© 2025 THE AUTHORS
Open access at https://www.minervamedica.it

European Journal of Physical and Rehabilitation Medicine 2025 October;61(5):709-22
DOI: 10.23736/S1973-9087.25.09089-6

SYSTEMATIC REVIEW

Upper extremity pain after stroke: a systematic review and meta-analysis on primary prevention

Memnune A. DENIZLI [1, 2] *, Gauthier EVERARD [3], Patricia DESSART [2], Samar M. HATEM [1, 4, 5, 6]

[1]Department of Physical Medicine & Rehabilitation, Centre Hospitalier Valisana – site VALIDA, Brussels, Belgium; [2]Department of Physical Medicine & Rehabilitation, UCLouvain, Brussels, Belgium; [3]Neuro Musculo Skeletal Lab (NMSK), Institut de Recherche Expérimentale et Clinique, UCLouvain, Brussels, Belgium; [4]Institute of Neuroscience, UCLouvain, Brussels, Belgium; [5]STIMULUS Research Group, Vrije Universiteit Brussel, Brussels, Belgium; [6]Department of Physical and Rehabilitation Medicine, Universitair Ziekenhuis Brussel, Faculty of Medicine and Pharmacy, Vrije Universiteit Brussel, Brussels, Belgium

*Corresponding author: Memnune A. Denizli, Department of Physical Medicine & Rehabilitation, Centre Hospitalier Valisana – site VALIDA, Avenue Josse Goffin 180, 1082 Brussels, Belgium. E-mail: memnune.denizli@student.uclouvain.be

This is an open access article distributed under the terms of the Creative Commons CC BY-NC-ND license which allows users to copy and distribute the manuscript, as long as this is not done for commercial purposes and further does not permit distribution of the manuscript if it is changed or edited in any way, and as long as the user gives appropriate credits to the original author(s) and the source (with a link to the formal publication through the relevant DOI) and provides a link to the license. Full details on the CC BY-NC-ND 4.0 are available at https://creativecommons.org/licenses/by-nc-nd/4.0/.

ABSTRACT

INTRODUCTION: Post-stroke upper extremity (UE) pain is a frequent and debilitating problem, with an incidence of 15 to 40% at 6 months. No clinical guidelines are available on the primary prevention of UE pain. The aim of this research was to identify and summarize the effectiveness of methods for the primary prevention of post-stroke UE pain.

EVIDENCE ACQUISITION: This systematic review received no external funding and was conducted according to PRISMA guidelines (PROSPERO registration number: CRD42023445110). Two independent investigators searched PubMed, PEDro, EMBASE, Cochrane Library, SCOPUS and EBSCO (Cinahl Complete) until January 30th, 2025, for eligible studies comparing adult stroke patients undergoing any type of prevention method to avoid the development of UE pain, with control patients. Meta-analysis, using a random-effects model, was performed per type of prevention method.

EVIDENCE SYNTHESIS: A systematic review of 29 eligible articles (total number of patients: N.=1436) identified 7 categories of prevention methods: orthotics, taping, exercise, positioning, neuromuscular stimulation, intramuscular drug injections and education. Meta-analysis showed with a very low level of certainty that orthotics (SMD=0.45; 95% CI=-0.24 to 1.14; P=0.2; I^2=80.96%), taping (SMD=-0.15; 95% CI=-0.69 to 0.39; P=0.58; I^2=68.4%) and exercise (SMD=-0.47; 95% CI=-1 to 0.06; P=0.08; I^2=60.36%) are not more effective than standard care for the prevention of UE pain after stroke. Due to a small number of studies, meta-analysis was not performed for other categories of primary prevention methods.

CONCLUSIONS: This meta-analysis revealed, with a very low-certainty of evidence, that the effect of primary prevention methods on UE pain after stroke is uncertain. An increased number of studies is necessary in this area of clinical research. A combination of methods may increase the clinical relevance of preventive strategies.

(*Cite this article as:* Denizli MA, Everard G, Dessart P, Hatem SM. Upper extremity pain after stroke: a systematic review and meta-analysis on primary prevention. Eur J Phys Rehabil Med 2025;61:709-22. DOI: 10.23736/S1973-9087.25.09089-6)

KEY WORDS: Stroke; Pain; Primary prevention; Hemiplegia; Shoulder.

Introduction

Upper extremity (UE) pain is a frequent problem after brain stroke, with an overall incidence of around 9-10% at admission, that increases to 15-40% six months after stroke.[1] Post-stroke UE pain may be severely debilitating for patients as it reduces participation in daily activities and rehabilitation, slows motor recovery, extends hospital stays, and lowers overall quality of life.[2, 3]

The term hemiplegic shoulder pain (HSP) is coined

to describe a variety of stroke-related pain syndromes, though its definition and differential diagnosis are unclear.[3] Different terms are used interchangeably in the literature such as "hemiplegic shoulder pain," "post-stroke shoulder pain" and "post-stroke upper extremity pain," to refer to pain developing in the UE following a stroke. Ryerson and Levit established a classification of four subtypes of HSP: joint pain caused mainly by glenohumeral subluxation, rotator cuff injury or frozen shoulder syndrome; muscle pain due to spasticity/increased muscle tone; altered sensitivity with central post-stroke pain (CPSP) and Shoulder-Hand syndrome (often considered as a form of complex regional pain syndrome, CRPS).[4] Incorrect handling, glenohumeral joint subluxation, flaccidity, spasticity, reduced range of motion and poor motor function are predisposing factors linked with HSP.[5] Subluxation and spasticity of the shoulder is associated with a biomechanical imbalance which can lead to soft tissue lesions, thus causing pain.[6] CPSP is a central neuropathic pain syndrome characterized by a constant or intermittent pain associated with sensory abnormalities, caused by a stroke involving the spinothalamocortical pathway. It occurs approximately in 8-14% of stroke patients, usually within the 6 first months.[6, 7] CRPS is characterized by severe diffuse pain, associated with sensory, motor, vasomotor, sudomotor and trophic signs. It occurs in 23-70% of hemiplegic stroke patients.[6, 8, 9] The causes of HSP are multifactorial and could be categorized as a combination of neurological (nociplastic or neuropathic pain) and mechanical etiologies, as suggested by Vasudevan *et al.*[10] The differential diagnosis of pain should be based on the location, the type of pain and the clinical examination.[7]

Recent guidelines on the management of acute stroke inconsistently take into account the prevention and management of post-stroke pain.[11, 12] The Canadian Stroke Best Practice Recommendations published in 2020 emphasize the importance of shoulder pain prevention after stroke, since once established, its treatment remains difficult.[13] These guidelines recommend: the use of joint protection strategies during the early or flaccid stage of recovery with correct positioning and support of the arm while resting (Evidence Level B), during mobilization or during wheelchair use (Evidence Level C) is recommended while sling use should be discouraged except in the flaccid stage (Evidence Level C); for patients with a flaccid arm, electrical stimulation should be considered (Evidence Level B); passive exercises with a shoulder abduction or flexion greater than 90° (Evidence Level B) and overhead pulley exercises (Evidence Level A) should be avoided; patient and their caregivers should be educated on the proper positioning and correct handling techniques of the upper limb (Evidence level A). The 2023 NICE guidelines have limited recommendations on the management of post-stroke shoulder/upper limb pain.[14] Thus, at present, guidelines focus mostly on preventing shoulder joint subluxation with limited evidence on how to prevent the development of UE pain after stroke.

A number of studies have examined how UE pain should be treated in this population.[5, 15] An overview of systematic reviews published in 2020 on the treatment interventions for Post-Stroke Shoulder Pain reported 11 interventions that reduced pain, among which acupuncture, orthoses, botulinum toxin injection, electrical stimulation and aromatherapy.[5] Another systematic review showed a significant reduction in HSP using specific rehabilitation techniques such as botulinum toxin injection, suprascapular nerve block or pulse radiofrequency and dry-needling in addition to standard rehabilitation.[15]

The management of post-stroke shoulder pain requires a multidisciplinary and multimodal approach.[16] Some therapies for treating UE pain, such as positioning, support, correct transfer techniques by caregivers and physical therapy, are suggested to be effective for the prevention of pain as well.[10]

The gradual increase of shoulder pain incidence within the first few months following stroke indicates the need for efficient prevention methods to avoid its occurrence in the (sub)acute phase. Preventing post-stroke UE pain may be more advantageous than focusing solely on treatment, as once established, pain often becomes chronic, difficult to manage, and linked to prolonged hospital stay, poorer rehabilitation outcomes, higher utilization of pain treatments, poorer sleep quality, reduced quality of life and a higher risk of mortality.[2, 6, 17-19] Effective preventive approaches may ease the burden on patients by supporting engagement in rehabilitation and enhancing quality of life.[17] No information on the cost-effectiveness of prevention or treatment of HSP is available to our knowledge.

This primary prevention of post-stroke UE pain needs to be based on the best available evidence. The current lack of a summary of available and effective methods for primary prevention jeopardizes evidence-based decision-making. Previous systematic reviews (without meta-analysis) on the primary prevention of post-stroke UE pain each were focused on one specific prevention method: electrical stimulation[20] and shoulder orthosis.[21] To the best of our knowledge, there is no publication available that systematically reviews all types of primary prevention methods.

To fill this knowledge gap, the aim of the present systematic review and meta-analysis was to identify and summarize the effects of any type of intervention (pharmacological, surgical, educational, rehabilitative, electrical or magnetic transcutaneous stimulation devices) for the primary prevention of UE pain after stroke. The primary outcome of the meta-analysis was the intensity (or presence) of UE pain at rest.

Evidence acquisition

The systematic review was registered on PROSPERO International Prospective Register of Systematic Reviews (registration number: CRD42023445110) and was carried out following the Preferred Reporting Items for Systematic Review and Meta-Analysis Guidelines (PRISMA).[22]

Identification

Publications were retrieved from six databases: Pubmed, PEDro, Embase, Cochrane Library, SCOPUS and EBSCO (Cinahl Complete). The search strategy included keywords and MeSH terms (when available) for stroke, pain, prevention and UE, and can be consulted in the Supplementary Digital Material 1: Supplementary Table I. Review authors also hand searched reference lists of relevant studies (see screening section).

Eligibility criteria

Studies were included if they were randomized-controlled trials, non-randomized clinical trials or prospective cohort studies, studying any intervention for primary prevention (pharmacological, surgical, educational, rehabilitative, medical device), with the primary or secondary outcome being any type of UE pain, with a study population of adult patients (N.>10) with a confirmed diagnosis of (sub) acute brain stroke. Publications in English, French, Spanish, Portuguese, German, Dutch or Turkish were eligible. There was no restriction on the publication date or limitation on the age range. Publications were included if the study population did not report UE pain before the prevention method was implemented. Any study solely reporting treatment results for UE pain was excluded from this systematic review.

Study selection process

All records were downloaded into Rayyan©.[23] First, duplicates were deleted. Then, the records were screened by two independent reviewers (MAD and SMH) based on the title and abstracts. In a next round, publications were assessed for eligibility based on their full text. Discrepancies were solved by discussion at the end of each screening round, and the third author (PD) was consulted in case of disagreement.

Data extraction and analysis

The following data were extracted from remaining publications: study design, country, patient characteristics (number, duration of stroke at inclusion), intervention group (type, frequency, dosage, duration, intensity, frequency of the intervention), control group, pain outcomes (type of pain outcome at baseline and last assessment, primary/secondary outcome), length of follow-up, information on compliance to the intervention and limitations of the study. Extracted data were recorded in a data extraction form by one reviewer (MAD), with the second reviewer (SMH) verifying the accuracy of the data report at each step of the process.

Methodological quality assessment

One reviewer (MAD) assessed the risk of bias of remaining publications for methodological quality using the modified Downs & Black checklist (D&B), which is a validated tool for the assessment of the methodological quality of both randomized and non-randomized studies of health care interventions.[24, 25] The second reviewer (SMH) independently reviewed each item of the D&B checklist.[24] Any discrepancies were resolved through thorough reading and discussion by both reviewers. Reasons for excluding an article from the systematic review and meta-analysis were lack of a detailed description of the intervention and/or pain outcome, or methodological poor quality (D&B checklist score ≤14). The D&B checklist consists of 27 items assessing quality of reporting (10 items), external validity (3 items), internal validity (13 items with 7 items evaluating the risk of bias and 6 items the confounding elements) and power (1 item). Each item is scored "yes" (1 point), "no" (0 point) or "unable to determine" (0 point). In accordance with previous studies using the D&B checklist, the methodological quality of articles was regarded as excellent (score ≥26), good (score between 20-25), fair (score between 15-19) or poor quality (score ≤14).[26-28]

Grouping interventions

Remaining publications were categorized according to the type of preventive method (orthotics, taping, exercise, positioning, neuromuscular stimulation, intramuscular drug

injections and education). These categories were not predetermined and were constituted through compiling similar interventions throughout the remaining articles.

Statistical analysis

The effect size of each study was calculated as a standardized mean difference (SMD) of the pain outcome between study arms of randomized controlled trials before (baseline) and after intervention (if multiple assessments: the latest). For three-arm studies, we prioritized the splitting approach.[29, 30] The pain outcome could be either a linear scale measurement (pain visual analogue scale (VAS) or pain Numerical Rating Scale (NRS)) or an incidence of pain. Ordinal scales (Likert scales) were converted to a binary scale (presence/absence of pain) providing thus a measure of incidence of pain. For incidence rates, the odds ratio (OR) was calculated and converted to standardized mean difference (SMD) using Cohen's d Test.

When necessary, original authors were contacted by e-mail to complete missing data, to provide raw data for meta-analysis or to clarify methodology. UE pain outcome data was extracted from a diagram for Dean *et al.*, using PlotDigitizer©.[31] Data expressed as median-IQR and mean-95% CI were converted to mean-SD according to the Cochrane Handbook.[32]

Subsequently, data was pooled per category of prevention method (orthotics, taping, exercise, positioning, neuromuscular stimulation, intramuscular drug injections and education). Meta-analysis of categories was performed only if at least 3 publications were available and when heterogeneity as assessed by using I^2 was lower than 85%. Publications for which these conditions were not met, were reported in a narrative synthesis. Random-effects model was used to calculate the pooled effect size and 95% confidence interval. The meta-analysis was conducted using Jamovi© software and results were presented as forest plots per category of prevention method. As stated above, statistical heterogeneity within each category was assessed using I^2. Heterogeneity was rated as considerable when $I^2 > 75\%$, substantial when $75\% > I^2 \geq 50\%$, moderate when $50\% > I^2 \geq 30\%$ and not significant when $I^2 < 30\%$. Publication biases and outlier data were assessed through funnel plots. Sensitivity analyses were conducted to assess the robustness of the decision we made to exclude outlier studies.

The certainty of the evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach, in accordance with the Cochrane Handbook for Systematic Reviews of Interventions.[30] Certainty was rated as high, moderate, low, or very low across five domains: the overall risk of bias, inconsistency (variation in study results beyond chance), indirectness (differences between the research question and the available evidence regarding population, intervention, comparator, or outcomes), imprecision (uncertainty in the effect estimate due to sample size or confidence interval width), and the suspicion of publication bias.[30] Evidence from randomized controlled trials started as high and was downgraded by one level for serious concerns and two levels for very serious concerns within each domain. All data of this research is available within the manuscript and its supplementary materials.

Evidence synthesis

Database screening

The database search of PubMed, PEDro, Embase, Cochrane Library, SCOPUS and EBSCO (Cinahl Complete) was conducted up to January 30th, 2025 (N.=1582). After duplicate removal (N.=276), 1306 records were screened based on titles and abstracts. Thereafter, 46 full texts remained. Eleven additional articles were obtained from handsearching. At the end of the screening process, 29 publications (N.=1436) met the inclusion criteria. The PRISMA flow diagram of the systematic review is presented in Figure 1.

Quality assessment of studies

Scores on the D&B checklist ranged from 8 to 26 (maximum score: 26). Three studies were excluded from the systematic review due to a poor methodological quality (score <14). Two studies were of excellent quality,[33, 34] twenty studies were of good quality[8, 9, 31, 35-51] and seven studies were of fair quality[52-58] (Supplementary Digital Material 2: Supplementary Table II).

Characteristics and main findings of studies included in the systematic review

The characteristics and main findings of included studies are summarized in Supplementary Digital Material 3, Supplementary Tables III-VIII.[8, 9, 31, 33-56, 58] Across studies, the average duration since stroke onset ranged from 24 hours to 57 days, and the duration of intervention from 2 weeks to 3 months. Most studies were randomized controlled trials (26 out of 29). Pain was a primary outcome in 10 of the 29 included studies. Seven different scales were used for reporting pain: Visual Analogue Scale (VAS,

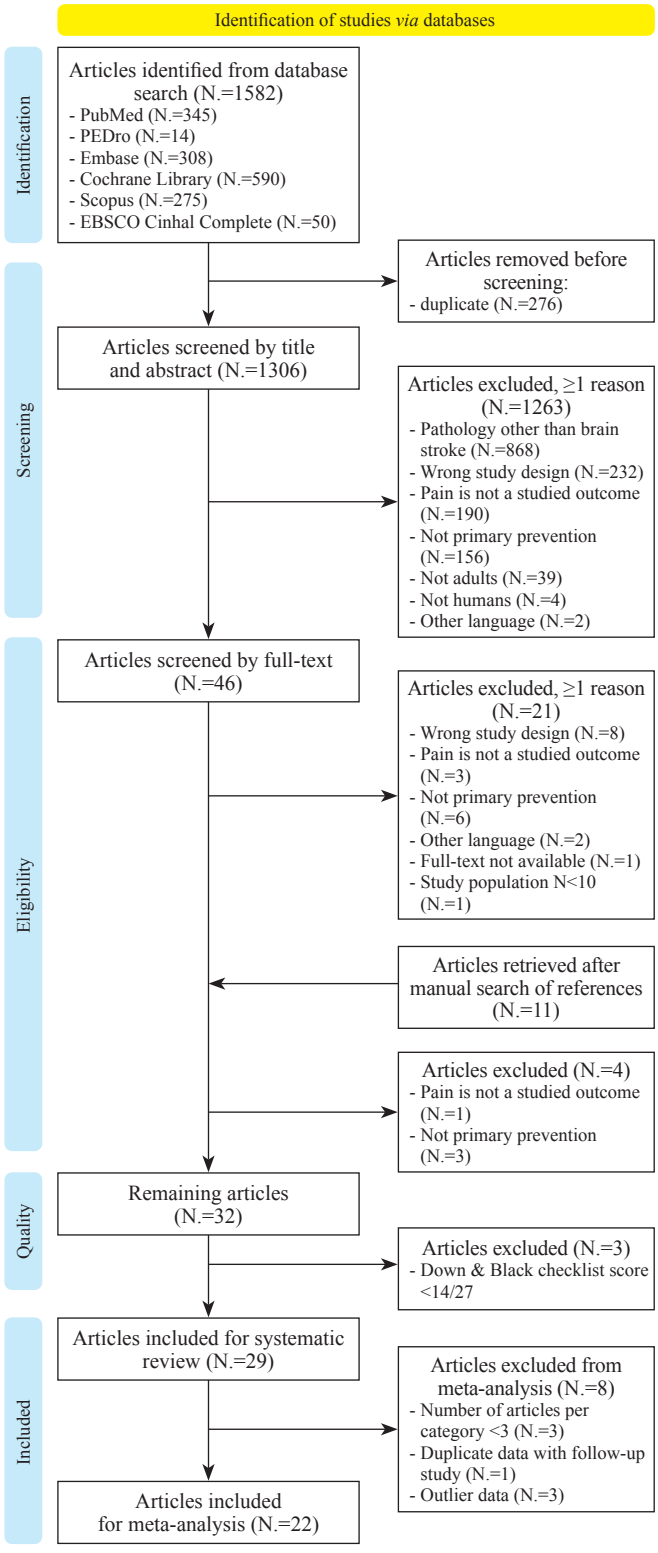


Figure 1.—PRISMA flow diagram of study selection process.

range: 0 to 100) (N.=16), incidence of pain (N.=9), pain subset of Shoulder-Hand Syndrome Score (range: 0 to 5) (N.=1), number of shoulder pain-free days (as part of the Ritchie Articular Index) (N.=1), Numerical Rating Scale (range: 0 to 10) (N.=3), Scale of Pain Intensity (range: 0 to 5) (N.=1), and a numerical five-point verbal rating scale (range: 0 to 5) (N.=2).

Seven different categories of interventions were identified: orthotics, taping, exercise, positioning, neuromuscular stimulation, intramuscular drug injections and education. The modalities of control interventions in randomized controlled trials are detailed in Supplementary Tables III-VIII,[8, 9, 31, 33-56, 58] with most studies implementing usual care as a control intervention.

Orthotics

Different types of UE orthotics were studied: shoulder slings,[36, 45, 50, 51] functional shoulder orthosis[8] and hand splints.[37, 52]

Ada *et al.* showed that the use of a modified lap-tray with a cylinder for the hand while sitting and the use of a triangular sling while walking and standing showed that patients reported less pain at rest (MD -0.7 out of 10, 95% CI -2.2; -0.8) and during shoulder external rotation (MD -1.7 out of 10, 95% CI -3.7; -0.3) compared to the use of a hemi-sling. The results were not statistically nor clinically significant, with most patients scoring only 1/10 on the VAS scale at last assessment.

Van Bladel *et al.* conducted a three-arm study comparing the use of the Actimove© sling (with forearm support to indirectly immobilize the shoulder) and the Shoulderlift© brace (supporting the shoulder joint directly with a retraction-elevation mechanism and allowing proximal movement of the arm) to the control group (no sling).[50] No significant changes of pain scores on the VAS were reported in all the groups and Actimove© group reported more pain at rest (P=0.036).

Kim MG *et al.* examined the effect of a dynamic shoulder sling (composed of a shoulder belt, a chest belt and a wrist belt with an elastic to adduct and retract the deltoid) in stroke patients with a shoulder subluxation on shoulder pain, compared to the use of a Bobath sling[45] and showed no significant difference of VAS at last assessment within groups (with mean VAS going from 1.35±2.64 at baseline to 1.7±2.6 at 8 weeks; P=0.4994) and between groups (with a mean VAS at 0.33±2.61 in the dynamic shoulder sling and 0.35±3.05 in the Bobath sling group; P=0.999).

Yildirim *et al.* compared the use of an shoulder supported sling (a modified triangular Bobath sling[59]) to the

use of forearm supported sling (holding the shoulder in adduction and internal rotation) in hemiplegic stroke patient with shoulder subluxation. At last assessment, no significant decrease in the severity of shoulder pain in either group (increase in mean VAS from 3.2±2.6 to 3.3±2; P=0.914 in the intervention group, decrease in mean VAS from 3.9±2.7 to 3.4±1.9; P=0.382 in the forearm supported sling group).

Hartwig *et al.* studied the effect of the use of Neuro-Lux© functional shoulder orthosis in hemiparetic stroke patients with glenohumeral joint subluxation on the development or progression of Shoulder-Hand Syndrome.[8] The Shoulder-hand syndrome scores improved in the intervention group and worsened in the control group with the analysis of covariance estimating the gain by the orthosis to be a lowering of the SHS score by 3,1 points (95% CI 1.9; 4.3, P<0,001). The scores on the pain subset of the SHS score (5-point ordinal scale with 0=no pain and 5=spontaneous pain) showed similar results with lower pain in the intervention group at last assessment (from mean 1.8±1.1 to 0.4±0.6) compared to the control group (from mean 1±1 to 1.8±1).

Two studies compared the used of an immobilizing hand splint in the neutral position to standard care. Lannin *et al.* showed an increase of upper extremity pain after the intervention (mean VAS 0.2, 95% CI -2.5; 2.7) but a decrease at last assessment (mean VAS -1, 95% CI -4.6; 2.2).[52] Burge *et al.* showed a significant decrease in the number of patients with hand pain at rest from 2 to 1 patient in the intervention group (P=0.004) and an increase of the incidence of pain in the control group (from 2 to 8 patients).[37]

Taping

Studies on shoulder taping varied with regards to the method of taping (mainly circumferential or longitudinal), the duration of intervention (2 to 6 weeks) and the control group, with two studies implementing sham taping as a control.[33, 39]

Griffin *et al.* compared shoulder strapping (using Ancliffe's method) to placebo strapping and standard care.[39] The results showed a delay in the onset and a lower incidence of pain in the therapeutic strapping group (mean 26.2 ±3.9 pain-free days with 1 out of 10 patients developing pain), compared to the placebo strapping (mean 19.1 ±10.8 pain-free days with 5 out of 10 patients developing pain) and to the standard care (mean 15.9 ±11.6 pain-free days with 5 out of 12 patients developing pain) with a significant difference in number of pain-free days between the therapeutic strapping and standard care group in the mean number of pain-free days (P=0.023).

Comley-White *et al.* compared longitudinal and circumferential shoulder strapping to standard care and observed slightly less shoulder pain with longitudinal strapping (incidence of pain reducing from 16.1% to 15.1%; P=0.92) whereas circumferential strapping prevented the shoulder pain from worsening (incidence of pain increasing from 17.1% to 18.1%) as much as in the control group (incidence of pain increasing from 16.1% to 24.3%; P=0.52).

Hanger *et al.* applied a shoulder strapping composed of three lengths of tape applied over an "undertape" and observed a trend of less pain in the intervention group (mean VAS 1.8±3.1 *vs.* 2.5±2.7 in the control group; P=0.09) in the exploratory analysis.[40]

Hochsprung *et al.* compared the application of shoulder strapping (using three strips over the anterior, medial and posterior deltoid muscle) to standard care and showed an increase of pain in both groups at last assessment (mean VAS 5.28±3.45 in the strapping group), with the highest change observed in the control group (means VAS 6.14±1.67, P<0.001).[42]

Huang *et al.* observed that the application of kinesiotaping to the affected shoulder did not change the incidence of shoulder pain (remaining at 57%), as opposed to sham taping which increased the incidence of pain (from 70% to 87%), with a significant difference in the prevalence of shoulder pain between both groups (P=0.03). No significant change in VAS scores were observed within (P=0.22) and between groups (P=0.17) (mean VAS 3.2±2.3 in the taping group and mean VAS 2.6±2.9 in the control group at last assessment).[44]

Pandian *et al.* showed that the use of a tri-pull shoulder taping method showed a better reduction of VAS score with a mean difference of 1.19 (95% CI 0.11; 2.26; P=0.03) compared to sham taping on last assessment, although the overall between group differences were not statistically significant (mean VAS 0.78, 95% CI -0.14; 1.7; P=0.1).[33]

Exercise

Exercises investigated for the primary prevention of UE pain were passive range of motion (ROM),[54] active exercises[48, 49, 55] and the use of a repetitive active reaching training arm device.[43] One study on exercise was a one-year follow-up of the initial trial with a duration of intervention varying between 4-7 weeks for inpatients and 6-11 weeks for outpatients.[48]

Huang *et al.* studied the impact of educational videos on shoulder positioning, transferring techniques and ROM

exercises performed by the patient and their caregivers, which did not show superiority (incidence increasing from 56% to 60%), with no significant change of mean NPS score compared to standard care.[54]

Kumar *et al.* compared overhead pulley exercises (moving the arm through a range of 130-150° of abduction) and skateboard exercises (performing a figure-eight pattern on a board in front of the patient, moving the arm through 90° of forward flexion, 90° of abduction and 45° of shoulder adduction) to passive shoulder ROM exercises.[55] The results showed a difference in the incidence of pain among groups: passive ROM (8%), skateboard (12%) and overhead pulley (63%).[55]

Sunderland *et al.* demonstrated that enhanced arm therapy in addition to standard care (including Bobath exercises, EMG biofeedback, micro-computer games and goal-setting) increased the incidence of pain compared to conventional therapy in severe strokes.[49] The follow-up publication at one-year observed that the incidence of pain was greater in the enhanced therapy group (33%) compared to conventional therapy (29%).[48]

Horsley *et al.* observed no benefit of repetitive active reaching training using the SMART Arm device over usual upper limb therapy in regards of pain prevention: both groups demonstrated small, non-significant increase in pain (mean VAS increasing from 4.4±2.5 to 5.2±2.4 in the intervention group and from 3.7±2.4 to 5.3±2.3 in the control group).[43]

Positioning

Positioning protocols mainly focused on arm positioning while lying down[31, 35, 38] or sitting.[31, 38] One study investigated the use of a modified wheelchair arm support.[47]

De Jong *et al.* implemented an arm positioning procedure carried out by nursing staff twice daily for 30 minutes during 5 weeks, with the shoulder in abduction and external rotation, elbow extended and supinated and did not observe a difference between the intervention and control group in terms of pain prevention (with a total incidence of shoulder pain at 76% for all subjects included in the study).[35]

Dean *et al.* implementated a daily positioning protocol during 6 weeks with three positions held 20 minutes each: maximum shoulder abduction with shoulder externally rotated and elbow flexed while lying supine, maximum shoulder external rotation with shoulder 90° abducted and elbow flexed while lying supine, 90° shoulder forward flexion with elbow and wrist extended and a cylinder in the hand while sitting.[31] At baseline, no subject in the experimental group had pain at rest and the control group had a low level of pain with the mean of around 1cm on the VAS. Scores did not change after 6 weeks, and pain scores were not significantly different between groups (P=0.985).

Glize *et al.* implemented specific positioning of the upper limb while lying in bed, sitting and during transfers, maintaining the shoulder in abduction and external rotation and keeping the elbow flexed and compared it to standard care (arm in neutral rotation and pillow under the hand while lying down, neutral rotation on arm rest, and shoulder adduction and internal rotation during transfers).[38] There was no difference in shoulder pain between the groups at last assessment (mean VAS 2.95±2.92 for the intervention group and 1.8±2.65 in the control group; P=0.12).

Pan *et al.*, used a modified wheelchair arm-support (with a thick handle at the hand which could be held by hand, used for at least 60 minutes/day, 6 days/week for 4 weeks) and showed significantly lower pain (mean VAS/NRS decreasing from 3 – IQR 6 to 0 – IQR 1) compared to standard care (mean VAS/NRS decreasing from 3,5 - IQR 7 to 3 – IQR 5) at 12 weeks (P<0.001). The incidence of shoulder pain was also significantly lower in the intervention group (2% *vs.* 10% in the control group) at 12 weeks assessment (P=0.034)[47] (Figure 2).[9, 31, 34-42, 44-48, 50-58]

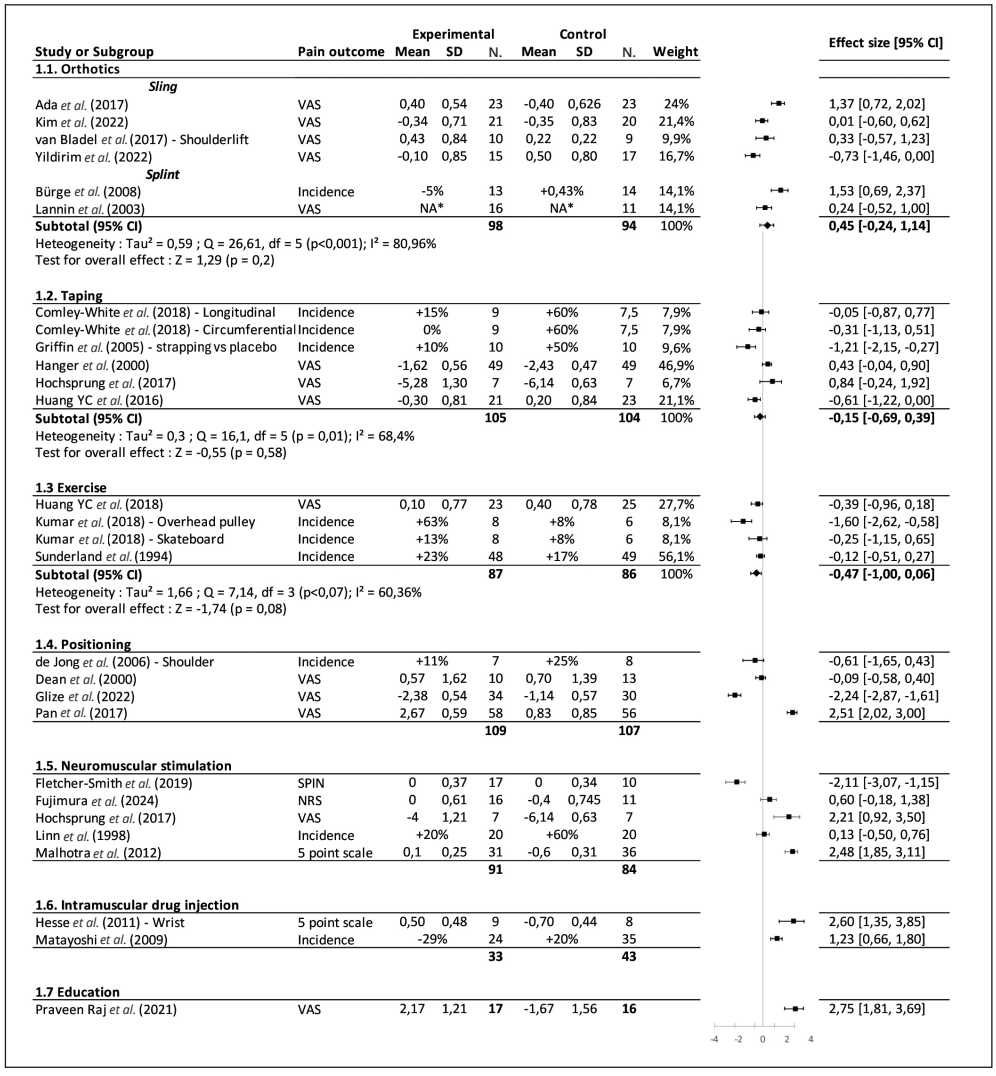
Neuromuscular stimulation

Neuromuscular stimulation protocols of the UE included electrical stimulation (NMES) of the shoulder[38, 53] or the wrist muscles[46, 58] and repetitive peripheral magnetic stimulation (rPMS) of the shoulder.[58]

Fletcher-Smith *et al.* studied electrical stimulation of the wrist extensors and flexors muscles for 30 minutes, 2x/day, 5 days/week for 3 months (with a two-channel constant current stimulator (maximum output: 100mA, pulse width: 450 μs, and a frequency between 40 and 60Hz as per participant preference, with current intensity increased to produce an alternating contraction of the flexor and extensor muscles).[58] Pain in the affected arm, measured by the Scale of Pain Intensity (SPIN, ordinal scale with 0=no pain and 5=pain as bad as it could be) were similar for both groups at 12 months assessment (median SPIN remaining at 0 with IQR 0-2 in the NMES group and decreasing from 0,5 with IQ5 0-2 to 0 with IQR 0-0,25 for the control group).

Malhotra *et al.* applied NMES to the wrist and finger extensors 2-3x/day, 5 days/week for 6 weeks (pulse width=300 μs; ON time=15 s with a ramp up time of 6 s and ramp down time of 6 s; OFF time=15 s; frequency of

Figure 2.—Forest plot of primary prevention methods for upper extremity pain after stroke. Meta-analysis is provided for the categories of orthotics, taping and exercise. Effect sizes are described for all included studies (except for outlier data).[9, 31, 34-42, 44-48, 50-58]
*Random effect meta-analysis was calculated from between-group differences provided by the authors.



40Hz), and observed lower pain (using a 5-point verbal rating scale, 0=no pain and 5=pain that could not be any worse) in the intervention group at 12 weeks (mean pain units/week decreasing from 0.5 – SE 0.17 to 0.4 – SE 0.18) compared to the control group (mean pain units/week increasing from 0.4 – SE 0.15 to 1 – SE 0,27) (P=0.07).

Hochsprung *et al.* applied on the anterior and posterior deltoid muscles a Neutotrac© NMES (composed of two channels with two electrodes each and a biofeedback system to enhance motor control; frequency of 30 Hz-50 Hz; pulse duration of 250 µs; ramp up time of 0.6; synchronous current for both channels; and 5-second contraction with 7 second-resting period) for 30 minutes daily during 4 weeks.[42] Although there was no report of pain at baseline, shoulder pain increased significantly for all patients throughout the follow-up period (P<0.001), with the highest change observed in the control group (mean VAS 6.14±1.67 *vs.* 4±3.21 for NMES group) at week 24.

Linn *et al.* applied NMES (composed of asymmetrical biphasic pulses with a pulse width of 300 µs; of 30 Hz; ON time=15 s with a ramp up time of 3 s and a ramp down time of 3 s; OFF time=15 s) on the supraspinous and posterior deltoid muscles, 4x/day with a minimum of 2 hours between sessions with a gradual increase of session duration from 30 minutes in week 1, 45 min in weeks 2-3 to 60 min in week 4.[56] Pain increased in both groups, as measured by the verbal rating scale (scale from 0=no pain to 4=very severe pain) and no significant difference was

found between groups in the pain measure.

One study investigated the use of rPMS on the supraspinatus, infraspinatus and posterior deltoid muscles daily for 6 weeks (using Pathleader TM, administered for 2s at 30 Hz with a 3s off time, 6000 pulses/muscle=17 minutes/session) but did not find a superiority (mean NRS decreasing from 0.9±2.7 to 0.3±1.3; P=0.11) compared to usual care (mean NRS increasing from 0.6±1.9 to 0.7±1.9; P=0.85) in terms of shoulder pain prevention.[34]

Intramuscular injection

Drugs studied were calcitonin[9] and botulinum toxin[41] (for intramuscular injection).

Hesse *et al.* included spastic hemiplegic stroke patients.[41] The intervention group underwent ultrasound guided Botulinum Toxin-A injections (Xeomin©) into the deep and superficial finger flexors (100 units) and the flexor carpi radialis and ulnaris (50 units) followed immediately by rapid mobilization of the wrist and finger joints, and showed a decrease in pain score at 6 months using a 5-point ordinal scale (0=no pain; 4=unbearable pain): decrease of the pain during wrist extension from 1.4±1.2 to 0.9±0.8 and finger extension from 1±0.9 to 0.7±0.7).

Matayoshi *et al.* studied the impact of preventive weekly intramuscular injection of 20 units of Elcatonin© while inpatient on CRPS onset by the time of discharge from the hospital or on the incidence of shoulder pain.[9] The mean number of injections was 12.1±4.2. The results of the study showed a significantly lower incidence of CRPS in the intervention group (12.5%, 95% CI 0; 25.7%) than in the control group (57.1%, 95% CI 40.7; 73.5%). Lower incidence of shoulder joint pain was observed in the intervention group after treatment completion (54.2%, 95% CI 32.4; 74.1%) compared to the control group (82.9%, 95% CI 70.4; 95.3%).

Education

One study described an educational program for the stroke patient's caregiver on shoulder care with 3 individual or one-to-one sessions of 30-60 minutes over 3 days: first session with an illustrated educational handbook (information about stroke, complications, shoulder pain and subluxation, correct handling and positioning, proper sling usage), second session with practical demonstrations and practice on proper positioning, handling and transfers, and third session with a recall and review for the caregivers.[57] At follow-up assessment, although the pain scores were similar in both groups, the number of stroke survivors with 'no pain' increased from 10 (59%) at baseline to 15 (88%) in the experimental group of 17 participants and reduced from 13 (81%) to 12 (75%) in the control group of 16 participants.

Meta-analysis

Two outliers were identified and excluded based on the funnel plot (van Bladel *et al.* Actimove©, Hartwig *et al.*) (Supplementary Digital Material 4: Supplementary Figure 1). Two more outliers were identified and excluded after performing a sensitivity analysis (Pandian *et al.*, Horsley *et al.*) (Supplementary Digital Material 5: Supplementary Figure 2). Results of pooled analyses are presented in Figure 2 and the certainty of evidence in the summary of findings table (Supplementary Digital Material 6: Supplementary Table IX, Supplementary Table X).

Orthotics

There is very low-certainty of evidence that orthotics are not significantly more effective than conventional therapies (SMD 0.45, 95% CI -0.24 to 1.14; 6 studies, 192 participants). There was considerable heterogeneity (I^2=80.96%).

Taping

There is very low-certainty of evidence that taping is not more effective than conventional therapies (SMD -0.15, 95% CI -0.69 to 0.39; 6 studies, 209 participants). There was substantial heterogeneity (I^2=68.4%).

Sensitivity analysis revealed that excluding one outlier study[33] improved heterogeneity (I^2=92.06 to I^2=68.4%) without changing the results (Supplementary Figure 2).

Exercise

There is very low-certainty of evidence that taping is not more effective than conventional therapies (SMD -0.47, 95% CI -1.00 to 0.06; 4 studies, 173 participants). There was substantial heterogeneity (I^2=60.36%).

Sensitivity analysis revealed that excluding one outlier study[43] improved heterogeneity (I^2=91.54 to I^2=60.36%) without changing the results (Supplementary Figure 2).

Positioning

As there was considerable heterogeneity (I^2=97.59%), we did not pool studies for meta-analysis in this category. Two studies[31, 35] reported neutral effects on pain. One study[47] reported less pain in the positioning group compared to the control group, while another study[38] reported less pain in the control group. There is very low-certainty of evidence.

Neuromuscular stimulation

As there was considerable heterogeneity (I^2=95.06%), even after outlier removal, we did not pool studies. Two studies[34, 42] reported neutral effects on pain. Two studies[42, 46] reported less pain in the neuromuscular stimulation group compared to the control group while another study[58] reported less pain in the control group. There is very low-certainty of evidence.

Intramuscular injection

As there were only two studies,[9, 41] we did not pool results for meta-analysis in this category. Both studies reported significantly less pain after intramuscular drug injection when compared to the control group. There is low-certainty of evidence.

Education

Only one study[57] assessed the effect of education on the prevention of post-stroke UE pain. Results of this study revealed significantly less pain for the intervention group.

Discussion

Summary of main results

To the best of our knowledge, this systematic review and meta-analysis is the first summary of evidence uniquely focused on the primary prevention of UE pain after stroke. Till now, no guidelines or recommendations are available on this subject. The broad scope of this systematic review and meta-analysis voluntarily aimed at identifying as many types of preventive methods as possible. Seven categories of interventions were identified for qualitative analysis: orthotics, neuromuscular stimulation, taping, positioning, exercise, intramuscular drug injections and education. The systematic review yielded a limited number of trials that reported pain as an outcome. Methods of retrieved publications were heterogeneous. Results of pooled analyses per category of intervention suggest, with a very-low certainty of evidence, non-significant preventive effects on pain for orthotics, taping and exercise. The effects of other preventive methods on UE pain were reported through a narrative synthesis. The effects of positioning, neuromuscular stimulation and education were uncertain, whereas there was a low certainty of evidence that intramuscular injections may decrease UE pain after stroke, when compared to conventional therapy.

Current evidence in UE pain prevention

Prevention methods should be implemented within the first months after stroke to avoid the development of UE pain (incidence of 15-40% 6 months after stroke).[1] There is a lack of studies to support current clinical practices used to prevent UE pain after stroke. Professional caregivers in neurological and rehabilitation units implement common-sense prevention protocols such as supportive arm positioning and/or arm slings when stroke patients are considered at risk of developing UE pain. The limited evidence from this systematic review and meta-analysis does not allow concluding on the sense (or missense) of these preventive measures. Given the high prevalence of stroke and subsequently of chronic UE pain, priority should be given to research protocols that investigate primary prevention methods.

Though the present meta-analysis does not indicate a significant effect of each primary prevention method separately, it is possible that a combination of interventions may be more effective than single interventions. We were not able to identify any study investigating a combination of preventive methods, though clinical pragmatism probably would favor this type of approach.

A recent systematic review and meta-analysis on the treatment of shoulder pain (of any origin), found that combinations of therapies led to a significant improvement of shoulder pain compared to single treatment modalities.[60] The NICE guidelines on stroke rehabilitation, updated in 2023, recommended interventions for treating UE pain are: correct UE positioning combined with taping, neuromuscular electrical stimulation, intra-articular glenohumeral corticosteroid injection or nerve block with a local anesthetic for managing shoulder pain after stroke.[14] In the same line of thought, combined interventions that target shoulder stability and muscle tone, such as taping in addition to neuromuscular stimulation, may be an interesting pathway to consider for preventing the occurrence of shoulder pain after stroke.

Agreements and disagreements with other studies or reviews

While this work focusses on primary prevention methods, prior systematic reviews have synthesized the effectiveness of specific interventions aimed at treating post-stroke UE pain. Nadler *et al.*, investigated shoulder orthoses for the prevention and reduction of hemiplegic shoulder pain and subluxation. Trialists reported that orthoses may reduce existing pain, but none of the included studies described the effectiveness of early application of an orthosis for the prevention of shoulder pain.[21]

A Cochrane systematic review summarizing the use of electrical stimulation for the prevention and treatment of post-stroke shoulder pain, did not find any significant changes in the incidence of shoulder pain.[20] Out of the four studies included in this review, one article did not deal with the prevention of pain whilst the other three articles did not distinguish between the intention to treat or to prevent pain. The evidence on the prevention of shoulder pain after stroke by using electrical stimulation, thus remains inconclusive in this systematic review.

Clinical implications

Though ineligible for meta-analysis in the present research, a few individual studies have shown promising results for preventing post-stroke upper extremity pain and deserve to be reflected upon.

First, two different studies investigated the use of a modified wheelchair arm-support with a cylinder for resting the affected hand. They demonstrated a lower incidence[47] and severity of pain[36] in the intervention group. This effect might be explained by the functional positioning of the upper extremity while sitting (shoulder in external rotation, wrist in neutral position, fingers half extended and thumb in abduction) and limiting the arm of falling from the armrest, thus causing less strain on soft tissues.

Second, an early botulinum toxin A forearm injection in spastic subacute stroke patients with a non-functional arm appeared to lower the intensity of pain at 6 months.[41] This effect may be explained by less development of muscle contractures. Weekly intramuscular Elcatonin© injection in severe hemiplegic stroke patients showed a significantly lower incidence of CRPS and shoulder joint pain.[9] Only one study was available for each drug. Further studies are needed to make clinical recommendations.

Third, caregiver's education on correct handling and positioning of the shoulder, and proper sling use during acute care in the hospital following a stroke, seems to lower the incidence of pain.[57] Proper care after hospital discharge relies partly on the caregivers. This type of educational program may play a role in preventing soft tissue injuries caused by mishandling or incorrect positioning.

In addition, some interventions may be of interest to reduce the incidence and/or the intensity of pain. Although, shoulder taping did not show a significant benefit in terms of prevention, it seemed to delay the onset[39, 53] and to reduce the severity[33, 39, 42, 44, 53] of shoulder pain. Hand splints did not prevent the occurrence of UE pain but lowered its intensity.[37, 52] These results using hand splints were significant in only one of two studies.[37] Further research is necessary to make clinical recommendations.

Enhanced ROM exercises of the shoulder, positioning protocols, NMES and rPMS of the shoulder did not seem to prevent the occurrence of UE pain. Results concerning NMES of the wrist muscles were not consistent, with one of two included studies showing a reduction of pain in the hand.[46]

Thus, some of the preventive methods that were not included in the meta-analysis, deserve further investigation.

Limitations of the study

First, the GRADE approach revealed a low to very low-certainty of evidence suggesting an important level of uncertainty regarding the effect of primary prevention methods on post-stroke UE pain. Imprecision was important as most included studies had small sample sizes or small to neutral effects. The estimates of the effectiveness of individual interventions were inconsistent, mostly due to the heterogeneity and the methodological limitations of individual studies. Despite the use of a random-effects model, statistical heterogeneity was found substantial to considerable and could partly be explained by the variation of study characteristics, duration of intervention and time of last assessment. In addition, the average follow-up period varied between 28 days and a year, leaving us with very little information on long-term effects of interventions.

Second, we included randomized and non-randomized controlled trials in this review as well as cohort studies which inherently have a lower methodological quality. Also, due to the nature of the studied interventions, blinding was not always feasible. While outcome assessments could have been blinded, some studies failed to implement this, introducing additional risk of bias (see item 15 of the Downs & Black checklist, Supplementary Table II). In line with these concerns, and though funnel plots and forest plots did not strongly suggest publication biases (except for intramuscular injection and education, where the number of included studies was also low), four outlier studies were unveiled (van Bladel *et al.* – Actimove©,[50] Hartwig *et al.*,[8] Horsley *et al.*,[43] Pandian *et al.*[33]). These outliers, along with the general methodological variability, further reinforce the uncertainty reflected in the GRADE assessment.

Third, HSP after stroke is a complex situation with a combination of neurological and mechanical etiologies.[10] Except for CRPS or shoulder-hand syndrome,[8, 9] the studies identified in this review did not allow to differentiate

between subtypes of UE pain (nociplastic, neuropathic, nociceptive), as these subtypes were not described.

It should be noted that 'pain at rest' was considered as the outcome measure for the present meta-analysis. Some publications reported other pain outcomes such as 'pain during passive motion by an examiner'. These alternative pain outcomes are described in the results of the systematic review.[34-36, 41, 43, 48] The large variety of ways in which pain during motion was assessed (goniometer, intensity of pain, presence of pain yes/no) did not allow to pool these data for interpretation.

Moreover, while in most included studies, pain ratings were obtained directly from patients, this was not the case in Hartwig *et al.*,[8] in which the patient's pain was estimated by the examiner using the Shoulder-Hand score. This added a further risk of bias. Similarly, the use of questionnaires such as the SPIN to rate pain, may be complex for stroke patients with cognitive limitations and may thus not provide a reliable pain evaluation (such as in Hesse *et al.*[41] or Fletcher-Smith *et al.*[58]).

Limitations of the review process

Despite conducting extensive searches across multiple databases and manually screening relevant sources, it is possible that some studies were overlooked. Additionally, the method used to classify and analyze the interventions may have introduced potential bias, as some outcomes required converting odds ratios into standardized mean differences. This methodological approach can introduce uncertainty in the pooled estimates and may limit the relevance of the results in clinical settings.

The strength of this meta-analysis may also have been hindered by the conversion of distinct pain measurement scales to obtain interpretable effect sizes. The wide variety of pain scales used to assess the presence and intensity of post-stroke pain was a limitation for the meta-analysis of this review. To this day, there is no consensus on the assessment of post-stroke pain and no standardized tool.[61] Edwards *et al.* conducted a systematic review on pain assessment tools used in stroke and identified 10 different tools, with three scales and three questionnaires used to assess shoulder pain: Faces Pain Scale (FPS), Numerical Rating Scales (NRS), VAS, Neuropathic pain Diagnostic Questionnaire (DN4), AbilityQ and ShoulderQ (developed specifically for stroke). These authors could not recommend a preferred tool due to substantial heterogeneity and limited literature.[62] For further research on the primary prevention of upper extremity pain, using a single relevant pain outcome scale, would facilitate the interpretation of results across studies and reduce the risk of bias. Furthermore, considering the variety and complexity of pain mechanisms, it could be useful to better characterize the type of pain reported by patients with appropriate scales such as the neuropathic pain symptom inventory.[63-65]

Moreover, several studies may have been underpowered to estimate the effect size of the preventive intervention, because the measurement of pain was not the primary outcome. Future research should prioritize pain as a primary outcome measure, ensuring that studies are adequately powered and utilize standardized pain assessment tools to enhance comparability and reliability of results.

Conclusions

This systematic review identified seven categories of interventions for the primary prevention of UE pain after stroke. Meta-analysis showed with a very low level of certainty that orthotics, taping and exercise are not more effective than standard care for the prevention of UE pain after stroke. Due to a small number of studies, meta-analysis was not performed for publications reporting preventive positioning, neuromuscular stimulation, intarmuscular drug injection and education.

The findings of this systematic review and meta-analysis did not allow for establishing clinical recommendations for the prevention of UE pain after stroke. Considering the debilitating impact of upper extremity pain on the rehabilitation treatment and prognosis of stroke patients, further research in single preventive approaches or in combinations of interventions for primary prevention of upper extremity pain should be prioritized.

References

1. Anwer S, Alghadir A. Incidence, Prevalence, and Risk Factors of Hemiplegic Shoulder Pain: A Systematic Review. Int J Environ Res Public Health 2020;17:4962.

2. Adey-Wakeling Z, Liu E, Crotty M, Leyden J, Kleinig T, Anderson CS, *et al.* Hemiplegic Shoulder Pain Reduces Quality of Life After Acute Stroke: A Prospective Population-Based Study. Am J Phys Med Rehabil 2016;95:758–63.

3. Bender L, McKenna K. Hemiplegic shoulder pain: defining the problem and its management. Disabil Rehabil 2001;23:698–705.

4. Ryerson S, Levit K. The shoulder in hemiplegia. Physical therapy of the shoulder. Churchill Livingstone. 1987;105–31.

5. Dyer S, Mordaunt DA, Adey-Wakeling Z. Interventions for Post-Stroke Shoulder Pain: An Overview of Systematic Reviews. Int J Gen Med 2020;13:1411–26.

6. Tan PL, Wee TC, Lim AT. Poststroke shoulder pain. Singapore Med J 2024;65:449–53.

7. Klit H, Finnerup NB, Jensen TS. Central post-stroke pain: clini-

cal characteristics, pathophysiology, and management. Lancet Neurol 2009;8:857–68.

8. Hartwig M, Gelbrich G, Griewing B. Functional orthosis in shoulder joint subluxation after ischaemic brain stroke to avoid post-hemiplegic shoulder-hand syndrome: a randomized clinical trial. Clin Rehabil 2012;26:807–16.

9. Matayoshi S, Shimodozono M, Hirata Y, Ueda T, Horio S, Kawahira K. Use of calcitonin to prevent complex regional pain syndrome type I in severe hemiplegic patients after stroke. Disabil Rehabil 2009;31:1773–9.

10. Vasudevan JM, Browne BJ. Hemiplegic shoulder pain: an approach to diagnosis and management. Phys Med Rehabil Clin N Am 2014;25:411–37.

11. Eapen BC, Tran J, Ballard-Hernandez J, Buelt A, Hoppes CW, Matthews C, *et al.* Stroke Rehabilitation: Synopsis of the 2024 U.S. Department of Veterans Affairs and U.S. Department of Defense Clinical Practice Guidelines. Ann Intern Med 2025;178:249–68.

12. Mead GE, Sposato LA, Sampaio Silva G, Yperzeele L, Wu S, Kutlubaev M, *et al.* A systematic review and synthesis of global stroke guidelines on behalf of the World Stroke Organization. Int J Stroke 2023;18:499–531.

13. Teasell R, Salbach N, Foley N, Mountain A, Cameron J, de Jong A, *et al.* Canadian Stroke Best Practice Recommendations: Rehabilitation, Recovery, and Community Participation following Stroke. Part One: Rehabilitation and Recovery Following Stroke; 6th Edition Update 2019. Cerebrovasc Dis 2025;54:429–40.

14. Stroke rehabilitation in adults | Guidance | NICE. 2013 Jun 12 [Internet]. Available from: https://www.nice.org.uk/guidance/cg162 [cited 2024, Feb 18]

15. de Sire A, Moggio L, Demeco A, Fortunato F, Spanò R, Aiello V, *et al.* Efficacy of rehabilitative techniques in reducing hemiplegic shoulder pain in stroke: systematic review and meta-analysis. Ann Phys Rehabil Med 2022;65:101602.

16. Torres-Parada M, Vivas J, Balboa-Barreiro V, Marey-López J. Post-stroke shoulder pain subtypes classifying criteria: towards a more specific assessment and improved physical therapeutic care. Braz J Phys Ther 2020;24:124–34.

17. Viktorisson A, Hashem AH, S Sunnerhagen K, Abzhandadze T. Predicting pain and its association with mortality in patients with stroke. BMC Neurol 2025;25:10.

18. Khatooni M, Dehghankar L, Samiei Siboni F, Bahrami M, Shafaei M, Panahi R, *et al.* Association of post-stroke hemiplegic shoulder pain with sleep quality, mood, and quality of life. Health Qual Life Outcomes 2025;23:32.

19. Haslam BS, Butler DS, Kim AS, Carey LM. Chronic pain following stroke: current treatment and perceived effect. Disabil Health J 2021;14:100971.

20. Price CI, Pandyan AD. Electrical stimulation for preventing and treating post-stroke shoulder pain: a systematic Cochrane review. Clin Rehabil 2001;15:5–19.

21. Nadler M, Pauls M. Shoulder orthoses for the prevention and reduction of hemiplegic shoulder pain and subluxation: systematic review. Clin Rehabil 2017;31:444–53.

22. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.

23. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev 2016;5:210.

24. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health 1998;52:377–84.

25. Aubut JA, Marshall S, Bayley M, Teasell RW. A comparison of the PEDro and Downs and Black quality assessment tools using the acquired brain injury intervention literature. NeuroRehabilitation 2013;32:95–102.

26. Hooper P, Jutai JW, Strong G, Russell-Minda E. Age-related macular degeneration and low-vision rehabilitation: a systematic review. Can J Ophthalmol 2008;43:180–7.

27. Schiltz M, Goudman L, Moens M, Nijs J, Hatem SM. The diagnostic value of physical examination tests in adhesive capsulitis: a systematic review. Eur J Phys Rehabil Med 2023;59:724–30.

28. Nascimento DD, Petriz B, Oliveira SD, Vieira DC, Funghetto SS, Silva AO, *et al.* Effects of blood flow restriction exercise on hemostasis: a systematic review of randomized and non-randomized trials. Int J Gen Med 2019;12:91–100.

29. Welch VA, Petkovic J, Jull J, Hartling L, Klassen T, Kristjansson E, *et al.* Chapter 16: Equity and specific populations. In: Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, *et al.*, editor(s). In: Cochrane Handbook for Systematic Reviews of Interventions Version 64 (updated August 2023) Cochrane, 2023.

30. Rücker G, Cates CJ, Schwarzer G. Methods for including information from multi-arm trials in pairwise meta-analysis. Res Synth Methods 2017;8:392–403.

31. Dean CM, Mackey FH, Katrak P. Examination of shoulder positioning after stroke: A randomised controlled pilot trial. Aust J Physiother 2000;46:35–40.

32. Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M, *et al.* Cochrane Handbook for Systematic Reviews of Interventions version 6.5. Cochrane; 2024.

33. Pandian JD, Kaur P, Arora R, Vishwambaran DK, Toor G, Mathangi S, *et al.* Shoulder taping reduces injury and pain in stroke patients: randomized controlled trial. Neurology 2013;80:528–32.

34. Fujimura K, Kagaya H, Itoh R, Endo C, Tanikawa H, Maeda H. Repetitive peripheral magnetic stimulation for preventing shoulder subluxation after stroke: a randomized controlled trial. Eur J Phys Rehabil Med 2024;60:216–24.

35. de Jong LD, Nieuwboer A, Aufdemkampe G. Contracture preventive positioning of the hemiplegic arm in subacute stroke patients: a pilot randomized controlled trial. Clin Rehabil 2006;20:656–67.

36. Ada L, Foongchomcheay A, Langhammer B, Preston E, Stanton R, Robinson J, *et al.* Lap-tray and triangular sling are no more effective than a hemi-sling in preventing shoulder subluxation in those at risk early after stroke: a randomized trial. Eur J Phys Rehabil Med 2017;53:41–8.

37. Bürge E, Kupper D, Finckh A, Ryerson S, Schnider A, Leemann B. Neutral functional realignment orthosis prevents hand pain in patients with subacute stroke: a randomized trial. Arch Phys Med Rehabil 2008;89:1857–62.

38. Glize B, Cook A, Benard A, Sagnier S, Olindo S, Poli M, *et al.* Early multidisciplinary prevention program of post-stroke shoulder pain: A randomized clinical trial. Clin Rehabil 2022;36:1042–51.

39. Griffin A, Bernhardt J. Strapping the hemiplegic shoulder prevents development of pain during rehabilitation: a randomized controlled trial. Clin Rehabil 2006;20:287–95.

40. Hanger HC, Whitewood P, Brown G, Ball MC, Harper J, Cox R, *et al.* A randomized controlled trial of strapping to prevent post-stroke shoulder pain. Clin Rehabil 2000;14:370–80.

41. Hesse S, Mach H, Froehlich S, Behrend S, Melzer I, Werner C. The early Botulinum Toxin A injection may prevent a disabling finger flexor stiffness six months later in subacute stroke patients. Neurol Rehabil. 2011;17:233–8.

42. Hochsprung A, Domínguez-Matito A, López-Hervás A, Herrera-Monge P, Moron-Martin S, Ariza-Martínez C, *et al.* Short- and medium-term effect of kinesio taping or electrical stimulation in hemiplegic shoulder pain prevention: A randomized controlled pilot trial. NeuroRehabilitation 2017;41:801–10.

43. Horsley S, Lannin NA, Hayward KS, Herbert RD. Additional early active repetitive motor training did not prevent contracture in adults receiving task-specific upper limb training after stroke: a randomised trial. J Physiother 2019;65:88–94.

44. Huang YC, Leong CP, Wang L, Wang LY, Yang YC, Chuang CY, *et al.*

Effect of kinesiology taping on hemiplegic shoulder pain and functional outcomes in subacute stroke patients: a randomized controlled study. Eur J Phys Rehabil Med 2016;52:774–81.

45. Kim MG, Lee SA, Park EJ, Choi MK, Kim JM, Sohn MK, *et al.* Elastic Dynamic Sling on Subluxation of Hemiplegic Shoulder in Patients with Subacute Stroke: A Multicenter Randomized Controlled Trial. Int J Environ Res Public Health 2022;19:9975.

46. Malhotra S, Rosewilliam S, Hermens H, Roffe C, Jones P, Pandyan AD. A randomized controlled trial of surface neuromuscular electrical stimulation applied early after acute stroke: effects on wrist pain, spasticity and contractures. Clin Rehabil 2013;27:579–90.

47. Pan R, Zhou M, Cai H, Guo Y, Zhan L, Li M, *et al.* A randomized controlled trial of a modified wheelchair arm-support to reduce shoulder pain in stroke patients. Clin Rehabil 2018;32:37–47.

48. Sunderland A, Fletcher D, Bradley L, Tinson D, Hewer RL, Wade DT. Enhanced physical therapy for arm function after stroke: a one year follow up study. J Neurol Neurosurg Psychiatry 1994;57:856–8.

49. Sunderland A, Tinson DJ, Bradley EL, Fletcher D, Langton Hewer R, Wade DT. Enhanced physical therapy improves recovery of arm function after stroke. A randomised controlled trial. J Neurol Neurosurg Psychiatry 1992;55:530–5.

50. van Bladel A, Lambrecht G, Oostra KM, Vanderstraeten G, Cambier D. A randomized controlled trial on the immediate and long-term effects of arm slings on shoulder subluxation in stroke patients. Eur J Phys Rehabil Med 2017;53:400–9.

51. Yildirim M, Öneş K, Ata İ, Çorum M, Gökşenoğlu G. Comparison of the Effectiveness of Two Different Types of Slings in Shoulder Subluxation After Stroke. Journal of Physical Medicine & Rehabilitation Sciences. 2022;25:233–9.

52. Lannin NA, Horsley SA, Herbert R, McCluskey A, Cusick A. Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. Arch Phys Med Rehabil 2003;84:297–302.

53. Comley-White N, Mudzi W, Musenge E. Effects of shoulder strapping in patients with stroke: A randomised control trial. S Afr J Physiother 2018;74:430.

54. Huang YC, Chuang CY, Leong CP, Wang L, Chen HL, Chiang CW. Effect of Comprehensive Postural Instructions and Range of Motion Exercises Via Educational Videos on Motor Function and Shoulder Injury in Stroke Patients With Hemiplegia: A Preliminary Study. J Manipulative Physiol Ther 2018;41:665–71.

55. Kumar R, Metter EJ, Mehta AJ, Chew T. Shoulder pain in hemiplegia. The role of exercise. Am J Phys Med Rehabil 1990;69:205–8.

56. Linn SL, Granat MH, Lees KR. Prevention of shoulder subluxation after stroke with electrical stimulation. Stroke 1999;30:963–8.

57. Praveen Raj J, Dsouza S, Sitaram A, Umakanth S. Effectiveness of Caregiver Education for Prevention of Shoulder Pain in Acute Stroke Survivors: a Randomised Controlled Trial. Disabil CBR Incl Dev 2021;32:66–80.

58. Fletcher-Smith JC, Walker DM, Allatt K, Sprigg N, James M, Ratib S, *et al.* The ESCAPS study: a feasibility randomized controlled trial of early electrical stimulation to the wrist extensors and flexors to prevent post-stroke complications of pain and contractures in the paretic arm. Clin Rehabil 2019;33:1919–30.

59. Yoon Y, Kim J, Lee K. The effect of modified triangular bobath slings on shoulder subluxation in stroke patients. J Korean Acad Reha- bil. Med (N Y) 2004;28:494–500.

60. Aguilar García M, González Muñoz A, Pérez Montilla JJ, Aguilar Nuñez D, Hamed Hamed D, Pruimboom L, *et al.* Which Multimodal Physiotherapy Treatment Is the Most Effective in People with Shoulder Pain? A Systematic Review and Meta-Analyses. Healthcare (Basel) 2024;12:1234.

61. de Vries N, Sloot P, Achterberg WP. Pain and pain assessment in stroke patients with aphasia: a systematic review. Aphasiology 2017:31.

62. Edwards SA, Ioannou A, Carin-Levy G, Cowey E, Brady M, Morton S, *et al.* Properties of Pain Assessment Tools for Use in People Living With Stroke: systematic Review. Front Neurol 2020;11:792.

63. Igawa Y, Osumi M, Takamura Y, Uchisawa H, Iki S, Fuchigami T, *et al.* Pathological features of post-stroke pain: a comprehensive analysis for subtypes. Brain Commun 2025;7:fcaf128.

64. Bouhassira D, Attal N, Fermanian J, Alchaar H, Gautron M, Masquelier E, *et al.* Development and validation of the Neuropathic Pain Symptom Inventory. Pain 2004;108:248–57.

65. Barbosa LM, da Silva VA, de Lima Rodrigues AL, Mendes Fernandes DT, de Oliveira RA, Galhardoni R, *et al.* Dissecting central post-stroke pain: a controlled symptom-psychophysical characterization. Brain Commun 2022;4:fcac090.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

Contributions to the conception or the design of the manuscript: Memnune A. Denizli, Samar M. Hatem, Patricia Dessart; Acquisition of data: Memnune A. Denizli, Samar M. Hatem; Review of extracted data and methodological quality assessment: Memnune A. Denizli, Samar M. Hatem and Patricia Dessart; Analysis and interpretation of data: Memnune A. Denizli, Samar M. Hatem, Gauthier Everard; Drafting the manuscript: Memnune A. Denizli, Samar M. Hatem; Critical revision of the manuscript: Samar M. Hatem, Gauthier Everard and Patricia Dessart. All authors read and approved the final version of the manuscript.

Acknowledgements

The authors acknowledge Céline Bugli as statistical advisor, from the Department of Statistical Methodology and Computing at UCLouvain (Belgium).

History

Manuscript accepted: November 18, 2025. - Manuscript revised: November 3, 2025. - Manuscript received: May 10, 2025.

Supplementary data

For supplementary materials, please see the HTML version of this article at www.minervamedica.it