

Review Article

Efficacy and safety of kinesiology tape for hemiplegic shoulder pain: A systematic review and meta-analysis of randomized controlled trials

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Abstract.

OBJECTIVE: The aim of this study was to examine the efficacy and safety of kinesiology tape in treating hemiplegic shoulder pain.

METHODS: Web of Science, MEDLINE, Embase, Cochrane Library, six other English databases and three Chinese databases (CNKI, VIP, Wan Fang) were searched for randomized controlled trials published prior to December 13, 2020 in English or Chinese on the use of kinesiology tape for hemiplegic shoulder pain.

RESULTS: Fourteen randomized controlled trials (679 patients) of good PEDro quality (6.43 ± 1.09) were included in this meta-analysis. The pooled results for pain (SMD -0.92 , 95% CI -1.10 to -0.74 , $P < 0.001$, 10 RCTs, 539 patients), range of motion (SMD 2.27 , 95% CI 1.23 to 3.32 , $P < 0.001$, 7 studies, 320 patients), the acromion humeral distance (SMD -0.62 , 95% CI -0.88 to -0.37 , $P < 0.001$, 7 RCTs, 246 patients) and the FMA-UE score (SMD 0.66 , 95% CI 0.41 to 0.91 , $P < 0.001$, 5 RCTs, 263 patients) suggested that therapeutic kinesiology tape relieved pain, increased ROM, shortened the acromion humeral distance and improved upper extremity motor function to a greater extent than the sham or blank control conditions. The pooled results for individual activity (SMD 0.42 , 95% CI -0.22 to 1.07 , $P = 0.199$, 5 RCTs, 199 patients) and quality of life (SMD 0.308 , 95% CI -0.288 to 0.903 , $P = 0.311$, 1 RCT, 44 patients) showed that the kinesiology tape group was not significantly different from the sham or blank control group. Publication bias was not observed. No adverse events were reported in any of the included studies.

CONCLUSION: KT relieved pain and improved the ROM, DAH and FMA-UE score in patients with HSP to a greater extent than did the sham KT or blank control conditions. The effects on independence in activities of daily living and quality of life and whether this method is superior to active treatment in patients with HSP were not verified. More rigorous, reasonably designed RCTs with large sample sizes are still needed in the future.

Keywords: Systematic review, meta-analysis, kinesiology tape, hemiplegic shoulder pain, randomized controlled trials

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1. Introduction

Hemiplegic shoulder pain (HSP) is a common complication that occurs in a significant proportion of stroke patients. Nadler et al. reported that 17% of surviving stroke patients developed shoulder pain within the first week and 22–40% developed it within the first 4–6 months [1]. In the general population, the prevalence of HSP ranges from 6.9% to 26% for point prevalence and up to 66.7% for lifetime prevalence. Differences in inclusion criteria and measurement approaches across previous studies may be causes of these wide ranges of incidence rates of HSP [2]. HSP can hinder an individual's ability to perform muscle contractions and use the limb [3]. In addition, HSP makes it difficult for individuals to exercise, slows motor function recovery and delays the rehabilitation process [4]. Decreasing athletic ability due to HSP can influence individuals' ability to perform activities of daily living and limit social participation [5]. The precise etiology of HSP is not very clear. Some studies have reported that it might involve both peripheral and central neuropathic mechanisms [2,6], while others have reported that is associated with altered somatosensory function and reduced cognitive-evaluative cortical somatosensory processing [6–8]. Currently, a common view is that rotator cuff injuries, subluxation of the humeral head, motor weakness, and spasticity are the primary contributors to poststroke HSP [9]. Despite the limited understanding of the etiology of HSP, various treatments, such as neuromuscular electrical stimulation (NMES), acupuncture, strapping, sling, handling, shoulder positioning, massage and pharmacological therapy, have been studied for the treatment of HSP over the past few decades [10]. Nevertheless, none of these treatments have been shown to have significant efficacy or strong supporting evidence [11].

Kinesiology tape (KT) is a common tool used in sports and rehabilitation [12]. Because hypotonicity in the early stages of stroke is an initiating factor for HSP, KT is usually used as a therapeutic tool for HSP to support the shoulder muscles [13,14]. A systematic review with a large sample size confirmed there is an association between shoulder subluxation and HSP [15]. Although KT can relieve pain and improve shoulder motor function [16], there is still no conclusive evidence to support the routine application of KT for HSP [2]. Thus, we conducted a systematic review and meta-analysis to examine the efficacy and safety of KT for HSP.

2. Methods

2.1. Search strategy

Electronic databases (Web of Science, MEDLINE, Embase, Cochrane Library, Wiley, Springer, Sciences Direct, Karger, PEDro, Scopus and CNKI, VIP, Wan Fang) were searched for articles published prior to December 13, 2020. The search terms were based on the PICOS principle (in Web of Science): (“Stroke” OR “shoulder pain” OR “hemiplegic shoulder pain” OR “shoulder subluxation” OR “shoulder-hand syndrome” OR “hand-shoulder syndrome” OR “hemiplegic hand”) AND (“Kinesio Taping” OR “kinesio tex tape” OR “Kinesiology tape” OR “Kinesio Tape” OR “Kinesiology Taping” OR “kinesio tex taping” OR “kinesiological taping” OR “Functional Fascial Taping” OR “Shoulder taping” OR “strapping”) AND (“placebo control” OR “bank control” OR “rehabilitation” OR “conventional treatment”) AND (“randomized controlled trials” OR “RCT” OR “randomized trials” OR “controlled trials”) in the title or abstract. The keywords were modified for the other databases (Supplementary Table 1). In addition, the reference lists of the retrieved articles were manually searched and reviewed. If discrepancies occurred, a consensus was reached through consultation. The searches were limited to studies published in English or Chinese.

2.2. Selection criteria

Study eligibility was determined independently by two authors (LLX and ZY) according to the following criteria. (1) For the participants, all of the participants had been diagnosed with ischemic or hemorrhagic stroke by computerized tomography or magnetic resonance imaging and were clinically confirmed to have HSP. (2) For the interventions and comparisons, the KT technique was used in the treatment groups, and a sham KT or blank control group was included. (3) For the outcomes, the primary outcome in the study was pain, as assessed by the visual analog scale (VAS) and the numerical pain rating scale (NPRS). The secondary outcomes included the range of motion (ROM), acromion humeral distance (AHD, distance from the lower margin of the acromion to the head of the humerus), Fugl-Meyer assessment for upper extremities (FMA-UE) score, individual activity (IA, as assessed by the Barthel index (BI), modified Barthel index (MBI), Shoulder Pain and Disability Index (SPADI), and Action Research Arm Test (ARAT)), quality of life (QOL) and

adverse events (AE). (4) For the study design, all the only randomized controlled trials (RCTs) that were in English or Chinese and aimed to investigate the efficacy and safety of KT were included. The exclusion criteria were as follows: (1) for the patients, the trial included patients with other conditions leading to hemiplegia (e.g., head injury, shoulder subluxation); (2) for the interventions, the trial administered complex treatment without specifying the sole effects of KT; (3) for the outcomes, the required data for this study were unavailable; and (4) for the design, the study was not an RCT. Disagreements were resolved by two authors (LLX and ZY) through discussion and consultation when necessary. A flowchart of the search process for this review was created in accordance with the 2009 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17].

2.3. Data extraction

Information on the following items was extracted from the included studies: first author, publication year, study period, age, sex, stroke duration, KT and control treatment protocols and measurement data. Based on the International Classification of Functioning, Disability and Health model (ICF) methods, data for the following four domains were extracted for this review: structure and function (pain, ROM, AHD, FMA-UE score), individual activities (MBI, SPADI, ARAT), social participation (QOL) and AEs. If the data sets overlapped or were duplicated, the articles with more information were retained. Disagreements were settled by discussion and consensus between the two authors (LLX and ZY).

2.4. Quality assessment

The methodological quality of all eligible RCTs was assessed independently by the two reviewers (LLX and ZY) using the Physiotherapy Evidence Database Scale (PEDro) [18]. The PEDro scale has been shown to have good interpretability and internal and external validity and contains 11 dichotomous (yes or no) items on the eligibility criteria, random allocation, concealment of allocation, group similarity at baseline, blinding of the therapists, blinding of the assessors, availability of key outcome measures of more than 85% of the subjects, intention-to-treat analysis, between-group statistical comparisons, and point measures and measures of variability. One point is awarded when a criterion is satisfied, and the maximum score is 10 points. Studies with scores of 9–10 points were considered to have

‘excellent’ quality, those with scores of 6–8 were of ‘good’ quality, those with scores of 4–5 were of ‘fair’ quality, and those with scores of less than 4 were of ‘poor’ quality. We considered RCTs with a score of ≥ 6 in this review, which typically represents a high-quality study [19]. The included RCTs were identified in the PEDro database (www.pedro.org.au) first and then manually scored if they were not found in the database. Any discrepancies in the ratings were resolved through discussion between two reviewers (LLX and ZY).

2.5. Statistical analysis

The effect size of the continuous data was expressed as the standard mean difference (SMD) and 95% confidence interval (CI). The mean difference (MD) and pooled standard deviation (SD) were calculated based on the methods [20]. $MD = (\text{mean posttreatment} - \text{mean pretreatment})$, $\text{pooled } SD = \sqrt{S_C^2}$, $S_C^2 = [(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2] / (n_1 + n_2 - 2)$, ($n_1 =$ sample size pretreatment; $n_2 =$ sample size posttreatment; $S_1 =$ SD pretreatment; $S_2 =$ SD posttreatment). The I^2 statistic was used to assess the level of statistical heterogeneity among the included studies; $P < 0.10$ and $I^2 > 50\%$ represented substantial heterogeneity [21]. The type of heterogeneity that existed was explained by using the following statistical methods: (1) sensitivity analysis; (2) subgroup analysis and meta-regression; and (3) a random-effects model using the DerSimonian-Laird method [22]. Publication bias was assessed with (1) funnel plots, (2) Begg’s test/Egger’s test, (3) a trim-and-fill adjusted analysis, and (4) the fail-safe number (N_{fs}) when necessary. The statistical analysis was executed by using a special edition of statistics and data science software (Stata SE, V.12.0; Stata Corp LP, College Station, TX, USA).

3. Results

3.1. Study selection and characteristics

A total of 272 relevant references were initially retrieved. After the titles, abstracts and full texts were screened carefully, 14 studies [23–36] with 679 patients were ultimately included in the meta-analysis. A flowchart of the search process is shown in Fig. 1. The included trials were published from 2013 to 2020. Therapeutic KT was used in the experimental groups, and either sham KT or conventional rehabilitation methods such as exercise therapy and electrotherapy (blank control group) were performed in the control groups.

Table 1
Methodological quality of the included studies. (PEDro)

ID	Author	1	2	3	4	5	6	7	8	9	10	11	Scores
[23]	Gabriela Lopes Dos Santos (2019)	Yes	1	1	1	0	0	1	1	1	1	1	8
[24]	Lin Yang (2018)	Yes	1	0	1	1	0	1	1	0	1	1	7
[25]	Yen-Chang Huang (2017)	Yes	1	0	1	1	0	1	1	0	1	1	7
[26]	Anja Hochsprung (2017)	Yes	1	0	1	0	0	1	0	0	0	1	4
[27]	Yu-Chi Huang (2016)	Yes	1	0	1	1	0	1	1	0	1	1	7
[28]	Subhasish Chatterjee (2016)	Yes	1	0	1	0	0	1	1	1	1	1	7
[29]	Paolo Pillastrini (2016)	Yes	1	1	1	0	0	1	1	1	1	1	8
[30]	Min-Yeong Heo (2015)	Yes	1	0	1	0	0	1	1	1	1	1	7
[31]	Jeyaraj D Pandian (2013)	Yes	1	1	0	0	0	1	0	1	1	0	5
[32]	Deng-Yao Li (2013)	Yes	1	0	1	0	0	1	1	0	1	1	6
[33]	Wen-Yu Zhu (2019)	Yes	1	0	1	0	0	1	1	0	1	1	6
[34]	Fang Wang (2018)	Yes	1	0	1	0	0	1	1	0	1	1	6
[35]	Bo-Han Shi (2018)	Yes	1	0	1	0	0	1	1	0	1	1	6
[36]	Li-Sheng Zhao (2017)	Yes	1	0	1	1	0	0	1	0	1	1	6

Notes: 1, Eligibility criteria; (the item does not contribute to total score, *This score has been confirmed*) 2, Random allocation; 3, Concealed allocation; 4, Baseline comparability; 5, Blind subjects; 6, Blind therapists; 7, Blind assessors; 8, Adequate follow-up; 9, Intention-to-treat analysis; 10, Between-group comparisons; 11, Point estimates and variability.

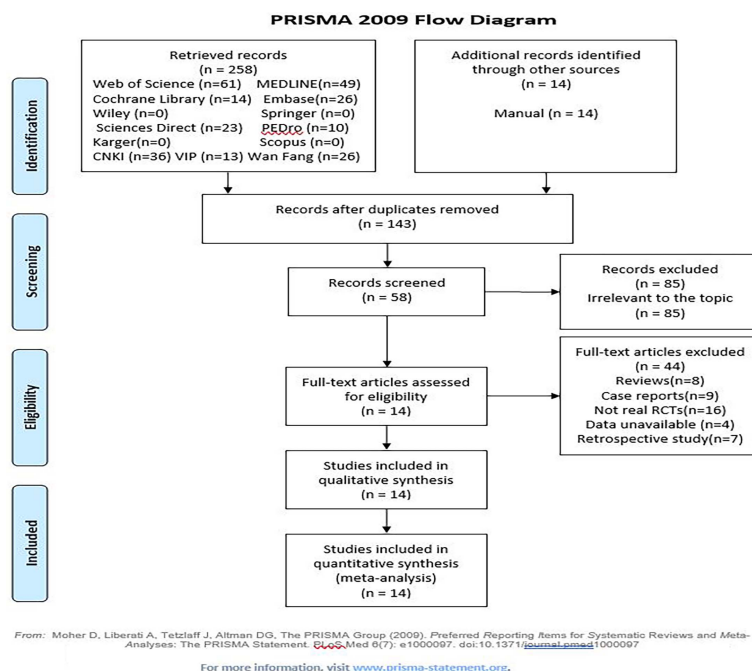


Fig. 1.

Among the included RCTs, the KT protocols differed substantially from each other. The tape remained in place from 15 minutes to 3 days, and the treatment duration ranged from 3 days to 8 weeks. The tape (5 cm width) was cut into a Y shape, X shape, or W shape or was not cut (I shape) and stretched with a tension of 10%–100% over the following four muscles: the supraspinatus, deltoid, brachii and trapezius. The sham tapes were applied at the same place with no tension. The conventional rehabilitation methods included phys-

ical therapy (passive and active assistance and active exercises), occupational therapy and electrotherapy. The outcomes included (1) pain (11 studies); (2) ROM (7 studies); (3) AHD (7 studies); (4) the FMA-UE score (7 studies); (5) IA (5 studies); (6) QOL (1 study); and (7) AE (0 studies). The characteristics of the included studies are detailed in Table 1. Based on the PEDro scale of bias tool, 12 studies had “good” methodological quality (6–8 scores). The quality assessment results are summarized in Table 2.

Table 2
Characteristics of the included studies

Study ID first author (year)	Patients (E/C)	Intervention	Comparison	Outcomes	Study design
[23] Gabriela Lopes Dos Santos (2019)	Cases: 13 (6/7) Age: 40–75 Stroke Duration: > 6 months	E: Muscles: deltoid Width: 5 cm Shape: NR Tension: 10%–15% Time/Frequency: 3 D, taping 3 days C: Blank control	E: True KT+CT C: Sham KT+CT	ROM	RCT
[24] Lin Yang (2018)	Cases: 19 (10/9) Age: 60 ± 2.3/ 59 ± 3.2 Stroke Duration: > 1 month, < 6 months	E: Muscles: Supraspinatus, deltoid, teres minor, biceps Width: 5 cm Shape: I shape Tension: First 4 cm: no tension, the rest: 15%–50% Time/Frequency: 10–12 h/Day C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	NPRS, ROM, ADH	RCT
[25] Yen-Chang Huang (2017)	Cases: 21 (11/10) Age: 59 ± 13/ 56 ± 13 Stroke Duration: < 6 months	E: Muscles: Supraspinatus, deltoid, biceps Width: 5 cm Shape: I shape Tension: 15%–75% Time/Frequency: Taping 3 days without 1 day C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	NPRS, ROM, SPADI	RCT
[26] Anja Hochsprung (2017)	Cases: 14 (7/7) Age: 63.71 ± 6.10/ 63 ± 11.63 Stroke Duration: < 24 hours	E: Muscles: deltoid Width: 5 cm Shape: I shape Tension: 10%–100% Time/Frequency: 4 W, taping 6 days without 1 day C: Sham KT Time: 10 minutes The other parameters were same with E group	E: True KT+CT C: Blank+CT	VAS, BI, BBS, ARAT	RCT
[27] Yu-Chi Huang (2016)	Cases: 44 (21/23) Age: 60.4 ± 11.8/ 62.2 ± 9.6 Stroke Duration: < 3 months	E: Muscles: Supraspinatus, deltoid Width: NR Shape: I shape Tension: 20%–30% Time/Frequency: Taping 3 days without 1 day C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	VAS, ROM, ADH, FMA-UE, MBI, SS-QOL	RCT
[28] Subhasish Chatterjee (2016)	Cases: 30 (15/15) Age: 63.20/62.80 Stroke Duration: acute stroke	E: Muscles: deltoid Width: NR Shape: NR Tension: NR Time/Frequency: 6 W, 3 days a week C: Blank control	E: True KT+CT C: Blank+CT	VAS, ROM, ADH, FMA-UE	RCT
[29] Paolo Pillastrini (2016)	Cases: 31 (16/15) Age: 66 ± 8.0/ 66 ± 11.0 Stroke Duration: > 2.9 year	E: Muscles: supraspinatus, deltoid, pectoralis major Width: 5 cm Shape: W-shape; Y-shape Tension: NR Time/Frequency: 15 minutes, 4 W, once a week C: Blank control	E: True KT+CT C: Blank+CT	VAS, ROM, MAS	RCT
[30] Min-Yeong Heo (2015)	Cases: 36 (18/18) Age: 57.1 ± 10.6/ 60.3 ± 10.4 Stroke Duration: acute stroke	E: Muscles: supraspinatus, pectoralis Width: NR Shape: NR Tension: NR Time/Frequency: 8 W C: Blank control	E: True KT+CT C: Blank+CT	VAS, ADH	RCT

Table 2, continued

Study ID first author (year)	Patients (E/C)	Intervention	Comparison	Outcomes	Study design
[31] Jeyaraj D Pandian (2013)	Cases: 162 (80/82) Age: 59 ± 13/ 60 ± 13 Stroke Duration: < 48 hours	E: Muscles: NR Width: NR Shape: NR Tension: NR Time/Frequency: NR C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	VAS, ROM, SPADI	RCT
[32] Deng-Yao Li (2020)	Cases: 60 (30/30) Age: 65.5 ± 4.92/ 65.5 ± 4.92 Stroke Duration: < 1 month	E: Muscles: supraspinatus, deltoid, trapezius Width: 5 cm Shape: Y shape; I shape Tension: 10%–50% Time/Frequency: 5 days a week for 4 weeks C: Blank control	E: True KT+CT C: Blank+CT	VAS, FMA-UE, MBI	RCT
[33] Wen-Yu Zhu (2019)	Cases: 93 (47/46) Age: 62.43 ± 4.15/ 61.25 ± 2.44 Stroke Duration: < 1 month	E: Muscles: supraspinatus, deltoid, trapezius Width: 5 cm Shape: X shape; I shape Tension: 10%–50% Time/Frequency: 24 hours, 5 per week for 3 weeks C: Blank control	E: True KT+CT C: Blank+CT	VAS, FMA-UE	RCT
[34] Fang Wang (2018)	Cases: 60 (30/30) Age: 50.93 ± 7.04/ 56.56 ± 7.3 Stroke Duration: NR	E: Muscles: supraspinatus, deltoid, biceps, trapezius Width: 5 cm Shape: I shape; Y shape; X shape Tension: 10%–30% Time/Frequency: 3 days, 8 sessions in 4 weeks C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	VAS, FMA-UE, MBI	RCT
[35] Bohan Shi (2018)	Cases: 56 (28/28) Age: 65.62 ± 11.87/ 64.76 ± 8.87 Stroke Duration: < 2 months	E: Muscles: supraspinatus, deltoid Width: NR Shape: X shape; I shape Tension: NR Time/Frequency: 2 days/session, 7 sessions with a day rest, for 6 weeks C: Blank control	E: True KT+CT C: Blank+CT	VAS, ADH, FMA-UE	RCT
[36] Li-Sheng Zhao (2017)	Cases: 40 (20/20) Age: 66.45 ± 9.57/ 68.45 ± 8.99 Stroke Duration: < 3 weeks	E: Muscles: supraspinatus, deltoid, trapezius, Width: 5 cm Shape: I shape Tension: 25%–30% Time/Frequency: NR C: Sham KT Tension: neutral The other parameters were same with E group	E: True KT+CT C: Sham KT+CT	ADH, FMA-UE	RCT

AHD: Acromion humeral distance; ARAT: Action Research Arm Test (0–57); BBS: Berg Balance Scale (0–56); BI: Barthel Index (0–100); C: Control group; CT: Conventional treatment; D: Day; E: Experimental group; FMA-UE: Fugl-Meyer assessment for upper extremity (0–66); KT: Kinesiology tape; MAS: Modified Ashworth Scale (0–4); MBI: Modified Bathel Index (0–100); NMES: Neuromuscular electrical stimulation; NPRS: Numerical pain rating scale (0–10); NR: No report; RCT: Randomized controlled trials; ROM: Range of motion; SPADI: Shoulder Pain and Disability Index (0–100); SS-QoL: Stroke-Specific Quality of Life (49–245); VAS: Visual analogue scale (0–10); W: Week.

4. Synthesis of results

4.1. Effect size of pain

Pain data assessed with VAS and NPRS were merged due to the high correlation [37]. The pooled effect size of pain (11 RCTs [24–34], 570 patients) showed significant heterogeneity ($I^2 = 81.3\%$, $P < 0.001$), which disappeared after excluding 1 study [29] (SMD -6.50 ,

95% CI -8.32 to -4.69) via sensitivity analysis ($I^2 = 48.5\%$, $P = 0.042$). Then, a fixed effect model was used, and the results showed that KT relieved pain in patients with HSP compared to the sham KT or blank control subgroup (SMD -0.92 , 95% CI -1.10 to -0.74 , $P < 0.001$, 10 RCTs, 539 patients), the forest plot is shown in Fig. 2A, and detailed information is available in Supplementary Table 2. The subgroup analysis showed that KT therapy was effective in reducing pain

compared to sham KT or blank control, and there were no differences between the two subgroups (Sham KT: SMD -0.82 , 95% CI -1.06 to -0.59 , $P < 0.001$, 5 RCTs, 306 patients; Blank control: SMD -1.05 , 95% CI -1.33 to -0.77 , $P < 0.001$, 5 RCTs, 233 patients, respectively). A further publication bias analysis was performed. The funnel plot was visually symmetrical (Fig. 3A) and suggested that no obvious publication bias existed, which was also verified by Begg's and Egger's tests ($P = 0.474$, $P = 0.689$, respectively, detailed in Supplementary Table 3).

4.2. Effect size of ROM

The effect size of ROM (7 studies, 320 patients) [23–25,27–29,31] was pooled with a random model and yielded positive results with significant heterogeneity ($I^2 = 90.0\%$, $P < 0.001$, SMD 2.27, 95% CI 1.23 to 3.32, $P < 0.001$). The forest plot of ROM suggested that KT improved the range of motion of the shoulder joint for HSP (Fig. 2B, more information in Supplementary Table 2). Subgroup analyses showed that there was no difference between the KT and blank control groups (SMD 4.01, 95% CI -2.01 to 10.04, $P = 0.192$; $I^2 = 96.9\%$; $P < 0.001$; 2 studies, 61 patients) in improving shoulder ROM in patients with HSP. In the analysis of publication bias analysis, the funnel plot was visually symmetrical (Fig. 3B) and confirmed by Begg's and Egger's tests ($P = 1.000$ and $P = 0.996$, respectively, Supplementary Table 3).

4.3. Effect size of AHD

The pooled effect size of AHD (7 RCTs, 246 patients, with fixed model) [24,25,27,28,30,35,36] showed that the KT reduced the distance from the acromion to the humeral head and prevented subluxation of the shoulder joint in patients with HSP without significant heterogeneity ($I^2 = 23.1\%$, $P = 0.253$, SMD -0.62 , 95% CI -0.88 to -0.37 , $P < 0.001$). The subgroup analysis suggested that KT reduced the AHD compared with sham KT or blank control (SMD -0.66 , 95% CI -1.03 to -0.29 , $P < 0.001$, 4 RCTs, 124 patients; SMD -0.59 , 95% CI -0.95 to -0.22 , $P = 0.002$, 3 RCTs, 122 patients, respectively). The forest plot of AHD is shown in Fig. 2C, and more information is detailed in Supplementary Table 2. In turn, publication bias analyses were conducted, and the funnel plot was first visually symmetrical (Fig. 3C). Then, Begg's and Egger's tests were performed, and no publication bias was observed ($P = 0.548$ and $P = 0.149$, respectively, Supplementary Table 3).

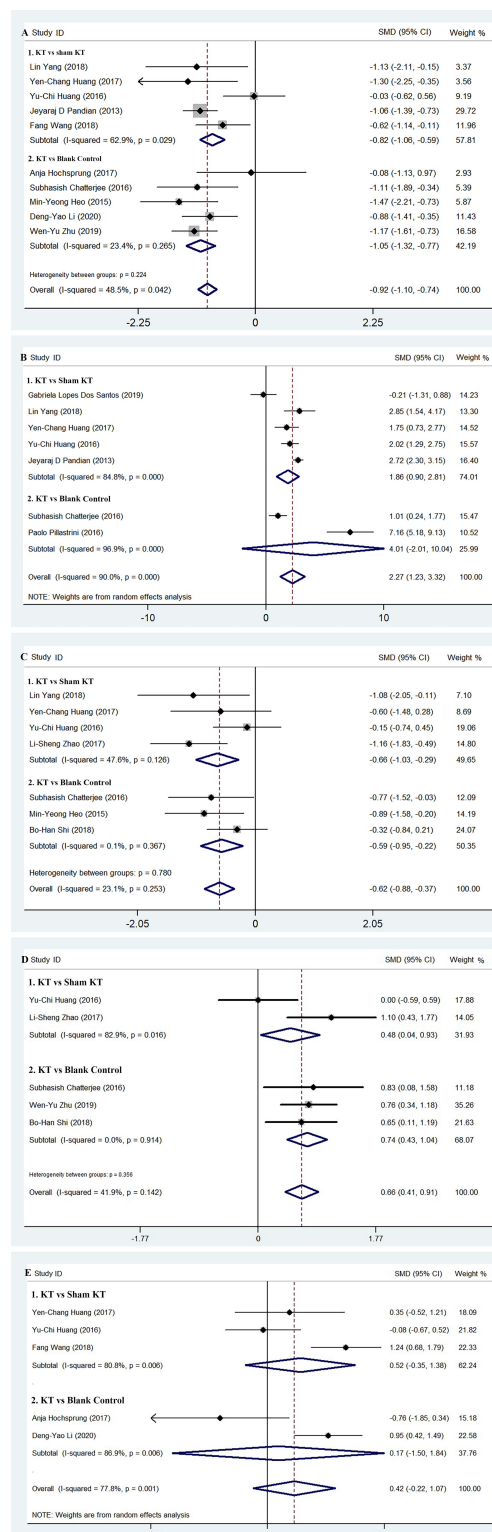


Fig. 2.

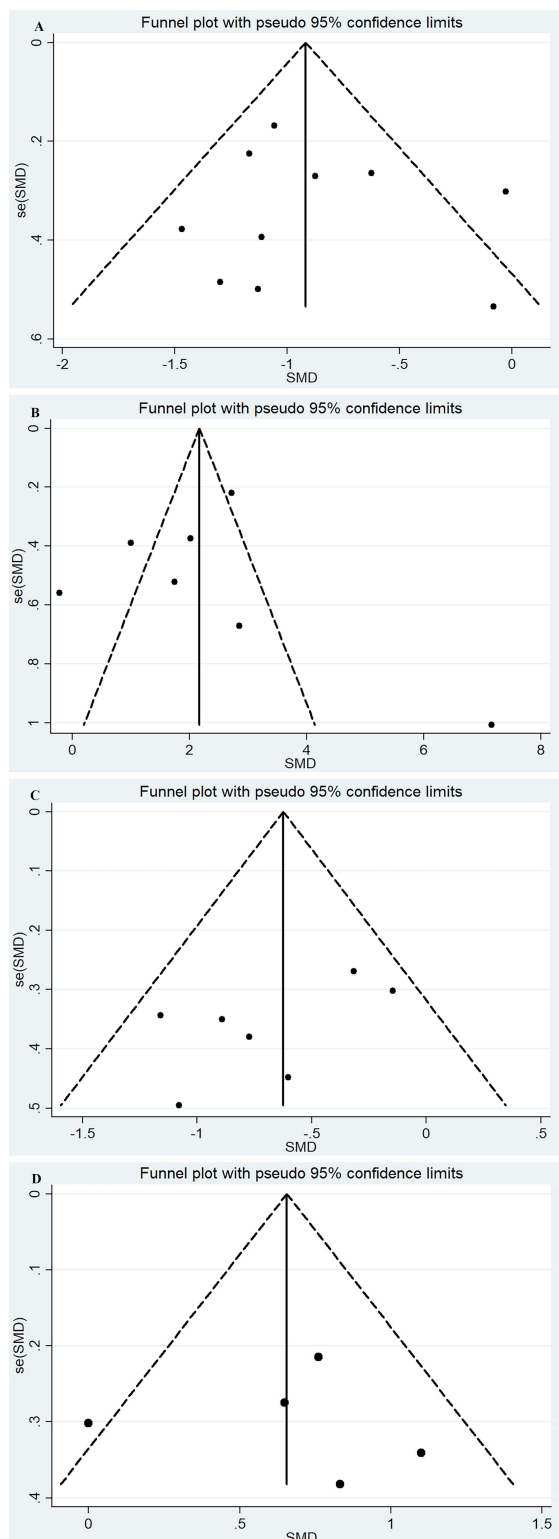


Fig. 3.

4.4. Effect size of FMA-UE

The FMA-UE data extracted from 7 studies [27,28, 32–36], (383 patients) were pooled with a random effect model and showed positive results with considerable heterogeneity ($I^2 = 85.2\%$, $P < 0.001$). Two studies [32,34] were excluded via sensitivity analysis ($I^2 = 41.9\%$, $P = 0.142$). The pooled effect size of the remaining and excluded studies both showed that KT improved upper extremity motor function (SMD 0.66, 95% CI 0.41 to 0.91, $P < 0.001$, 5 RCTs, 263 patients; 2 RCTs, 120 patients, respectively), which are detailed in forest plots (Fig. 2D). Then, subgroup analysis was conducted, and the results showed that KT significantly improved upper extremity motor function compared with both sham KT and blank control (SMD 0.48, 95% CI 0.04 to 0.93, $P < 0.05$, 2 RCTs, 84 patients; SMD 0.74, 95% CI 0.43 to 1.04, $P < 0.001$, 3 RCTs, 179 patients; Supplementary Table 2). Finally, publication bias analyses were performed, and the funnel plot was symmetrical in visual inspection and was verified by Begg's and Egger's tests ($P = 1.000$ and $P = 0.946$, respectively, Supplementary Table 3).

4.5. Effect size of IA and QOL

The IA data were synthesized from the BI, MBI, and SPADI data (5 RCTs [25–27,32,34], 232 patients). A higher score indicates more severe pain and disability on the SPADI scale, while it indicates more independence on the BI and MBI. Hence, the MD of the SPADI score was subtracted by the maximum (100) and reversed in the same direction as BI and MBI. The pooled effect size (including subgroup analysis) with a random effect model showed no improvement in individual daily living activity (SMD 0.42, 95% CI -0.22 to 1.07 , $P = 0.199$; $I^2 = 77.8\%$, $P = 0.001$; 5 RCTs, 199 patients; Fig. 2E, detailed in Supplementary Table 2). Then, the publication bias analyses were not conducted. The meta-analysis of QOL was not performed because it was only performed in 1 study [26] with negative results (SMD 0.26, 95% CI -0.34 to 0.85 , $P = 0.393$; SMD 0.31, 95% CI -0.29 to 0.90 , $P = 0.311$). More information is detailed in Supplementary Table 2.

4.6. Adverse events

In all included studies, it was reported that no adverse events related to KT therapy occurred. Therefore, it is safe to use KT for the treatment of HSP.

5. Discussion

With the present meta-analysis, KT could relieve pain, improve the range of motion, reduce AHD and improve FMA-UE for HSP compared to sham KT or blank control. However, KT did not improve daily living activity or quality of life in patients with HSP, and a KT value superior to active treatment control was still not concluded.

Kinesiology tape is commonly used to treat musculoskeletal disorders [9], such as acromion impingement pain, neck pain, low back pain, and knee pain [38–42]. In particular, several studies have shown that bandaging with tape has a positive effect on shoulder pain [43,44]. This might be related to the fact that KT treatment reduced soft tissue inflammation, improved muscle strength and alleviated joint pain. However, the mechanisms of KT in HSP remain uncertain. ROM limitation of the shoulder joint might be the main dysfunction in patients with HSP, and ROM limitation mainly contributes to shoulder pain [45,46]. Previous studies reported two potential mechanisms of KT treatment in HSP. The gate control theory considered that KT can increase excitatory afferent stimulation and can cut off or block part of the pain signal conduction to the central nervous system so that subjective pain perception is reduced [47]. Another potential mechanism is that KT can stimulate cutaneous mechanoreceptors to enhance proprioception [49,50], in turn activating large-diameter fibers (including A-beta fibers) to activate inhibitory interneurons to block pain signals conducted by small-diameter fibers, such as C- and A-delta fibers.

In the present study, 3–6 weeks of KT treatments relieved pain, improved ROM of the shoulder joint and improved FMA-UE for HSP compared with the sham or blank control. The results were similar with the previous studies. Jae-Man Yang et al. confirmed that KT relieved shoulder pain by creating wrinkles to reduce the pressure of mechanoreceptors and to increase the space underlying the tissues through its lifting effects, which in turn increased blood circulation [50]. The other two studies reported that shoulder movement was restricted in all directions [45] in HSP patients and increased significantly after KT treatment [51].

The present study also verified the value of KT in improving subluxation due to HSP. The pooled effect size of AHD showed that after 3–6 weeks of KT treatment, the distance between the acromion and humeral head was significantly shortened. Muscle weakness or paralysis after strokes can lead to poor shoulder protection and are associated with frequent soft tissue in-

juries of the affected shoulders during daily living activities or rehabilitation [52]. The most important muscles in preventing subluxation of the glenohumeral joint are the posterior fibers of the deltoid, supraspinatus, and infraspinatus [53]. The weak or paralyzed muscles could not maintain the head of the humerus in the glenoid fossa, and subluxation occurred. Furthermore, it will lead to overstretching, injury, or edema in the soft tissue. The current results confirmed that KT provided mechanical support to the subluxed shoulder and maintained persistent proprioceptive feedback and sensory stimulation, which increased sensory input from mechanoreceptors to primary somatosensories in the contralateral cortex through the thalamus [54,55]. It reminded patients themselves to handle the upper extremity properly and prevented or mitigated subluxation. Likewise, a sling can also provide mechanical support. Moreover, it brings benefits to patients with HSP in shoulder subluxation and walking efficiency [56]. One study showed that 15–20 minutes of exercise could cause rigid tape to lose its ability to restrain the joints [57]. Therefore, kinesiology tape would be a better choice for treatment that not only can provide effective support for the shoulder but also has no restriction. Meanwhile, its elastic properties are consistent with kinesiology and are little affected by movement.

Unfortunately, the present study showed that KT could not improve individual daily living activity or the quality of life in patients with HSP. The difference between KT and active treatment, such as NMES, acupuncture, shouldering, sling, etc., was still not verified.

Compared with two reviews published recently [58, 59], our study verified similar results that KT works in relieving pain and in improving shoulder ROM, shoulder subluxation and FMA-UE for HSP, but there were still some differences. First, the present review performed a more comprehensive literature search (14 RCTs in 13 databases) than the previous 2 reviews (9 studies in 7 databases; 8 studies in 4 databases). Second, the present review conducted a more informative investigation on the effects of KT on HSP compared to sham or blank controls, including pain, ROM, AHD, FMA-UE, individual daily living activity and quality of life based on the ICF foundation.

5.1. Limitations

There were several limitations in the present study. First, the number of RCTs and the sample size were still small. Second, all the studies included in this meta-

analysis reported only short-term effects (3–4 weeks). Third, this study focused on patients with chronic convalescent stroke within 1 to 6 months after stroke onset. Therefore, no conclusions can be drawn for patients with acute or subacute stroke. Fourth, there was diversity of and variation in the KT protocols. The selected taping muscles, taping time and frequency, treatment duration and taping shape and tension showed significant heterogeneity in the included studies. Therefore, more rigorously designed RCTs with larger sample sizes and with longer follow-up evaluations are needed in the future. Standardized protocols of KT therapy should also be recommended.

5.2. Implication

To the best of our knowledge, this is the first meta-analysis to evaluate the effectiveness and safety of KT therapy versus sham KT for treating HSP. In the present study, after rigorous meta-analysis, it was concluded that KT did have significant effects on reducing pain, increasing ROM, and shortening the subluxation distance of the shoulder joint but not on improving daily living activity and quality of life for hemiplegic shoulder pain without side effects. Interestingly, we also found that four muscles (supraspinatus, deltoid, brachii and trapezius) were most commonly used to treat HSP. The findings were similar to those of other published reviews.

6. Conclusions

This systematic meta-analysis provided currently available evidence to confirm the KT value for relieving pain and to improve the ROM, DASH and FMA-UE in patients with HSP compared with sham KT or blank controls. The effects of KT on daily living activity and quality of life and the value superior to active treatment in patients with HSP were not verified. More rigorous, reasonably designed RCTs with large sample sizes are still needed in the future.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplementary data

The supplementary files are available to download from <http://dx.doi.org/10.3233/BMR-200323>.

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