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REVIEW ARTICLE

SHOULDER ULTRASOUND IMAGING IN THE POST-STROKE POPULATION: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Objective: **Post-stroke shoulder pain is a serious challenge for stroke survivors. The aim of this meta-analysis was to review the literature to confirm information on structural changes in post-stroke shoulders detected by ultrasound examination.**

Methods: **PubMed, Embase, Web of Science and ClinicalTrials.gov were searched until 7 December 2022, for studies describing shoulder sonographic findings in stroke patients. Two independent authors selected the studies, extracted the data, and performed the critical appraisal.**

Results: **A total of 23 clinical studies were included. The most prevalent pathologies in hemiplegic shoulders pertained to the biceps long head tendon (41.4%), followed by the supraspinatus tendon (33.2%), subdeltoid bursa (29.3%), acromioclavicular joint (15.0%), and subscapularis tendon (9.2%). The common pathological findings encompassed bicipital peritendinous effusion (39.2%), biceps tendinopathy (35.5%), subdeltoid bursitis (29.3%) and supraspinatus tendinopathy (24.6%). Biceps long head tendon and supraspinatus tendon abnormalities were observed significantly more in the hemiplegic (vs contralateral) shoulders, with odds ratios of 3.814 (95% confidence interval 2.044–7.117) and 2.101 (95% confidence interval 1.257–3.512), respectively. No correlation was observed between motor function and shoulder pathology.**

Conclusion: **Ultrasonography enabled the identification of common shoulder pathologies after stroke. Further research is needed to establish the association between these changes and the clinical course of stroke patients.**

Key words: hemiplegia; rotator cuff; pain; ultrasonography; rehabilitation.

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LAY ABSTRACT

Stroke is a debilitating disease affecting thousands of people worldwide. Post-stroke shoulder pain is a prevailing complication among stroke survivors that negatively impacts their rehabilitative endeavours and quality of life. Musculoskeletal ultrasound is a practical tool for investigating soft-tissue pathologies. Through comprehensive literature review and analysis, this study found that abnormalities in the biceps long head tendon, supraspinatus tendon, subdeltoid bursa, acromioclavicular joint, and subscapularis tendon were common. Specifically, the most frequent pathologies were bicipital peritendinous effusion, biceps tendinopathy, subdeltoid bursitis, supraspinatus tendinopathy, and supraspinatus partial thickness tear. Ultrasound is useful in uncovering these lesions and guiding relevant interventions in case of painful shoulder after stroke.

Stroke is a major cause of mortality and morbidity, with over 100 million survivors worldwide (1). The musculoskeletal system is affected at multiple levels following a cerebrovascular event, such as weakness, impaired sensation, abnormal muscle tone, autonomic dysfunction, and pain. The incidence of post-stroke hemiplegic shoulder pain is particularly high, ranging from 34% to 84% (2). Tenderness at the bicipital groove and supraspinatus muscle appears to be the most common complaint (3).

The everyday functioning of the shoulder joint depends upon an intrinsic framework of articulations, muscles, and connective tissues. However, the anatomical structure of the shoulder, which allows freedom of movement of the shoulder, makes it vulnerable to injuries (4). Likewise, numerous pathologies have been described in hemiplegic shoulder pain, including rotator cuff disorders, adhesive capsulitis, shoulder subluxation, spasticity, shoulder-hand syndrome, and post-stroke central pain (5). These problems can simultaneously occur in stroke patients, undermining their rehabilitation process and quality of life (6). Data regarding the aforementioned shoulder pathologies after stroke are insufficient (3, 7–9).

Ultrasonography has emerged as an accessible tool to diagnose diverse soft-tissue problems owing to its portability, non-invasiveness, economic efficiency, and zero radiation (10). The imaging technique also allows for real-time guided interventions, which is an advantage over magnetic resonance imaging (MRI).

Furthermore, comparable diagnostic accuracy of ultrasonography and MRI in detecting shoulder pathologies has been demonstrated (11, 12). Although several studies have reported ultrasonographic findings of hemiplegic shoulders, their sample sizes were relatively small (13–15). To the best of our knowledge, no systematic review has investigated this subject. Therefore, the aim of this meta-analysis is to provide insights into the pathological changes in post-stroke hemiplegic shoulders using ultrasonography. Such data could be used to determine the relevant treatment strategies for hemiplegic shoulder pain.

METHODS

Protocol registration

This meta-analysis was performed in accordance with the PRISMA 2020 guidelines (Table SI) (16). The study protocol was registered on inplasy.com (registration number: INPLASY2022120075).

Database search

To identify potentially eligible studies, 3 electronic databases (PubMed, Embase, and Web of Science) were systematically searched from inception to 7 December 2022, without any language restrictions. The following key words were used: ("ultrasound" OR "sonography" OR "ultrasonography") AND ("stroke" OR "post-stroke" OR "hemiplegic") AND ("shoulder" OR "upper limb" OR "arm"). The reference lists of the retrieved articles were manually checked for additional studies. ClinicalTrials.gov was searched for unpublished data from the ongoing trials. The search strategy is described in the Table SII.

Inclusion and exclusion criteria

The PICO (population, intervention, comparison, and outcome) question was formulated as follows: What were the ultrasound findings of hemiplegic shoulders (outcome) in post-stroke patients (population), and how did those structural abnormalities differ between hemiplegic and non-hemiplegic shoulders (comparison) ? Clinical studies that examined hemiplegic shoulders with ultrasound and reported at least 1 pathological finding were included. Articles were excluded if ultrasound was employed as a treatment modality rather than as a diagnostic tool or if only shoulder subluxation was described. Case reports, letters, editorials, commentaries, posters, and unpublished articles were also excluded. Two independent authors (TY-L. and PC-S.) evaluated the titles and abstracts of the papers. Eligible articles were read in the full text to ensure that all inclusion/exclusion criteria were met. Any disagreement during the entire procedure was resolved through discussion with the corresponding author.

Methodology quality appraisal

The methodological quality of the included studies was graded using the Newcastle-Ottawa scale (17). The checklist, designed for assessing the quality of non-randomized studies, contained 7 items in 3 domains: selection, comparability, and outcome. A maximum of 5 stars could be awarded to the selection domain, 2 to the comparability domain, and 3 to the outcome domain. Study quality was judged as very high with a score of $\geq$9, high with a score of 7 or 8, satisfactory with a score of 5 or 6, and unsatisfactory with a score of $\leq$4.

Data extraction

Two authors (TY-L. and PC-S.) separately collected the pathological shoulder findings from each included study and sorted them into an Excel spreadsheet (Microsoft Corp., Redmond, WA, USA). All differences were inspected and adjudicated by the corresponding author. Other information extracted included the first author, year of publication, study design, number of participants, age and hemiplegic side of the participants, and mean time elapsed since stroke onset.

Statistical analysis

The primary outcome was the prevalence of pathological structures and findings on ultrasound imaging of the hemiplegic shoulders (in comparison with the non-hemiplegic side). The effect sizes were the percentage for reporting the prevalence and odds ratios for quantifying the association of categorical variables. Subgroup analysis was conducted to determine differences in motor function of the affected upper extremities. Data were pooled using the random effects model, considering significant variations in ultrasound scanning protocols and different stages of stroke (18). Between-study heterogeneity was assessed using I^2 and Cochran's Q statistics. An I^2 value >50% was considered as significant heterogeneit (19). Publication bias was evaluated using Egger's test and visual inspection of the funnel plot in the pooled analysis, with more than 10 studies included (20). The analysis was conducted using Comprehensive Meta-Analysis software (version 3; Biostat, Englewood, NJ, USA), with a 2-tailed p-value < 0.05 deemed statistically significant.

RESULTS

Literature search

The search identified 970 publications. After removing duplicates and title/abstract readings, 928 articles were discarded. The full texts of the remaining 42 studies were then assessed carefully. A further 19 articles were excluded: 13 did not report specific shoulder pathological findings, 4 did not evaluate shoulder structures, and 2 included only patients with low motor function (Table SIII). A total of 23 studies (13–15, 21–40) were included in the final quantitative analysis (Fig. 1). Details of data extraction from the included trials are listed in Table SIV.

Study characteristics

The 23 included studies included 1,509 participants, age range 20–96 years. Among them, 14 studies (13–15, 21–31) evaluated only the hemiplegic shoulders, whereas 9 (32–40) reported comparative/bilateral ultrasound examinations. The majority of the studies were published in Asia, 8 in Taiwan (13, 14, 23, 26–28, 32, 36), 7 in South Korea (15, 21, 24, 33–35, 38), 2 in Turkey (25, 29) and 1 in India (30). The mean duration since stroke onset ranged widely between 17 days (13) and 26 months (30). More than half of the studies analysed more than 50 participants (14, 15, 22–25, 29, 31, 32, 35, 37–39). The characteristics of the studies are shown in Table I.

Quality assessment

Only 3 studies (22, 24, 25) performed power calculations and therefore fulfilled Item 3 (justified and satisfactory sample size). One point was deducted from Item 6 (validated method) in 8 articles (21, 22, 25, 27, 28, 30, 37, 38) due to the lack of a detailed description of the ultrasound findings. Lee et al. (32) did not elaborate on the stroke type of the participants and lost 1 point in Item 4 (ascertainment of diagnosis). Full marks were scored for all other items for all recruited papers. According to the Newcastle-Ottawa scale, 16 studies (13–15, 22–26, 29, 31, 33–36, 39, 40) were of very high quality and 7 (21, 27, 28, 30, 32, 37, 38) of high quality (Table II).

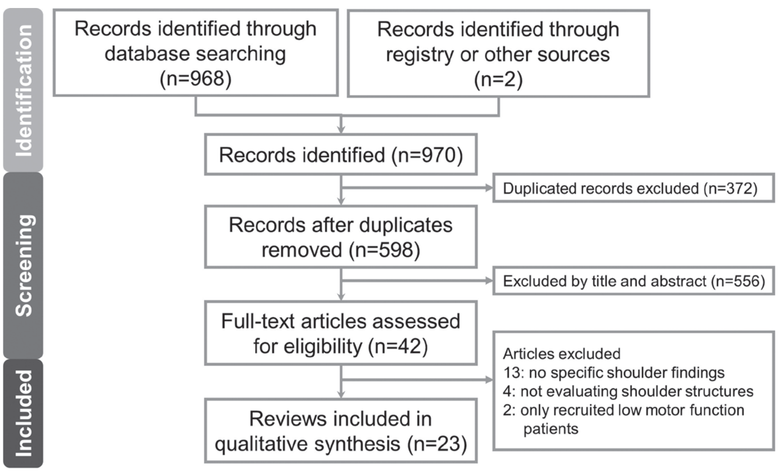

Fig. 1. Flow diagram for the literature search.

Ultrasound findings (general)

Hemiplegic shoulder pathologies pertained to various structures, most commonly being the biceps long head tendon (41.4%; 95% confidence interval (95% CI) 33.3–50.1%; I^2 86.2%; Fig. S1), followed by the supraspinatus tendon (33.2%; 95% CI 24.13–43.6%; I^2 86.1%; Fig. S2), subdeltoid bursa (29.3%; 95% CI 21.9–38.0%; I^2 87.4%; Fig. S3), acromioclavicular joint (15.0%; 95% CI, 3.5–46.0%; I^2 93.4%; Fig. S4), and subscapularis tendon (9.2%; 95% CI 3.4–22.4%; I^2 87.6%; Fig. S5). Regarding the prevalence of specific pathological findings, bicipital peritendinous effusion ranked first (39.2%; 95% CI, 35.1–43.5%; I^2 87.3%; Fig. S6), followed by biceps tendinopathy (35.5%; 95% CI 18.0–57.9%; I^2 92.6%; Fig. S7), subdeltoid bursitis (29.3%; 95% CI, 21.9–38.0%; I^2 87.4%; Fig. S3), supraspinatus tendinopathy (24.6%; 95% CI 13.8–39.9%; I^2 88.5%; Fig. S8), supraspinatus partial-thickness tear (14.5%, 95% CI, 6.8–28.2%; I^2 89.0%; Fig. S9), infraspinatus tendinopathy (14.1%; 95% CI 7.4–25.3%; I^2 79.4%; Fig. S10), biceps tendon tear (8.1%; 95% CI 2.7–22.1%; I^2 68.3%; Fig. S11), supraspinatus full-thickness tear (3.5%; 95% CI 1.9–6.5%; I^2 <0.01%; Fig. S12), and infraspinatus tendon tear (2.0%; 95% CI 0.6–6.6%; I^2 <0.01%; Fig. S13).

Ultrasound findings (hemiplegic vs non-hemiplegic shoulders)

Compared with the non-hemiplegic side, hemiplegic shoulders had an increased risk of developing pathologies in the biceps long head tendon (odds ratio (OR) 3.814; 95% CI 2.044–7.117; I^2 70.1%; Fig. 2A) and supraspinatus tendon (OR 2.101; 95% CI 1.257–3.512; I^2 27.0%; Fig. 2B). A similar increased risk was not observed for the subscapularis tendon (OR 1.808; 95% CI 0.285–11.479; I^2 35.0%; Fig. S14), acromioclavicular joint (OR 1.556; 95% CI 0.530–4.570; I^2 <0.01%; Fig. S15), and infraspinatus tendon (OR 1.764; 95% CI 0.294–10.591; I^2 35.0%; Fig. S16).

Regarding specific pathologies, hemiplegic shoulders had an increased risk of developing biceps peritendinous effusion (OR 3.081; 95% CI 1.801–5.272; I^2 56.2%; Fig. 3A), biceps tendinopathy (OR 12.894; 95% CI 1.718–96.798; I^2 76.9%; Fig. 3B), subdeltoid bursitis (OR 3.747; 95% CI 2.242–6.264; I^2 26.6%; Fig. 4A), supraspinatus tendinopathy (OR

Table I. Characteristics of the included studies

Reference	Country	Study type	Duration since stroke onset, days (mean)	Partici-pants *n*	Age, years Mean (range)	Hemiplegic side (right/ left)	Ultrasound machine/transducer
Studies evaluating only the hemiplegic shoulder							
Pong et al., 2009 (13)	Taiwan	Prospective, case-control	17.3	34	66.6 (42–85)	15/19	Sequoia 512 ultrasound/(Siemens, Germany) 5–10 MHz linear array transducer
Huang et al., 2010 (14)	Taiwan	Crosssectional	19.7	57	59.9 (47–74)	20/37	Terason t3000 (Terason, USA) /5–12 MHz linear array transducer
Kim et al., 2011 (15)	South Korea	Retrospective	43.8	82	63.5 (41–85)	33/49	EnVisor HD (Philips, Netherlands) /7–15 MHz high resolution linear probe
Pompa et al, 2011 (21)	South Korea	Retrospective	35.4	41	72.3 (41–85)	24/17	NA/5–12 MHz linear transducer
Zaiton et al, 2011 (22)	Egypt	Prospective, case-control	68.2	106	57.0 (40–78)	39/67	Nemio XG (Toshiba, Japan)/6–12 MHz linear phased array transducer
Pong et al., 2012 (23)	Taiwan	Prospective, longitudinal	46.1	76	59.7 (30–87)	NA	Terason t3000 (Terason, USA)/5–12 MHz linear array transducer
Rah et al., 2012 (24)	South Korea	Multicentre, randomized, triple-blind, placebo-controlled	23.6	58	56.6 (20–70)	Dominant: 33 Non-dominant: 25	Logiq P6 (GE Healthcare, US), Accuvix XQ (Samsung Medison, Korea), SonoAce X8 (Samsung Medison, Korea), HD 11XE (Philips, Netherlands)/5–13 MHz linear array transducers
Doğun et al., 2014 (25)	Turkey	Retrospective	49.0	68	63.7 (43–82)	36/32	ATL HDI 1500 (Philips, Netherlands)/ superficial probe
Huang et al., 2017 (26)	Taiwan	Double-blind, placebo-controlled	71.1	21	57.4 (43–72)	9/12	Aplio 300 TUS-A300 (Toshiba, Japan) /5–12 MHz high-resolution linear scanner
Huang et al., 2018 (27)	Taiwan	Randomized, double-blinded controlled	89.0	27	50.5 (49– 72)	11/16	ACUSON S2000 (Siemens, Germany)/9–14 MHz linear array transducer
Lin et al., 2018 (28)	Taiwan	Retrospective	78.2	26	66.5 (38–91)	10/16	Acuson X300 (Siemens, Germany)/ 4.4–13.0 MHz linear transducer
Korkmaz et al. 2020 (29)	Turkey	Cross-sectional	390.0	64	63.1 (18–75)	31/33	Logic e portable (GE HealthCare, US)/5–12 MHz linear array transducer
Arya et al., 2021 (30)	India	Prospective, case-series	792.0	8	53.3 (35–76)	4/4	LOGIQ S8 (GE HealthCare, USA)/4–15 MHz linear-array probe
El-Sonbaty et al., 2022 (31)	Egypt	Cross-sectional	254.3	210	61.7 (59–67)	97/113	Xario 200 (Toshiba, Japan)/7–14 MHz. linear phased array transducer
Studies comparing bilateral shoulders							
Lee et al., 2002 (32)	Taiwan	Prospective, case-control	308.7	82	61.0 (20–87)	37/45	ATL HDI 1500 (Philips, Netherlands)/ 5–12 MHz high-resolution linear scanner
Park et al, 2007 (33)	South Korea	Prospective, single blind	30.0	41	56.0 (34–78)	15/26	Sonoace 9900 (Samsung Medison, Korea)/5–12 MHz linear array transducer
Baek et al., 2009 (34)	South Korea	Prospective, case-control	43.0	36	62.9 (49–77)	9/27	SonoAce 8800 (Samsung Medison, Korea)/5–9 MHz linear array transducer
Lee et al., 2009 (35)	South Korea	Prospective, case-control	91.0	71	60.0 (23–78)	34/38	iU22 (Philips, Netherlands)/1217 MHz highresolution electronic linear array transducer
Huang et al., 2012 (36)	Taiwan	Cross-sectional	22.0	39	65.0 (54–76)	NA	HD 11XE (Philips, Netherlands)/5–12 MHz high-resolution linear scanner
Pop et al., 2013 (37)	Poland	Retrospective	243.8	182	63.0 (21–96)	90/92	EUB-565 (Hitachi, Japan)/7.5 MHz high-resolution linear scanner
Yi et al., 2013 (38)	South Korea	Cross-sectional	54.0	55	63.5 (45–80)	16/39	Accuvix V20 (Samsung Medison, Korea)/NA
Mohamed et al., 2014 (39)	Egypt	Prospective, case-control	61.9	80	62.3 (35–75)	63/17	Model unspecified (Biomedical, Denmark)/12 MHz linear array transducer
Idowu et al., 2017 (40)	Nigeria	Prospective, case-control	NA	45	62.0 (50–77)	26/19	Mindray DC-7 (Mindray, China)/7–12 MHz linear transducer

NA: not available

4.722; 95% CI 1.482–15.046; I^2 47.4%; Fig. 4B), and supraspinatus partial-thickness tear (OR 2.302; 95% CI 1.467–3.612; I^2 <001%; Fig. 4C). No increased risk was observed for supraspinatus full-thickness tear (OR 0.695; 95% CI 0.184–2.621; I^2 <001%; Fig. S17).

Ultrasound findings (shoulders with high vs low motor function)

Based on the Brunnstrom stage, the categorization of hemiplegic shoulders into high and low motor functions was available in 3 studies. Compared with shoulders with high motor function, those with low motor function did not have an increased risk of developing pathologies in the biceps tendon (OR 0.769; 95% CI 0.196–3.020; I^2 <001; Fig. S18), subscapularis tendon (OR 0.784; 95% CI 0.155–3.961; I^2 <001; Fig. S19), subdeltoid bursa (OR 0.627; 95% CI 0.070–5.573; I^2 75.2%; Fig. S20) and supraspinatus tendon (OR, 2.206; 95% CI 0.951–5.116; I^2 <001; Fig. S21).

Publication bias

Publication bias was analysed in the pooled analysis for the prevalence of pathologies of the biceps long head tendon, subdeltoid bursa, and supraspinatus tendon,

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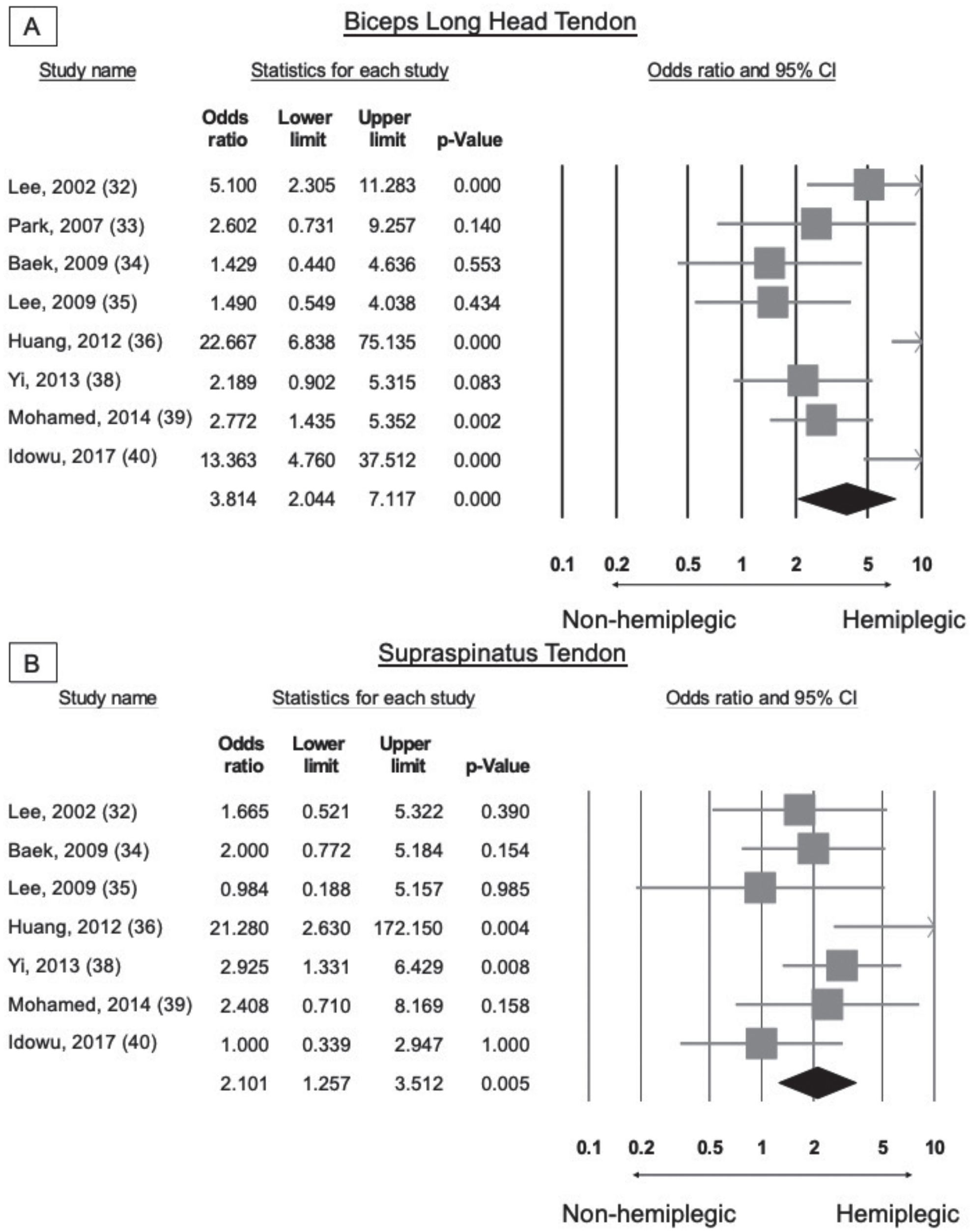

Fig. 2. Comparison of the prevalence of pathologies regarding (A) the biceps long head and (B) supraspinatus tendons (hemiplegic vs non-hemiplegic sides).

and the existence of biceps peritendinous effusion. None of the *p*-values examined by Egger's test were less than 0.05 (Figs S22–S25).

DISCUSSION

In this meta-analysis, several ultrasound findings were common in post-stroke hemiplegic shoulders. The top-ranking structure with pathologies was the biceps long head tendon, followed by the supraspinatus tendon, subdeltoid bursa, acromioclavicular joint, and subscapularis tendon. The most frequent hemiplegic shoulder pathologies were bicipital peritendinous effusion, biceps tendinopathy, subdeltoid bursitis, supraspinatus tendinopathy, and supraspinatus partial-thickness tear. The prevalence of pathologies was significantly higher in the hemiplegic (vs non-hemiplegic) shoulders, but only for the biceps long head and supraspinatus tendons. In addition, impaired upper-limb motor function was not associated with an increased incidence of shoulder pathologies.

The biceps long head tendon was the primary lesion site in hemiplegic shoulders, with a pooled prevalence of 41.4% according to the current meta-analysis.

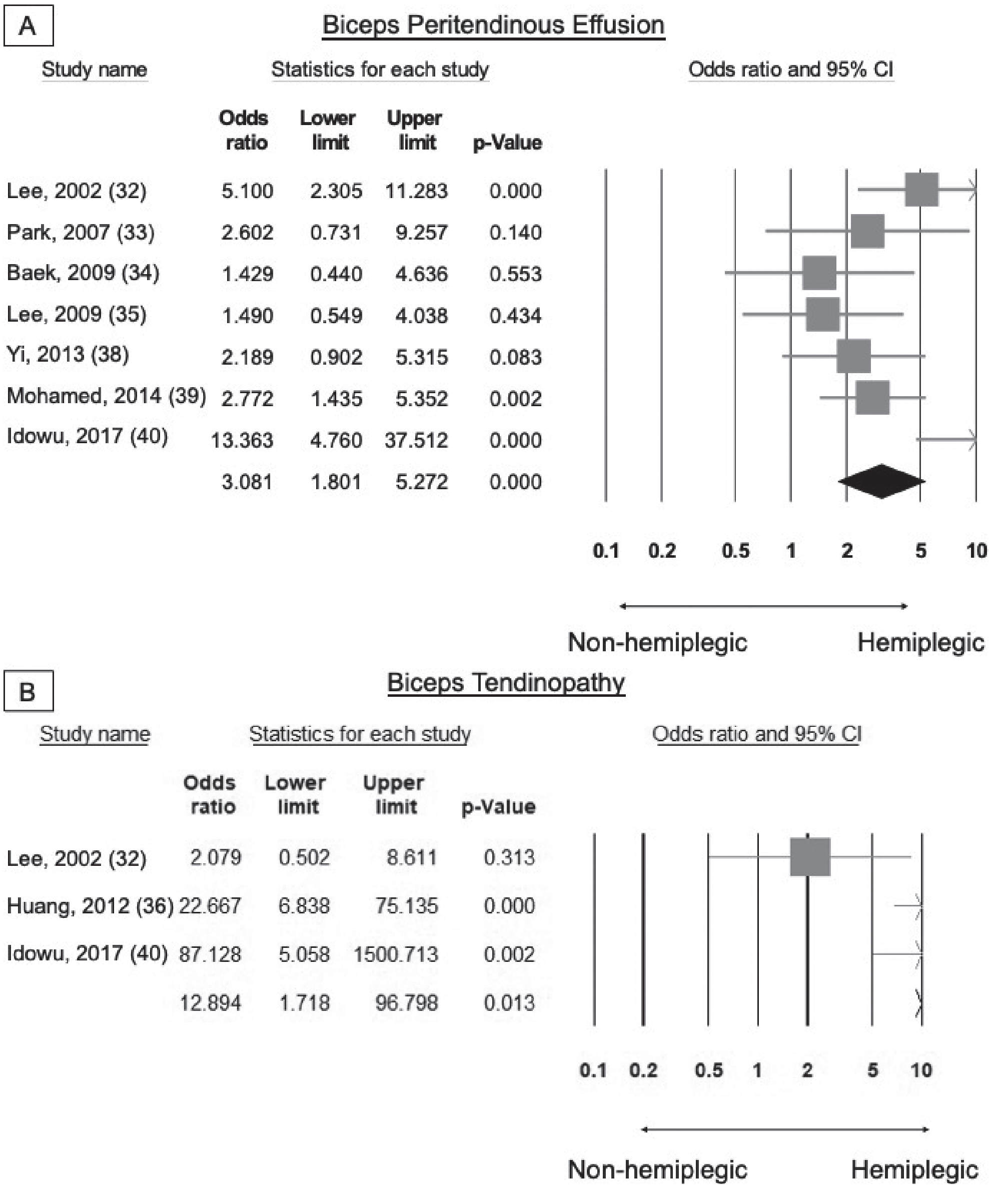

Fig. 3. Comparison of the prevalence regarding biceps (A) peritendinous effusion and (B) tendinopathy (hemiplegic vs non-hemiplegic sides).

Peritendinous effusion and tendinopathy were the first and second most commonly reported biceps pathologies, respectively. This tendon originates intra-articularly from the supraglenoid tubercle of the scapula, exits the joint, and enters the rotator cuff interval (41). Proximal to the intertubercular groove of the humeral head, it is enveloped by the coracohumeral and superior glenohumeral ligaments as well as fibres from the supraspinatus and subscapularis tendons (42, 43). These soft-tissue restraints maintain it in place (43). Hence, it is not surprising that injuries in the surrounding structures can cause secondary irritation and disrupt its anatomical integrity. Studies reported associations between peritendinous effusion and supraspinatus/subscapularis tears, subscapularis tendinopathy, subdeltoid bursitis, and dynamic subacromial impingement (44, 45). In addition, as the tendon sheath extends directly from the glenohumeral cavity, bicipital peritendinous effusion may reflect intra-articular abnormalities. Similarly, biceps tendinopathy rarely occurs alone, and is often accompanied by other shoulder pathologies (43). Mechanical stress from the neighbouring structures or the coracoacromial arch can result in tendon inflammation, degeneration, fraying, tearing, and ultimately, rupture. Since the biceps long head tendon helps anchor the humeral head in the glenoid fossa, its derangement can lead to further shoulder instability and tissue damage, exacerbating dysfunctional biomechanics (41).

Pathologies of the supraspinatus tendon was present in one-third (33.2%) of the hemiplegic shoulders

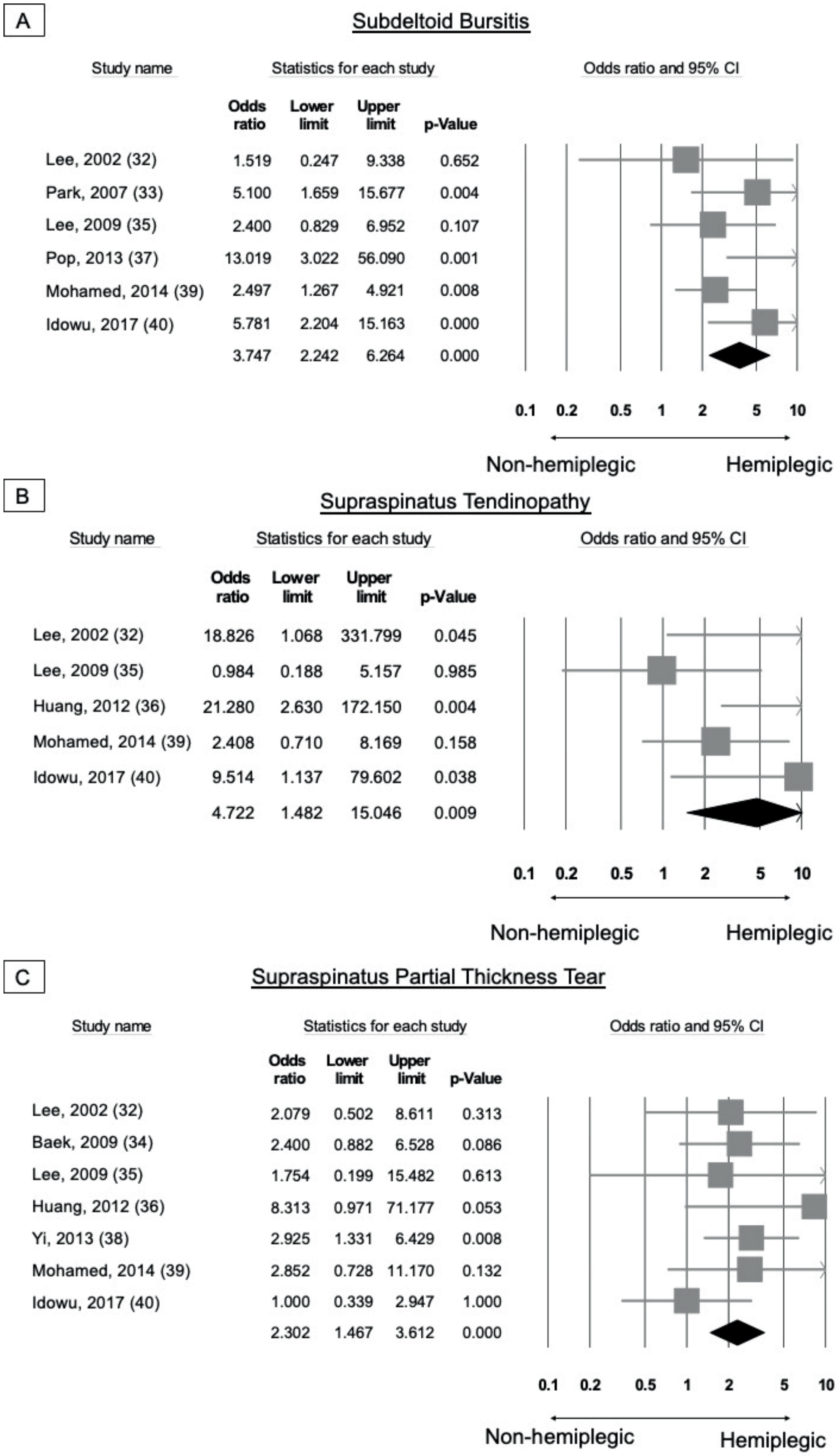

Fig. 4. Comparison of the prevalence regarding (A) subdeltoid bursitis, (B) supraspinatus tendinopathy and (C) partial thickness tear (hemiplegic vs non-hemiplegic sides).

Table II. Methodological quality assessment using the Newcastle-Ottawa Scale

	Selection				Comparability	Outcome		
Author, year	Representativeness	Selection	Sample size	Diagnosis	Cofounders	Validated method	Statistical test	Total score
Studies evaluating only the hemiplegic shoulder								
Pong et al., 2009 (13)	*	*		**	**	**	*	9
Huang et al., 2010 (14)	*	*		**	**	**	*	9
Kim et al., 2011 (15)	*	*		**	**	**	*	9
Pompa et al, 2011 (21)	*	*		**	**	*	*	8
Zaiton et al, 2011 (22)	*	*	*	**	**	*	*	9
Pong et al., 2012 (23)	*	*		**	**	**	*	9
Rah et al., 2012 (24)	*	*	*	**	**	**	*	10
Doğun et al., 2014 (25)	*	*	*	**	**	*	*	9
Huang et al., 2017 (26)	*	*		**	**	**	*	9
Huang et al., 2018 (27)	*	*		**	**	*	*	8
Lin et al., 2018 (28)	*	*		**	**	*	*	8
Korkmaz et al., 2020 (29)	*	*		**	**	**	*	9
Arya et al., 2021 (30)	*	*		**	**	*	*	8
El-Sonbaty et al., 2022 (31)	*	*		**	**	**	*	9
Studies comparing bilateral shoulders								
Lee et al., 2002 (32)	*	*		*	**	**	*	8
Park et al, 2007 (33)	*	*		**	**	**	*	9
Baek et al., 2009 (34)	*	*		**	**	**	*	9
Lee et al, 2009 (35)	*	*		**	**	**	*	9
Huang et al., 2012 (36)	*	*		**	**	**	*	9
Pop et al., 2013 (37)	*	*		**	**	*	*	8
Yi et al., 2013 (38)	*	*		**	**	*	*	8
Mohamed et al, 2014 (39)	*	*		**	**	**	*	9
Idowu et al, 2017 (40)	*	*		**	**	**	*	9

*Number of points earned in each item.

according to the current meta-analysis. The supraspinatus muscle has 2 main tasks: to perform arm abduction along with the deltoid, and to maintain the stability of the glenohumeral joint (46). Several factors can make it susceptible to injury in stroke. First, shoulder kinematics are altered by weakness, spasticity, contracture, and proprioception deficiency. The supraspinatus would have to compensate for the weakened deltoid during shoulder movements. Failure of scapular stabilizers (e.g. trapezius, rhomboid, and serratus anterior muscles) generates shearing forces on the rotator cuff muscles (23, 47). Likewise, the dominant flexor tone of the upper extremity results in depression of the scapula and exposes the supraspinatus to tension. Secondly, suboptimal positioning and traction forces from gravity, transfer, or inappropriate exercises also contribute to potential trauma. In particular, shoulder subluxation quickly appears in a large proportion of patients with stroke (48). Third, a cadaveric study demonstrated short muscle fibres and long resting sarcomeres in the supraspinatus, which was ideal for maintaining the humeral head in the shallow glenoid due to large passive tension (49). However, this exquisite architectural arrangement also implies that minor stretches would exert great restoring forces. Multifactorial tensile stress, coupled with the sensitive nature of the muscle, can lead to fatigue, stiffening, and tears after stroke.

The third most widely seen pathological site in hemiplegic shoulders was the subdeltoid bursa, with a prevalence of 29.3% among the enrolled studies. The extra-articular space is situated atop the rotator cuff tendon and beneath the deltoid muscle, acromioclavicular joint, and acromion (50). The physiological fluid within thin, slippery synovial membranes helps reduce friction between adjacent tissues with normal thicknesses within 2 mm (51). Thickening of the subdeltoid bursa could be a consequence of chronic impingement by the proliferation of protective bursal fluid, as well as cellular infiltration and collagen deposition in its wall (52, 53). Another origin of subdeltoid effusion is injury to the compromised rotator cuff muscles after stroke. Under normal circumstances, the bursa is separated from the glenohumeral joint; nonetheless, a full-thickness rotator cuff tear could create a communication between them (54). In fact, concurrent joint effusion is a highly specific sign of rotator cuff tears (sensitivity 22%; specificity 99%; positive predictive value 95%) (55).

Of the 9 studies that listed bilateral ultrasonographic findings, there was a significantly higher incidence of biceps long head tendon and supraspinatus tendon lesions in the hemiplegic shoulders. Biceps peritendinous effusion, biceps tendinopathy, subdeltoid bursitis, supraspinatus tendinopathy, and supraspinatus partial-thickness (but not full-thickness) tears were more common in hemiplegic shoulders. Full-thickness supraspinatus tears were observed in only 3.5% of post-stroke shoulders. This might indicate opportunities for successful non-operative treatment of hemiplegic shoulder pain due to commonly encountered rotator cuff tendon disorders.

Only 3 studies divided the patients according to their Brunnstrom stage. There was no statistical difference in the incidence of pathological shoulder structures between the high and low motor function groups. This could possibly be attributed to the small sample sizes. In addition, ultrasound examinations in the current meta-analysis were performed in the relatively early stages of post-stroke (range of mean duration since stroke 17–44 days). Therefore, discrepancies between the hemiplegic shoulders with high vs low motor function might not have been apparent. Moreover, although shoulders with worse function experienced greater musculoskeletal imbalances, those with better recovery might have been more actively used, potentially making them prone to overuse injuries.

Some limitations should be considered when interpreting the results of this meta-analysis. First, the scanning protocols and reporting formats varied among studies. For example, not all studies differentiated between partial- and full-thickness tears; therefore, their respective prevalence could not always be promptly extracted. Secondly, the timing of the ultrasound examinations was inconsistent; mostly being in the subacute phase. Due to the vastly different time-points of evaluation, both within each study and between the included papers, it was not possible to perform in-depth analysis of the influence of stroke chronicity on lesion types. The development of pertinent pathologies and their relationship with hemiplegic shoulder pain should be explored in future studies. Finally, few studies have categorized hemiplegic shoulders by motor function or by the presence/severity of pain. More research on such issues is needed to improve patient care and facilitate the use of ultrasound in stroke.

In conclusion, abnormalities of the biceps long head tendon, supraspinatus tendon, subdeltoid bursa, acromioclavicular joint, and subscapularis tendon are commonly observed in post-stroke hemiplegic shoulders. Likewise, bicipital peritendinous effusion, biceps tendinopathy, subdeltoid bursitis, supraspinatus tendinopathy, and supraspinatus partial-thickness tears were the most frequent pathological findings. Of note, ultrasound is useful in uncovering these lesions and guiding relevant interventions in case of painful shoulders. Further research is needed to decipher the clinical course of structural changes in the post-stroke shoulder and their correlation with pain and motor recovery.

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