage electrical discharge to create a shockwave in water, which is then directed towards the treatment area. The electromagnetic method works by generating a magnetic field that produces shockwaves. Crystals that expand and contract in response to electrical pulses are used in the piezoelectric technique, which generates precise shockwaves⁽⁸⁾.

On the other hand, radial ESWT (R-ESWT) produces pressure waves that disperse radially from the applicator's tip, affecting superficial tissues. Radial waves are commonly generated pneumatically, where a projectile is accelerated and strikes a transmitter, producing the shockwave. As the wave travels, its peak pressure is highest at the point of origin and gradually diminishes as it penetrates deeper into the tissue. Compared to F-ESWT, R-ESWT is primarily used for treating broader and more superficial areas of the body⁽³⁾. Both types have been used for GTPS in clinical practice. Focused ESWT may be selected to target specific degenerative spots in the gluteal tendons, while radial ESWT might be used for more diffuse lateral hip pain or if a broader stimulation is desired. The choice of technique depends on availability and practitioner preference, but both aim to achieve similar biological effects in the tendon⁽⁹⁾. Radial ESWT is generally more accessible and cost-effective, making it a common choice in outpatient settings, whereas focused ESWT delivers deeper, more precise energy and may be better suited for localized pathology. Although current evidence does not clearly favor one modality, ongoing studies continue to assess their relative efficacy and long-term outcomes^(8,9).

Given the limited and mixed evidence regarding the efficacy of ESWT for GTPS, this systematic review will critically assess and compare the effectiveness of ESWT with other non-surgical treatment modalities for GTPS. Compared to treatments such as corticosteroid injections, which may provide only short-term relief, or physiotherapy, which may not fully resolve symptoms in chronic cases, ESWT offers a promising alternative due to its non-invasive mechanism and regenerative potential⁽⁵⁾. By analyzing available clinical evidence, this review seeks to determine whether ESWT offers the most significant improvements in pain, functionality, and overall patient satisfaction compared to others in patients with GTPS.

2. Methods

This systematic review was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and is registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the reference number CRD420251006652.

2.1 Eligibility criteria

The PRISMA PICOS framework consists of five different categories that help to assess which articles can be included in research. These are Population (P), Interventions (I), Comparators (C), Outcomes (O), and Study Design (S). We limited the search to clinical trials and English-language articles to ensure methodological rigor and facilitate accurate assessment and interpretation; non-English studies were excluded due to the lack of reliable translation resources, which could introduce misinterpretation or bias. Postmenopausal women were excluded because this population presents specific hormonal and musculoskeletal characteristics that may influence pain perception, tendon structure, and treatment response, potentially affecting the generalizability of findings to the broader GTPS population without such factors⁽¹⁰⁾.

A- Population

- Inclusion: Studies that focused on patients aged 18 years and older diagnosed with GTPS were included. No minimum number of patients required.
- Exclusion: Studies were excluded if the population included pregnant women, children, cancer patients, or if the study population was limited to post-menopausal women only.

B- Intervention

- Inclusion: Studies investigating ESWT, PRP and CSI for GTPS were included.
- Exclusion: Excluded papers focused on Surgical interventions.

C- Comparator

- Inclusion: No specific inclusion criteria were applied exclusively based on the comparator conditions.
- Exclusion: Studies that compare the intervention with Surgical interventions.

D- Outcome

- Inclusion: Articles were included if they reported outcomes on pain, function, and patient satisfaction in GTPS patients.

- Exclusion: Studies that focused on outcomes that are irrelevant to our research were excluded.

E- Study design

- Inclusion: All phases of clinical trials were included (Randomized Controlled trials: single blinded, double blinded, parallel-group, crossover, cluster, factorial, adaptive). Non-English studies were excluded
- Exclusion: All non-RCTs were excluded (pilot studies, systematic reviews, cohort studies, case reports, case-control studies, non-randomized studies).

2.2 Data sources and search strategy

On March 4, 2025, a comprehensive electronic literature search was conducted in PubMed, OVID Medline, and Embase databases to identify studies on conservative and non-surgical treatments for Greater Trochanteric Pain Syndrome (GTPS). Search terms were structured to capture a broad range of interventions, including: (Platelet-Rich Plasma or PRP), (Dry Needling), (extracorporeal shock wave therapy or ESWT), (shockwave), (Shock Waves), (injection), (corticosteroid), (glucocorticoid), (Exercise), (infiltration), (acupuncture), and (non-surgical), combined with the term (Greater trochanteric pain syndrome). Terms were adapted for each database using title/abstract fields. Additionally, the reference lists of included articles were screened manually to identify any potentially missed studies.

2.3 Study selection

To determine whether the studies met the inclusion criteria, three independent reviewers (AHA, MKA, and MAH) evaluated each report separately, following a standardized methodology established prior to the search to minimize bias. After completing their assessments, they compared their findings. Disagreements between reviewers were resolved by discussing them with a fourth reviewer (MMG) who used Rayyan to assess his decision making.

Duplicate records were identified and removed using EndNote and Rayyan, which reduced the total number of articles. Titles and abstracts were then screened for relevance to the research question using Rayyan, resulting in the exclusion of studies not related to the non-surgical management of GTPS. The remaining articles were carried forward for further evaluation.

A full-text eligibility assessment was subsequently conducted, and only studies meeting all inclusion criteria were selected. Some papers were excluded due to the specific population studied. The final set of eligible articles was then included in this systematic review.

2.4 Data extraction process

Three reviewers (AHA, MKA and MAH) independently extracted data from the articles and the outcomes were compared to ensure consistency. All reviewers followed a specific process while extracting the data aligned with the predefined inclusion and exclusion criteria. Disagreements were resolved by involving a fourth reviewer (MMG).

2.5 Assessment of methodological quality/risk of bias

Two tools were used to evaluate the methodological quality and risk of bias in the 16 eligible clinical trials: the Physiotherapy Evidence Database Scale (PEDro scale) and the Cochrane Risk of Bias Tool. All articles were independently reviewed using both tools by three reviewers (AHA, MKA and MAH), and their individual assessments were compared and discussed to ensure consensus.

First, the PEDro scale was used to assess methodological quality and partially the risk of bias. The PEDro scale is a validated tool commonly used to evaluate the quality of clinical trials in the field of physiotherapy. It consists of an 11-item checklist focusing on trial design, execution and statistical analysis. Each criterion is scored as one if met, and zero if not met. The checklist assesses whether the eligibility criteria were clearly defined, whether participants were randomly allocated, whether randomization was concealed, similarity of groups at baseline, blinding of subjects, blinding of therapists, blinding of assessors, adequacy of follow-up, intention-to-treat analysis, between-group comparisons, and reporting of point estimates and variability measures such as standard deviations.

The total PEDro score ranges from 0 to 10, with the first item (eligibility criteria) not included in the total score. Clinical trials scoring 6 or higher are generally considered to have high methodological quality, those scoring 4-5 are considered moderate quality, and score below 4 are classified as low quality.

Secondly, the Cochrane Risk of Bias Tool was used to assess the risk of bias across seven domains: randomisation and allocation concealment, blinding of participants and therapists, blinding of outcome assessors, handling of missing data, reporting of planned outcomes and other potential sources of bias. This tool evaluates the likelihood of selection, performance, detection, attrition and reporting bias.

Each reviewer assessed all seven domains for each study assigning judgements of "low risk", "high risk", or "unclear risk" to each domain. The overall risk of bias for each study was determined by aggregating the judgments across all domains.

The GRADE approach was used to evaluate the certainty of evidence across five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Assessment was informed by forest plots, effect size distributions, and confidence intervals. Visual tools such as forest plots and inconsistency graphs (e.g., funnel plot, I^2 statistic) were utilized to interpret heterogeneity and guide downgrading decisions. Each domain was independently judged by the reviewers before reaching consensus.

2.6 Process of data average formulation

The aim of this research is to compare various conservative therapies used in the management of GTPS. To achieve this, we evaluated three main therapies: ESWT, PRP and CSI. Multiple clinical trials utilised different outcome measures to assess the efficacy of these interventions. One commonly used outcome measure is the Visual Analogue Scale (VAS), which evaluates pain intensity. In this study, we used the equation below to calculate the average VAS score for each conservative therapy at baseline, 3 months, 6 months and 12 months.

$$\text{Average (VAS)} = \frac{[(\text{VAS score trial 1} \times \text{total of cohort sample size in trial 1}) + (\text{VAS score trial 2} \times \text{total of cohort sample size in trial 2}) + \dots]}{\text{Total of cohort sample size in all trials}}$$

3. Results

3.1. Study Selection

A total of 432 studies were retrieved from three electronic databases: PubMed, OVID Medline, and Embase. After limits applied and records screened, 389 articles were removed using End-Note and Rayyan, reducing the total number of articles to 43. Titles and abstracts were then screened for relevance to the review question using Rayyan, leading to the exclusion of 24 studies that did not pertain to the non-surgical management of Greater Trochanteric Pain Syndrome. This process left 19 articles for further evaluation.

A full-text eligibility assessment was subsequently conducted, and only studies that met all inclusion criteria were selected. Three papers were excluded due to the specific population studied, resulting in a final total of 16 eligible articles for inclusion in this systematic review. Figure 1 provides a summary of the inclusion and exclusion criteria applied in this study.

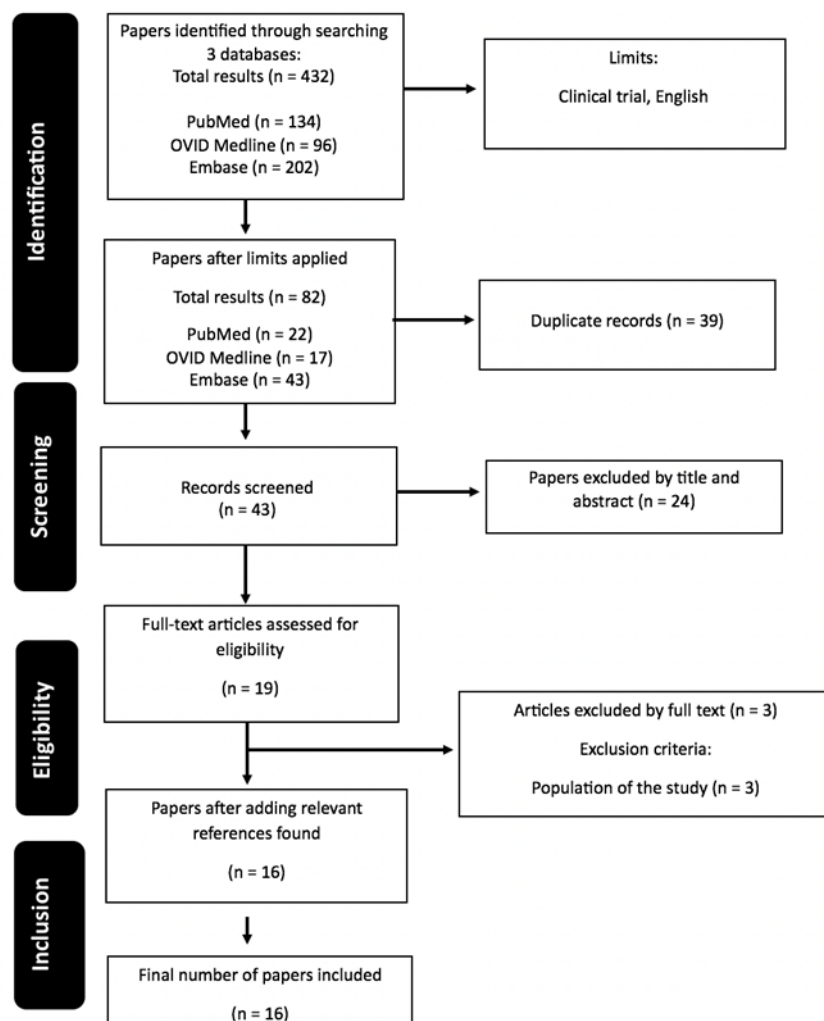


Figure 1. PRISMA framework.

3.2 Study Characteristics

Table 1 summarizes the main characteristics of the 16 included studies. It presents studies of extracorporeal shockwave therapy (ESWT), platelet-rich plasma (PRP) injections and corticosteroid injections (CSI).

3.2.1 Sample Characteristics

A total of 1,275 individuals diagnosed with GTPS were included across all studies. These individuals presented with lateral hip pain, tenderness over the greater trochanter, and discomfort during walking, stair climbing, or lying on the affected side. Of the total sample, 168 participants were male (13.1%) and 1,107 were female (86.8%). The overall mean age of participants was 57.99 years.

When stratified by treatment group, studies evaluating ESWT included 471 participants, comprising 86 males and 385 females. PRP studies involved 391 participants, with 41 males and 350 females. Studies examining CSI included a total of 413 participants, of whom 41 were male and 372 were female.

3.2.2 Assessment and Intervention

A total of 16 randomized controlled trials (RCTs) were eligible for inclusion in this review, each assessing different non-surgical management options for GTPS. Six RCTs evaluated the effectiveness of ESWT in reducing pain and improving function⁽¹⁰⁻¹⁵⁾. Another six RCTs investigated the role of PRP injections in managing patients with GTPS⁽¹⁶⁻²¹⁾. Lastly, four RCTs examined the effects of CSI on pain relief and quality of life⁽²²⁻²⁵⁾.

All 16 RCTs are summarized and analyzed in this section, with brief definitions of the outcome measures used in each trial. In addition, the methodological quality and risk of bias of each RCT were assessed and rated.

3.2.3 Outcome measurements:

Outcome measurements are essential tools for assessing the effectiveness of interventions, particularly in musculoskeletal and orthopedic research. In this review, various outcome measures were used to assess pain, physical function, overall patient improvement, and quality of life, with outcomes typically quantified using numerical scales and scores.

Both the Numerical Pain Rating Scale (pNRS) and Visual Analogue Scale (VAS) were used to measure pain intensity on a 0–10 scale, with higher scores indicating greater pain. Furthermore, the Harris Hip Score (HHS) and its modified version (mHHS) were used to assess hip function on a 0–10 scale, where higher scores indicate better function.

Table 1. Summary of RCTs Characteristics

Study	Population		Treatment arm	Preparation	Control arm
	Treatment	Control			
Heaver et al., 2021 ⁽¹¹⁾	Total 95		F-ESWT	Shock: 2500, Guidance: Palpation, Target: Most tender area, Energy Flux Density: 0.15-0.35 mJ/mm2	CSI: 80 mg methylprednisolone, 3.5 ml 0.5% bupivacaine and 3.5 ml 1% lignocaine
	48	47			
Çağlar Yağcı et al., 2023 ⁽¹²⁾	Total 60		R-ESWT	Shock: 2000, Guidance: Palpation, Target: Greater trochanter, Energy Flux Density: 2 bars, Frequency: 12 Hz	CSI: a mixture of 1 mL of 40 mg triamcinolone acetonide and 2 mL of 2% prilocaine hydrochloride
	32	28			
Ramon et al., 2020 ⁽¹³⁾	Total 103		Electromagnetic F-ESWT	Shock: 2000, Guidance: Ultrasound, Target: Greater trochanter, Energy Flux Density: 0.20 mJ/mm2, Frequency: 5 Hz	F-ESWT was used with 2000 shocks and 0.01 mJ/mm² (lowest) at 5 Hz
	53	50			
Carlisi et al., 2018 ⁽¹⁴⁾	Total 50		Piezoelectric F-ESWT	Shock: 1800, Guidance: Ultrasound, Target: Greater trochanter, Energy Flux Density: 0.15 mJ/mm2, Frequency: 4 Hz	UST (ROLAND, RT-20 series); daily for 10 days, 10 minutes each at frequency 1 MHz; intensity of 1.5 W/cm², area of 5 cm2
	26	24			
Notarnicola et al., 2023 ⁽¹⁵⁾	Total 30		Electromagnetic F-ESWT	Shock: 2000, Guidance: Ultrasound, Target: Greater trochanter, Energy Flux Density: 0.03 – 0.17 mJ/mm2 Frequency: 4 Hz	Eccentric exercises 5 days a week for 4 weeks (20 sessions) including piriformis muscle stretching, gluteal muscle stretching, wall squat with a ball, leg lift and iliotibial band stretching
	15	15			
Wheeler et al., 2022 ⁽¹⁶⁾	Total 120		R-ESWT	Shock: 2000, Guidance: Palpation, Energy Flux Density: Maximal comfortably tolerated, Frequency: 20 Hz	R-ESWT minimal dose with 500 shocks and 1.4 bar at 20 Hz
	57	63			
Begkas et al (2020) ⁽¹⁷⁾	Total:24		Single LR-PRP injection	Details of kit: SW-PRP system by NTTL Biologica, Volume of delivered: 4mL PRP	Single GCCS injection (Methylprednisolone)
	12	12			
Fitzpatrick et al (2018) ⁽¹⁸⁾	Total:80		Single L-PRP injection	GPS III Kit, Biomet Biologics, PRP platelet concentration: 964x109/L, PRP leucocyte concentration: 35.8 x109/L, Volume of delivered: 6-7mL PRP	Single BCCS injection
	40	40			
Fitzpatrick et al (2019) ⁽¹⁹⁾	Total:80		Single LR-PRP injection	GPS III Kit, Biomet Biologics, PRP platelet concentration: 964x109/L, PRP leucocyte concentration: 35.8 x109/L, Volume of delivered: 6-7mL PRP	Single BCCS injection
	40	40			
Thompson et al (2019) ⁽²⁰⁾	Total: 48		Single PRP injection	Recover™ platelet separation collecting system, PRP platelet concentration: 1232.2 x109/L, PRP leucocyte concentration: 29.5 x109/L, Volume of delivered: 5mL PRP	PI (5 ml isotonic saline with 1ml xylocaine)
	24	24			
Atilano et al (2024) ⁽²¹⁾	Total:81		Single subfascial PRP injection	PRP platelet concentration: ≈ 920 x109/L, PRP leucocyte concentration: Not assessed, Volume of delivered: 3-5mL PRP	Enthesis needling
	39	42			
Atchia et al (2025) ⁽²²⁾	Total:79		Single LR-PRP injection	SW-PRP system by NTTL Biologica), Volume of delivered: 4mL LR-PRP	PI (0.9% Saline solution
	39	40			
Brinks et al., 2011 ⁽²³⁾	Total:120		CSI	CSI dose: 40mgtriamcinolone acetate, Anesthetic: 1% or 2% lidocaine, Volume: 5ml	UC: Analgesia PRN
	60	60			
Mellor et al., 2016 ⁽²⁴⁾	Total:204		WS: CSI	CSI dose: 1 ml Celestone or 1ml Kenacort, Anesthetic: 2ml bupivacaine or 1 ml marcaine, Volume: 2-3 ml	EDX: 14 sessions over 8 weeks Or Watch and see
	CSI: 66	EDX:69			
Brennan et al, 2017 ⁽²⁵⁾	Total: 43		CSI	CSI dose: 2 mL methylprednisolone acetate 80mg, Anesthetic: 4 mL 1% lidocaine; 4 mL 0.25% marcaine, Volume: 10 ml	DN: Needle length: 50 to 100mm
	22	21			
Nissen et al., 2018 ⁽²⁶⁾	Total: 46		CSI	CSI dose:1 ml betamethasone7 mg, Anesthetic: 4ml 1% lidocaine, Volume: 5ml	PI: 5ml sterile saline solution
	21	25			

RCT = randomized clinical trial, CSI = Corticosteroid injection, PRP = Platelets-rich plasma, LR-PRP = Leukocyte-rich platelets rich plasma, PI: Placebo intervention, ml: milliliter, mm: millimeter, UST: Ultrasound Scan Therapy, UC: Usual care, DN: Dry needling, EDX: Education plus exercise, GCCS = Guided Corticosteroid, BCCS = Blinded Corticosteroid, SW-PRP: Single-Spin Whole blood Platelet-Rich Plasma, Hz: Hertz

3.3 Synthesis of Results

3.3.1 Extracorporeal Shockwave Therapy

All six RCT aimed to assess the effect of ESWT on a total of 471 patients with GTPS, predominantly females with a mean age of 58.4 years as demonstrated in Table 2. The RCTs utilized different ESWT settings and modalities. Four studies used focused extracorporeal shockwave therapy (F-ESWT) as the primary intervention: two employed electromagnetic-type devices^(13,15), one used piezoelectric-type⁽¹⁴⁾, and one did not specify the type⁽¹¹⁾. The remaining two RCTs used radial ESWT (R-ESWT) as the main intervention^(12,16).

These trials compared ESWT to CSI^(11,12), ultrasound therapy (UST)⁽¹⁴⁾, exercise⁽¹⁵⁾, and placebo^(13,16). The primary outcomes were pain reduction and improvement in physical function, assessed using various tools.

When comparing ESWT to corticosteroids, both Heaver et al. and Çağlar Yağcı et al. reported similar short and mid-term outcomes^(11,12). For instance, in the Heaver et al. trial, the 3-month follow-up VAS scores were 44.0 ± 25.9 for the ESWT group and 48.2 ± 26.5 for the CSI group. However, at 12 months, ESWT demonstrated superior long-term pain improvement, with VAS scores of 37.1 ± 3.26 for ESWT versus 55.0 ± 2.87 for CSI⁽¹¹⁾.

Roman et al. used electromagnetic F-ESWT versus sham F-ESWT (with the lowest energy density) and found considerable pain reduction at 2 months favouring the active treatment, with VAS scores of 2.0 ± 2.1 versus 4.7 ± 2.1 ⁽¹³⁾.

Carlisi et al., who used piezoelectric F-ESWT, also demonstrated significant pain reduction compared to UST, using the p-NRS scale. At 2 months, p-NRS scores were 2.08 ± 2.12 for ESWT and 3.36 ± 2.14 for UST; at 6 months, 0.79 ± 1.28 versus 2.03 ± 2.09 ⁽¹⁴⁾.

Notarnicola et al. compared electromagnetic F-ESWT with eccentric exercise and reported no clear differences in pain reduction at 2, 4, and 6 months. The p-NRS scores were 5.4 ± 2 , 4.5 ± 2 , and 3.9 ± 1.8 for ESWT, versus 5.5 ± 1.6 , 5.0 ± 2.3 , and 4.3 ± 2.6 for the control group⁽¹⁵⁾.

Lastly, Wheeler et al. assessed R-ESWT using p-NRS compared to control. While notable improvement was seen in both groups at 6 weeks, 3 months, and 6 months, there was no significant difference between them. Scores for the treatment group were 5.0 ± 2.4 , 4.7 ± 2.6 , and 4.6 ± 2.8 , respectively, versus 4.5 ± 2.4 , 4.4 ± 2.7 , and 4.0 ± 2.7 in the control group⁽¹⁶⁾.

3.3.2 Platelet-Rich Plasma

Six trials have been conducted to examine the efficacy of PRP in 392 patients with GTPS, from various clinical settings (Table 2)⁽¹⁷⁻²²⁾. The populations in these trials were very similar, mainly consisting of females with a mean age of approximately 55 years. Multiple PRP preparations were used, as nearly every trial employed a different method for preparing the injection. Three trials compared PRP injections to CSI⁽¹⁷⁻¹⁹⁾, two trials compared PRP to placebo interventions^(20,22), and one trial compared PRP to enthesi needling⁽²¹⁾.

The comparisons were primarily based on pain reduction and improvement in function, measured using various outcome tools. Begkas et al. and Fitzpatrick et al. reported that CSI injec-

tions demonstrated greater short-term efficacy (within the first 2–4 weeks) compared to PRP⁽¹⁷⁻¹⁹⁾. In the Begkas trial, VAS scores at 4 weeks were 2.56 ± 0.752 (CSI) and 4.64 ± 0.789 (PRP). However, PRP injections proved considerably more effective than CSI in the longer term (beyond 12 weeks)⁽¹⁷⁾. In the Atilano et al. trial, PRP was compared with enthesis needling VAS tools. The results showed PRP was substantially better throughout the entire follow-up period. At 12 months, PRP group scores were 4.03 (VAS), compared to 3.79 in the needling group⁽²¹⁾. Although PRP showed significant superiority over CSI and enthesis needling, the trials that compared PRP to placebo were inconclusive. In both the Thompson et al. study and the HIPPO trial, PRP did not demonstrate substantial pain reduction^(20,22). In the Thompson trial, 12-month follow-up using the numerical rating scale revealed very similar scores across different pain subgroups⁽²⁰⁾. In the HIPPO trial, using VAS and mHHS scores at 12 months, the PRP group scored 5.0, and 58.6 ± 22.9 respectively, compared to 5.0 and 60.0 ± 17.2 in the placebo group⁽²²⁾.

3.3.3 Corticosteroids Injection

Four trials have been conducted to examine the efficacy of CSI in patients with GTPS from various clinical settings (Table 2)⁽²³⁻²⁶⁾. The populations in these trials were quite similar, consisting mostly of females with a mean age of approximately 59 years. The primary outcome in all studies was pain reduction, assessed using tools such as the Visual Analogue Scale (VAS) and Numerical Rating Scale (NRS).

Brinks et al. reported that patients who received CSI experienced greater reductions in pain at rest and during activity at the 3-month follow-up compared to the usual care group. The adjusted differences were 1.18 for pain at rest and 1.30 for pain with activity. However, at the 12-month follow-up, pain levels had decreased in both groups with no significant difference between them: 0.14 for pain at rest and 0.45 for pain with activity⁽²³⁾. In the second trial, Mellor et al. showed that at the 8-week follow-up, patients in the education plus exercise (EDX) group reported less pain on the NRS compared to the CSI and watch-and-see (WS) groups. The mean scores were 1.5 ± 1.5 for EDX, 2.7 ± 2.4 for CSI, and 3.8 ± 2.0 for WS. During the 12 months follow-up, EDX resulted in better global improvement than CSI, although estimates were compatible in pain intensity⁽²⁴⁾. Both EDX and CSI were superior to WS in reducing pain. In the third trial by Brennan et al., a noninferiority test with a 1.5-point margin showed that DN was non-inferior to CSI, rejecting the null hypothesis of CSI being superior. The maximum difference in pain scores between the groups was 1.3 ± 2.6 at three weeks⁽²⁵⁾. In the trial by Nissen et al., CSI was compared to placebo saline injection. Pain reduction one month after injection was similar between groups: -1.5 for CSI and -2.5 for placebo⁽²⁶⁾.

Table 2. Summary of RCTs Findings.

Study	Findings	
Heaver et al., 2021 ⁽¹¹⁾	F-ESWT VAS (mean ± SD)	CSI VAS (mean ± SD)
	Baseline: 69.8 ± 16.9	Baseline: 70.1 ± 16.5
	3 mo: 44.0 ± 25.9 <i>P</i> = 0.39	3 mo: 48.2 ± 26.5 <i>P</i> = 0.39
	12 mo: 37.1 ± 3.26 <i>P</i> = 0.007	12 mo: 55.0 ± 2.87 <i>P</i> = 0.007
Çağlar Yağcı et al., 2023 ⁽¹²⁾	R-ESWT VAS Mean ± SD	CSI VAS Mean ± SD
	Baseline: 6.84 ± 0.95	Baseline: 6.96 ± 0.99
	3w: 1.09 ± 0.96 <i>P</i> = 0.001	3w: 0.78 ± 0.73 <i>P</i> = 0.001
	3 mo: 1.03 ± 1.03	3 mo: 0.78 ± 0.83
Ramon et al., 2020 ⁽¹³⁾	F-ESWT: Mean ± SD	Sham ESWT: Mean ± SD
	VAS at Baseline: 6.3 ± 1.8	VAS at Baseline: 6.3 ± 1.4
	VAS at 2 mo: 2.0 ± 2.1 <i>P</i> = 0.001	VAS at 2 mo: 4.7 ± 2.1 <i>P</i> = 0.001
	HHS at Baseline: 65.0 ± 13.5 <i>P</i> = 0.71	HHS at Baseline: 65.9 ± 11.2 <i>P</i> = 0.71
	HHS at 3 mo: 90.4 ± 10.3 <i>P</i> < 0.001	HHS at 3 mo: 78.0 ± 11.7 <i>P</i> < 0.001
	HHS at 6 mo: 91.0 ± 10.3 <i>P</i> < 0.001	HHS at 6 mo: 79.4 ± 12.5 <i>P</i> < 0.001
Carlisi et al., 2018 ⁽¹⁴⁾	F-ESWT P-NRS Mean ± SD	UST P-NRS Mean ± SD
	Baseline: 5.12 ± 2.17	Baseline: 4.93 ± 1.72
	2mo: 2.08 ± 2.12 <i>P</i> = 0.02	2mo: 3.36 ± 2.14 <i>P</i> = 0.02
	6mo: 0.79 ± 1.28 <i>P</i> = 0.047	6mo: 2.03 ± 2.09 <i>P</i> = 0.047
Notarnicola et al., 2023 ⁽¹⁵⁾	F-ESWT P-NRS Mean ± SD	Exercise p-NRS Mean ± SD
	Baseline: 8.3 ± 0.9	Baseline: 7.7 ± 1.4
	2mo: 5.4 ± 2.0	2mo: 5.5 ± 1.6
	6mo: 3.9 ± 1.8	6mo: 4.3 ± 2.6
Wheeler et al., 2022 ⁽¹⁶⁾	3 Sessions R-ESWT P-NRS Mean ± SD	Minimal dose R-ESWT P-NRS Mean ± SD
	Baseline: 6.7 ± 1.5	Baseline: 6.1 ± 1.8
	3 mo: 4.7 ± 2.6 <i>P</i> = 0.686	3 mo: 4.4 ± 2.7 <i>P</i> = 0.686
	6mo: 4.6 ± 2.8 <i>P</i> = 0.841	6mo: 4.0 ± 2.7 <i>P</i> = 0.841
Begkas et al (2020) ⁽¹⁷⁾	PRP: Mean ± SD	CSI: Mean ± SD
	VAS at pre-injection: 7.21 ± 0.760 <i>P</i> value >0.05	VAS at pre-injection: 7.15 ± 0.582 <i>P</i> value >0.05
	VAS at 3mo: 3.16 ± 0.866 <i>P</i> value <0.05	VAS at 3mo: 6.57 ± 0.915 <i>P</i> value <0.05
	VAS at 6mo: 1.52 ± 0.505 <i>P</i> value <0.05	VAS at 6mo: 6.98 ± 0.691 <i>P</i> value <0.05
	HHS at Baseline: 55.91 ± 9.82 <i>P</i> value >0.05	HHS at Baseline: 56.72 ± 9.93 <i>P</i> value >0.05
	HHS at 3mo: 86.12 ± 0.78 <i>P</i> value <0.05	HHS at 3mo: 86.61 ± 4.71 <i>P</i> value <0.05
	HHS at 6mo: 96.17 ± 0.71 <i>P</i> value <0.05	HHS at 6mo: 57.92 ± 11.13 <i>P</i> value <0.05
Fitzpatrick et al (2018) ⁽¹⁸⁾	L-PRP: mHHS Mean ± SD	CSI: mHHS Mean ± SD
	Baseline: 53.77 ± 12.08	Baseline: 54.15 ± 10.88
	6w: 68.79 ± 13.33	6w: 69.51 ± 14.78
	3mo: 74.05 ± 13.92 <i>P</i> value = .04	3mo: 67.13 ± 16.04 <i>P</i> value = .04
Fitzpatrick et al (2019) ⁽¹⁹⁾	L-PRP: mHHS Mean ± SD	CSI mHHS Mean ± SD
	6mo: 77.60 ± 11.88 <i>P</i> value = 0.0003	6mo: 65.72 ± 14.78 <i>P</i> value = 0.0003
	12mo: 78.18 ± 14.53	12mo: 70.53 ± 23.80
	24mo: 82.59 ± 9.71 <i>P</i> value < 0.0001	24mo: 71.27 ± 25.78 <i>P</i> value < 0.0001

Study	Findings		
Thompson et al (2019) ⁽²⁰⁾	PRP: NRS as Worst pain		PI: NRS as Worst pain
	Baseline: 6		Baseline: 7
	3 mo: 3		3 mo: 3.5
	12 mo: 0		12 mo: 2
Atilano et al (2024) ⁽²¹⁾	PRP: VAS Mean		DN: VAS Mean
	3 mo: 2.35 P=.058		3 mo: 1.02 P=.058
	6 mo: 2.87 P=.862		6 mo: 2.99 P=.862
	12 mo: 4.03 P=.716		12 mo: 3.79 P=.716
Atchia et al (2025) ⁽²²⁾	PRP: Median		PI: Mean
	VAS at Baseline: 6.0 P=0.47		VAS at Baseline: 7.0 P=0.47
	VAS at 3 mo: 4.5 P=0.98		VAS at 3 mo: 4.5 P=0.98
	VAS at 12 mo: 5.0 P=0.31		VAS at 12 mo: 5.0 P=0.31
	mHHS at Baseline: 49.5 P=0.056		mHHS at Baseline: 43.5 P=0.056
	mHHS at 3 mo: 59.0 P=0.27		mHHS at 3 mo: 54.2 P=0.27
	mHHS at 12 mo: 58.6 P=0.77		mHHS at 12 mo: 60.0 P=0.77
Brinks et al., 2011 ⁽²³⁾	CSI: VAS Mean		UC: VAS Mean
	Baseline: 5 at rest, 6.9 with activity		Baseline: 5.4 at rest, 6.8 with activity
	3mo: 2.4 at rest, 3.7 with activity		3mo: 3.8 at rest, 4.9 with activity
	12mo: 2.1 at rest, 2.8 with activity		12mo: 2.3 at rest, 3.4 with activity
Mellor et al., 2016 ⁽²⁴⁾	CSI: NRS Mean ± SD	EDX: NRS Mean ± SD	WS: NRS Mean ± SD
	8w: 2.7 ± 2.4	8w: 1.5 ± 1.5	8w: 3.8 ± 2.0
	3mo: 2.5 ± 2.1	3mo: 1.7 ± 1.7	3mo: 3.6 ± 2.2
	12mo: 2.3 ± 1.9	12mo: 2.1 ± 2.2	12mo: 3.2 ± 2.6
Brennan et al, 2017 ⁽²⁵⁾	CSI: NRS Mean ± SD		DN: NRS Mean ± SD
	Baseline: 6.1 ± 2.1		Baseline: 5.4 ± 1.8
	3W: 2.7 ± 2.9		3w: 4.0 ± 2.2
	6w: 3.9 ± 3.7		6w: 2.8 ± 2.4
Nissen et al., 2018 ⁽²⁶⁾	CSI: NRS Mean		PI NRS Mean
	Baseline: 6.1		Baseline: 6.6
	2w: 3.9		2W: 4.4
	4w: 4.4		4w: 4.3

RCT = randomized clinical trial, VAS = Visual Analogue Scale, NRS = Numeric Rating Scale, HHS = Harris Hip Score, mHHS = Modified Harris Hip Score, CSI = Corticosteroid injection, PRP = Platelets-rich plasma, LR-PRP = Leukocyte-rich platelets rich plasma, SD = Standard deviation, PI = Placebo intervention, UC: Usual care, DN: Dry needling, EDX: Education plus exercise

3.3.4 Comparison of F-ESWT, PRP and CSI using VAS

Table (3) summarizes the average VAS scores for the three main conservative therapies evaluated in our research: F-ESWT, PRP, and CSI. All three therapies had similar baseline VAS scores, averaging 6.62, 6.28, and 6.96, respectively. At the 3-month follow-up, F-ESWT demonstrated the greatest pain relief with an average VAS score of 3.14, compared to PRP (3.39) and CSI (3.78).

At 6 months, PRP showed slightly better outcomes than CSI, with scores of 4.46 and 4.54, respectively. F-ESWT was not followed up with VAS scores at this time point. After 12 months, F-ESWT and CSI showed identical average VAS scores of 3.71, while PRP had a higher score of 4.52.

Table 3. Summary of average VAS outcomes for F-ESWT, PRP and CSI.

	F-ESWT	PRP	CSI
Baseline	6.62 (n=101)	6.28 (n=51)	6.96 (n=147)
3 mo	3.14 (n=101)	3.39 (n=90)	3.78 (n=147)
6 mo	NA	4.46 (n=90)	4.54 (n=72)
12 mo	3.71 (n=48)	4.52 (n=78)	3.71(n=107)

VAS = Visual Analogue Scale, F-ESWT = Focused Extracorporeal Shockwave therapy, CSI = corticosteroid injection, PRP = Platelets-rich plasma, n = number of patients, NA = Not available

3.3.5 Comparison of F-ESWT, PRP and CSI using Function and Quality of Life measurements

Across interventions, hip function improved from baseline and generally tracked pain. In the ESWT arm, Ramon et al. reported HHS rising from 65.0 ± 13.5 at baseline to 90.4 ± 10.3 at 3 months and 91.0 ± 10.3 at 6 months, exceeding sham 65.9 ± 11.2 at baseline, 78.0 ± 11.7 at 3 months and 79.4 ± 12.5 at 6 months⁽¹³⁾.

For PRP, Begkas et al. showed HHS gains from 55.91 ± 9.82 to 86.12 ± 0.78 (3 mo) and 96.17 ± 0.71 (6 mo); the CSI comparator moved 56.72 ± 9.93 to 86.61 ± 4.71 (3 mo) but declined by 6 months (57.92 ± 11.13)⁽¹⁷⁾. In longer-term PRP data, mHHS increased to 77.60 ± 11.88 (6 mo), 78.18 ± 14.53 (12 mo), and 82.59 ± 9.71 (24 mo) versus CSI 65.72 ± 14.78 , 70.53 ± 23.80 , and 71.27 ± 25.78 , respectively. Earlier PRP follow-up likewise favored PRP at 3 months (mHHS 74.05 ± 13.92 vs CSI 67.13 ± 16.04)^(18,19). Atchia et al. showed modest, similar mHHS changes for PRP and placebo at all timelines⁽²²⁾.

Overall, ESWT and PRP demonstrate early and sustained functional gains, while CSI’s functional benefit is most apparent short-term with attenuation by 6–12 months in some trials; quality-of-life instruments were less consistently reported but generally moved in the same direction as function.

3.3.6 Assessment of methodological quality/risk of bias

The methodological quality of the included randomized controlled trials was assessed using the PEDro scale. All studies scored highly, indicating good methodological rigor across the trials, as summarized in Table. 4.

Risk of bias was evaluated using the Cochrane Risk of Bias Tool. Thirteen studies were judged to have a low risk of bias^(12,14-16,18-26), reflecting consistent adherence to core methodological standards. Two studies were rated as having a moderate risk of bias due to concerns related to missing outcome data and incomplete reporting^(11,17). One study was rated as having a high risk of bias, primarily due to selective reporting and deviations from the intended intervention protocol⁽¹³⁾.

Table 4. PEDro scale & Cochrane Risk of Bias assessment for all RCTs.

Study	Q1–Q11 (Yes/11)	Quality Rating	D1–D5 Summary	Risk of Bias
Brinks et al. 2011 ⁽²³⁾	9/11	High	Low, Some, Low, Low, Low	Low
Mellor et al. 2016 ⁽²⁴⁾	9/11	High	Low, Some, Low, Low, Low	Low
Brennan et al. 2017 ⁽²⁵⁾	10/11	High	Low, Some, Low, Low, Low	Low
Carlisi et al. 2018 ⁽¹⁴⁾	10/11	High	Low, Low, Low, Some, Low	Low
Fitzpatrick et al. 2018 ⁽¹⁸⁾	10/11	High	Low, Low, Low, Low, Low	Low
Nissen et al. 2018 ⁽²⁶⁾	11/11	High	Low, Low, Low, Low, Some	Low
Fitzpatrick et al. 2019 ⁽¹⁹⁾	11/11	High	Low, Low, Low, Low, Low	Low
Thompson et al. 2019 ⁽²⁰⁾	9/11	High	Low, Low, Low, Low, Low	Low
Ramon et al. 2020 ⁽¹³⁾	11/11	High	Low, Low, High, Some, High	High
Begkas et al. 2020 ⁽¹⁷⁾	8/11	High	Low, Some, Low, Some, Some	Moderate
Heaver et al. 2021 ⁽¹¹⁾	10/11	High	Low, Low, High, Some, Low	Moderate
Wheeler et al. 2022 ⁽¹⁶⁾	11/11	High	Low, Low, Low, Some, Low	Low
Çağlar et al. 2023 ⁽¹²⁾	10/11	High	Low, Low, Low, Some, Low	Low
Notarnicola et al. 2023 ⁽¹⁵⁾	8/11	High	Low, Low, Low, Some, Low	Low
Atilano et al. 2024 ⁽²¹⁾	10/11	High	Low, Low, Low, Low, Some	Low
Atchia et al. 2025 ⁽²²⁾	9/11	High	Low, Low, Low, Low, Some	Low

The GRADE assessment (Figure2) indicates moderate-certainty evidence that ESWT, PRP injections, and CSI significantly reduce pain in patients with GTPS. Most included studies were well-conducted RCTs with low risk of bias, and the populations, interventions, and outcomes were directly applicable to the review question. On average, pain scores improved by approximately 3 points on the 0–10 VAS at short-term follow-up (3 months), with these improvements largely maintained at mid- and long-term follow-up (6–12 months).

However, the evidence was downgraded for inconsistency due to heterogeneity across studies, both in terms of intervention type and effect size. Imprecision was not downgraded, as most studies demonstrated sufficiently narrow confidence intervals that did not cross the line of no effect, and estimates generally exceeded the minimal clinically important difference (MCID) threshold for VAS (1.0). Overall, the evidence supports a meaningful reduction in pain with conservative treatments for GTPS, though variability in outcomes across studies and interventions warrants cautious interpretation of the exact magnitude of benefit.

VAS Outcome	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Overall certainty
3 months	Not Serious	Serious	Not Serious	Not Serious	Undetected	Moderate (⊕⊕⊕⊖)
6 months	Not Serious	Serious	Not Serious	Not Serious	Undetected	Moderate (⊕⊕⊕⊖)
12 months	Not Serious	Serious	Not Serious	Not Serious	Undetected	Moderate (⊕⊕⊕⊖)

Figure 2. GRADE Assessment for VAS Outcome.

The forest plot (Figure 3) summarizes the standardized mean differences (Cohen's *d*) for pain reduction as measured by VAS across studies evaluating F-ESWT, PRP, and CSI at multiple timepoints. Most studies demonstrated a favorable effect on pain, with effect sizes generally clustering between small to large magnitudes. F-ESWT showed large and sustained effects, particularly at 12 months in Heaver et al.⁽¹⁰⁾ ($d = 3.42$), while PRP studies such as Begkas et al.⁽¹⁷⁾ and Atilano et al.⁽²¹⁾ reported moderate improvements at 3 to 12 months. CSI, represented by Brinks et al.,⁽²³⁾ showed minimal changes over time with small or negligible effect sizes. The heterogeneity in effect sizes and confidence intervals, particularly in PRP and F-ESWT subgroups, reflects variations in population characteristics, protocols, and follow-up durations.

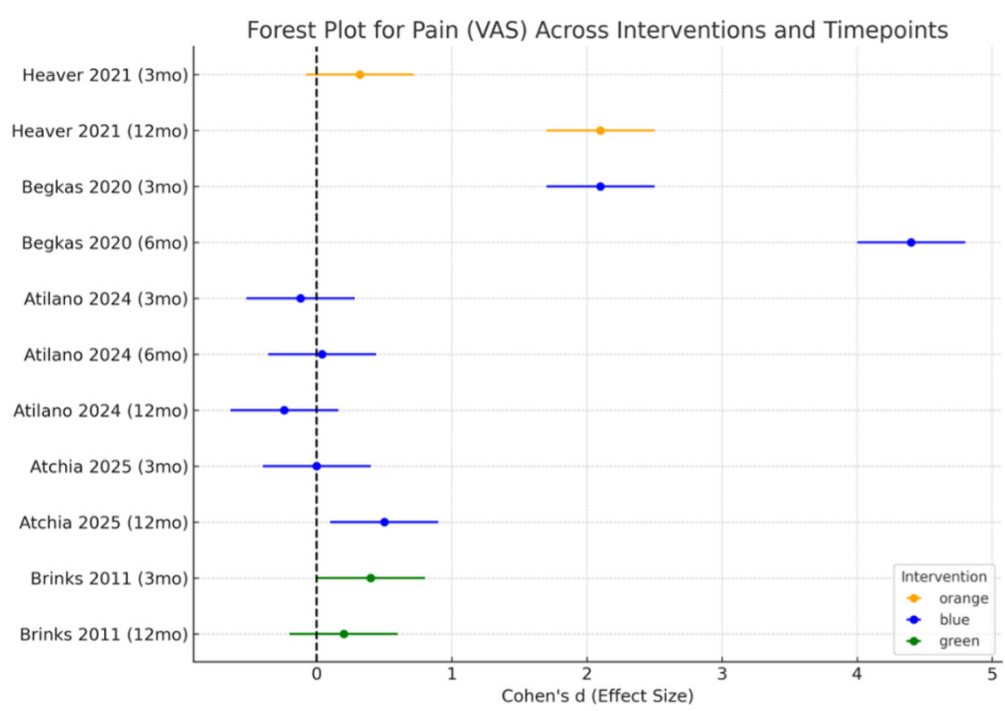


Figure 3. Forest Plot for Pain (VAS) Across Interventions and Timepoints.

An imprecision assessment (Figure 4) based on the calculated effect sizes and 95% confidence intervals revealed variability in estimate precision across the included studies. While studies like Heaver 2021⁽¹¹⁾ (3mo) and Begkas 2020⁽¹⁷⁾ (3mo) demonstrated effect sizes well above the minimal clinically important difference (MCID) with relatively narrow confidence intervals, other studies such as Atchia 2025⁽²²⁾ (3mo, 12mo) and Brinks 2011⁽²³⁾ (3mo, 12mo) presented estimates that clustered closely around the null effect, suggesting limited or uncertain benefit. Importantly, although some studies (e.g., Heaver 2021⁽¹¹⁾ (12mo)) had wider confidence intervals due to larger variance and sample size imbalance, most intervals did not cross the line of no effect. This pattern supports a likely beneficial effect overall but also reflects heterogeneity in precision. Given the consistency of clinically meaningful effects and the lack of major overlap with null results in most cases, the certainty of evidence was not downgraded for imprecision in the GRADE assessment.

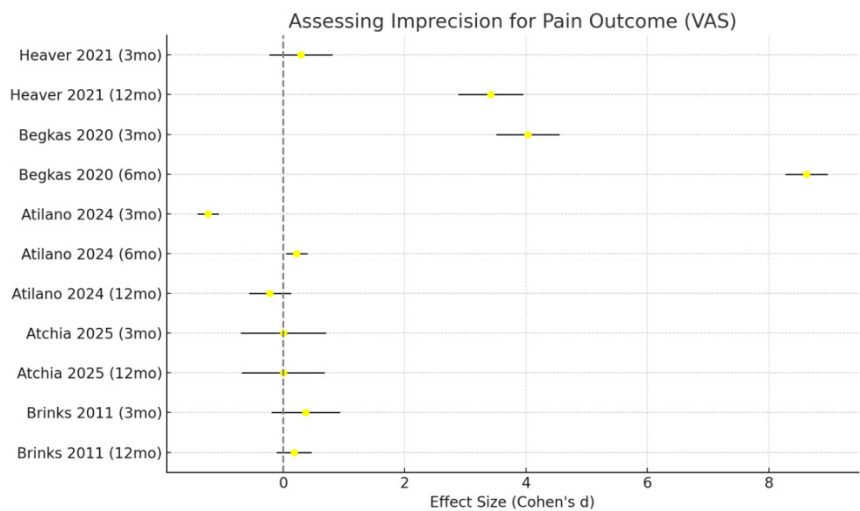


Figure 4. Assessing imprecision for Pain (VAS)

To evaluate consistency (Figure 5), we calculated the I^2 statistic based on the pooled results from all included studies measuring pain reduction via the VAS. The resulting I^2 value was 68%, indicating a moderate to substantial level of heterogeneity among the studies. As visualized in the inconsistency funnel plot, this degree of heterogeneity suggests variability in effect estimates that is unlikely to be due to chance alone. The divergence may stem from differences in follow-up durations, interventions (F-ESWT, PRP, CSI), baseline characteristics, or methodological quality across trials. While overlapping confidence intervals were observed in some comparisons, the overall inconsistency warrants caution in drawing generalized conclusions. Therefore, the GRADE certainty in the evidence was rated down by one level due to inconsistency, reflecting a reduced confidence in the precision and reproducibility of the pooled treatment effect.

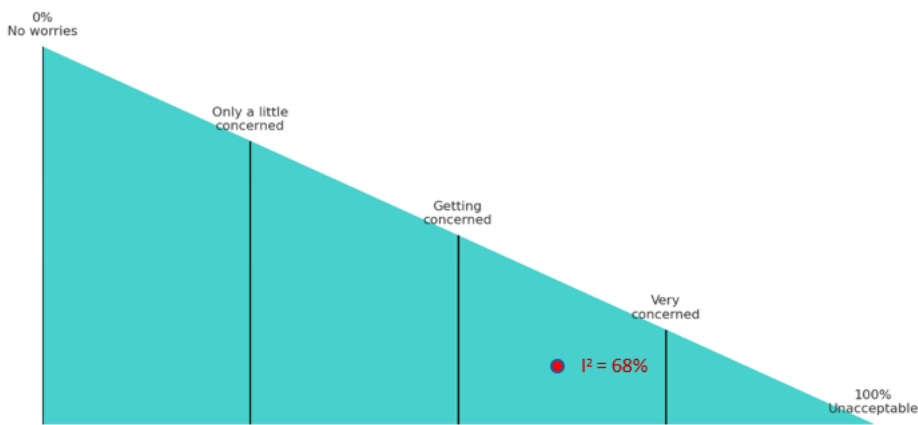


Figure 5. Consistency of Effects Across Studies

4. Discussion

Our systematic review provides critical insights into the relative effectiveness of three widely used non-surgical treatments for GTPS: F-ESWT, PRP, and CSI, as measured by the VAS for pain. This outcome measure was chosen because it was the most commonly used in the clinical trials, allowing us to calculate an average of the results.

Based on the synthesis of the initial results, it can be interpreted that F-ESWT achieved the lowest final pain scores (3.14), compared to CSI (3.78) and PRP (3.39). These results support the idea that F-ESWT improves pain relief by enhancing tissue healing, promoting local blood flow, and controlling inflammatory responses^(5,7). Based on the 3-month comparison, F-ESWT may offer quicker early pain relief and could potentially serve as a favourable first-line non-surgical treatment for initial pain management.

In addition to pain, several of the included studies evaluated functional outcomes and quality of life, which were part of the predefined objectives of this review. Although a wide range of assessment tools were used, limiting direct comparisons, relevant findings can still be summarized. Functional improvement was commonly assessed using both the modified Harris Hip Score (mHHS) and Harris Hip Score (HHS)^(13,17,18,19,22), which was reported in five trials and showed consistent improvement across all intervention types. Regarding quality of life, various tools were employed, including the EQ-5D, SF-12, and SF-36. While results varied, most studies that included these instruments reported favorable changes following treatment, particularly in the ESWT and PRP groups.

The clinical improvements observed with F-ESWT may be partially explained by its underlying biomechanical and neurophysiological effects. Mechanistically, ESWT is thought to promote tissue regeneration through mechanotransduction, enhance local blood flow via neovascularization, and modulate inflammation. Additionally, neurophysiological responses such as desensitization of nociceptors and reduction in peripheral nerve fiber excitability may contribute to the observed analgesic effects. These combined mechanisms provide a plausible biological rationale for the superior short-term and sustained pain relief associated with ESWT in patients with GTPS^(3,4).

At the 6-month follow-up, no VAS score data were available for F-ESWT. However, a comparison was made between the effectiveness of PRP and CSI. PRP emerged as a slightly better option, scoring 4.46 compared to CSI's 4.54. These results may be attributed to the proposed mechanism of PRP, which improves tendon healing by releasing growth factors over time⁽⁶⁾. This suggests PRP may be beneficial in managing chronic GTPS.

The long-term outcomes (12 months) showed that both F-ESWT and CSI achieved an identical average VAS score of 3.71. These results indicate that either treatment can be effective for providing long-term pain relief. The mechanism behind this sustained effect remains unclear. Although PRP outperformed CSI at the 6-month mark, its effectiveness appeared to decline over the longer term.

4.1 Heterogeneity of Interventions and Outcome Measures

The included RCTs exhibited considerable heterogeneity in both the interventions studied and the outcomes measured. Intervention protocols differed widely across studies. ESWT was delivered with varying parameters (focused vs. radial ESWT, different energy flux densities, shock frequencies, and total shocks), and injection-based treatments were not uniform (trials used different corticosteroid compounds/doses and divergent platelet-rich plasma preparation methods). Outcome assessment tools were likewise inconsistent between studies. Some trials measured pain using a VAS or a NRS, while others evaluated functional improvement with instruments like the HHS or its modified version, alongside various quality-of-life questionnaires. This inconsistency in outcome measures complicates direct comparison of results across trials and hinders synthesis of the evidence, as pooling data is challenging when endpoints differ. In effect, the heterogeneity in both intervention delivery and outcome reporting limits the interpretability of overall treatment effectiveness and undermines the feasibility of any meaningful quantitative synthesis of the results

4.2 Psycho-social aspects

GTPS is a complex condition that impacts various aspects of an individual's life. It is increasingly recognised as a syndrome that extends beyond biological pathology. The biopsychosocial model helps in understanding the full picture of this syndrome⁽²⁷⁾. The biological aspects were already discussed earlier in our research. Psychological factors associated with GTPS—including anxiety, depression, pain catastrophizing, and kinesiophobia—can dramatically affect pain perception, adherence to treatment, and consequently the outcomes of the management plan. These factors may lead to maladaptive coping strategies, ultimately contributing to the failure of non-surgical treatments, which is the main focus of our systematic review⁽²⁸⁾.

Another important factor that significantly influences treatment outcomes is the social component. GTPS affects a patient's social life in various ways. For example, reduced mobility can limit participation in social activities, thereby diminishing overall quality of life⁽²⁹⁾.

In our systematic review, ESWT demonstrated potential as a biological treatment for GTPS. However, integrated treatment approaches must be employed to address psychological and social barriers in order to optimize treatment outcomes. To address these aspects, it is essential to design clinical trials that combine ESWT with psychosocial interventions such as cognitive behavioural therapy, patient education, and support programs, in order to assess the influence of psychosocial factors on GTPS⁽²⁹⁾.

4.3 Clinical applicability

When evaluating non-surgical interventions for GTPS, clinical applicability, including cost, availability, and provider requirements, must be considered. ESWT, although associated with higher initial costs due to specialized equipment and operator expertise, may offer cost-efficiency in the long term due to its sustained therapeutic effect and limited need for repeated sessions⁽¹³⁾. However, its global availability remains uneven, particularly in resource-limited or rural settings. Administration typically requires trained physiatrists, sports physicians, or physiotherapists with formal training in shockwave application⁽⁹⁾. PRP injections, while increasingly popu-

lar, involve substantial setup costs for blood preparation systems and require aseptic technique and procedural skill, often delivered by orthopedic surgeons or interventional physicians⁽⁶⁾. CSI remains the most widely available and affordable option, often administered in primary care or outpatient orthopedic settings. While cost-effective for short-term relief, repeated use may raise safety concerns⁽²³⁾. Overall, treatment selection should consider not only clinical efficacy but also access to infrastructure, training, and long-term practicality.

4.4 Adverse effects

While generally safe, each non-surgical intervention for GTPS carries specific adverse effect profiles that must be considered in clinical decision-making. ESWT is typically well tolerated but may cause localized pain, skin reddening, or mild hematoma at the application site; these effects are usually transient and self-limiting⁽⁹⁾. PRP injections may lead to post-injection soreness, swelling, and localized inflammation, reflecting the body's biological response to the autologous product; serious complications are rare⁽⁶⁾. CSI, although widely accessible and effective in the short term, carry higher risks with repeated use, including tendon weakening or rupture, skin atrophy, and systemic effects such as hyperglycemia or infection⁽³⁰⁾. Awareness of these potential adverse effects is crucial when weighing treatment options, especially in recurrent or long-term management strategies.

4.5 Limitations

In our systematic review, several limitations have been identified. Firstly, although all the assessed clinical trials used multiple outcome measurements to evaluate their results, only one outcome measurement, VAS was used to formulate our summary result. This decision is based on few key reasons. First, VAS was consistently the most used outcome measurement across the included trials. Although the VAS score only evaluates subjective pain levels, other outcome measurements used in the trials also assessed different aspects of the syndrome, such as quality of life, physical examination findings, patient satisfaction, and psychological well-being.

Another limitation is that not all included trials used VAS, which means our summarized table omits a considerable amount of data from other valuable outcome measurements. This may have influenced our interpretation of the results and could lead to different conclusions. However, it is noteworthy that in the main findings as shown in Table 2, several alternative outcome measurements exhibited a trend similar to that of VAS in terms of pain relief, functionality and quality of life.

Regarding our search criteria, this review included only randomized controlled trials, excluding other types of studies such as case-control studies, case reports, and cohort studies. This exclusion may have limited the depth and variability of the evidence base, potentially impacting the overall conclusions.

This review excluded non-English studies to minimize the risk of misinterpretation and ensure consistency in quality appraisal. Non-English full-text extraction of parameter details risks translation errors; given that machine translation can misrender medical content, thus this review prioritized auditable, English-language extraction. Moreover, many outcomes are patient-reported outcome measures (PROMs); without verified cross-cultural validity invariance, pooling

different language versions can add heterogeneity; Therefore, this review emphasized instruments reported in English. However, this decision may have introduced language bias and led to the omission of relevant findings from non-English-speaking regions. Additionally, a pooled quantitative synthesis was not performed due to substantial heterogeneity in intervention protocols, follow-up durations, and outcome measures, which would have undermined the validity of any combined estimates. This limitation was further compounded by the review team's limited experience with advanced statistical methods required to conduct a robust meta-analysis, raising the risk of analytical error or misrepresentation had it been attempted.

Finally, only 16 studies met our eligibility criteria, which are a relatively small number of trials and generalizability of the findings. Additionally, the sample sizes in the included studies were relatively small, possibly influenced by age and gender distribution among GTPS patients.

4.6 Standardized preparation method

A major limitation identified across all clinical trials included in our systematic review is the lack of standardized preparation and administration protocols for each non-surgical treatment discussed. Important heterogeneity was observed in the parameters used for ESWT, with trials employing either F-ESWT or R-ESWT, which differ in energy density, imaging guidance, frequency, and number of shocks. As previously mentioned in the introduction, F-ESWT is commonly used for deeper target tissues due to its precision, whereas R-ESWT is more superficial and dispersive⁽⁹⁾. The use of different ESWT modalities with varying settings can substantially affect treatment outcomes and make direct comparisons across studies more difficult. It is also noticeable that most clinical trials struggled to justify the chosen treatment parameters.

The same applies to both CSI and PRP injections. There was considerable variation in the types of corticosteroids used (e.g., triamcinolone, methylprednisolone), as well as in doses, volumes, use of local anesthetic, and imaging guidance. Similarly, PRP preparations lacked consistency across trials, with differences in platelet concentrations and injection protocols.

The absence of an evidence-based consensus on standardized protocols for the preparation and administration of conservative interventions highlights the need for future trials. Such studies should aim to assess and compare different settings to establish well-documented, uniform preparation techniques. This could considerably enhance reproducibility, reduce clinical heterogeneity, and improve the accuracy of meta-analyses ultimately facilitating the development of optimized management strategies for GTPS.

Conclusions

This systematic review compared three non-surgical treatments for GTPS: ESWT, PRP injections, and CSI. All improved pain and function to varying degrees. ESWT consistently provided sustained relief, CSI offered short to medium-term benefits, and PRP showed midterm improvements with greater variability. Many studies also reported gains in quality of life and mobility, reinforcing the value of these treatments. However, heterogeneity in treatment protocols in ESWT parameters and PRP or CSI preparation limits reliable comparisons. GTPS also affects psychological well-being and daily life, suggesting future management should combine phys-

ical therapies with psychosocial support. In terms of cost-effectiveness, ESWT has higher up-front costs but may lower overall expenses by reducing repeat treatments. While most studies were of high quality, GRADE rated the overall evidence as moderate due to heterogeneity and some risk of bias. Findings should therefore be interpreted cautiously. Overall, ESWT appears promising, but further high-quality research using standardized methods is needed to confirm its role in clinical practice.

References

1. Speers CJB, Bhogal GS. Greater trochanteric pain syndrome: a review of diagnosis and management in general practice. *Br J Gen Pract*. 2017 Oct;67(663):479–80. doi:10.3399/bjgp17X693041
2. Ho GWK, Howard TM. Greater trochanteric pain syndrome: more than bursitis and iliotibial tract friction. *Curr Sports Med Rep*. 2012;11(5):232–8. doi:10.1249/JSR.0b013e31826c1dc3
3. Ryskalin L, Morucci G, Natale G, Soldani P, Gesi M. Molecular mechanisms underlying the pain-relieving effects of extracorporeal shock wave therapy: a focus on fascia nociceptors. *Life (Basel)*. 2022;12(5):743. doi:10.3390/life12050743
4. Pumarejo Gomez L, Li D, Childress JM. Greater trochanteric pain syndrome (greater trochanteric bursitis). In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; [updated 2024 Jan; cited 2025 Jun 11]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK555896/>
5. Marín-Pena O, Papavasiliou AV, Olivero M, Galanis N, Tey-Pons M, Khanduja V. Non-surgical treatment as the first step to manage peritrochanteric space disorders. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(12):2417–23. doi:10.1007/s00167-020-06366-x
6. Alves R, Grimalt R. A review of platelet-rich plasma: history, biology, mechanism of action, and classification. *Skin Appendage Disord*. 2017;4(1):18–24. doi:10.1159/000477353
7. Cheng JH, Wang CJ. Biological mechanism of shockwave in bone. *Int J Surg*. 2015 Dec;24(Pt B):143–6. doi:10.1016/j.ijsu.2015.10.051
8. van der Worp H, van den Akker-Scheek I, van Schie H, Zwerver J. ESWT for tendinopathy: technology and clinical implications. *Knee Surg Sports Traumatol Arthrosc*. 2013 May;21(6):1451–8. doi:10.1007/s00167-012-2009-5. PMID: 22547246; PMCID: PMC3657080
9. Korakakis V, Whiteley R, Tzavara A, Malliaropoulos N. The effectiveness of extracorporeal shockwave therapy in common lower limb conditions: a systematic review including quantification of patient-rated pain reduction. *Br J Sports Med*. 2018 Jun;52(6):387–407. doi:10.1136/bjsports-2016-097347.
10. Ganderton CL, Semciw AI, Cook J, Pizzari T. Does menopausal hormone therapy (MHT), exercise or a combination of both, improve pain and function in post-menopausal women with greater trochanteric pain syndrome (GTPS)? A randomised controlled trial. *BMC Womens Health*. 2016;16:32. doi: 10.1186/s12905-016-0311-9
11. Heaver C, Pinches M, Kuiper JH, Thomas G, Lewthwaite S, Burston BJ, Banerjee RD. Greater trochanteric pain syndrome: focused shockwave therapy versus an ultrasound guided injection: a randomised control trial. *Hip Int*. 2023;33(3):490-9. doi: 10.1177/11207000211060396
12. Çağlar Yağcı H, Yağcı İ, Bağcıer F. Comparison of shock wave therapy and corticosteroid injection in the treatment of greater trochanteric pain syndrome: a single-blind, randomized study. *Turk J Phys Med Rehabil*. 2023;69(2):180-7. doi: 10.5606/tftrd.2023.12106

- 13.** Ramon S, Russo S, Santoboni F, Lucenteforte G, Di Luise C, de Unzurrunzaga R, Vetrano M, Albano M, Baldini R, Cugat R, Stella G, Balato G, Seijas R, Nusca SM, Servodidio V, Vulpiani MC. Focused shockwave treatment for greater trochanteric pain syndrome: a multicenter, randomized, controlled clinical trial. *J Bone Joint Surg Am.* 2020;102(15):1305-11. doi: [10.2106/JBJS.20.00093](https://doi.org/10.2106/JBJS.20.00093)
- 14.** Carlisi E, Cecini M, Di Natali G, Manzoni F, Tinelli C, Lisi C. Focused extracorporeal shock wave therapy for greater trochanteric pain syndrome with gluteal tendinopathy: a randomized controlled trial. *Clin Rehabil.* 2019;33(4):670-80. doi: [10.1177/0269215518819255](https://doi.org/10.1177/0269215518819255)
- 15.** Notarnicola A, Ladisa I, Lanzilotta P, Bizzoca D, Covelli I, Bianchi FP, Maccagnano G, Farì G, Moretti B. Shock waves and therapeutic exercise in greater trochanteric pain syndrome: a prospective randomized clinical trial with cross-over. *J Pers Med.* 2023;13(6):976. doi: [10.3390/jpm13060976](https://doi.org/10.3390/jpm13060976)
- 16.** Wheeler PC, Dudson C, Calver R, Goodall D, Gregory KM, Singh H, Boyd KT. Three sessions of radial extracorporeal shockwave therapy gives no additional benefit over “minimal-dose” radial extracorporeal shockwave therapy for patients with chronic greater trochanteric pain syndrome: a double-blinded, randomized, controlled trial. *Clin J Sport Med.* 2022;32(1):e7-e18. doi: [10.1097/JSM.0000000000000880](https://doi.org/10.1097/JSM.0000000000000880)
- 17.** Begkas D, Chatzopoulos ST, Touzopoulos P, Balanika A, Pastroudis A. Ultrasound-guided platelet-rich plasma application versus corticosteroid injections for the treatment of greater trochanteric pain syndrome: a prospective controlled randomized comparative clinical study. *Cureus.* 2020 Jan 7;12(1):e6583. doi: [10.7759/cureus.6583.17](https://doi.org/10.7759/cureus.6583.17)
- 18.** Fitzpatrick J, Bulsara MK, O'Donnell J, McCrory PR, Zheng MH. The effectiveness of platelet-rich plasma injections in gluteal tendinopathy: a randomized, double-blind controlled trial comparing a single platelet-rich plasma injection with a single corticosteroid injection. *Am J Sports Med.* 2018 Mar;46(4):933–9. doi: [10.1177/0363546517745525](https://doi.org/10.1177/0363546517745525).
- 19.** Fitzpatrick J, Bulsara MK, O'Donnell J, Zheng MH. Leucocyte-rich platelet-rich plasma treatment of gluteus medius and minimus tendinopathy: a double-blind randomized controlled trial with 2-year follow-up. *Am J Sports Med.* 2019 Apr;47(5):1130–7. doi: [10.1177/0363546519826969](https://doi.org/10.1177/0363546519826969)
- 20.** Thompson G, Pearson JF. No attributable effects of PRP on greater trochanteric pain syndrome. *J R Soc Med.* 2019 Dec 13;132(1507):22–32. doi: [10.1177/0141076819877537](https://doi.org/10.1177/0141076819877537)
- 21.** Atilano L, Martin N, Martin JI, Iglesias G, Mendiola J, Bully P, Aiyegbusi A, Rodriguez-Palomo JM, Andia I. Ultrasound-guided subfascial platelet-rich plasma injections versus enthesi needling for greater trochanteric pain syndrome: a randomized controlled trial. *Orthop J Sports Med.* 2024 May 14;12(5):23259671241249123. doi: [10.1177/23259671241249123](https://doi.org/10.1177/23259671241249123)
- 22.** Atchia I, Ali M, Oderuth E, Holleyman R, Malviya A. Efficacy of platelet-rich plasma versus placebo for the treatment of greater trochanteric pain syndrome: a double-blinded randomized controlled trial. *J Bone Joint Surg Am.* 2025 Mar 5;107(5):444–51. doi: [10.2106/JBJS.24.00763](https://doi.org/10.2106/JBJS.24.00763)
- 23.** Brinks A, van Rijn RM, Willemsen SP, Bohnen AM, Verhaar JAN, Koes BW, Bierma-Zeinstra SMA. Corticosteroid injections for greater trochanteric pain syndrome: a randomized controlled trial in primary care. *Ann Fam Med.* 2011 May-Jun;9(3):226–34. doi: [10.1370/afm.1232](https://doi.org/10.1370/afm.1232)
- 24.** Mellor R, Grimaldi A, Wajswelner H, Hodges P, Abbott JH, Bennell K, Vicenzino B. Exercise and load modification versus corticosteroid injection versus 'wait and see' for persistent gluteus medius/minimus tendinopathy (the LEAP trial): a protocol for a randomised clinical trial. *BMC Musculoskelet Disord.* 2016 Apr 30;17:196. doi: [10.1186/s12891-016-1043-6](https://doi.org/10.1186/s12891-016-1043-6)

- 25.** Brennan KL, Allen BC, Munoz Maldonado Y. Dry needling versus cortisone injection in the treatment of greater trochanteric pain syndrome: a noninferiority randomized clinical trial. *J Orthop Sports Phys Ther.* 2017 Apr;47(4):232–9. doi:10.2519/jospt.2017.6994
- 26.** Nissen MJ, Brulhart L, Faundez A, Finckh A, Courvoisier DS, Genevay S. Glucocorticoid injections for greater trochanteric pain syndrome: a randomised double-blind placebo-controlled (GLUTEAL) trial. *Clin Rheumatol.* 2019 Mar;38(3):647–55. doi:10.1007/s10067-018-4309-6
- 27.** Plinsinga ML, Coombes BK, Mellor R, et al. Individuals with persistent greater trochanteric pain syndrome exhibit impaired pain modulation and widespread hyperalgesia. *Pain Med.* 2020;21(10):2284–96 doi: 10.1093/pm/pnaa047
- 28.** Hampton M, Alvie K, Harrison N, et al. Pain catastrophizing, anxiety, and depression in hip pathology. *Bone Joint J.* 2019;101-B(7):800–7. doi: 10.1302/0301-620X.101B7.BJJ-2018-1309.R1
- 29.** Andreasen J, Juul-Kristensen B, Rathleff MS, et al. “I feel I have been taken seriously”—A qualitative study of women’s experiences of treatment for greater trochanteric pain syndrome. *PLoS One.* 2022;17(10):e0274984. doi: 10.1371/journal.pone.0278197
- 30.** Gaujoux-Viala C, Dougados M, Gossec L. Efficacy and safety of steroid injections for shoulder and elbow tendonitis: a meta-analysis of randomised controlled trials. *Ann Rheum Dis.* 2009 Dec;68(12):1843–9. doi: 10.1136/ard.2008.099572

Editorial information

✉ Correspondence

mohammedashk99@gmail.com

Dates

Received: 15.07.2025

Accepted: 07.09.2025

Published: 09.10.2025

Funding

This research received no external funding.

Registration

Registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the reference number CRD420251006652.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

Suggested citation

Ashkanani M, Ashkanani A, Husain M, Garashi M, Al Boloushi Z. Comparative Effectiveness of Extracorporeal Shockwave Therapy, Platelet-Rich Plasma, and Corticosteroid Injections in Greater Trochanteric Pain Syndrome: A Systematic Review of Randomized Controlled Trials. *Invasive Physiother Musculoskelet Med.* 2025;1:e15. doi: 10.63360/ipmm.v1.e15

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