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SYSTEMATIC REVIEW

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Efficacy of different analgesic strategies combined with conventional physiotherapy program for treating chronic shoulder pain: a systematic review and network meta-analysis

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Abstract

Background This study aims to investigate the efficacy of five analgesic strategies combined with conventional physiotherapy program (CPT) in managing chronic shoulder pain.

Methods Two authors independently screened studies, extracted data using a pre-formatted chart, and assessed bias using the Cochrane Risk of Bias tool. A network meta-analysis was performed by the Stata 17.0 and R 4.3.2 software.

Results A total of 14 studies with 862 subjects were identified. These analgesic strategies included extracorporeal shock wave therapy (ESWT), suprascapular nerve block (SSNB), corticosteroid injection (CSI), hyaluronic acid injection (HAI), and kinesio taping (KT). ESWT plus CPT was the most efficient intervention in alleviating pain intensity and improving physical function. SSNB plus CPT was the optimal intervention in improving shoulder mobility. Compared to CPT alone, CSI + CPT only significantly improved the SPADI total score, but showed no difference in pain intensity or shoulder mobility. HAI + CPT showed no significant difference in improving pain intensity, physical function, or shoulder mobility compared to CPT alone. Adding KT to CPT did not yield additional benefits in improving shoulder mobility.

Conclusion Overall, in managing chronic shoulder pain, ESWT + CPT was the most effective intervention for reducing pain intensity and improving physical function. SSNB + CPT was optimal for enhancing shoulder mobility. Future rigorous clinical trials with larger sample sizes and higher methodological rigor are strongly required to confirm the current results.

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Keywords Shoulder pain, Physiotherapy, Analgesic strategies, Network meta-analysis

Introduction

Shoulder pain is the third most common musculoskeletal complaint, with a lifetime incidence of up to 67%, significantly impacting patients' quality of life and posing a massive socio-economic burden on the healthcare system [1, 2]. Chronic shoulder pain, defined as shoulder pain persisting for more than three months, has a significant impact on functional ability, psychosocial well-being, and metabolic stress [3]. Chronic shoulder pain is caused by multiple shoulder conditions including subacromial impingement syndrome, tendinopathy, rotator cuff tears, and adhesive capsulitis [2]. Subacromial impingement syndrome, primarily caused by subacromial pathology, is a leading contributor to shoulder pain [4]. Tendinopathy may arise due to repeated shoulder movements, particularly during overhead activities or heavy lifting [5]. Rotator cuff tears often lead to shoulder pain and functional impairment, necessitating treatment tailored to the severity, including conservative management or surgical repair [6]. Adhesive capsulitis is characterized by pain and stiffness, commonly associated with synovitis and contracture of the synovial capsule [7]. These shoulder conditions can cause chronic shoulder pain and are typically accompanied by stiffness, reduced range of motion, and limited participation [8].

The complex anatomy of the shoulder joint, the wide range of pathogenic factors, and the absence of standardized diagnostic criteria pose a significant dilemma for diagnose [9–12]. Consequently, the term "non-specific shoulder pain" is frequently used in both clinical practice and research studies [13]. A review has emphasized the need for future research targeting undivided subjects with "general" shoulder pain [14]. Besides, several such studies already yielding valuable clinical insights [15–18]. For example, a recent NMA compared the effectiveness of different exercise therapies in alleviating chronic shoulder pain [15]. Thus, performing a network meta-analysis based solely on chronic shoulder pain is reasonable.

Several conservative treatments of chronic shoulder pain have been proposed and assessed, such as non-steroidal anti-inflammatory drugs (NSAIDs), conventional physiotherapy program (CPT), and other analgesic strategies. NSAIDs are not always effective and may increase the risk of cardiovascular, gastrointestinal, liver or renal complications [9, 19]. CPT, the first line therapy, includes exercise therapy, physical factor therapy, joint mobilization, massage therapy, and stretching [20, 21]. It is helpful in alleviating pain, increasing muscle strength and joint stability, and facilitating function recovery [22, 23]. Additionally, CPT can rectify biomechanical issues by improving muscle extensibility, increasing range of motion, enhancing stability of the rotator cuff muscles, and correcting scapulohumeral rhythm [24, 25]. Recent evidence unveiled that there was no significant difference in reducing pain and improving physical function between physiotherapy and surgery for adults with shoulder pain [26–28]. These evidence also strengthen the necessity of CPT in the management of shoulder pain. Nevertheless, it also has some limitations. For instance, the efficacy of exercise may be compromised due to inherent challenges such as insufficient self-initiative and inadequate external supervision. Furthermore, manual therapy may transiently exacerbate pain and symptoms of patients with shoulder pain. Therefore, it is crucial to explore alternative treatments to complement or improve the therapeutic efficacy of CPT [29].

Besides NSAIDs and CPT, various analgesic strategies are widely used in clinical practice for treating chronic shoulder pain, such as extracorporeal shock wave therapy (ESWT), suprascapular nerve block (SSNB), corticosteroid injection (CSI), hyaluronic acid injection (HAI), and kinesio taping (KT). Numerous randomized controlled trials (RCTs) and reviews have demonstrated that these interventions can alleviate pain and improve joint function in individuals with shoulder pain [20, 21, 26–28, 30–35]. However, these interventions may be limited in their long-term efficacy as they offer only temporary pain relief and anti-inflammatory effects without rectifying fundamental biomechanical issues. Recurrence of symptoms post-intervention is common due to biomechanical issues, such as imbalance in the rotator cuff muscles, postural dysfunction, and changes in shoulder-thoracic kinematics.

Recent well-designed RCTs have proven that combining CPT with analgesic strategies results in better outcomes than CPT alone. Previous network meta-analyses (NMAs) have compared the efficacy of various shoulder joint drug injections for shoulder disorders. However, they have not compared the effectiveness of different analgesic strategies when combined with CPT. This gap hinders the selection and promotion of the optimal treatment protocols in clinical practice. Therefore, this study aims to conduct a systematic review and NMA to evaluate the efficacy of five analgesic strategies combined with CPT in treating chronic shoulder pain. The findings will provide evidence-based clinical recommendations.

Methods

Protocol and registration

This study was conducted by Preferred Reporting Items for Systematic Reviews and Meta-Analysis for Network

Meta-Analysis (PRISMA-NMA) [36]. A prospective protocol for the NMA has been reported on PROSPERO (CRD 42024519473).

Search strategy

We systematically searched Pubmed, Web of Science, Embase, and Cochrane Library from their inceptions to April 15, 2024. The search terms used were: "Shoulder Pain", "Rotator Cuff Injury", "shoulder impingement syndrome", "adhesive capsulitis", "frozen shoulder", "shoulder girdle", "physiotherapy", "physical therapy", "steroid", "corticosteroid", "extracorporeal shock wave therapy", "kinesio taping", "kinesiology taping", "Suprascapular Nerve Block", "suprascapular nerve blocks", "hyaluronic acid", "randomized", "random", "randomly", and "randomised". Additionally, the references cited in the included articles were traced to identify any further eligible studies. The specific search strategies are given in Table S1.

Inclusion criteria

I. Type of study: RCTs with parallel design were included.
II. Subjects: adults (≥ 18 years) were diagnosed with shoulder pain lasting at least 3 months, including rotator cuff tendinopathy, shoulder impingement syndrome, frozen shoulder, adhesive capsulitis, non-specific shoulder pain, and shoulder myofascial pain.
III. Types of interventions: acceptable interventions were mainly various analgesic strategies combined with CPT. Analgesic strategies included CSI, HAI, SSNB, ESWT, and KT.
IV. Comparison: CPT alone or intercomparison between interventions.
V. Outcome measures: outcomes encompassed data on pain intensity assessed by Visual Analogue Scale (VAS) and Shoulder Pain and Disability Index pain (SPADI pain), physical function measured by SPADI disability and SPADI total, and shoulder mobility measured by shoulder range of motion (ROM).

Exclusion criteria

Studies that met any of the following criteria were strictly excluded: (1) studies specifically focused on patients with post-mastectomy shoulder pain; (2) studies published as conference abstracts, trial registry records, animal studies, reviews, meta-analyses, protocols, case reports, or letters; (3) incomplete trial data; (4) irrelevant trial outcome indicators; (5) inappropriate interventions; (6) insufficient patient information; (7) non-English studies.

Screening and data extraction

The retrieved articles were uploaded into Endnote X9 software, and then duplicates were removed. Two authors independently scrutinized the titles and abstracts for an initial screening, and conducted a meticulous full-text reading of selected RCTs for the final decision. The following data were collected and summarized by two authors using a pre-formatted chart: first author, publication year, country, study design, sample size, participant age, disease type, pain duration, intervention protocols (intervention modalities and duration), and outcome assessments (VAS, SPADI pain, SPADI total, SPADI disability, and shoulder ROM). Any discrepancies were resolved through collaboration with other authors. If complete data were not available, we contacted the corresponding author for missing information. When necessary, the mean and standard deviation were calculated using the Cochrane Handbook formulas based on the baseline and outcome data.

Risk of bias

Two authors independently performed quality assessment of the included studies via the Cochrane Collaboration's tool. Seven items of bias were as follows: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Any disagreements were resolved by achieving a consensus. The risk of bias for each domain was rated as low, unclear, or high. Studies with low bias risk in three or more domains were rated moderate to high quality. Publication bias was evaluated using a comparison-adjusted funnel plot and Egger's test.

Data synthesis and analysis

A frequentist NMA using random-effects model was adopted to pool direct and indirect evidence simultaneously. All analyses were achieved using Stata/MP statistical software version 17.0, R statistical software version 4.3.2, and RStudio statistical software version 22023.09.1–494 [37–39]. Mean difference (MD) with a 95% confidence interval (CI) was used to evaluate the effect size of the continuous variables. If a closed loop was formed, we examined statistical inconsistency between direct and indirect evidence using local (the node-splitting technique) and global (the design-by-treatment interaction technique) models [40]. If $P>0.05$, it suggested that there was no statistically significant difference between the two kinds of evidence, and a consistency model analysis was used for analysis [41]. A network plot was created to show the relationships among the different interventions. The size of nodes reflects the sample size of each intervention, and the thickness of lines corresponds to the quantity of RCTs with direct comparisons.

Then, a league table was created to present the outcome for all paired comparisons, incorporating both direct and indirect comparisons. Subsequently, the surface under the cumulative ranking surve (SUCRA) probabilities were computed to compare the efficacy of different treatment approaches for each outcome. And a larger SUCRA value suggests a better effect of the intervention. Then, cumulative probability line charts were created. Finally, the potential publication bias in NMA was examined using a comparison-adjusted funnel plot and Egger's test. Egger's test was performed using Rstudio, and if $P > 0.05$, it indicated that there was no significant publication bias.

Results

Study selection

The preliminary search identified 1248 records, of which 527 duplicate records were removed. After reviewing titles and abstracts, 48 studies remained. After excluding 1 unavailable studies, the full texts of the reserved 47 studies were further evaluated for their eligibility. Following the screening criteria, 14 studies were selected for our NMA with a total of 862 patients [42–55]. The process of literature screening is shown in Fig. 1.

Study characteristics

A total of 14 eligible studies [42–55] and 6 interventions fulfilled the inclusion criteria and were included for analysis. The different interventions of included studies were defined in Table 1. The characteristics of the included RCTs are presented in Table 2. They were carried out in 6 different countries and published from 2011 to 2024. Egypt has contributed four articles, the highest number among all countries. The sample sizes spanned from 30 to 97. The average age of patients ranged from 30.47 to 71.3 years old. Participants in the included studies were diagnosed with chronic shoulder pain. Multiple studies reported the effectiveness of different interventions: 5 studies for "CSI+CPT" [42, 44, 51–53], 5 studies for "HAI+CPT" [43, 45, 46, 49, 55], 2 studies for "SSNB+CPT" [42, 51], 4 studies for "ESWT+CPT" [47, 50, 52, 54], 1 studies for "KT+CPT" [48], and 14 studies for "CPT" [42–55]. The duration of intervention in the included studies varied from 4 weeks to 12 weeks, including 4 weeks for 4 studies [47, 50, 52, 54], 6 weeks for 2 studies [44, 48], 8 weeks for 1 studies [53], and 12 weeks for 7 studies [42, 43, 45, 46, 49, 51, 55]. The indicators of pain intensity encompassed VAS score and SPADI pain score. VAS score was reported in 5 studies [47, 50, 51, 53, 55], and SPADI pain score was reported in 6 studies [42–44, 53–55]. The indicators of physical function encompassed SPADI disability score and SPADI total score. The SPADI disability score was reported in 6 studies [42–44, 53–55], while the SPADI total score was reported in 8 studies [42–44, 51–55]. The indicators of shoulder mobility included flexion, abduction, and external rotation ROM. The flexion ROM was measured in 8 studies [42, 47, 48, 50–53, 55]; the abduction ROM was reported in 8 studies [42, 47, 48, 50–53, 55], and the external rotation ROM was reported in 9 studies [42, 45–47, 49–51, 53, 55].

Quality assessment

Among all the included studies, eight (57.1%) studies [43, 47, 48, 50, 52–55] used a computer or a random number table and were rated as low risk in random sequence generation. Five studies [42, 44–46, 51] lacked a clear description of the random allocation method and were assessed as unclear risk. Five (35.7%) studies [48, 50, 52, 53, 55] used a sealed envelope to conceal assignment scheme and were judged as low risk in allocation concealment. The remaining nine studies [42–47, 49, 51, 54] presented uncertain risk due to a lack of clear description of the allocation concealment. In blinding participants and personnel, ten studies had unclear risk [42–44, 46–48, 50, 52–54], and four studies had high risk [45, 49, 51, 55]. Five RCTs [50, 52–55] blinded the outcome evaluators. One study [44] was rated as high attrition bias owing to a dropout rate exceeding 20%, while three studies had unclear risk, and ten studies [42, 43, 46, 48, 50–55] had low risk in this aspect. All included studies were assessed as low risk in reporting bias. Other bias were evaluated as unclear risk in all studies. In summary, six studies were rated as high quality [48, 50, 52–55], one studies [43] were rated as moderate quality, and seven studies were rated as low quality [42, 44–47, 49, 51]. The funnel plots were symmetrical, and the P values of Egger's test were exceeding 0.05, suggesting the absence of publication bias among the studies. Risk of bias assessment of the studies is illustrated in Fig. 2.

Network meta-analysis

Pain intensity

Five studies with 362 subjects assessed the efficacy of 5 interventions in reducing VAS score, and the network plot is depicted in Fig. 3A. The VAS score is commonly used to measure pain intensity, and a higher score signifies greater pain intensity. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: $P=0.15$; local: $P>0.05$) (Table S2). Figure 4A is the league table of VAS, presenting the two-by-two comparison matrix for reducing VAS score. Compared with CPT, SSNB+CPT (MD: -0.56; 95% CI: -0.96 to -0.16) and ESWT+CPT (MD: -1.06; 95% CI: -1.40 to -0.71) had significant effects on reducing VAS score. ESWT+CPT was significantly more effective than CSI+CPT (MD: 0.84; 95% CI: 0.24 to 1.43). As shown in Fig. 4B, results of SUCRA analysis unveiled that ESWT+CPT had the highest probability of being best

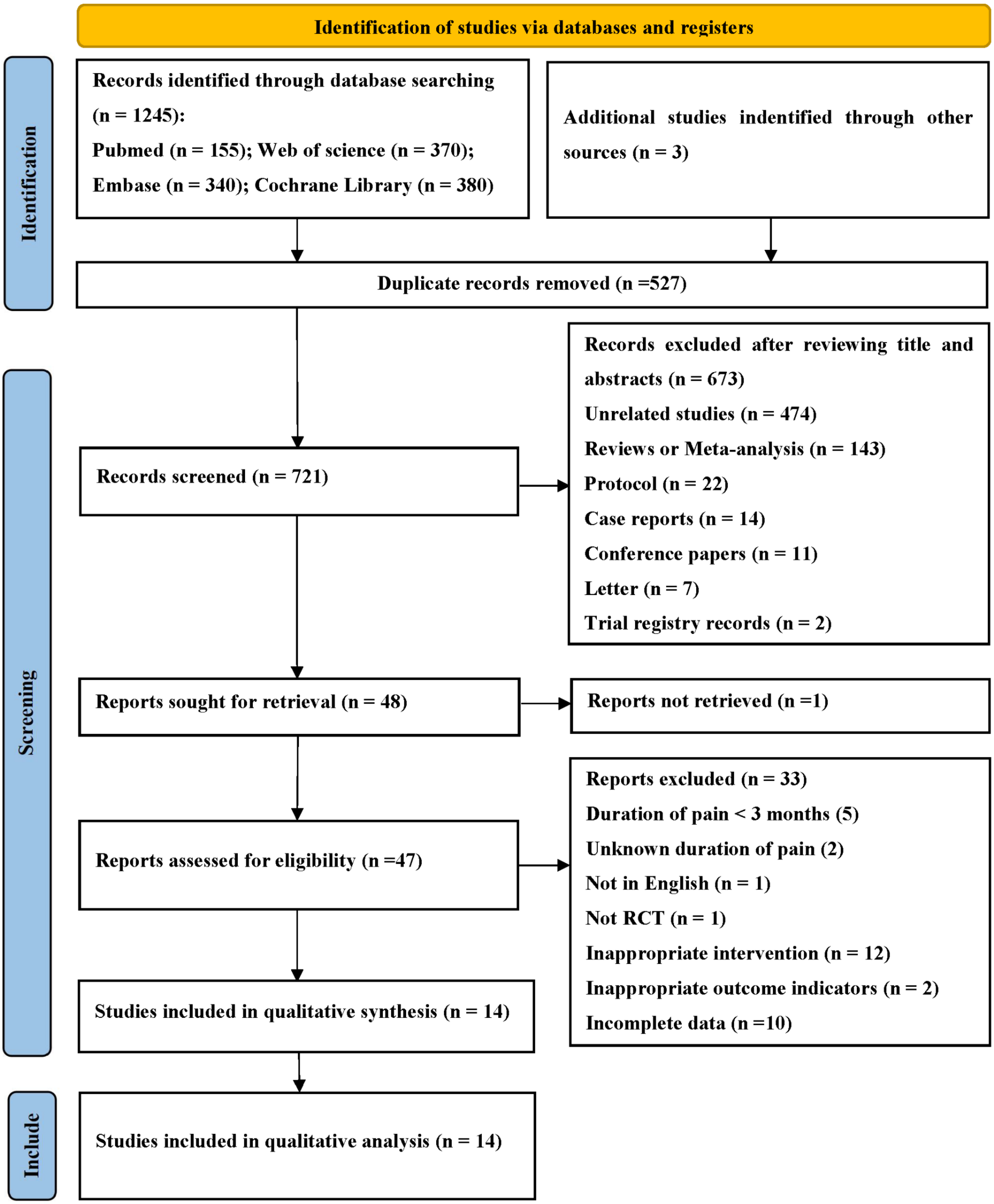

Fig. 1 Flow diagram of studies selection

Table 1 Abbreviations and definition of interventions

Abbreviations	Interventions arm	Definition
CSI	corticosteroid injection	CSI is commonly used clinically to alleviate inflammation-related pain. The corticosteroids used in the included studies were triamcinolone or methylprednisolone [56].
HAI	hyaluronic acid injection	HA is the primary component of synovial fluid and provides lubrication and shock absorption to the joint [45].
SSNB	suprascapular nerve block	SSNB is a therapy for alleviating shoulder pain by blocking somatic and autonomic neural transmission between the shoulder and spinal cord [32]. It may be applied with local anesthetics.
ESWT	extracorporeal shock wave therapy	ESWT is a therapy that focuses high-amplitude sound waves on the target area [57]. It can effectively treat a wide range of musculoskeletal dysfunctions and illnesses [58].
KT	kinesio taping	KT is believed to relieve pain, improve proprioceptive feedback, and enhance joint sensorimotor control. It is widely used in the rehabilitation of musculoskeletal disorders.
CPT	conventional physiotherapy program	CPT is a multimodal approach that includes exercise therapy, physical factor therapy, joint mobilization, massage therapy, and stretching [59]. The type and focus of CPT varies depending on the underlying pathophysiological mechanisms of shoulder pain [20].

(95.1%), followed by SSNB+CPT (61.5%), HAI+CPT (57.8%), CSI+CPT (27.8%), and CPT (7.8%). We were unable to identify publication bias using a funnel plot or Egger's test because the number of included studies in this outcome was less than 10.

A total of 6 with 316 patients were included to compare the effects of 5 interventions on SPADI pain score in subjects with shoulder pain, and the network plot is shown in Fig. 3B. The SPADI questionnaire is a standardized tool used to assess pain and functional limitations in individuals with shoulder problems. It consists of two subscales: the Pain subscale and the Disability subscale. A higher SPADI pain score signifies more severe pain intensity. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: $P=0.84$; local: $P>0.05$) (Table S2). Figure 5A is the league table of SPADI pain, presenting the two-by-two comparison matrix for reducing SPADI pain score. Compared with CPT, SSNB+CPT (MD: -12.60; 95% CI: -19.79 to -5.41) and ESWT+CPT (MD: -30.53; 95% CI: -36.94 to -24.12) had significant effects on reducing SPADI pain score. ESWT+CPT was significantly more effective than CSI+CPT (MD: 27.61; 95% CI: 19.32 to 35.90), HAI+CPT (MD: 29.84; 95% CI: 20.21 to 39.46), and SSNB+CPT (MD: 17.93; 95% CI: 8.30 to 27.56). As shown in Fig. 5B, the findings of SUCRA analysis indicated that ESWT+CPT had the highest probability of being best (100.0%), followed by SSNB+CPT (74.6%), CSI+CPT (38.8%), HAI+CPT (22.3%), and CPT (14.3%). We were unable to identify publication bias using a funnel plot or Egger's test because the number of included studies in this outcome was less than 10.

Physical function

A total of 6 with 316 subjects were included to compare the effects of 5 interventions on SPADI disability score in patients with shoulder pain, and the network plot is shown in Fig. 3B. A higher SPADI disability score indicates more severe disabilities. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: $P=0.14$; local: $P>0.05$) (Table S2). Figure 6A is the league table of SPADI disability, presenting the two-by-two comparison matrix for reducing SPADI disability score. ESWT+CPT was significantly more effective than HAI+CPT (MD: 23.87; 95% CI: 1.03 to 46.71) and CPT (MD: -25.25; 95% CI: -42.96 to -7.54). As shown in Fig. 6B, outcomes of SUCRA analysis unveiled that ESWT+CPT had the highest probability of being best (96.2%), followed by SSNB+CPT (55.6%), CSI+CPT (52.4%), HAI+CPT (28.1%), and CPT (17.6%). Funnel plot and Egger's test were not performed because the number of included studies in this outcome was less than 10.

Eight studies with 473 subjects assessed the efficacy of 5 interventions in reducing SPADI total score, and the network plot is shown in Fig. 3C. A higher total SPADI score indicates poorer shoulder function. The design-by-treatment interaction model did not detect any inconsistency ($P=0.32$). However, small percentages of local inconsistency were observed between some comparisons in SPADI total (1/6 loops) (Table S2). The league table of SPADI total is shown in Fig. 7A which exhibits the two-by-two comparison matrix for reducing SPADI total score. Compared with CPT, CSI+CPT (MD: -8.50; 95% CI: -16.21 to -0.78) and ESWT+CPT (MD: -17.07; 95% CI: -28.32 to -5.82) had significant effects on reducing SPADI total score. As shown in Fig. 7B, results of SUCRA analysis unveiled that ESWT+CPT had the highest probability of being best (94.6%), followed by CSI+CPT (62.6%), SSNB+CPT (54.6%), HAI+CPT (24.0%), and CPT (14.2%). The symmetrical funnel plot and Egger's test ($P=0.61$) indicated that there was no significant publication bias (Fig. 7C).

Shoulder mobility

Eight studies with 529 subjects examined the efficacy of 6 interventions in improving flexion ROM, and the

Table 2 Characteristics of the included studies

Study	Country	Study design	Disease type	Pain duration	Sample size	Age(year)	Intervention	Control	Course	Outcomes
				Mean(SD)/[Range]	E/C	Mean(SD)/[Range]				
Abdelshafi et al. (2011) [42]	Egypt	single-blind, randomized	chronic shoulder pain	at least three months	20/20/19	E1: 45.6 ± 8.8 E2: 41.1 ± 6.8 C: 41.8 ± 8.3	CSI + CPT SSNB + CPT	CPT	12 weeks	②③④⑤⑥⑦
Hsieh et al. (2012) [43]	China	single-blind, randomized	adhesive capsulitis	last up to 12 months	32/31	E: 52.6 ± 6.3 C: 56.4 ± 9.0	HAI + CPT	CPT	12 weeks	②③④
Maryam et al. (2013) [44]	Iran	single-blind, randomized	frozen shoulder	4–6 months	22/19	E: 53.71 ± 6.69 C: 53.73 ± 7.49	CSI + CPT	CPT	6 weeks	②③④
Di Giacomo et al. (2015) [45]	Italy	single-blind, randomized	shoulder OA	Mean: 10.6 months	31/30	E: 49 to 82 C: 42.80 ± 3.88	HAI + CPT	CPT	12 weeks	⑦
Di Giacomo et al. (2017) [46]	Italy	single-blind, randomized	shoulder OA	at least 6 months but less than 2 years	39/39	E: 71.3 ± 6.7 C: 69.8 ± 6.4	HAI + CPT	CPT	3 months	⑦
Duymaz et al. (2019) [47]	Turkey	single-blind, randomized	calcific tendinitis	more than three months	40/40	E:54.33 ± 9.88 C: 51.31 ± 8.86	ESWT + CPT	CPT	4 weeks	①⑤⑥⑦
de Oliveira et al. (2021) [48]	Canada	single-blind, randomized	rotator cuff–related shoulder pain	E: 20.6 ± 27.7 months C: 24.6 ± 25.7 months	25/23	E: 30.9 ± 9.0 C: 52.13 ± 3.06	KT + CPT	CPT	6 weeks	⑤⑥
Di Giacomo et al. (2021) [49]	Italy	single-blind, randomized	glenohumeral OA	Mean: 11.2 months	30/30	E: 67.1 C: 64.2	HAI + CPT	CPT	3 months	⑦
Yehia et al. (2022) [50]	Egypt	single-blind, randomized	adhesive capsulitis	E: 6.1 ± 2.32 months C: 6.3 ± 2.58 months	31/31	E: 52.7 ± 7.8 C: 52.4 ± 7.1	ESWT + CPT	CPT	4 weeks	①⑤⑥⑦
Mardani-Kivi et al. (2022) [51]	Iran	non-blinded, randomized	idiopathic frozen shoulder	at least three months	32/31/34	E1: 47.75 ± 10.95 E2: 48.57 ± 10.66 C: 49.20 ± 11.77	CSI + CPT SSNB + CPT	CPT	12 weeks	①④⑤⑥⑦
ElGendy et al. (2023) [52]	Egypt	double-blind, randomized	subacromial impingement syndrome	more than three months	20/20/20	E1: 30.47 ± 3.69 E2: 31.94 ± 4.66 C: 32.72 ± 4.38	CSI + CPT ESWT + CPT	CPT	4 weeks	④⑤⑥

Table 2 (continued)

Study	Country	Study design	Disease type	Pain duration	Sample size	Age(year)	Intervention	Control	Course	Outcomes
				Mean(SD)/[Range]	E/C	Mean(SD)/[Range]				
Hsieh et al. (2023) [53]	China	single-blind, randomized	chronic subacromial bursitis	more than three months	28/33	E: 54.2 ± 10 C: 56.9 ± 10	CSI + CPT	CPT	8 weeks	①②③④⑤⑥⑦
Khalifa et al. (2023) [54]	Egypt	single-blind, randomized	hemiplegic shoulder pain	E: 5 ± 0.845 months C: 5.2 ± 0.862 months	15/15	E: 51.60 ± 5.32 C: 50.80 ± 6.81	ESWT + CPT	CPT	1 month	②③④
Wu et al. (2024) [55]	China	single-blind, randomized	adhesive capsulitis	more than three months	31/31	E: 52.94 C: 54.35	HAI + CPT	CPT	12 weeks	①②③④⑤⑥⑦

Notes: E, experiment group; C, control group; OA, osteoarthritis; CPT, conventional physiotherapy program; CSI, corticosteroid injection; ESWT, extracorporeal shock wave therapy; KT, kinesio taping; SSNB, suprascapular nerve block; HAI, hyaluronic acid injection; VAS, Visual Analogue Scale score; SPADI, Shoulder Pain and Disability Index; ROM, range of motion; ①, VAS; ②, SPADI pain; ③, SPADI disability; ④, SPADI total; ⑤, Flexion; ⑥Abduction; ⑦, External rotation

network plot is shown in Fig. 3D. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: P=0.56; local: P>0.05) (Table S2). The league table of flexion is shown in Fig. 8A, which presents the two-by-two comparison matrix for improving flexion ROM. Compared with CPT, SSNB+CPT (MD: 15.20; 95% CI: 1.56 to 28.85), and ESWT+CPT (MD: 14.37; 95% CI: 3.06 to 25.68) had significant effects on improving flexion ROM. As shown in Fig. 8B, results of SUCRA analysis indicated that SSNB+CPT had the highest probability of being best (81.2%), followed by ESWT+CPT (78.1%), CSI+CPT (49.4%), HAI+CPT (43.5%), KT+CPT (30.3%), and CPT (17.5%). The symmetrical funnel plot and Egger's test (P=0.74) indicated that there was no significant publication bias (Fig. 8C).

Eight studies with 529 subjects assessed the efficacy of 6 interventions in improving abduction ROM, and the network plot is shown in Fig. 3E. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: P=0.67; local: P>0.05) (Table S2). Figure 9A is the league table of abduction, showing the two-by-two comparison matrix for improving abduction ROM. Compared with CPT, SSNB+CPT (MD: 22.02; 95% CI: 4.70 to 39.35), and ESWT+CPT (MD: 16.58; 95% CI: 1.69 to 31.46) had significant effects on improving abduction ROM. As shown in Fig. 9B, outcomes of SUCRA analysis revealed that SSNB+CPT had the highest probability of being best (84.5%), followed by ESWT+CPT (70.2%), HAI+CPT (45.5%), CSI+CPT (44.2%), KT+CPT (40.8%), and CPT (14.9%). The symmetrical funnel plot and Egger's test (P=0.77) indicated that there was no significant publication bias (Fig. 9C).

Nine studies with 620 subjects evaluated the efficacy of 5 interventions in improving external rotation ROM, and the network plot is shown in Fig. 3F. Both the design-by-treatment interaction model and the node-splitting method did not detect any inconsistency (global: P=0.71; local: P>0.05) (Table S2). Figure 10A is the league table of abduction, displaying the two-by-two comparison matrix for improving external rotation ROM. Compared with CPT, SSNB+CPT (MD: 16.48; 95% CI: 8.08 to 24.88), and ESWT+CPT (MD: 12.46; 95% CI: 4.32 to 20.60) showed significant improvement in external rotation ROM. SSNB+CPT was significantly more effective than CSI+CPT (MD: -11.32; 95% CI: -19.67 to -2.97) and HAI+CPT (MD: -15.41; 95% CI: -25.74 to -5.08). Compared with HAI+CPT, ESWT+CPT (MD: -11.39; 95% CI: -21.48 to -1.31) had significant effects on improving external rotation ROM. As shown in Fig. 10B, results of SUCRA analysis confirmed that SSNB+CPT had the highest probability of being best (93.5%), followed by ESWT+CPT (78.4%), CSI+CPT (45.0%), HAI+CPT (21.7%), and CPT (11.4%). The symmetrical funnel plot and Egger's test (P=0.94) indicated that there was no significant publication bias (Fig. 10C).

Discussion

To the best of our knowledge, this is the first systematic review and NMA to examine the therapeutic effects of five analgesic strategies combined with CPT for chronic shoulder pain. NMA can compare multiple treatments by combining direct and indirect evidence and perform relative ranking. According to the results of NMA, ESWT+CPT ranked highest in alleviating pain intensity and improving physical function compared to other interventions+CPT; SSNB+CPT was the best

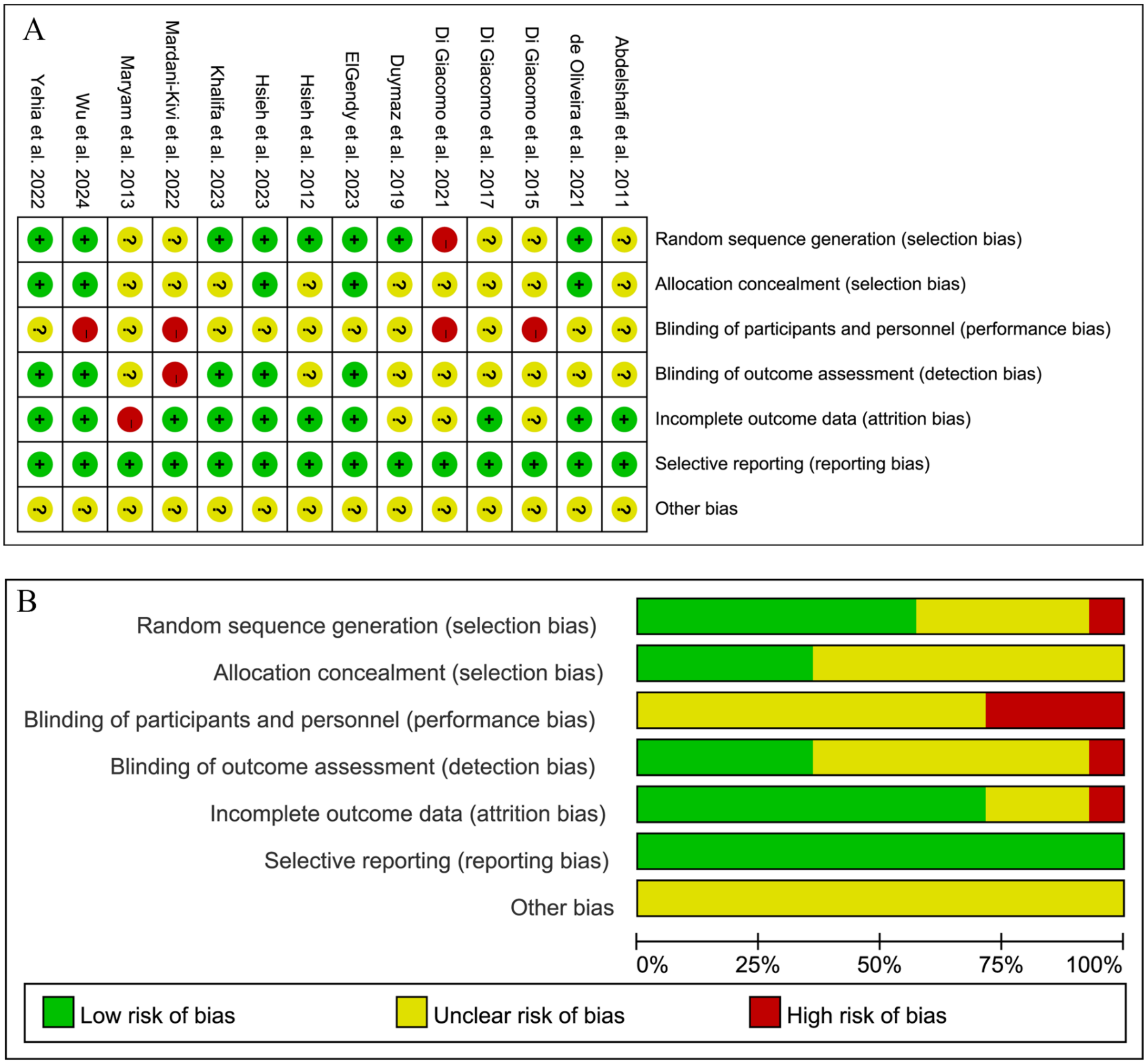

Fig. 2 Risk of bias. (**A**) Risk of bias summary; (**B**) Risk of bias graph

intervention in improving shoulder mobility. Compared to CPT alone, ESWT+CPT significantly improved pain intensity, physical function, and shoulder mobility; SSNB+CPT significantly improved pain intensity and shoulder mobility; CSI+CPT significantly improved the SPADI total score in patients with chronic shoulder pain, but showed no difference in pain intensity or shoulder mobility. HAI+CPT showed no significant difference in improving pain intensity, physical function, or shoulder mobility compared to CPT alone. The addition of KT to CPT had no significant effect on improving shoulder mobility.

Chronic shoulder pain is caused by diverse pathologies like tendon tears, tendinopathy, ligament instability, bursitis, and arthropathy, posing significant challenges for clinical management [17]. Effective management requires integrating multiple intervention methods, as comprehensive approaches often have more effective and longer-lasting effects than single treatments. CPT is a multimodal approach that includes exercise therapy, physical factor therapy, joint mobilization, massage therapy, and stretching [59]. Exercise is a central component of CPT and is strongly recommended as the initial approach for alleviating pain, enhancing mobility, and improving function in patients with subacromial shoulder pain [24, 60]. Based on surveys, in the rehabilitation of musculoskeletal shoulder issues, the following principles are commonly applied: patients are permitted to

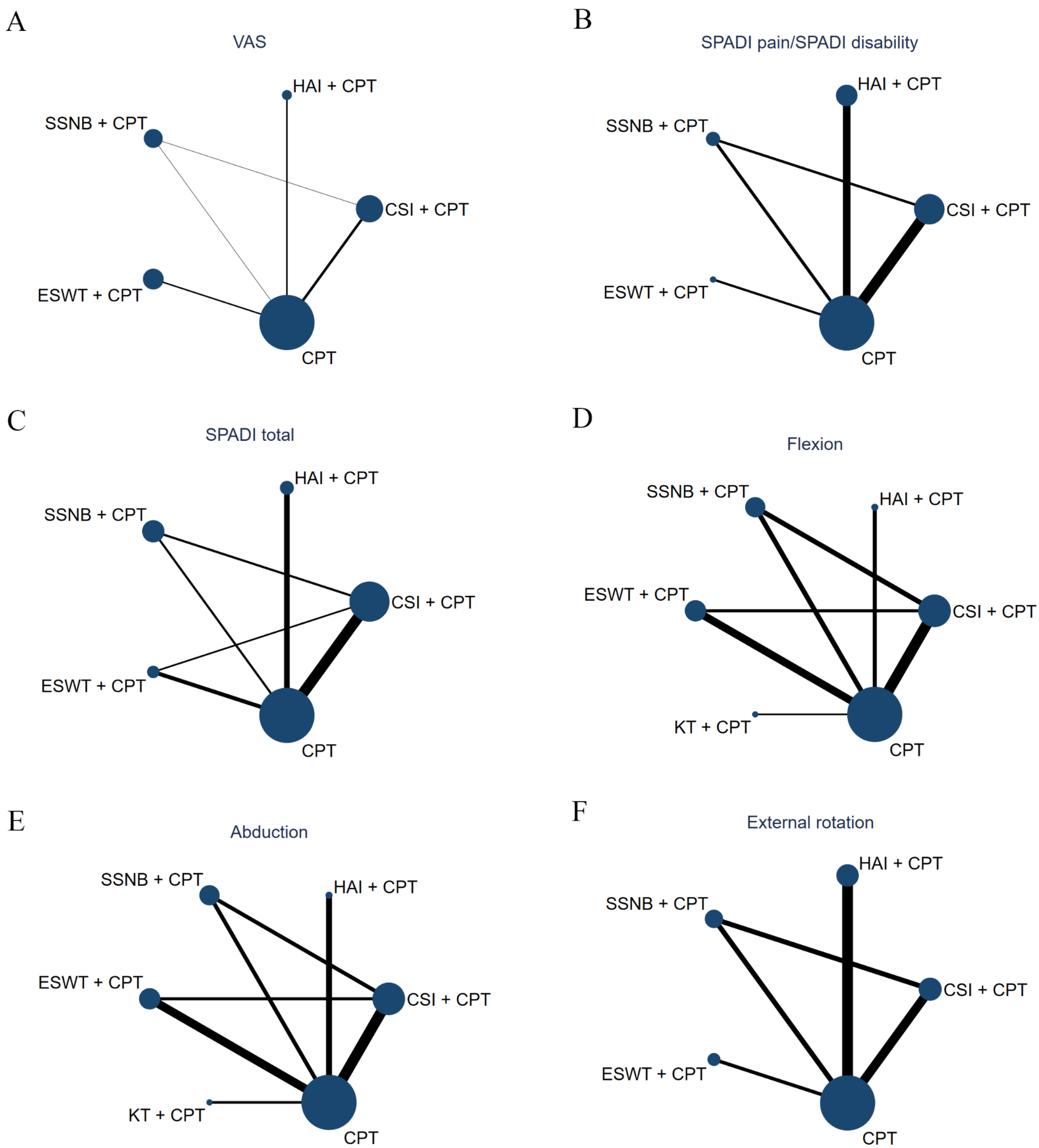

Fig. 3 The network plots. (**A**) VAS; (**B**) SPADI pain/SPADI disability; (**C**) SPADI total; (**D**) Flexion; (**E**) Abduction; (**F**) External rotation

experience mild discomfort (rated below 5/10 on a VAS) during exercise sessions, which should include some resistance. Further, the expected duration of exercise spans 12 weeks [61, 62]. However, exercise often causes discomfort and hinders patients from fully engaging in the rehabilitation program. Pain relief facilitates patients to engage CPT, consequently enhancing overall effectiveness. Consequently, the combined application of analgesic strategies and CPT is gaining popularity in the management of chronic shoulder pain.

We found that ESWT+CPT ranked highest in alleviating pain intensity and improving physical function compared to other interventions+CPT. The greater effectiveness of the combined approach can be attributed to the fact that physical therapists use ESWT before addressing biomechanical issues with CPT. CPT can increase subacromial space, enhance movement control,

A

VAS

CSI + CPT				
0.36 (-0.67,1.39)	**HAI + CPT**			
0.34 (-0.06,0.74)	**-0.02 (-1.00,0.96)**	**SSNB + CPT**		
0.84 (0.24,1.43)*	**0.48 (-0.48,1.44)**	**0.50 (-0.02,1.01)**	**ESWT + CPT**	
-0.22 (-0.73,0.28)	**-0.58 (-1.48,0.32)**	**-0.56 (-0.96,-0.16)***	**-1.06 (-1.40,-0.71)***	**CPT**

B

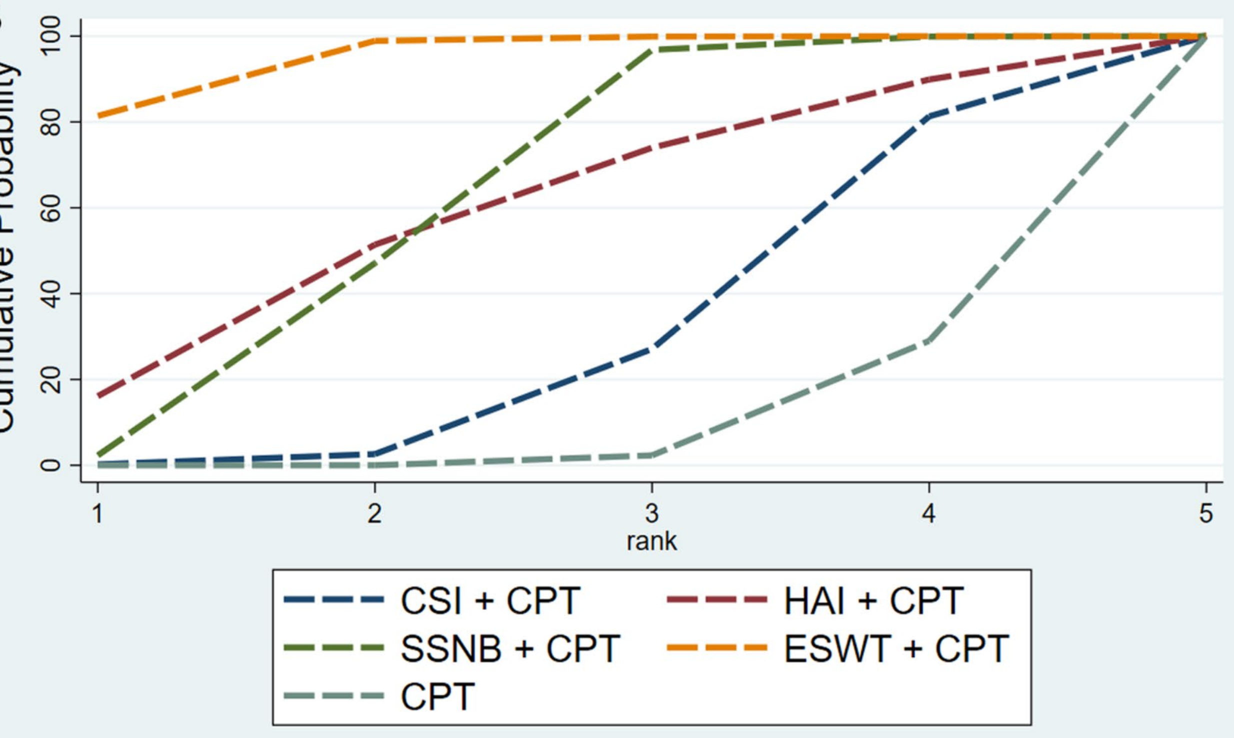

Fig. 4 Visual Analogue Scale score (VAS). (**A**) The league table of VAS. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD < 0 suggests that this intervention is more effective in reducing VAS score compared to other interventions. Data marked with an asterisk (*) indicates significant group differences (*P* < 0.05); (**B**) Cumulative probability line chart of VAS

restore normal scapulohumeral rhythm, improve proprioception, and ultimately improve shoulder joint function [22, 23]. Pain can restrict shoulder joint mobility by inducing arthrogenic muscle inhibition [63]. Therefore, preemptively addressing pain prior to initiating exercise programs can enhance effectiveness in reducing pain-related functional impairments over the short and medium-term [64]. There are two main hypotheses explaining the analgesic effect of ESWT. One of the mechanisms, known as the hyper-stimulation theory, suggests that ESWT induces the release of analgesic molecules by activating the descending inhibitory system, thereby alleviating pain [65]. Secondly, ESWT may lower the concentration of substance P levels in the target

A

SPADI pain

CSI + CPT				
-2.23 (-11.13,6.68)	HAI + CPT			
9.68 (3.12,16.25)*	11.91 (1.74,22.08)*	SSNB + CPT		
27.61 (19.32,35.90)*	29.84 (20.21,39.46)*	17.93 (8.30,27.56)*	ESWT + CPT	
-2.92 (-8.19,2.35)	-0.69 (-7.88,6.49)	-12.60 (-19.79,-5.41)*	-30.53 (-36.94,-24.12)*	CPT

B

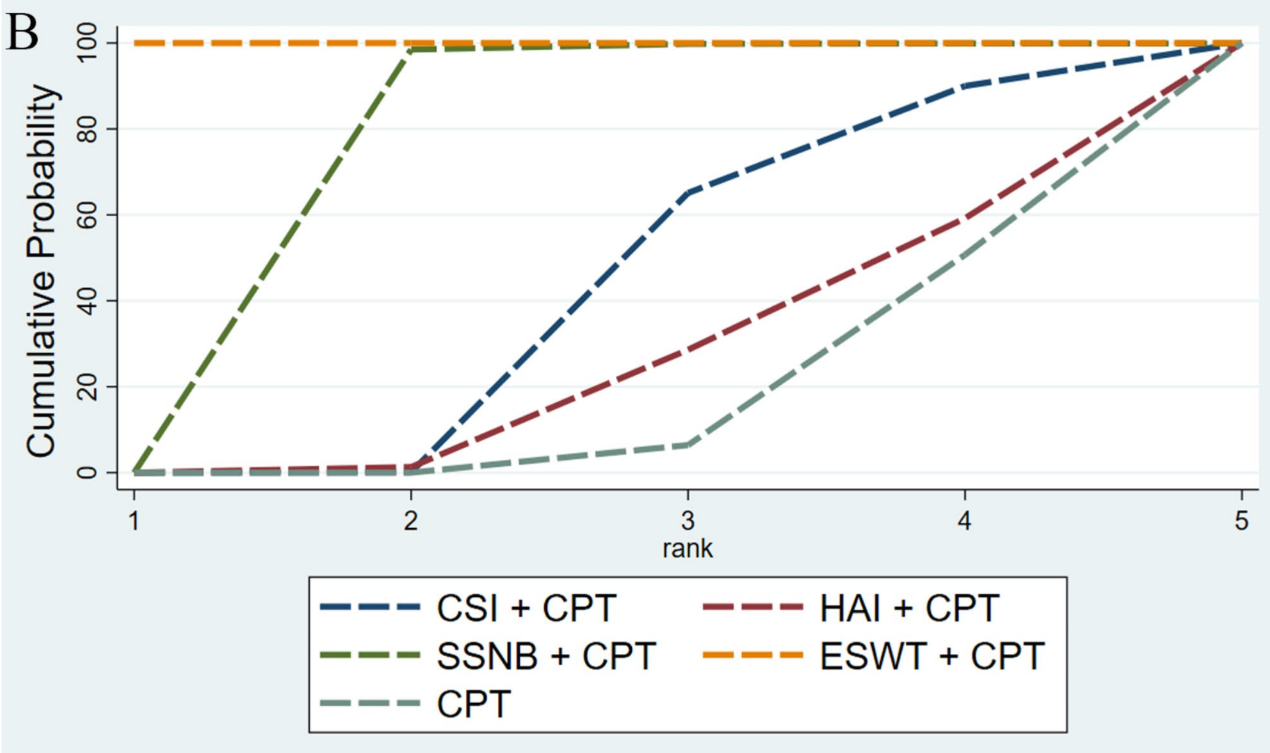

Fig. 5 SPADI pain. (**A**) The league table of SPADI pain. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD < 0 suggests that this intervention is more effective in reducing SPADI pain score compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of SPADI pain

tissue and dorsal root ganglia, thereby impairing the pain transmission to the brainstem. Furthermore, the interstitial and extracellular responses caused by the shock wave can produce multiple biological effects, including vascularization, protein biosynthesis, cell proliferation, neuroprotection, and chondroprotection [66]. These biological effects result in long-term improvements in pain and function. A recent RCT demonstrated that in patients with chronic shoulder pain, ESWT+exercise exhibited greater efficacy in reducing pain intensity compared to rehabilitation alone, which was consistent with our outcome [67].

Compared to CPT alone, SSNB+CPT significantly improved pain reduction and shoulder mobility, but no significant differences were observed in improving physical function. Recent research has shown that continuous SSNB combined with intensive rehabilitation is an effective treatment for patients with chronic

A

SPADI disability

CSI + CPT				
-5.49 (-23.55,12.57)	**HAI + CPT**			
1.45 (-15.05,17.95)	**6.94 (-14.90,28.78)**	**SSNB + CPT**		
18.38 (-2.39,39.15)	**23.87 (1.03,46.71)***	**16.93 (-7.21,41.07)**	**ESWT + CPT**	
-6.87 (-17.73,3.99)	**-1.38 (-15.81,13.05)**	**-8.32 (-24.73,8.09)**	**-25.25 (-42.96,-7.54)***	**CPT**

B

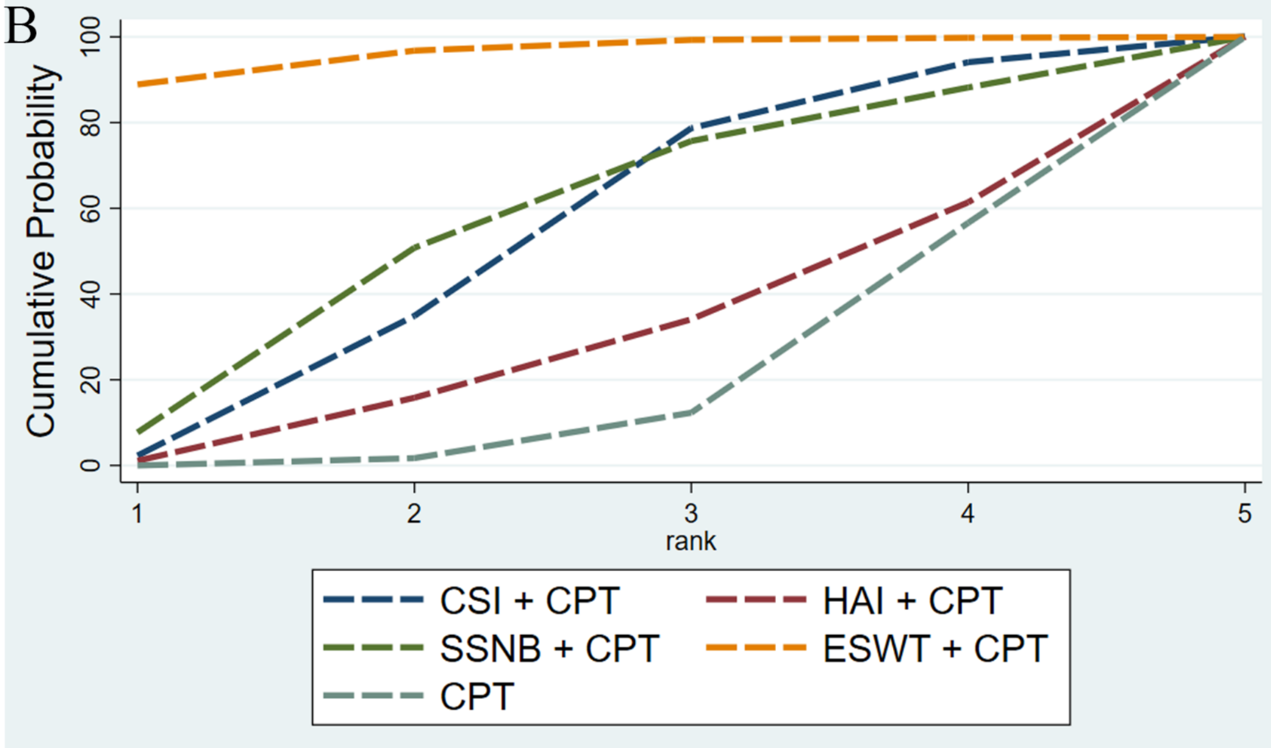

Fig. 6 SPADI disability. (**A**) The league table of SPADI disability. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD < 0 suggests that this intervention is more effective in reducing SPADI disability score compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of SPADI disability

adhesive capsulitis unresponsive to conventional therapies [68]. Parashar et al. also suggested that combining SSNB with non-invasive rehabilitation was more effective for treating idiopathic frozen shoulder than non-invasive rehabilitation alone, aligning with our findings [69].The suprascapular nerve supplies sensory fibers to around 70% of the shoulder joint and directly innervates the supraspinatus and infraspinatus muscles [70]. SSNB can alleviate pain and improve shoulder joint motion by blocking the suprascapular nerve [71]. Previous research on adhesive capsulitis showed that the effects of SSNB surpassed the pharmacological effects of anesthetics, potentially due to desensitization from reduced peripheral nociceptive input or decreased central sensitivity [72, 73]. In terms of improving physical function. researchers found that SSNB significantly improved disability scores

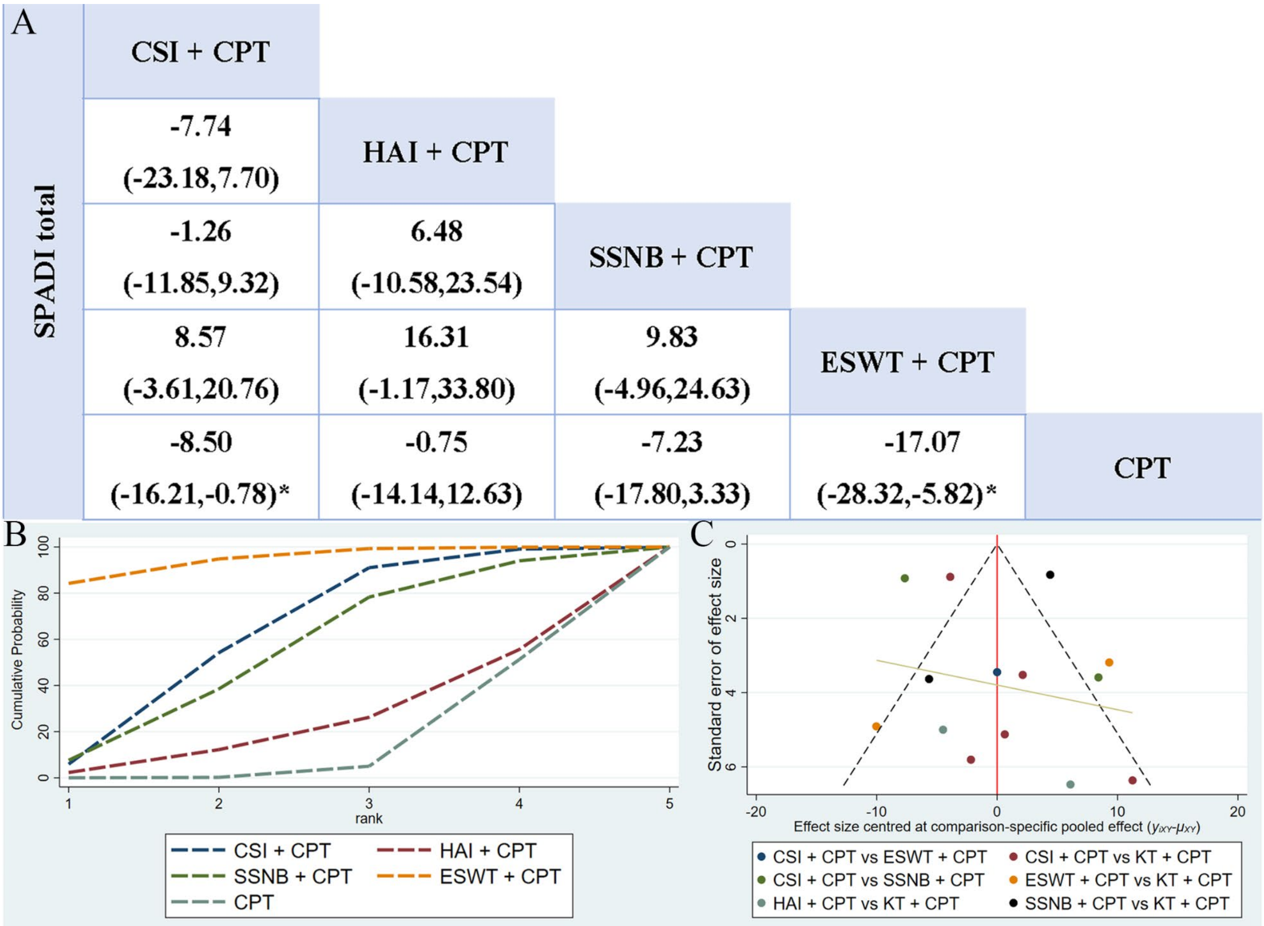

Fig. 7 SPADI total. (**A**) The league table of SPADI total. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD < 0 suggests that this intervention is more effective in reducing SPADI total score compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of SPADI total; (**C**) The funnel plots of SPADI total

in the treatment of chronic shoulder pain compared to placebo [72, 74, 75]. However, our study yielded an opposite result, possibly due to limited evidence from only one included study in the NMA. Thus, more studies are strongly required to confirm the efficacy of SSNB+CPT in improving physical function compared to CPT alone.

Compared to CPT alone, CSI+CPT significantly improved the SPADI total score in patients with chronic shoulder pain, but showed no difference in pain intensity or shoulder mobility. A prior study found that subacromial injection of betamethasone and xylocaine was no more effective than xylocaine alone in improving shoulder mobility or alleviating impingement signs in patients with chronic rotator cuff tendinosis, which was consistent with our finding [76]. More recently, a meta-analysis indicated that CSI provide only small and transient pain relief for a limited number of patients with rotator cuff tendinopathy, and do not alter the natural progression of the disease [77]. A systematic review reported that a single CSI in conjunction with home exercise may be beneficial for patients with frozen shoulder lasting less than 6 months [78]. Therefore, there is currently no conclusive evidence supporting the effectiveness of CSI in managing chronic shoulder pain. Given the potential side effects of CSI, such as the risk of tendon damage with repeated use, caution should be taken when combining with physical therapy [79].

In our NMA, we found that compared to CPT alone, HAI+CPT had no significant effect on improving pain intensity, physical function, or shoulder mobility in patients with chronic shoulder pain. HA, a non-sulfated glycosaminoglycan, is thought to protect tissues from environmental damage and to promote regeneration and repair in articular cartilage, synovial tissue, and synovial fluid [80]. A multicenter RCT found no significant difference between HAI and phosphate-buffered saline in treating chronic shoulder pain related to glenohumeral osteoarthritis, which was consistent with our finding

A

Flexion						
	CSI + CPT					
	2.34 (-22.71,27.39)	**HAI + CPT**				
	-7.76 (-21.41,5.89)	**-10.10 (-36.78,16.58)**	**SSNB + CPT**			
	-6.93 (-20.68,6.82)	**-9.27 (-34.83,16.30)**	**0.83 (-16.30,17.96)**	**ESWT + CPT**		
	6.14 (-15.76,28.04)	**3.80 (-26.26,33.86)**	**13.90 (-9.85,37.65)**	**13.07 (-9.42,35.56)**	**KT + CPT**	
	7.44 (-2.66,17.54)	**5.10 (-17.83,28.03)**	**15.20 (1.56,28.85)***	**14.37 (3.06,25.68)***	**1.30 (-18.14,20.74)**	**CPT**

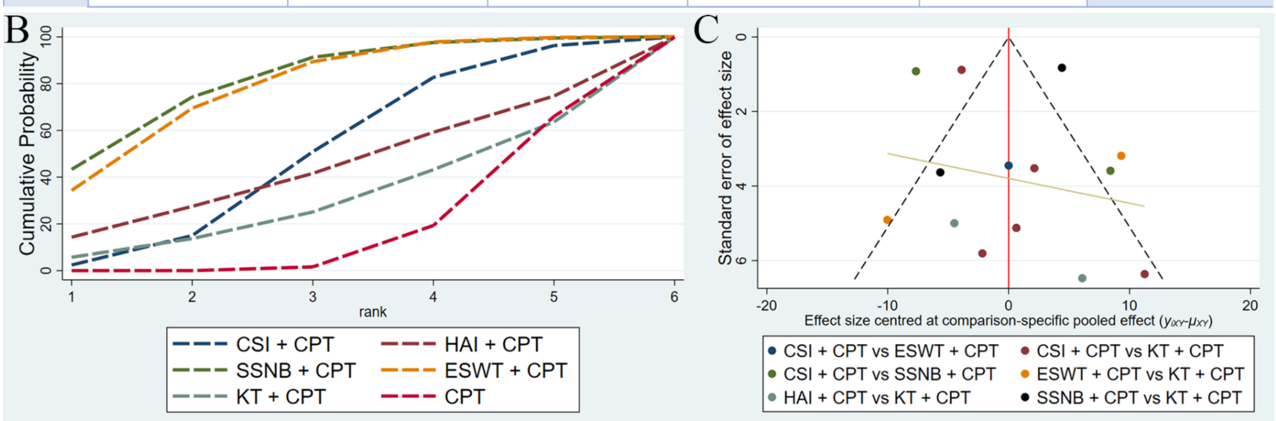

Fig. 8 Flexion. (**A**) The league table of flexion. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD > 0 suggests that this intervention is more effective in reducing flexion ROM compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of flexion; (**C**) The funnel plots of flexion

[81]. Similarly, in the management of chronic subacromial bursitis, a previous study also found no difference between the HAI group and the saline group in improving SPADI scores [82]. However, Blaine et al. found that HAI was both effective and well-tolerated in treating persistent shoulder pain that was unresponsive to other standard nonoperative interventions [83]. Jiménez et al. indicated that subacromial HAI was notably effective for patients with reduced subacromial space or cuff tears, but showed limited effectiveness in those with acromioclavicular osteoarthritis [84]. The evidence regarding the effectiveness of HAI for chronic shoulder pain is contradictory, highlighting the need for high-quality basic science studies and RCTs to better assess its efficacy.

Our analysis showed that for patients receiving CPT treatment, the combination of KT did not yield additional benefits in improving shoulder mobility. KT, an elastic therapeutic tape, is widely used for a variety of musculoskeletal disorders. Some researchers believed that KT could increase the non-noxious stimulus through the skin, thereby lessening the input of painful stimulus induced by complex pathogenic factors. KT is also considered to elevate fascia and soft tissues, creating additional space and reducing localized pressure, ultimately improving circulation and lymphatic drainage [35]. However, two prior systematic reviews indicated that current evidence does not recommend the application of KT in clinical practice [35, 85]. Likewise, a recent meta-analysis also suggested that KT for rotator cuff disease has uncertain efficacy in improving active ROM when compared to sham taping [86]. These evidence all aligned with our findings.

To the best of our knowledge, this is the first study to evaluate the therapeutic effects of five analgesic strategies combined with CPT for patients with chronic shoulder pain. As chronic shoulder pain requires multidisciplinary management, comparing these combined approaches is more in line with clinical practice. We performed a comprehensive ranking of ESWT+CPT, SSNB+CPT, CSI+CPT, HAI+CPT, and KT+CPT to identify the best combined approaches for improving pain intensity, physical function, and shoulder mobility in patients with chronic shoulder pain. There were still several limitations in this study. Firstly, our study

A

Abduction

CSI + CPT					
0.53 (-35.46,36.53)	**HAI + CPT**				
-13.29 (-30.55,3.97)	**-13.82 (-51.58,23.93)**	**SSNB + CPT**			
-7.84 (-25.78,10.10)	**-8.38 (-45.07,28.32)**	**5.45 (-16.60,27.49)**	**ESWT + CPT**		
2.23 (-27.34,31.81)	**1.70 (-41.07,44.47)**	**15.52 (-16.17,47.22)**	**10.08 (-20.35,40.50)**	**KT + CPT**	
8.73 (-4.31,21.78)	**8.20 (-25.34,41.74)**	**22.02 (4.70,39.35)***	**16.58 (1.69,31.46)***	**6.50 (-20.04,33.04)**	**CPT**

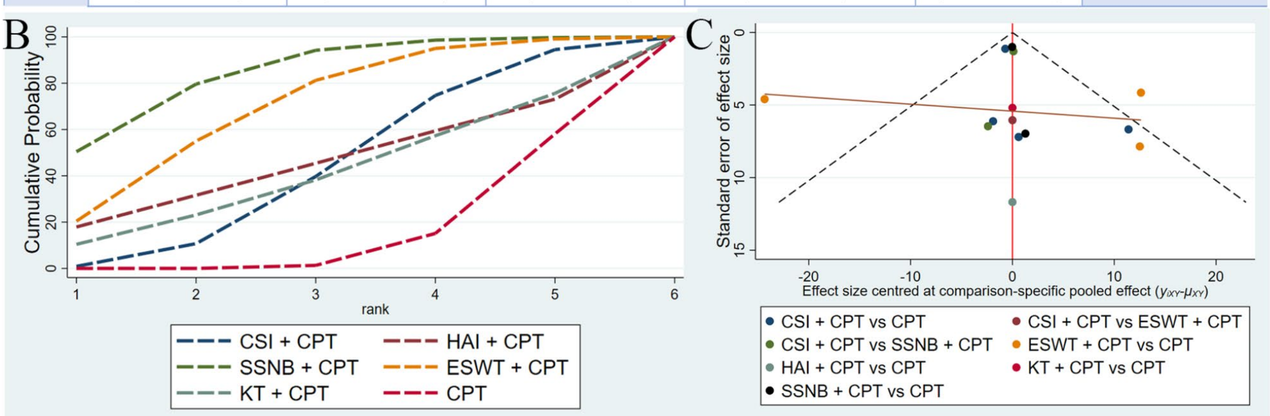

Fig. 9 Abduction. (**A**) The league table of abduction. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD > 0 suggests that this intervention is more effective in reducing abduction ROM compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of abduction; (**C**) The funnel plots of abduction

aims to compare interventions from a broad perspective, thus omitting detailed specific interventions such as CPT. Likewise, several factors such as injection site, injection dose, energy levels, and intervention durations are also ignored, possibly inducing some bias. Secondly, the methodological quality of these included studies is not high. Pain and functional improvement, as subjective indicators, may introduce bias in the results. Thirdly, we included only English-language papers, possibly leading to linguistic bias. Finally, the findings should be interpreted cautiously due to the limited number of clinical trials for head-to-head comparisons between these interventions.

Conclusion

Overall, in managing chronic shoulder pain, ESWT+CPT was the most effective intervention for reducing pain intensity and improving physical function. SSNB+CPT was optimal for enhancing shoulder mobility. Compared to CPT alone, CSI+CPT only significantly improved the SPADI total score, but showed no difference in pain intensity or shoulder mobility. HAI+CPT had no significant difference in improving pain intensity, physical function, or shoulder mobility compared to CPT alone. Adding KT to CPT did not yield additional benefits in improving shoulder mobility. Due to the existing limitations of this study, our findings should be interpreted cautiously. Future clinical trials with larger sample sizes and higher methodological rigor are strongly required to confirm the current results.

A

External rotation

CSI + CPT				
4.09 (-5.42,13.60)	HAI + CPT			
-11.32 (-19.67,-2.97)*	-15.41 (-25.74,-5.08)*	SSNB + CPT		
-7.30 (-18.35,3.74)	-11.39 (-21.48,-1.31)*	4.02 (-7.77,15.81)	ESWT + CPT	
5.16 (-2.22,12.53)	1.07 (-4.92,7.05)	16.48 (8.08,24.88)*	12.46 (4.32,20.60)*	CPT

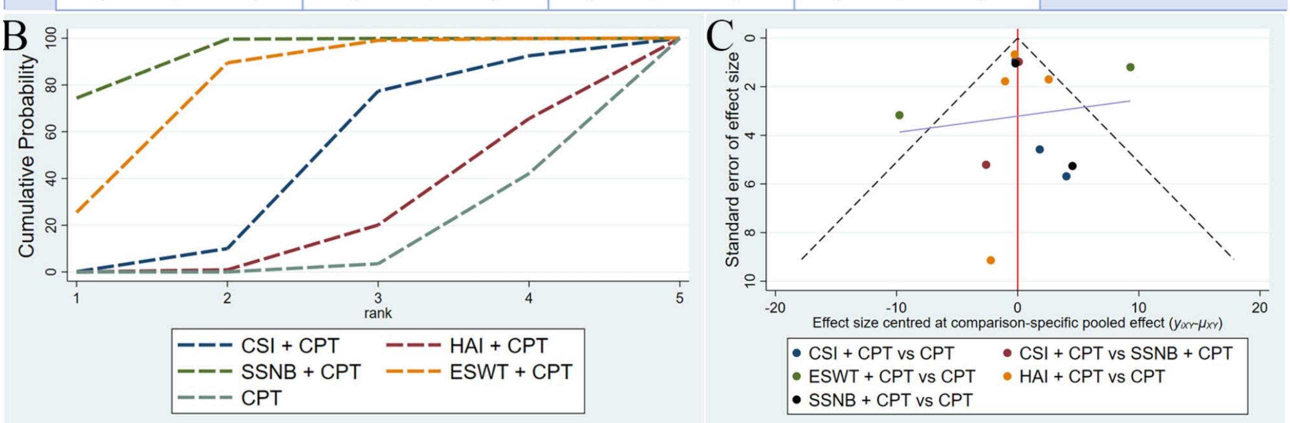

Fig. 10 External rotation. (**A**) The league table of external rotation. MD with a 95% CI was used to evaluate the effect size. The comparisons in the lower left triangle should be read in a left-to-right manner. MD > 0 suggests that this intervention is more effective in reducing external rotation ROM compared to other interventions. Data marked with an asterisk (*) indicates significant group differences ($P < 0.05$); (**B**) Cumulative probability line chart of external rotation; (**C**) The funnel plots of external rotation

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Acknowledgements
Not applicable.

Author contributions
All authors contributed to the study conception. Yasu Zhang and Qian Gao designed the search strategies. Fangjie Yang and Mengyang Pan screened eligible studies. Xinmin Li and Jing Wang collected and summarized the data. Fangjie Yang, Zhenfei Duan, Chunlin Ren, and Pengxue Guo analyzed the data. Fangjie Yang and Xinmin Li wrote initial draft of the manuscript. All authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Ethical Approval and Consent to participate are not applicable. The study protocol was registered at PROSPERO (CRD 42024519473).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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