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SYSTEMATIC REVIEW

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Platelet-rich plasma and corticosteroid injection for tendinopathy: a systematic review and meta-analysis

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Abstract

Objective In this systematic review and meta-analysis, we evaluated and compared the efficacy and safety of platelet-rich plasma injection into corticosteroid injection in the treatment of tendinopathy.

Methods We searched PUBMED, EMBASE, Cochrane Library, SCOPUS, and Web of Science to identify randomized controlled trials on the PRP injection versus CS injection in treatment of tendinopathy.The meta-analysis was performed using the Revman 5.4 software.

Result We found 27 RCT studies with a total of 1779 patients enrolled. 8 rotator cuff injuries, 7 humeral external epicondylitis, 10 plantar fasciitis, and 2 tenosynovitis. The results of the meta-analysis showed that there were no significant group differences in the results of patients with rotator cuff injury comparing the pain visual analog scale score and functional measures at 1 month after receiving injection treatment. After three months of receiving PRP treatment, the VAS scores showed greater improvement compared to the CS group(OR = -1.64,95%CI [-2.97,-0.31],$P = 0.02$), while there was no statistically significant difference in shoulder joint function between the two groups at the 3–6 month post-treatment mark. Patients with plantar fasciitis showed no significant differences in VAS and AOFAS scores after receiving PRP or CS injections at 1 and 3 months. However, at the 6-month mark, the PRP group demonstrated significantly better VAS and AOFAS scores compared to the CS group(OR = -1.41,95%CI [-1.88,-0.44],$P < 0.00001$; OR = 7.19,95%CI [2.41,11.91],$P = 0.003$). 1 month after CS injection in patients with tenosynovitis, the VAS score was lower than that of the PRP group; patients with elbow epicondylitis had better improved upper limb function rating scale scores 1 month after CS injection compared to the PRP group. In patients with tenosynovitis, the VAS scores were superior to the CS group six months after PRP treatment(OR = -0.72,95%CI [-1.04,-0.40],$P < 0.00001$); similarly, patients with lateral epicondylitis exhibited better VAS, DASH scores than the CS group three and twelve months post-PRP treatment(OR = -9.76,95%CI [-10.89,-8.63],$P = 0.0002$; OR = -0.97,95%CI [-1.87,-0.06],$P < 0.0001$; OR = -18.03,95%CI [-31.61,-4.46],$P = 0.009$).

Conclusion PRP can effectively improve pain and functional impairment in patients with tendinopathy, and its mid-term efficacy is superior to that of corticosteroids. However, the long-term efficacy remains to be further clinically verified.

Keywords Platelet-rich plasma, Corticosteroid, Tendinopathies, Systematic review, Meta-analysis

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Introduction

Tendinopathy, a clinical syndrome, is characterized by persistent localized tendon pain and functional impairment. It is predominantly induced by repetitive mechanical loading, a phenomenon commonly termed "overuse." In contrast to tendon ruptures, tendinopathy is marked by abnormal tendon tissue with an intact tendon structure. Clinically, it is primarily manifested as pain, limitation of activity, and functional deficits [1, 2]. Tendinopathy, the most prevalent musculoskeletal disorder, has an etiology that remains elusive and is often precipitated by the complex interaction of various factors [3, 4]. Tendinopathy is categorized into two subtypes: tendonitis, which is characterized by inflammation, and tendon degeneration, which is distinguished by degenerative alterations in the tendon's structure [5–7].

Research indicates that there are various treatment methods for tendinopathy, encompassing physical therapy, non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections(CS), and platelet-rich plasma (PRP) therapy. At present, corticosteroid injections are the predominant treatment for chronic tendinopathy, demonstrating efficacy in providing short-term alleviation. Studies indicate that corticosteroid injections are particularly effective in managing acute or subacute tendinitis, with the most favorable injection timing likely being within the initial weeks [8]. The combined application of hormones and local anesthetics exerts an anti-inflammatory effect, which can provide favorable short-term outcomes within a brief period. However, it fails to address the underlying tendon pathology or promote tendon healing and may even exacerbate tendinopathy. PRP, a biologic product derived from autologous peripheral blood, has the capacity to facilitate the healing of tendons, ligaments, and bones [9]. It has emerged as a novel therapeutic option in the management of tendinopathy, being utilized as either a standalone or adjunct treatment in both conservative and surgical approaches [10]. In recent years, PRP has become one of the most frequently employed injectable biologics in the field of sports medicine. PRP, which is replete with a high concentration of platelets and a plethora of growth factors such as Platelet-Derived Growth Factor (PDGF), Vascular Endothelial Growth Factor (VEGF), and Fibroblast Growth Factor (FGF), creates a microenvironment that is highly conducive to cell growth and proliferation [11]. Existing research findings have demonstrated that cytokines can ameliorate tendon healing by modulating inflammation, promoting angiogenesis, facilitating cell migration and proliferation, as well as stimulating the synthesis of the extracellular matrix [11]. PRP being an autologous blood product, does not trigger immune rejection reactions. The small number of white blood cells it contains can be distributed on the synovial surface, thereby alleviating inflammatory responses and exhibiting a certain degree of anti-infective effect [12]. Over the past few years, PRP injection therapy has accelerated the healing of injured tendons, ligaments, muscles, and joints. However, the evidence of its therapeutic efficacy varies considerably across specific indications.

Recently, numerous randomized controlled trials (RCTs) have evaluated the application of PRP in orthopedics, particularly concerning tendon and ligament injuries. Several clinical trials have been conducted to explore the relationship between CS and PRP in the treatment of tendinopathy; however, there is still no consensus on which method should be the preferred treatment for tendinopathy. The effectiveness of tendinopathy treatments continues to be a contentious issue in the medical community [13–16]. This study presents a meta-analysis to compare the clinical efficacy of PRP and CS injections, thereby offering evidence-based guidance for the selection of tendinopathy treatment modalities.

Materials and methods

This systematic review was conducted according to recommended PRISMA checklist guidelines [17]. The protocol is registered on PROSPERO (registration number CRD42024600129). The objective of this protocol is to assess the utility of PRP injections within non-surgical orthopedic interventions.

Inclusion and exclusion criteria

Inclusion criteria

(1) Type of study: Published RCT study. (2) Research subjects: Individuals with a clear diagnosis of tendinopathy, regardless of age, gender or nationality. (3) Intervention: Administration of intra-articular injection of PRP to the test group and intra-articular injection of corticosteroid to the control group. (4) At least one of the following outcome indicators: VAS, DASH, AOFAS, WORC. (5) No application of language exclusions.

Exclusion criteria

(1) Duplicate publications or studies with similar data. (2) Reviews, meeting, abstracts, meta, case reports. (3) The experimental group received other therapeutic interventions. (4) Incomplete, unclear, or obviously erroneous data that could not be resolved by contacting the authors.

Search strategy

We conducted a comprehensive literature search across PUBMED, EMBASE, Cochrane, SCOPUS, and Web of Science databases up to September 30, 2024, employing a search strategy that incorporated Medical Subject Headings (MeSH) terms and keywords. To enhance the

search's specificity and sensitivity, we utilized the following MeSH terms and keyword combinations: "Corticosteroid", "Steroid", "Steroids", "Hormones", "Hormone", "Hormone Receptor Agonists", "Hormone Receptor", "Agonists", "Receptor Agonists", "Platelet Rich Plasma", "Plasma", "Platelet-Rich", "platelet-rich plasma", "Tendinopathy", "Tendinopathies", "Tendonopath", "Tendonopathies", "Tendinitis", "Tendinitides", "Tendinosis", "Tendinosis", "Tendinoses", "Tendonosis", "Tendonoses", "Achilles tendinopathy", "plantar fasciitis", "lateral epicondylitis", "tennis elbow", "patellar tendinopathy", "carpal tunnel syndrome", "rotator cuff tendinopathy". Using the same selection criteria mentioned above, we manually searched the reference lists of review articles and included studies to identify other potentially eligible studies. Articles published in peer-reviewed journals before September 2024 were searched. Due to limited data sources, only papers published in English were considered. The same search was performed on other databases. Detailed search materials will be provided in the supplementary materials.

Data extraction

For each RCT included in the systematic review, two reviewers (YY and QL) extracted the following data independently: first author, year of publication, study design, participant characteristics (sample size, age, gender), outcome measures, follow-up duration, and primary results. In the context of this review, the assessment of PRP or CS in orthopedic surgery or postoperative settings was excluded, and we focused on four disease groups: 1. Rotator cuff injuries; 2. Lateral epicondylitis; 3. Plantar fasciitis; 4. Tenosynovitis. Any discrepancies in the cross-checking procedure were resolved through a consensus discussion or, otherwise, arbitrated by a third researcher (KGY).

Risk of bias assessment

Using the Cochrane collaboration tool (Cochrane Handbook for Systematic Review of Interventions) to assess the methodological quality of each included study [18]. The tool assesses studies across several criteria: A) sequence generation, B) allocation concealment, C) participant blinding, D) completeness of outcome data (including attrition), E) selective reporting, and F) other potential biases. For each criterion, the procedures conducted in each study were described based on the information collected, and were rated as "high", "low" or "unclear" risk of bias. Two reviewers independently evaluated the included studies against these criteria and resolved any discrepancies through discussion until consensus was achieved.

Statistical analysis

The selected observational outcomes from the literature were assessed using Review Manager 5.4 software. For continuous variables, this review employed the Mean Difference (MD), and for binary outcomes—including adverse events and patient satisfaction—a 95% confidence interval was applied alongside the MD. When the units of the original outcome measures were not consistent, the Standardized Mean Difference (SMD) was used in place of the MD. For continuous outcomes, the scores were reported as means and standard deviations (SD), with a p-value less than 0.05 indicating statistical significance. The heterogeneity assessment utilized the I2 statistic, with an I2 value above 50% suggesting high heterogeneity,warranting the use of a random effects model. Conversely, when the I^2 statistic is less than 50%, it suggests low heterogeneity, and a fixed effects model should be employed.

Outcomes

The evaluation of the study outcomes primarily focuses on pain, functional assessments, efficacy rates, and adverse events. Pain levels were evaluated using a VAS, ranging from 0 (no pain) to 10 (most severe pain). The functional assessment tools include: 1. The DASH questionnaire, used for evaluating functional limitations in conditions like rotator cuff injuries and lateral epicondylitis, with higher scores indicating greater functional impairment; 2. The AOFAS, used to assess the severity of plantar fasciitis, where higher scores suggest less severe symptoms; 3. The WORC, scored from 0 (worst quality of life) to 100 (best quality of life). Lastly, the efficacy of the two treatment modalities and the incidence of serious adverse events (e.g., injection site infections and inflammatory reactions) were also assessed. The short-term therapeutic effect assessment time is within 3 months after treatment, the medium-term therapeutic effect is from 3 to 6 months after treatment, and the long-term therapeutic effect is more than 6 months after treatment.

Results

After cross-referencing five databases, a total of 1159 articles were obtained; among these, 316 articles were excluded due to duplication. After reviewing the titles and abstracts, 761 articles were deemed not to meet the inclusion criteria and were excluded. A full-text review was conducted on the remaining 82 articles, resulting in the exclusion of 55 articles that did not meet the selection standards. The reasons for exclusion included non-RCT studies ($n=23$), meta-analyses and review articles ($n=13$), studies using surgery as a control

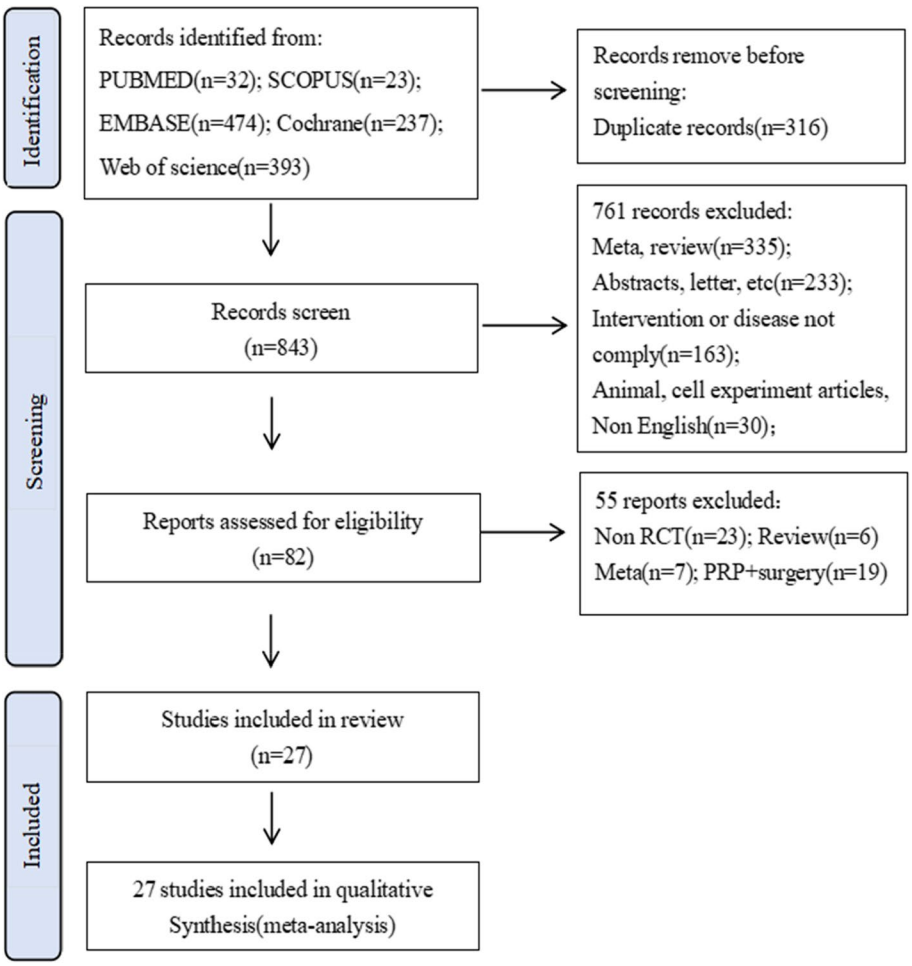


Fig. 1 Flow chart

group ($n=19$). Ultimately, 27 articles were included in this study, as illustrated in Fig. 1.

Characteristics of selected studies

In this systematic review, a total of 27 studies were included [1, 2, 8, 13–16, 19–38], with 8 studies concentrating on rotator cuff injuries, 7 on lateral epicondylitis, 10 on plantar fasciitis, 2 on tenosynovitis. The experimental and control groups collectively included 992 patients across all studies, which featured small sample sizes ranging from 15 to 60 cases. The commonly reported outcomes encompassed pain and functional assessments. For assessing pain, the VAS was the predominant method. The functional measurements reported included both specific assessments for tendon pathologies and general scales (DASH for lateral epicondylitis and Tenosynovitis; ROM, WORC, ASES for shoulder cuff injuries; FFI, AOFAS for Plantar fasciitis). Of the 30 trials, 11 documented cure rates, and 4 trial reported on the incidence of adverse events. Characteristics of studies are shown in Table 1.

Risk of bias

In the assessment of bias risk across 27 studies, 6 demonstrated a high risk of bias in at least one domain, whereas 26 studies indicated an unclear risk of bias in at least one area. Predominantly, studies were rated with an "unclear risk of bias" attributable to the inadequate reporting of allocation concealment. The majority of studies omitted details on blinding, resulting in the classification of blinding as "unclear risk of bias" for most. Two studies failed to report data for each primary outcome, potentially due to loss to follow-up or patient withdrawal, and were consequently rated as having a "high risk of bias" The remaining studies provided data for the primary outcomes, leading to a "low risk of bias" classification for attrition. In these 27 RCTs, no additional risks were identified, and thus, all were rated as having a low risk of bias. The bias risk assessment is depicted in Figs. 2 and 3.

Table 1 Characteristics and main results of the included studies on the use of PRP, CS for tendinopathies

Study (year) ref	Age(year)		Gender(M/F)		Sample size		Study design	Disease	Outcomes	Follow(month)	Main results
	EG	CG	EG	CG	EG	CG					
Shams (2016) [8]	52 ± 12	50 ± 10	10/10	11/9	20	20	RCT	rotator cuff tears	VAS, ASES, CMS	1.5, 3, 6 month	without statistically significant differences between the two groups
Dadgostar (2016) [13]	57.3 ± 9.8	53. ± 7.24	5/25	6/22	30	28	RCT	rotator cuff tears	VAS, DASH, WORC, ROM	3 month	PRP and steroid injections are both effective
Ibrahim (2018) [16]	46.8 ± 10.6	41. ± 12.5	6/9	7/8	15	15	RCT	rotator cuff tendinopathy	VAS, SDQ, ROM	2 month	Both PRP and corticosteroidinjections were effective in the treatment of RCT
Thepsoparn (2021) [21]	51.3 ± 10.3	62.4 ± 10.5	3/12	3/13	15	16	RCT	Supraspinatus Tears	VAS, OSS	1, 6 month	PRP showed superior benefits over the corticosteroid at 6-month follow-up
Saleem (2022) [26]	55.2 ± 5.2	55.9 ± 4.3	24/6	22/8	30	30	RCT	Rotator Cuff Tendinopathy	VAS, ROM	1, 3 month	improvement in pain intensity and range of movements after PRP administration
Hewavithana (2023) [28]	58.27 ± 9.44	55.73 ± 10.57	10/20	7/23	30	30	RCT	shoulder-impingementsyndrome	VAS, DASH	3, 6, 12, month	PRP was effective in long-term improvement in shoulder abduction
Kumar (2022) [31]	> 18		NR	NR	20	20	RCT	Rotator Cuff Tendinopathy	VAS, OSS	1, 3 month	Long-term effect was more in case of PRP group as compared to steroid
Kwong (2021) [32]	49.94 ± 9.70	49.08 ± 9.54	16/31	19/33	47	52	RCT	Rotator Cuff Tears	VAS, ASES, WORC	1, 3, 12 month	No sustained benefit of PRP over steroid at 12 months
Gosens (2011) [1]	46.8 ± 8.5	47.3 ± 7.8	23/28	23/26	51	49	RCT	Lateral epicondylitis	VAS, DASH	1, 2, 3, 6, 12, 24 month	PRP reduces pain and Increases function significantly
Varshney (2016) [14]	20–60		NR	NR	33	50	RCT	Elbow Epicondylitis	VAS, MAYO	1, 2, 6 month	Treatment of patients with epicondylitiswith PRP exceeding the effect of corticosteroid
Wahhab (2018) [20]	39.4 ± 11.4	41.9 ± 11.8	17/23	19/21	40	40	RCT	Lateral epicondylitis	VAS, Grip, tedema	1, 3 month	PRP is suggested to be an effective treatment for lateral epicondylitis than corticosteroids
Arik (2014) [29]	43.7 ± 7.8	46.7 ± 8.4	11/29	10/30	40	40	RCT	lateral epicondylitis	VAS, PRTEE, Grip	0.5, 1, 3 month	PRP was more effective than corticosteroid in pain,function, and grip strength
Peerbooms (2010) [33]	47.3 ± 7.6	46.9 ± 8.4	25/26	23/26	51	49	RCT	Lateral epicondylitis	VAS, DASH	1, 2, 3, 6, 12 month	Treatment of chronic lateral epicondylitis with PRP exceeding the effect of corticosteroid
Gupta (2019) [35]	15–55		21/22	25/12	43	37	RCT	Lateral epicondylitis	VAS, DASH, MEPS, GSS	1.5, 3, 12 month	patients receiving PRP injections fare better at 3 and 12 months
Yadav (2015) [37]	20–60		10/20	7/23	30	30	RCT	Lateral epicondylitis	VAS, DASH, MGS	0.5, 1, 3 month	PRP is a superior treatment option for longer duration efficacy
Study (year) ref	Age(year)		Gender(M/F)		Sample size		Study design	Disease	Outcomes	Follow(month)	Main results
	EG	CG	EG	CG	EG	CG					

Table 1 (continued)

Monto (2014) [2]	21–74		8/12	9/11	20	20	RCT	plantar fasciitis	AOFAS	3, 6, 12, 24 month	PRP was more effective and durable than cortisone injection for the plantar fasciitis
Jain (2018) [15]	37.7 ± 10.3	38.9 ± 9.5	20/20	26/14	40	40	RCT	plantar fasciitis	AOFAS, VAS, FAI	1, 3, 6 month	treatment of plantar fasciitis with steroid or PRP injection was equally effective
Sawan (2023) [18]	46.67 ± 6.33	44.4 ± 7.36	9/21	4/26	30	30	RCT	plantar fasciitis	AOFAS, VAS, RM	1, 1.5, 3, 6 month	PRP injection is safer with better analgesia and functional outcome than steroid for plantar fasciitis
Vahdatpour (2015) [19]	45.44 ± 7.74	47.12 ± 10.7	4/12	5/11	16	16	RCT	plantar fasciitis	VAS, RM	1, 3, 6 month	The healing effect of PRP may be begun at least 3 months after injection
Khurana (2020) [23]	32.57 ± 4.98	34.7 ± 5.46	34/24	31/29	58	60	RCT	plantar fasciitis	AOFAS, VAS, RM	0.5, 1, 3, 6 month	PRP provides better painrelief and function as compared to steroid injection
Kumar (2024) [24]	20–60		NR	NR	30	30	RCT	plantar fasciitis	AOFAS, VAS	0.5, 1, 3, 6 month	PRP are superior to corticosteroid in terms of long-term pain functional
Sharma (2023) [27]	42.9 ± 10.3	44.7 ± 11.6	6/39	8/37	45	45	RCT	plantar fasciitis	AOFAS, VAS	3, 6 month	The PRP injection showed a better outcome than the steroid injection
Olivo (2017) [30]	24–61		NR	NR	14	14	RCT	plantar fasciitis	AOFAS, VAS, FADI	0.5, 1, 2, 3, 6 month	PRP demonstrates an efficacy equal to that of steroids
Peerbooms (2019) [34]	50.73 ± 11.33	47.5 ± 11.19	15/48	18/34	63	52	RCT	plantar fasciitis	FFI, AOFAS	1, 3, 6, 12 month	improvement in pain intensity and range of movements after PRP administration
Tabrizi (2019) [36]	33.6 ± 8.5	31.7 ± 7.5	1/14	1/15	15	16	RCT	plantar fasciitis	FFI, VAS	6 month	injection with corticosteroid was more effective than PRP at reducing pain and improving function
Kumar (2023) [22]	35.83 ± 8.48	37.8 ± 6.44	8/22	10/20	30	30	RCT	tenosynovitis	VAS, DASH, MMWS	1, 3, 6, 12 month	PRP is equally effectiveas corticosteroid
Shoma (2023) [25]	45.6 ± 10.4	46.9 ± 11.3	12/21	9/22	33	31	RCT	tenosynovitis	VAS, MAYO	1, 3, 6 month	PRP provides better functional than corticosteroid in tenosynovitis

AOFAS American Orthopaedic Foot and Ankle Society, *ASES* American Shoulder and Elbow Surgeons, *CMAP* compound muscle action potential, *CMS* Constant-Murley Shoulder joint score scale, *CSA* cross-sectional area, *DASH* disabilities of the Arm, Shoulder and Hand questionnaire, *DML* distal motor latency, *FADI*Foot and ankle disability index, *FAI* Foot and Ankle Outcome Instrument, *FFI* foot function index, *GSS* Southampton protocol for grip strength measurement, *MAYO* Elbow joint function score, *MEPS* Elbow joint clinical scoring system, *MGS* grip strength, *MHHS* Modified Harris Hip Score, *MMWS* Mayo Wrist Score, *NR* no report, *OSS* Oxford Shoulder Score, *PRTEE* Patient-Rated Tennis Elbow Evaluation, *RCT* randomized controlled trial, *RM* Roles-Maudsley Score, *ROM* range of motion, *SCV* sensory nerves conduction velocity, *SDQ* Strengths and Difficulties Questionnaire, *SNAP* sensory nerve action potential, *VAS* visual analog scale, *WORC* Western Ontario Rotator Cuff

Shoulder cuff injuries

Eight studies evaluated the reduction in pain associated with shoulder cuff injuries using changes in VAS scores, comparing the efficacy of (PRP and CS treatments. Furthermore, shoulder joint functionality was assessed using questionnaires (DASH, WORC, ASES, OSS). At one month post-treatment, no statistically significant differences were observed in VAS scores between the two groups (5 studies, PRP group: 142 participants; CS group: 146 participants). Nonetheless, at three months post-treatment, the PRP group demonstrated superior improvement in shoulder joint VAS scores compared to the CS group (6 studies, PRP group: 157 participants; CS group: 161 participants; OR = -1.64,95%CI [-2.97,-0.31],$P = 0.02$; Fig. 4). However, when assessing improvements in shoulder joint function at 1, 3, and 6 months post-treatment with either PRP or CS, no significant differences were noted between the groups (Fig. 4).

Lateral epicondylitis

In assessing the efficacy and safety of PRP versus CS treatments for lateral epicondylitis using VAS and DASH scores, seven studies reveal no significant difference in VAS scores one month post-treatment. Nonetheless, at three months post-treatment, patients in the PRP group exhibited greater improvements in VAS scores than those in the CS group (seven trials, PRP group: 228 patients; CS group: 290 patients; OR = -0.97,95%CI [-1.87,-0.06],$P = 0.04$; Fig. 5). Data from three clinical trials indicate that the PRP group's VAS score improvements were sustained and superior to the CS group at six months post-treatment (PRP group: 135 patients; CS group: 148 patients; OR = -2.70,95%CI [-4.13,-1.28],$P = 0.0002$; Fig. 5). At twelve months, no significant differences in VAS score improvements were observed between the two groups (three trials, PRP group: 145 patients; CS group: 145 patients). Analysis of the DASH scale scores at one month post-treatment shows that the CS group had lower scores, signifying better elbow functionality (four trials, PRP group: 175 patients; CS group: 170 patients). However, at three and twelve months post-treatment (three trials, PRP group: 145 patients; CS group: 145 patients; OR = -0.97,95% CI [-1.87,-0.06],$P < 0.00001$; OR = -18.03,95% CI [-31.61,-4.46],$P = 0.009$; Fig. 5), the DASH scores for the PRP group were consistently lower than the CS group, suggesting that initial improvements in elbow function were attributed to the CS treatment. This suggests that while the short-term efficacy of PRP for lateral epicondylitis is comparable to CS, but its medium efficacy is superior (Fig. 5).

Plantar fasciitis

Seven studies reported VAS scores for pain and functional scores using the AOFAS and FFI. At 1 and 3 months post-treatment, no significant differences in pain improvement were observed between the PRP and CS groups. Nonetheless, at 6 months post-treatment, the PRP group exhibited superior pain improvement compared to the CS group(OR = -1.41,95%CI [-1.88,-0.44],$P < 0.00001$; Fig. 6). Analysis of AOFAS scores revealed no significant differences in functional outcomes between the two groups at 1 and 3 months post-treatment. In contrast, the AOFAS scores of the PRP group were significantly higher at 6 months post-treatment, indicating better functional outcomes(OR = 7.19,95% CI [2.41,11.91],$P = 0.003$; Fig. 6). These findings suggest that PRP treatment for plantar fasciitis has comparable short-term efficacy to CS, yet shows superior mid-term efficacy. Long-term efficacy comparisons necessitate additional clinical trials for validation (Fig. 6).

Tenosynovitis

Two studies, comprising 63 participants in the PRP group and 61 in the CS group, assessed the effects of PRP and CS treatments on VAS scores for tenosynovitis, along with finger joint function scores using the DASH and MAYO scales. The findings indicated that at one month post-treatment, the VAS scores were lower in the CS group(OR = 0.31,95% CI [0.02,0.59],$P = 0.04$; Fig. 7). Nonetheless, at three months post-treatment, no statistically significant differences were observed between the two groups(OR = -1.23,95% CI [-1.23,0.57],$P = 0.06$; Fig. 7). By six months post-treatment, patients in the PRP group exhibited greater pain improvement(OR = -0.72,95% CI [-1.04,-0.40],$P < 0.00001$; Fig. 7). The structural scoring results revealed no statistically significant differences between the treatment groups at one, three, and six months post-treatment, suggesting that PRP may provide superior mid- to long-term pain relief compared to CS for tenosynovitis (Fig. 7).

Efficiency and adverse events

No participants reported any serious adverse events (eg.,infections, inflammatory responses, severe pain, etc.) in the follow-up period in either the PRP or CS group. However, most trials did not describe the monitoring process for identifying or recording complications, and typically limited their reports to a single statement indicating the absence of complications. Other less severe short-term adverse events, primarily mild pain

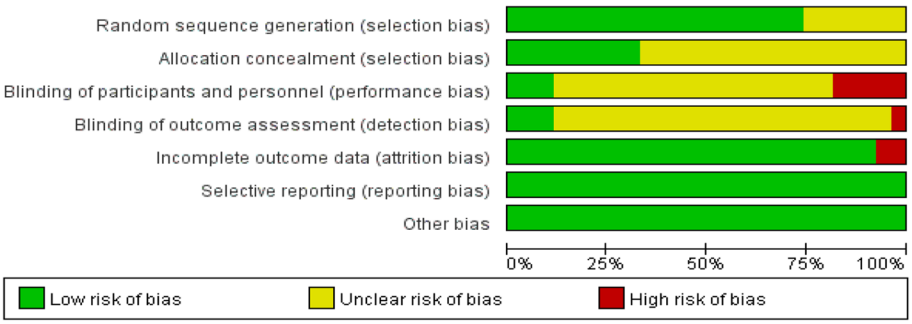


Fig. 2 Risk of bias graph

at the injection site and skin rashes, were recorded and reported in four trials (PRP group: 108 participants, CS group: 107 participants) (OR = 0.35,95%CI [0.17, 0.72], $P = 0.004$;Fig. 9). Additionally, we assessed the treatment efficacy recorded in ten articles (PRP group: 413 patients, CS group: 403 patients) and found that the treatment efficacy in the PRP group was higher compared to the CS group (OR = 3.09, 95% CI [2.18, 4.39], $p < 0.00001$; Fig. 9). These two results suggest that the efficacy of PRP treatment for tendinopathy may be superior to that of CS, along with a higher safety profile(Fig. 8).

Sensitivity analysis

In this review, we performed sensitivity analyses of the primary.

outcomes by removing Low-quality literature study. The results showed thatthe pooled analysis results were stable for the primary outcomes(Fig. 9).

Publication bias

Funnel plots tests were performed only for outcome measures in more than ten studies. The funnel plot for the efficiency was symmetric, as shown in Fig. 10, indicates no significant publication bias.

Discussion

Tendon injuries are generally caused by overuse, leading to a series of pathological manifestations such as lipid deposition, proteoglycan accumulation, a reduction in type I collagen, and severe inflammatory responses [39]. Numerous studies have indicated that hormone injection can rapidly and effectively alleviate pain and improve function; however, the long-term outcomes are poor, and recurrence is common. Prolonged use of hormones can exacerbate local tendon tissue degeneration and necrosis, resulting in muscle atrophy [40]. In recent years, an increasing number of studies and meta-analyses have confirmed that PRP injection therapy can effectively relieve pain in patients with tendinopathy or improve joint function [41]. The advantage of PRP lies in its high concentration of growth factors, which can stimulate angiogenesis and promote tendon cell proliferation, offering significant long-term efficacy. However, there are still certain drawbacks, including a lack of standardized preparation protocols and optimal dosing, as well as relatively high treatment costs [42].

PRP is currently widely used in clinical practice for the treatment of musculoskeletal diseases. Over the past few years, PRP injections have accelerated the recovery of injured ligaments, tendons, muscles, and joints, although the evidence of its therapeutic efficacy is highly variable [16]. For this reason, we compared it with the traditional treatment for tendinopathy, steroid injections, to assess its effectiveness and safety. However, the optimal treatment for tendinopathy remains uncertain.

In this meta-analysis, we included 27 studies that evaluated patients with rotator cuff injuries, lateral epicondylitis, plantar fasciitis, and tenosynovitis. The efficacy of PRP compared to CS varied across different conditions. Notably, in the short term, both treatments showed no significant differences in pain relief or functional improvement, with CS injections demonstrating a more pronounced effect on pain reduction. However, in the medium term, PRP exhibited superior efficacy in alleviating pain.Interestingly, our analysis of data regarding rotator cuff injuries, and tendinitis, revealed that although PRP showed a significant advantage over the control group in mid-term pain outcomes, this benefit did not extend to functional score. The meta-analysis results demonstrate that at three months post-treatment for patients with rotator cuff injuries, and at six months for those with tenosynovitis, the VAS scores in the PRP group exhibited significant improvements over the control group. However, across all time points assessed, no significant differences were observed in the DASH, WORC, and MAYO scores between the PRP and CS groups. This could be attributed to the subjective nature of many questions within the questionnaires. For

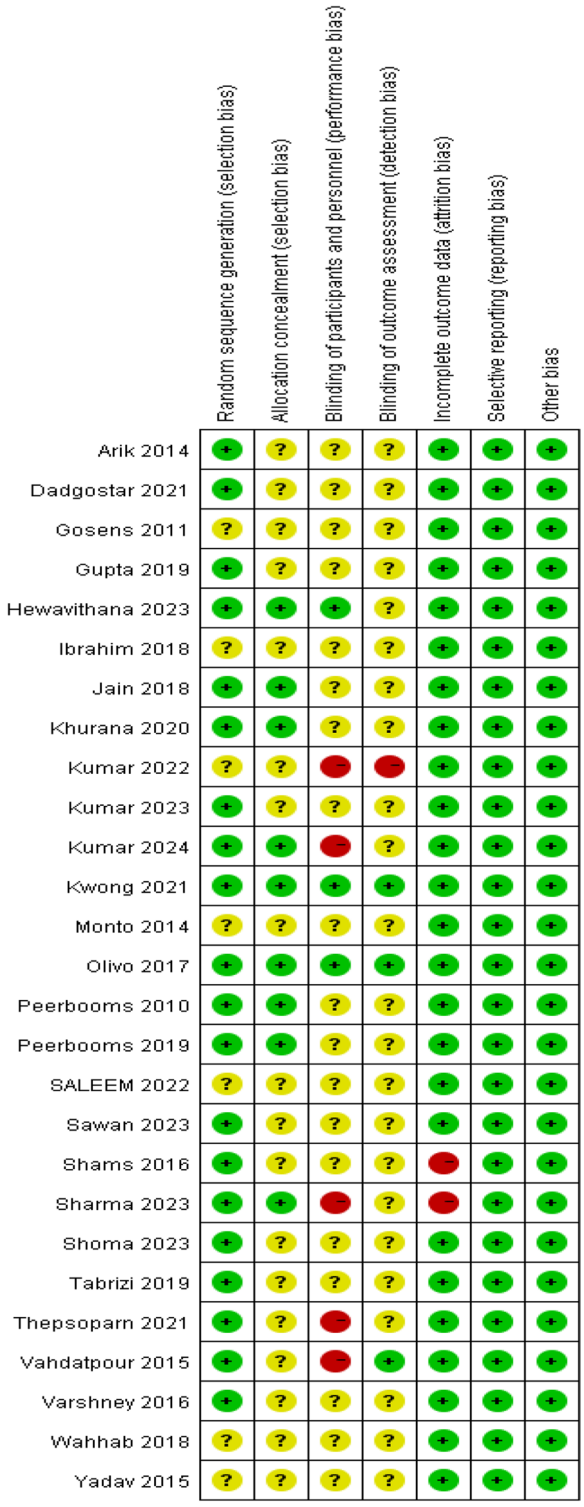


Fig. 3 Risk of bias summary

instance, the DASH questionnaire comprises five items on shoulder symptoms and twenty-five on functional tasks [43, 44]. It evaluates a range of shoulder function domains, including work-related activities, recreational activities, and emotional responses to symptoms. The discrepancies observed in this meta-analysis may relate to the diversity of shoulder function components assessed by each questionnaire, varying between unidimensional and multidimensional constructs. Moreover, questionnaires differ in its reliability and validity that ranges from good to excellent.Meanwhile, in early-stage rotator cuff injury, patients often cannot move their shoulder joints due to pain. This can lead to extensive adhesions in the soft tissues around the joint, muscle spasms, and contractures of ligaments and the joint capsule, thereby impairing joint function. Both PRP and CS joint perfusion therapies can effectively alleviate pain in the short term. However, improving shoulder joint function requires not only repairing damaged tendons and soft tissues in the rotator cuff but also functional exercise. Functional exercise can relieve adhesions in the ligaments and tendons around the joint, thus improving joint dysfunction. Consequently, the recovery of shoulder function often lags behind the improvement of pain symptoms. This study needs a longer follow-up period to explore the relationship between rotator cuff function recovery and pain improvement after PRP joint injection. This will provide more evidence for tendon injury treatment. The analysis of results for lateral epicondylitis and plantar fasciitis reveals a significant correlation between pain improvement and enhancement of functional scores. The meta-analysis results indicate that patients with lateral epicondylitis experienced greater improvements in pain and DASH scores after three months of PRP treatment compared to the control group. Similarly, patients with plantar fasciitis demonstrated superior pain relief and AOFAS score improvements six months post-PRP treatment, suggesting a significant correlation.

Lateral epicondylitis and plantar fasciitis typically result from overuse and strain, causing tendon degeneration and muscle origin degeneration [45, 46]. This degenerative process subsequently prompts the release of aseptic inflammation, manifesting as pain and functional impairment [47]. Rotator cuff injuries often stem from repetitive strain, leading to tears in the supraspinatus and infraspinatus muscles at their attachment points within the rotator cuff, thereby causing pain and functional limitations [48].

Based on the findings of this meta-analysis, we conclude that PRP injection therapy is effective for improving pain associated with tendinopathy and exhibits superior mid-term efficacy compared to CS. Moreover, in conditions characterized by aseptic inflammation, pain induction, or associated functional impairments, PRP shows superior therapeutic outcomes over CS. This superiority can be attributed to the release of macrophages

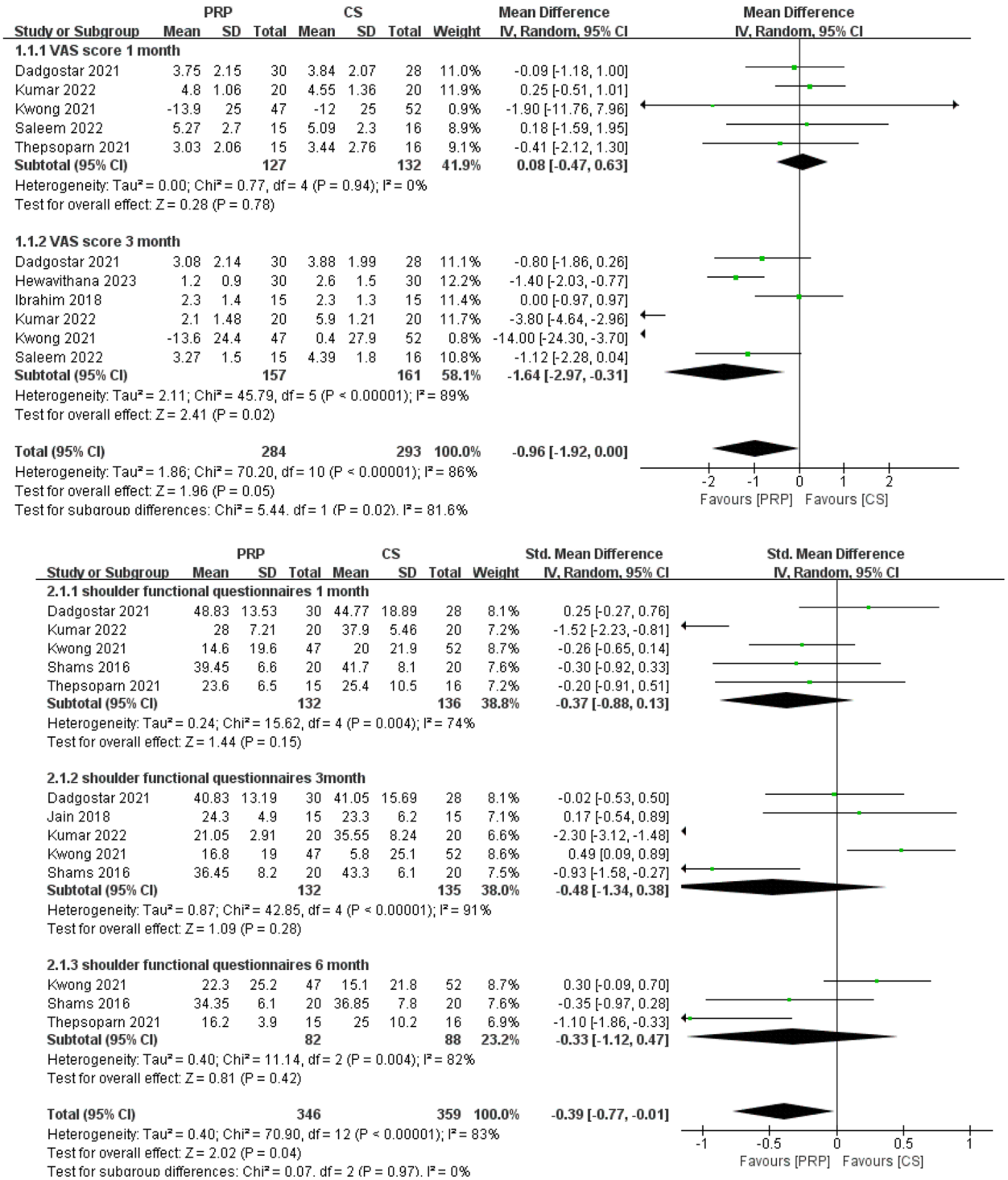


Fig. 4 Forest plot. Rotator cuff tendinopathy. Outcomes: visual analog scale score for pain, and shoulder functional questionnaires. PRP: platelet-rich plasma; CS: corticosteroid; SD: standard deviation; 95%CI: 95% confidence interval

and growth factors upon PRP activation, facilitating the clearance of necrotic tissue and dampening inflammatory responses. However, in cases of functional impairments resulting from muscle, tendon injuries, or nerve compression, there is no significant statistical difference observed between PRP and CS. The impact of PRP on tendon

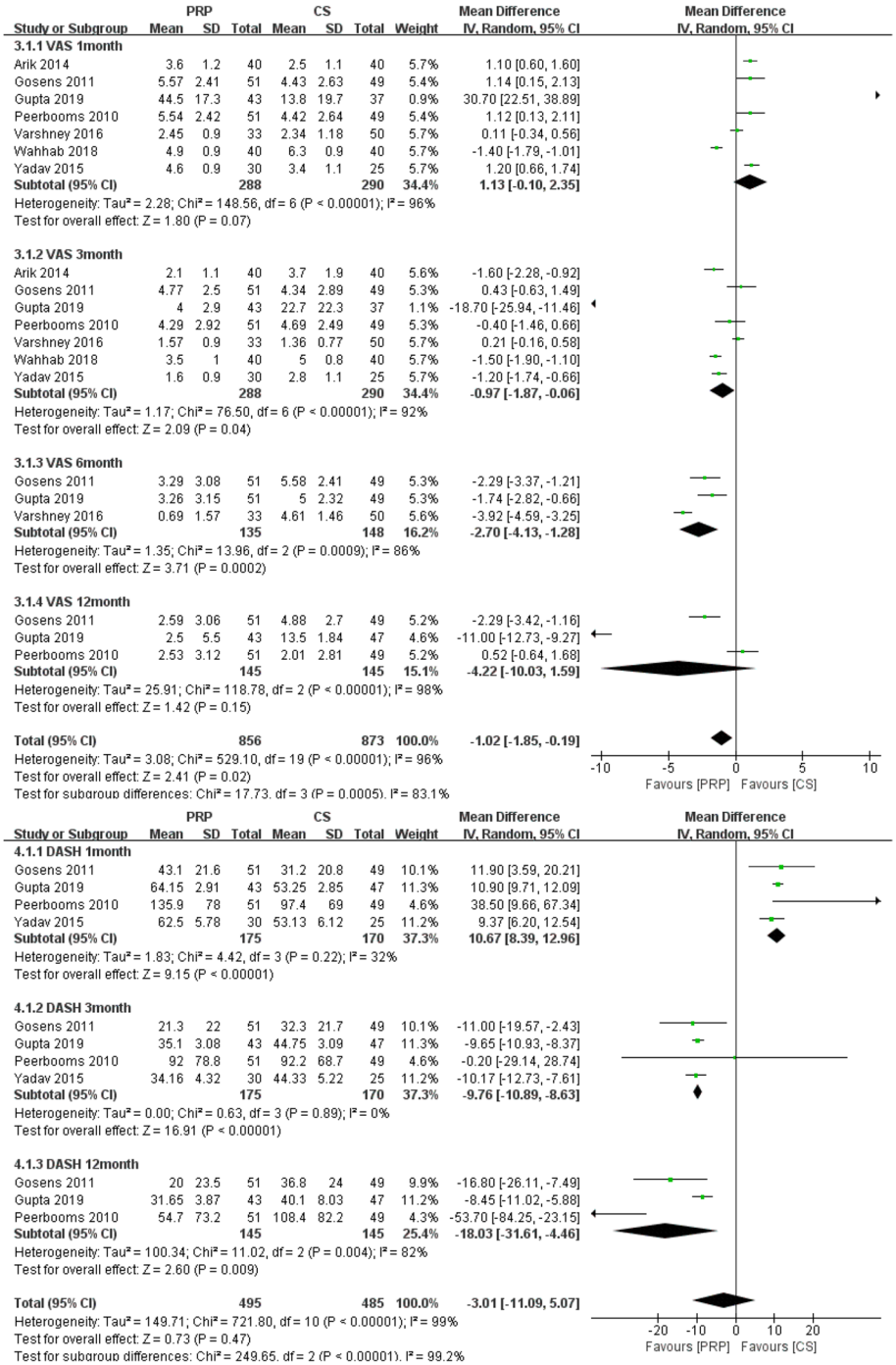


Fig. 5 Forest plot.humeral external epicondylitis. Outcomes: visual analog scale score for pain, and Disabilities of the Arm, Shoulder and Hand. PRP: platelet-rich plasma; CS: corticosteroid; SD: standard deviation; 95%CI: 95% confidence interval

healing and therapeutic outcomes remains unclear [49]. Some studies have indicated that the white blood cells in PRP enhance pro-inflammatory activity through the expression of catabolic cascades and the release of inflammatory markers, which may potentially influence the expression of other growth factors within PRP [50]. Moreover, the relatively small area of the glenoid fossa in the shoulder joint can only accommodate one-third to one-fourth of the humeral head. This structural configuration endows the shoulder joint with a relatively large

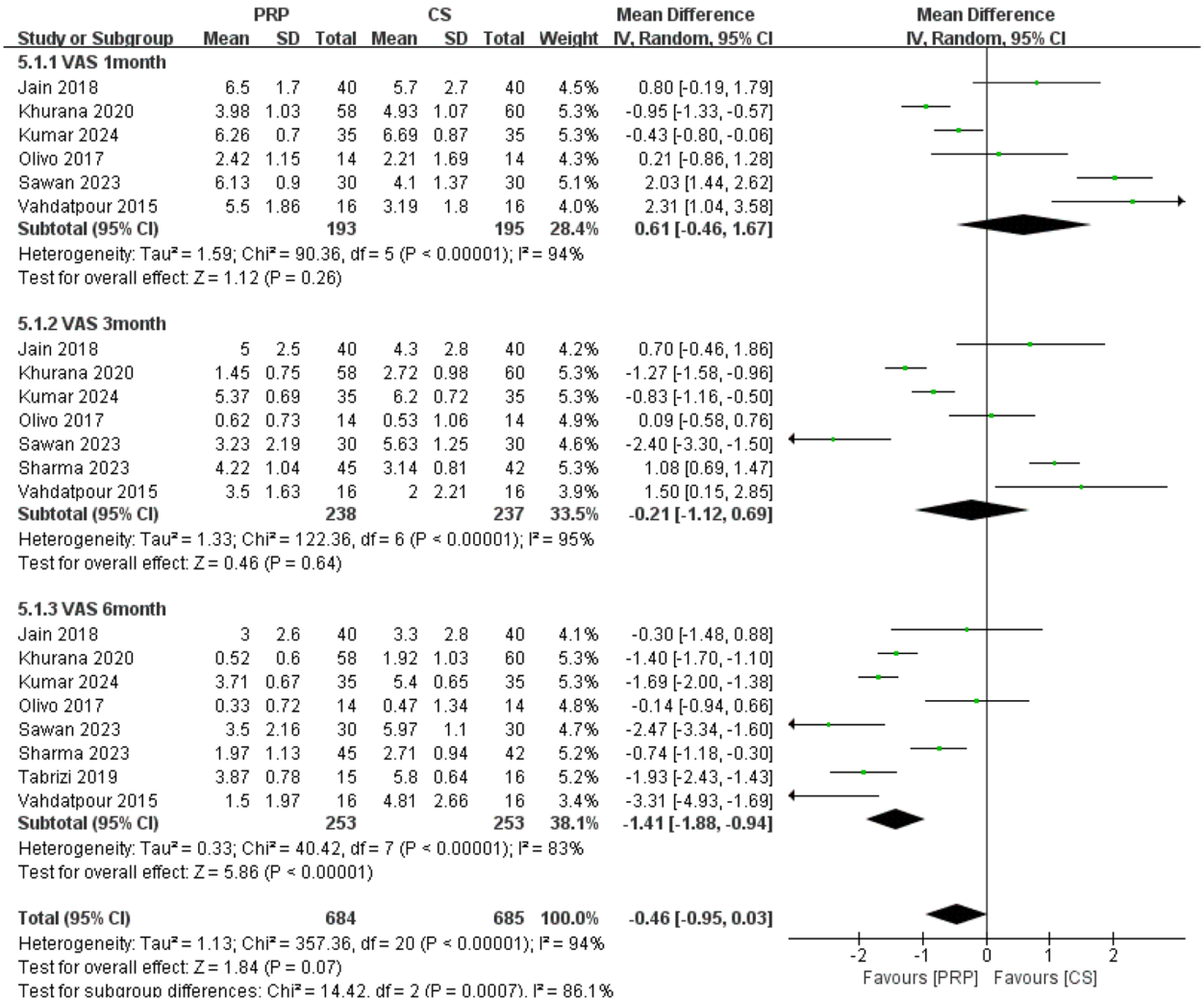
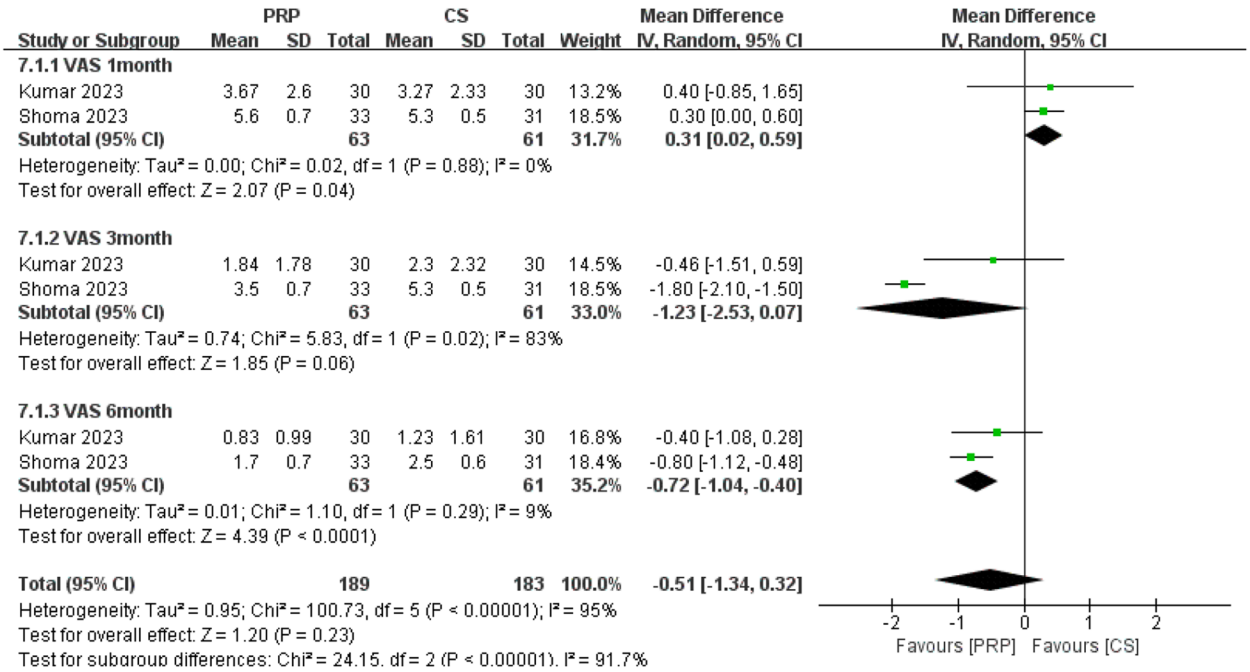


Fig. 6 Forest plot. plantar fasciitis. Outcomes: visual analog scale score for pain, and Ankle Hindfood Scale. PRP: platelet-rich plasma; CS: corticosteroid; SD: standard deviation; 95%CI: 95% confidence interval

range of motion, yet it consequently exhibits relatively poor stability. The maintenance of stability in the shoulder joint, which is crucial for performing various movements, relies on the rotator cuff muscles [51]. Therefore, it may require a longer follow-up period to determine the effect of PRP on functional improvement. The follow-up duration in the literature selected for this study is still relatively short, and there is a deficiency in research on PRP's improvement of functional impairments. Hence, evidence regarding PRP's enhancement of tendonopathy functional activities still awaits further large-scale, multicenter clinical studies with longer follow-up periods.

Overall, PRP effectively alleviates tendon pain and functional impairment, exhibiting superior mid-term efficacy and enhanced safety. However, this study does have certain limitations: firstly, the inclusion of a broad range of diseases without in-depth investigation into specific condition indicators may diminish the credibility of the findings. Additionally, the limited number of studies, specifically two articles related to tenosynovitis, coupled with inconsistent reported indicators for rotator cuff injuries, poses a significant risk of impacting the final outcomes. In future clinical studies, emphasis should be placed on the comprehensiveness and consistency of outcome measures. Furthermore, the duration of follow-up is frequently insufficient; the longest follow-up in the included studies was 24 months, with only 8 out of 27 trials assessing the long-term ($\geq$12 months) effects of PRP. Consequently, comparisons of each clinical condition at the 12-month mark are often restricted to just one or two



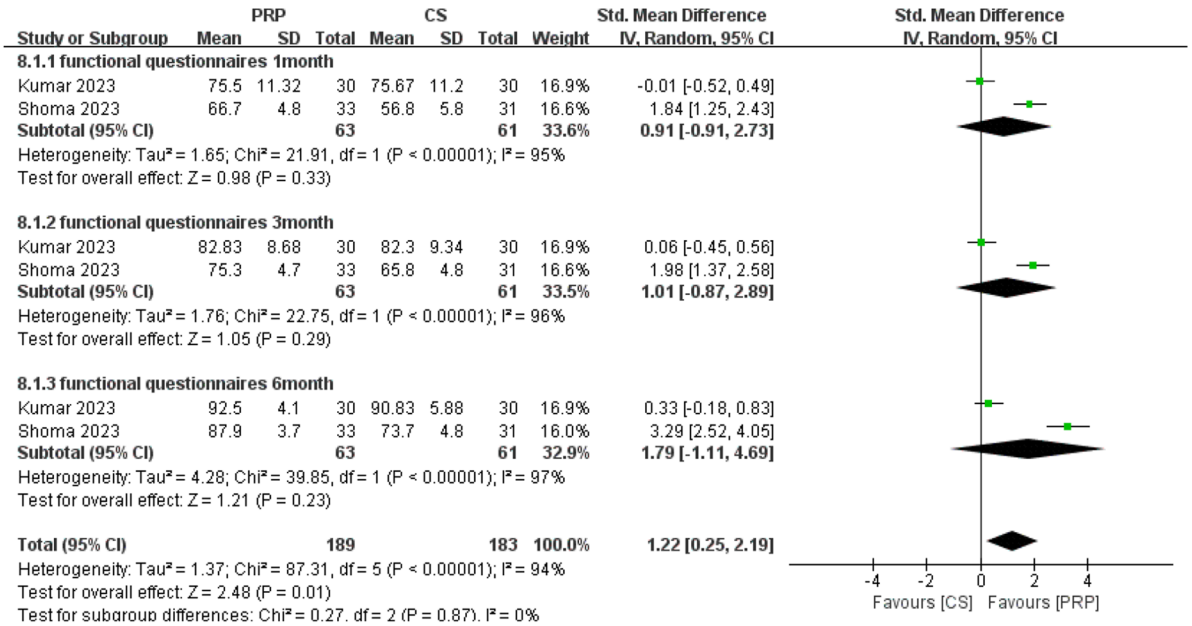


Fig. 7 Forest plot. tenosynovitis. Outcomes: visual analog scale score for pain, and Ankle Hindfood Scale. PRP: platelet-rich plasma; CS: corticosteroid; SD: standard deviation; 95%CI: 95% confidence interval

trials. As suggested by some researchers, the optimal clinical benefits of PRP in orthopedics may become apparent in the long-term phase. However, in the long-term follow-up analyzed in this study, PRP did not demonstrate a significant advantage over the control group. Currently, there is an absence of definitive methodological characteristics required to confirm the clinical efficacy of PRP in treating tendinopathies. Furthermore, there is no clear consensus regarding the types of products, standards, or application protocols. The methods for producing PRP are highly variable, contingent upon the diverse instruments and concentration techniques employed.

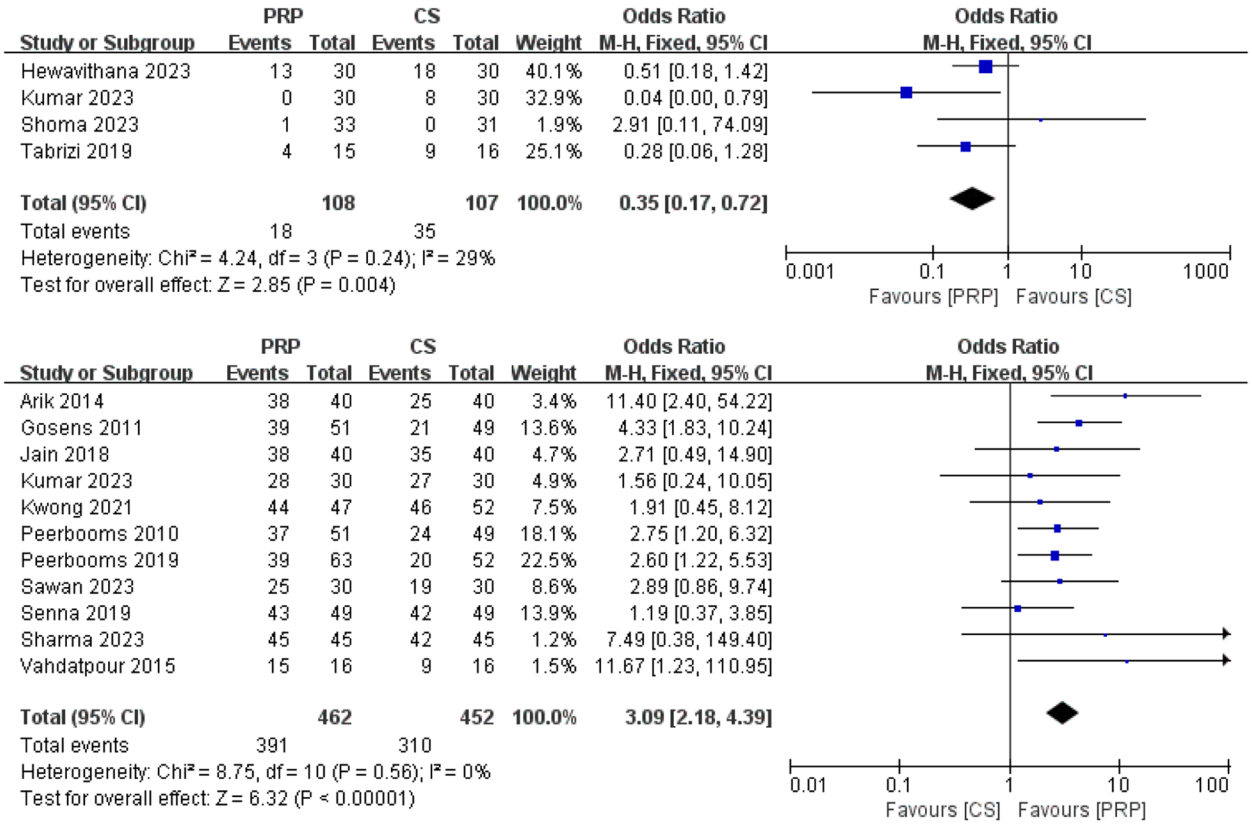


Fig. 8 Forest plot. Outcome: treatment response and adverse events. PRP: platelet-rich plasma; CS: corticosteroid; M-H: Mantel–Haenszel; 95%CI: 95% confidence interval

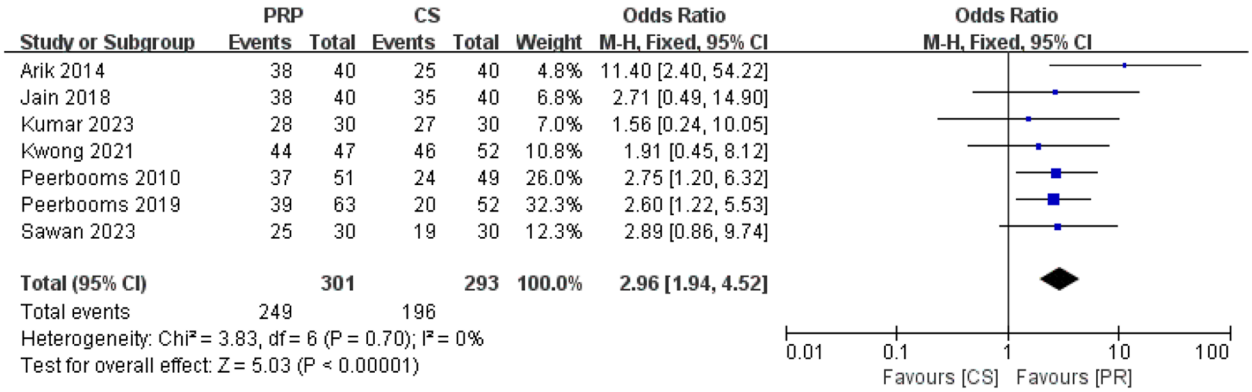


Fig. 9 Sensitivity analysis for efficiency

Not all PRP treatments are uniform; significant variations are attributed to the initial blood volume, the centrifugation system employed, the platelet concentration within the PRP, and the method of activation. Standardization of the PRP dosage administered each time is essential. The injection depth and the spacing between injection sites are also critical.

Conclusions

This meta-analysis has shown that that PRP may offer a favorable therapeutic effect on tendinopathy, with superior mid-term efficacy compared to CS, particularly regarding pain improvement. Furthermore, in terms of AEs incidence, the rate associated with PRP injections is lower than that with CS injections, implying a potentially

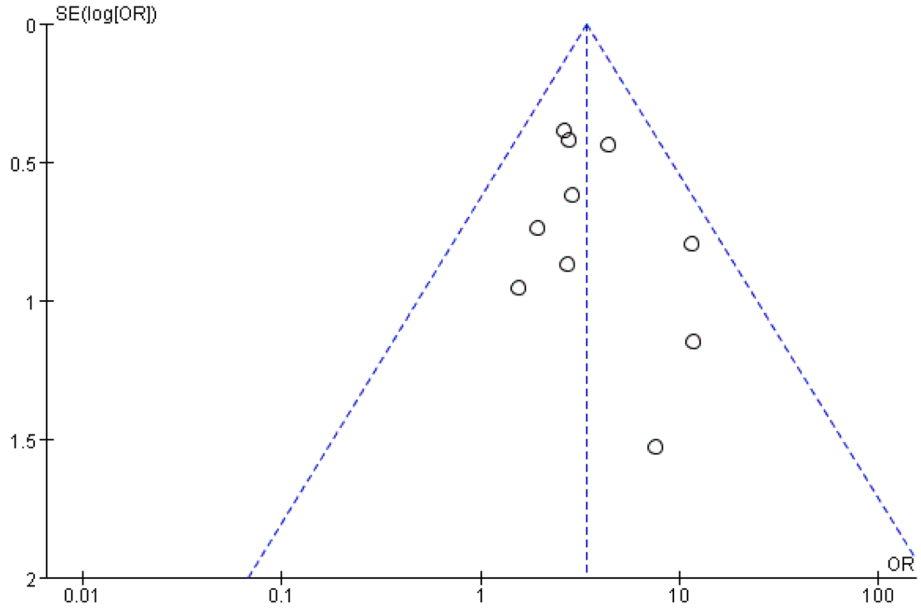


Fig. 10 The funnel plot for the efficiency

higher safety profile for PRP compared to CS. However, additional well-designed, large-scale randomized controlled trials are necessary to more accurately establish the indications for PRP as a conservative orthopedic treatment, along with its long-term benefits and optimal treatment protocols.

Abbreviations

RCTs	Randomized controlled trials
PRP	Platelet-rich plasma
CS	Corticosteroid
NSAIDs	Non-steroidal anti-inflammatory drugs
MD	Mean Difference
SMD	Standardized Mean Difference
SD	Standard deviations
AOFAS	American Orthopaedic Foot and Ankle Society
DASH	Disabilities of the Arm, Shoulder and Hand questionnaire
FFI	Foot function index
VAS	Visual analog scale
WORC	Western Ontario Rotator Cuff
ASES	American Shoulder and Elbow Surgeons
OSS	Oxford Shoulder Score
ROM	Range of motion
MAYO	Elbow joint function score

Supplementary Information

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Supplementary Material 1.

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To the best of our knowledge, no conflict of interest, financial or other.

Clinical trial number

Not applicable.

Authors' contributions

YZ and LM conceived and designed the study. YY and QL developed the search strategy and did the literature search. KG assessed the quality of study. YZ, TX and WZ collected the data and performed all analysis. YZ and LM contributed to writing of original manuscript. All authors read and approved the final manuscript.

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Data availability

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics approval and consent to participate

Since our study is a meta-analysis, an Ethical Review Committee Statement is not required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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