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Treatment of neurogenic scapular winging: a systematic review on outcomes after nonsurgical management and tendon transfer surgery

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Background: Scapular winging is a rare condition of the shoulder girdle that presents challenging treatment decisions for clinicians. To inform clinical practice, clinicians need guidance on what the best treatment decision is for their patients, and such recommendations should be based on the total evidence available. Therefore, the purpose of this review was to systematically review the evidence regarding nonsurgical management and tendon transfer surgery of patients with neurologic scapular winging due to serratus anterior (SA) or trapezius (TP) palsy.
Methods: PubMed, Embase, Web of Science, Cochrane Library, Emcare, and Academic Search Premier were searched up to April 5, 2022, for studies reporting on clinical outcomes after nonsurgical management and tendon transfer surgery of scapular winging due to weakness of the SA or TP muscle**.** The Integrated quality Criteria for Review Of Multiple Study (ICROMS) tool was used to classify the quality of the studies. Primary outcomes were the fraction of patients with spontaneous recovery after nonsurgical management and improvement in shoulder function, pain scores, and shoulder scores after tendon transfer surgery. Data were pooled if data on the same outcome were available for at least 3 studies, using random-effects meta-analysis.
Results: Twenty-three (10 moderate-quality [MQ] and 13 low-quality) studies were included. Six studies (3 MQ; 234 shoulders) reported on outcomes after nonsurgical management of SA palsy, whereas 12 (6 MQ; 221 shoulders) and 6 studies (1 MQ; 80 shoulders) evaluated the outcomes of tendon transfer for SA or TP palsy (1 study addressed both). Spontaneous recovery of scapular winging with nonsurgical management varied between 21% and 78% across studies after a median follow-up of 72 months. For surgical management of SA palsy, pooling data in a meta-analysis showed that patients on average improved by 47° (95% confidence interval [CI]: 34-61, $P \leq .001$) in active forward flexion, had lower visual analog scale scores for pain (mean difference [MD]: −3.0, 95% CI: −4.9 to −1.0, $P = .003$), and had substantial improvements in American Shoulder and Elbow Surgeons (MD: 24, 95% CI: 9-39, $P = .002$) and Constant

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scores (MD: 45, 95% CI: 39-51, $P \leq .001$). Patients with TP palsy on average improved by 36° (95% CI: 21-51, $P \leq .001$) in active forward flexion after tendon transfer. Statistical pooling was not possible for other outcome measures as insufficient data were available.
Conclusion: A substantial part of nonsurgically managed patients with scapular winging seem to have persistent complaints, which should be part of the information provided to patients. Data pooling demonstrated significant improvements in shoulder function, pain scores, and shoulder scores after tendon transfer surgery, but higher quality evidence is needed to allow for more robust recommendations and guide clinical decision-making on when to perform such functional surgery.
Level of evidence: Level IV; Systematic Review

Keywords: Scapular winging; scapula alata; serratus anterior; trapezius; long thoracic nerve; spinal accessory nerve; shoulder; surgery

Scapular winging, or scapula alata, is a rare scapulothoracic disorder with altered motion and positioning of the scapula (ie, scapular dyskinesis), characterized by medial border prominence of the scapula with respect to the thorax either at rest or during motion.[18,19] This abnormal scapular motion originates from the inability of the scapulothoracic muscles to stabilize the scapula against the thorax and can be caused by various different causes, including neurologic injury, soft-tissue and bone abnormalities, or it may be secondary to other disorders of the shoulder joint.[20,26] Frequently, it has a neurologic origin that results in a loss of motor function of either the serratus anterior (SA) or trapezius (TP) muscle because of pathology of the long thoracic or spinal accessory nerve, respectively.[13,14] Scapular winging has been associated with a great variety of underlying etiologies (eg, trauma, inflammation, iatrogenic injury, and myopathy),[28,36,45] and therefore it is often misdiagnosed in clinical practice.[4,21,37]

In clinical practice, scapular winging is often associated with pain, weakness, and decreased active range of motion of the shoulder.[13,36] Most patients with a functional deficit due to scapular winging are thought to recover spontaneously within 24 months, but this is based on only a few studies.[14,32] Nonsurgical management (eg, prevention of overuse and physical therapy) can be given to relieve symptoms and maintain shoulder function.[26] Tendon transfer surgery can be considered for patients without functional recovery after 2 years of nonsurgical management.[14,25] These surgical techniques aim to restore scapulothoracic motion by transferring the pectoralis major (PM) or the rhomboids and levator scapulae muscles (Eden-Lange procedure) to the scapula as a substitute for the loss in SA or TP function, thus improving shoulder functionality.[13,14,26]

Several studies have examined the outcomes after nonsurgical management and tendon transfer surgery for scapular winging due to SA or TP palsy, but these often included small numbers of patients. Therefore, the results of individual studies may not be generalizable to the general population and provide limited information for clinician decision-making. To inform clinical practice, clinicians need guidance on what the best treatment decision is for their patients, and such recommendations should be based on the total evidence available. Therefore, the purpose of this study was to systematically review the evidence regarding the effect of nonsurgical management and tendon transfer surgery in adult patients with scapular winging due to SA or TP palsy and to increase the statistical power by pooling data. Specifically, we wanted (1) to assess which fraction of patients recover with nonsurgical management and over what period of time, and (2) to evaluate to which extent patients improve after tendon transfer in pain, function, and shoulder scores as well as the amount of complications.

Methodology

Protocol and registration

This review has been conducted following the published guidelines by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[27] The review protocol was registered at PROSPERO—international prospective register of systematic reviews (registration number: CRD42020203579) before conducting the search.[33]

Search strategy and selection

In cooperation with a trained information specialist (JWS), a search strategy was composed. The following databases were searched up to April 5, 2022: PubMed, Embase (OVID version), Web of Science, Cochrane Library, Emcare (OVID version), and Academic Search Premier (EBSCOhost). The query consisted of the phrasing of various variants of scapular winging (see Supplementary Appendix S1). In addition, we checked the reference lists from all included studies for any potentially related articles not identified by the initial search.

After the primary search, the list of references was imported to EndNote (Version X9; Clarivate Analytics, Philadelphia, PA, USA) to remove duplicates and subsequently exported to Rayyan for study selection.[30] Two researchers (THG and HG) independently screened all titles and abstracts identified by the search strategy. All articles reporting on clinical outcomes after nonsurgical management or tendon transfer surgery for scapular winging in adult patients due to weakness of the SA or TP were assessed for eligibility. The exclusion criteria were cadaveric or animal studies, adolescent population (under 18 years of age; single cases in a larger group were no reason for exclusion), scapular winging caused by myopathic disorders (eg, facioscapulohumeral muscular dystrophy; single cases in a larger group were no reason for exclusion), other surgical interventions than tendon transfers (eg, nerve surgery or scapulothoracic fusion), and insufficient clinical outcome data reported (ie, nonsurgical management studies had to report on the fraction of patients who recover with nonsurgical management, while at least 1 of the following outcomes had to be reported for surgical studies: pain scores, range of motion, or shoulder scores). Meta-analysis and systematic reviews were not included but were checked for individual studies that could be included. Letters to the editor, meeting abstracts, and case reports were also excluded as these do not contain empirical data, have insufficiently detailed information, or precede a fully published article. In addition, publications in other languages than Dutch or English and articles in non–peer-reviewed journals were also excluded. All eligible studies were assessed for study population overlap. In case of overlapping populations in different publications, the author was contacted to verify this and the study with most complete data was included. The reasons for exclusion at each stage were recorded and are shown in a PRISMA flow diagram (Fig. 1). In case of uncertainty regarding the eligibility of an article, disagreements were solved by means of discussion with a third independent reviewer (JN).

Assessment of methodological quality

Quality assessment was performed independently by 2 researchers (THG and HG) using the Integrated quality Criteria for Review Of Multiple Study designs (ICROMS) tool.[50] This grading system allows for the assessment of a large range of study designs. The ICROMS tool scores 7 domains on an ordinal scale, for which the specific criteria considered in every domain are described in Supplementary Appendix S2. Each specific criterion was assessed as being met (2 points), unclear (1 point), or not met (0 points). Studies must meet mandatory criteria (indicated in bold in Supplementary Appendix S2), and a minimum score should be included for evidence synthesis, depending on the study design. For noncontrolled before-after studies, which is the design of all studies included in the present systematic review, the minimum score is 22. However, we opted to include all studies as valuable information can be lost because of the exclusion of studies, but used the risk of bias score to interpret the quality of individual studies. Studies scoring at least 22 points and fulfilling the mandatory criteria were therefore classified as high-quality (HQ) studies. Studies scoring at least 22 points, but failing to fulfill the mandatory criteria were classified as moderate-quality studies (MQ). Studies scoring less than 22 points were classified as low-quality (LQ) studies. Disagreements were solved via discussion with a third reviewer (JN) and reaching consensus.

Data extraction and synthesis of results

Two researchers (THG and HG) independently extracted the data from the included articles using a standardized data-extraction sheet. The following data were extracted from all articles: author, title, year of publication, study design, diagnostic criteria for scapular winging, intervention, number of patients/shoulders, patient characteristics (eg, age, sex, causative factors of winging, symptom duration, and the extent of scapular winging), duration of follow-up and clinical outcomes, including fraction of patients with spontaneous recovery (ie, resolved scapular winging as defined in each study), time to recovery, shoulder function, pain scores, shoulder scores, residual winging as defined in each study (see Supplementary Appendix S3), and complications. Outcomes of studies were collected in the original units including range, confidence intervals (CIs), or standard deviations (SD).

Data were pooled in a meta-analysis if a specific outcome measure was reported in at least 3 articles studying the same intervention, using a random-effects model, in RevMan v5.4.[34] The differences in outcomes before and after the intervention were calculated and analyzed using weighted mean differences along with the 95% CI. If the 95% CIs were lacking, they were calculated from the reported P values.[1] Forest plots were used to present the results from individual studies and the pooled effect size. Heterogeneity in the pooled effect was evaluated using the I^2 index. We considered I^2 >50% to indicate substantial heterogeneity.[16] A P value of <.05 was considered significant. The synthesis without meta-analysis (SWiM) guideline was used for the narrative description of data that did not allow pooling.[5]

Results

Study selection

The search yielded 3.231 records of which 2.021 were unique records. After screening abstracts for eligibility, 1.872 records were excluded, leaving 149 full-text papers to be screened on eligibility. A total of 11 papers (mostly old, range: 1945-1998) could not be retrieved and were excluded from analysis. Two studies were excluded after consultation of the authors because they described overlapping populations[47,48] with more complete papers with regard to the research questions.[32,46] Finally, 23 studies were included for evidence synthesis (Fig. 1). No additional studies were found by checking references of included studies. Six studies evaluated nonsurgical management,[11,15,17,28,32,46] and 17 studies evaluated surgical treatments.[2,3,6-9,13,22,29,31,35,38-42,49] No studies compared nonsurgical management with surgical treatment.

Quality assessment

All 23 studies were noncontrolled before-after studies. Only 10 studies (43%) achieved the minimum ICROMS score (22 points), but all failed to meet all specific mandatory criteria and were therefore labeled as MQ studies (Table I). ICROMS scores of the other studies ranged from 4 to 20 points and were labeled as LQ studies. Six of the 10 MQ studies were published in 2015 or, more recently, compared with only 1 of the 13 LQ studies.

Study characteristics

Characteristics of all included studies are shown in Table II. In all studies, diagnosis was based on the clinical

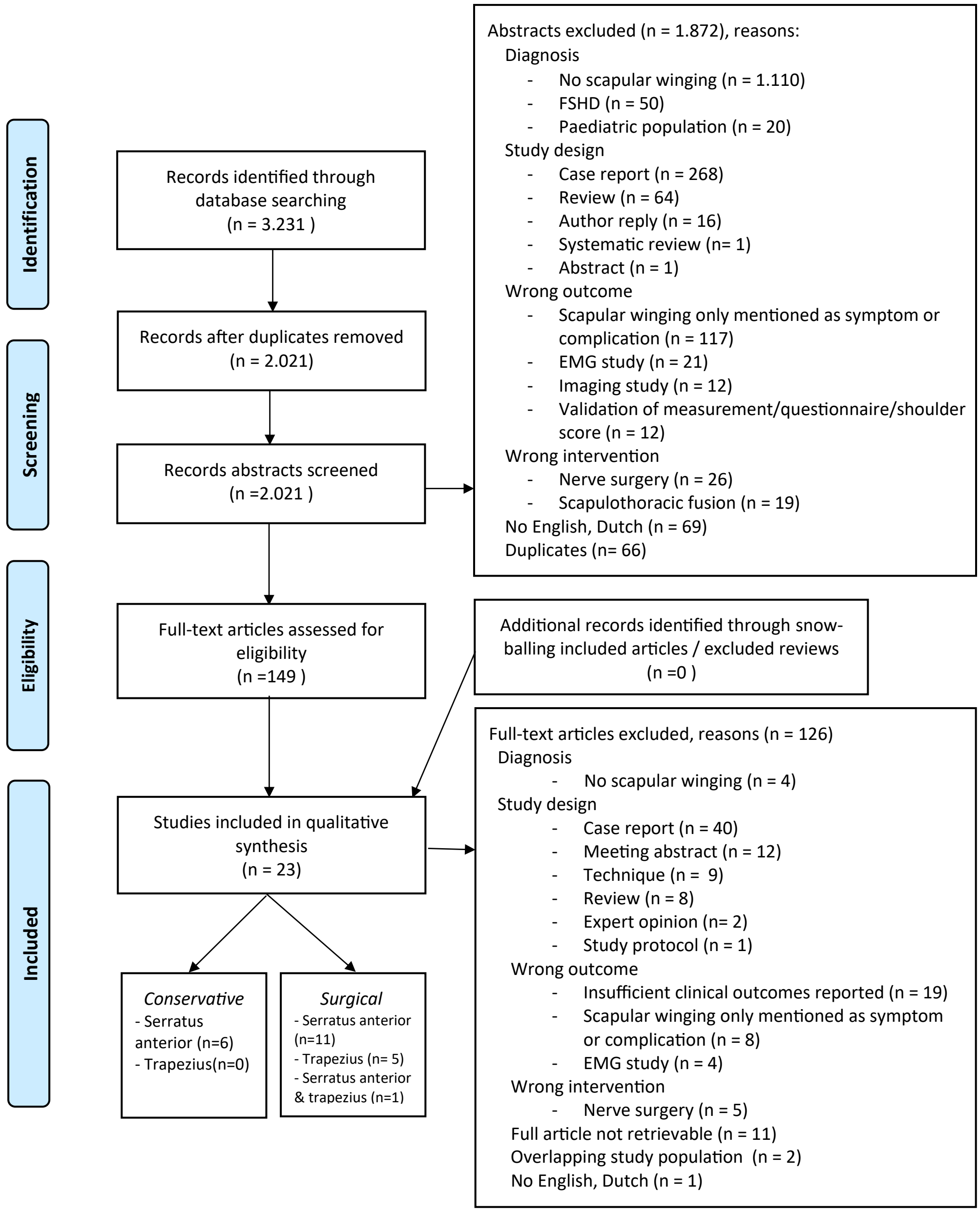

Figure 1 Flow diagram. *FSHD*, Facioscapulohumeral dystrophy; *EMG*, electromyography.

assessment of patients, but diagnostic criteria were poorly described (see Supplementary Appendix S3) and differed significantly between studies (eg, the number of patients with diagnosis confirmed by electromyography). Across all studies and treatments, 535 shoulders with scapular winging were included. In total, 455 patients (85%) had scapular winging due to SA palsy, mostly caused by trauma (48%). These patients had a mean age of 34 years (SD: 3.3), of whom 46% were female. Of these 455 patients, 234 (51%) received nonsurgical management, whereas 221 patients (49%) underwent PM transfer. In the remaining 80 patients (15%), scapular winging was caused by TP palsy, with the majority the result of iatrogenic injury (68%). These patients had a mean age of 35 years (SD: 6.8), of whom 55% were female. All 80 patients underwent the (modified) Eden-Lange procedure.

Nonsurgical management

Six studies reported clinical outcomes after nonsurgical management for SA paralysis, 3 MQ and 3 LQ studies including a total of 234 shoulders.[11,15,17,28,32,46] Two MQ

Table I ICROMS risk of bias (RoB) assessment

Author (year)	1A*	1B*	1C	2C*	3E	3F	4C	5A	5D*	6C	7A	7B	7C	7D	7E	ICROMS score
Li (2017)[22]	2	2	2	2	2	2	1	2	0	2	2	2	2	0	2	25
Elhassan (2015)[8]	2	2	2	2	0	2	2	2	0	2	2	2	2	0	2	24
Vastamaki (2015)[46]	2	2	2	2	0	2	2	2	0	2	2	2	2	0	2	24
Elhassan (2015)[9]	2	2	2	2	0	2	1	2	0	2	2	2	2	0	2	23
Noerdlinger (2002)[29]	2	0	2	2	2	2	2	0	0	2	2	2	2	0	2	22
Tauber (2008)[41]	2	2	2	2	0	2	2	2	0	2	2	2	2	0	0	22
Pikkarainen (2013)[32]	2	2	0	2	0	2	2	2	0	2	2	2	2	0	2	22
Streit (2012)[40]	2	2	0	2	0	2	2	2	0	2	2	2	2	0	2	22
Chalmers (2015)[6]	2	2	2	2	0	2	0	2	0	2	2	2	2	0	2	22
Ng (2021)[28]	2	2	0	2	0	2	2	2	0	2	2	2	2	0	2	22
Galano (2008)[13]	2	2	0	2	0	2	2	2	0	0	2	2	2	0	2	20
Steinmann (2003)[39]	2	0	0	2	2	2	2	0	0	0	2	0	2	0	2	16
Amroodi (2018)[2]	2	2	0	2	0	2	2	2	0	0	2	0	2	0	0	16
Perlmutter (1999)[31]	2	2	0	2	0	2	2	1	0	0	2	0	2	0	0	15
Teboul (2004)[42]	1	0	0	2	0	2	2	2	0	2	1	0	2	0	0	14
Connor (1997)[7]	2	0	0	2	0	2	1	1	0	0	2	0	2	0	0	12
Romero (2003)[35]	2	0	0	2	0	2	2	0	0	2	0	0	2	0	0	12
Warner (2001)[49]	2	0	0	2	0	2	0	2	0	0	0	0	2	0	0	10
Bigliani (1996)[3]	2	0	0	2	0	0	2	1	0	0	2	0	2	0	0	9
Kauppila (1996)[17]	2	1	0	2	0	0	2	0	0	0	0	0	2	0	0	9
Foo (1983)[11]	1	0	0	1	0	0	2	1	0	0	0	0	2	0	0	7
Goodman (1975)[15]	1	0	0	2	0	0	2	0	0	0	0	0	1	0	0	6
Stein (2006)[38]	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	4

ICROMS, Integrated quality Criteria for Review Of Multiple Study designs.
Points should be given to every criterion.
0 = did not fulfill the criteria; 1 = unclear if criteria are fulfilled; and 2 = did fulfill the criteria.
The green highlighted study has an ICROMS score ≥22, and fulfills the mandatory criteria, and was therefore classified as low RoB/high quality. The gray highlighted studies have an ICROMS ≥22 points, but do not fulfill the mandatory criteria, and were therefore classified as moderate RoB/moderate quality. The red highlighted studies have an ICROMS <22 points, and do not fulfill the mandatory criteria, and were therefore classified as high RoB/low quality.
* Indicates the mandatory criteria and these criteria are darker colored.

and 3 LQ studies described the natural course of SA palsy without any particular treatment with physical therapy as cointervention in part of these patients, but did not report on the same clinical outcomes. One MQ study evaluated the effect of bracing therapy (Table I).

All studies reported on the number of patients with recovery of their winging. Completely resolved scapular winging after nonsurgical management varied between studies from 21% to 78% after a median follow-up of 72 months. Three of these studies (2 MQ and 1 LQ) described the average time to recovery, which varied from 13 to 25 months, respectively.[11,28,32] Active forward flexion was reported in 2 MQ studies and improved from 144° and 137° to 161° and 156°, respectively, after nonsurgical management.[32,46] Three studies (2 MQ and 1 LQ) described shoulder function in terms of persistent functional limitations after nonsurgical management, with the number of patients with persistent functional limitations varying between 18% and 42%.[15,32,46] Three studies (2 MQ and 1 LQ) reported on pain; all studies showed that only few patients were completely pain free with nonsurgical management (12%, 18%, and 30% of patients).[17,32,46] No studies reported on clinical outcomes after nonsurgical management for TP palsy.

Surgical management of SA palsy

Twelve studies (221 shoulders; 6 MQ and 6 LQ studies) reported on clinical outcomes after a tendon transfer for SA paralysis and a median follow-up of 47 months (Table II).[6-8,13,22,29,31,38-41,49] Overall, 98 shoulders had a direct PM transfer, whereas 123 shoulders had a PM transfer with augmentation of an allograft or autograft tendon (eg, tibialis anterior, fascia lata, semitendinosus, and gracilis).

Preoperative and postoperative active forward flexion were reported in 12 studies, of which 7 studies provided sufficient information for their data to be pooled (Fig. 2, *a*).[6,8,13,22,31,40,41] On average, forward flexion improved significantly after PM transfer with a mean improvement of 47° (95% CI: 34-61, $P \leq .001$), but substantial heterogeneity was present between studies ($I^2 = 66\%$). Studies not

Table II Study characteristics and outcomes

Conservative (serratus anterior palsy)

Author (year)	Shoulders (n)	Mean age in years (range)	% Female	Mean follow-up in months (range)	Etiology	% EMG-proven	% Previous surgery	Intervention	Cointervention (%)	Mean time to recovery in months (range)	Reported outcome measures	% Persistent winging	Complications
Goodman (1975)[15]	12	NR (5-55)[*]	58	54 (12-84)	Tra: 3 Iat: 2 Idi: 3 Oth: 4	67	NR	No specific intervention	Physical therapy (83)	NR	-	75	NA
Foo (1983)[11]	20	38 (18-70)	60	62 (6-144)	Tra: 3 Oth: 17	NR	NR	No specific intervention	Physical therapy (25)	13 (6-24)	-	25	NA
Kauppila (1996)[17]	26	37 (16-71)[*]	NR	72 (24-132)	Iat: 26	100	NR	No specific intervention	Physical therapy (50) Bracing (65)	NR	-	73	NA
Pikkarainen (2013)[32]	37	34 (12-54)[*]	43	204 (24-360)	Tra: 12 Oth:25	100	NR	No specific intervention	Physical therapy (46)	16 (2-30)	RoM	22	NA
Vastamaki (2015)[46]	55	30 (15-52)[*]	24	264 (120-336)	Tra: 46 Idi:8 Oth:1	100	NR	Bracing	Physical therapy (44)	NR	RoM	31	NA
Ng (2021)[28]	84	38 (15-77)[*]	35[†]	NR	Tra: 33 Iat: 2 Oth: 2 NAM: 47	100	NR	No specific intervention	NR	Tra cohort (n = 33): 25 (6-48) NAM cohort (n = 47): 16 (3-36)	-	Tra cohort: 79 NAM cohort: 53	NA

Surgical (serratus anterior palsy)

Study (year)	Shoulders (n)	Mean age in years (range)	% Female	Mean follow-up in months (range)	Etiology	% EMG-proven	% Previous surgery	Surgical technique PM transfer (n)	Graft (type)	Mean time to surgery in months	Reported outcome measures	% Persistent winging	Complications (n)
Connor (1997)[7]	11	34 (20-52)	64	27 (12-60)	Tra: 9 Iat: 1 Idi: 1	91	64	Indirect	Fascia lata (autograft)	27	RoM VAS ASES	36	-
Warner (2001)[49]	8	32 (24-43)	50	40 (12-86)	Tra: 8	63	63	Indirect	Semitendinosus and gracilis (autograft)	32	RoM	0	Infection requiring debridement and removal of graft (1)
Perlmutter (1999)[31]	16	33 (20-55)	56	40 (16-132)	Tra: 7 Iat: 7 Idi: 2	100	56	Indirect	Fascia lata (autograft)	40	RoM CS	25	Transfer rupture (2)

Noerdlinger (2002)[29]	15	33 (17-44)[*]	40	NR	Tra: 12 Iat: 1 Idi: 2	73	53	Indirect	Fascia lata (autograft)	NR	RoM ASSES	60	Frozen shoulder (2) Muscle bulging (1)
Steinmann (2003)[39]	9	34 (21-47)	44	34 (24-60)	Tra: 7 Iat: 2	100	22	Indirect	Fascia lata (autograft)	70	RoM ASES	33	Frozen shoulder (2) Seroma (1)
Stein (2006)[38]	10	NR	NR	NR	NR	100	NR	Direct	NA	NR	RoM	10	Transfer rupture (1)
Galano (2008)[13]	11	34 (18-48)	82	72 (24-240)	Tra: 6 Iat: 2 Idi: 2 Oth: 2	91	27	Direct	NA	72	RoM VAS ASES	0	Infection (1) Transfer rupture (1)
Tauber (2008)[41]	12	42 (27-75)	42	24 (18-56)	Tra: 5 Iat: 6 Idi: 1	100	NR	Direct	NA	93	RoM VAS CS	8	Neurologic (1) Transfer rupture (1)
Streit (2012)[40]	26	33 (15-53)[*]	57	58 (12-120)	Tra: 6 Idi: 20	100	38	Direct (n = 4) Indirect (n = 22)	Semitendinosus (autograft)	22	RoM VAS ASES	19	Hematoma (1) Neurologic (4)
Chalmers (2015)[6]	24	30 (NR)	63	29 (NR)	Tra: 18 Iat: 2 Idi: 4	71	46	Direct (n = 10) Indirect (n = 14)	Direct: Achilles (allograft) Indirect: Tibialis anterior tendon (allograft)	29	RoM VAS ASES SST	8	Infection (2) Persistent pain (1) Frozen shoulder (1)
Elhassan (2015)[8]	51	31 (14-65)[*]	45	NR	NR	58	NR	Direct	NA	NR	RoM CS SSV DASH	12	Infection (2) Hematoma (5) Persistent pain (3) Frozen shoulder (3) Neurologic 3) Transfer rupture (1)
Li (2017)[22]	28	38 (22-56)	46	21 (14-30)	Tra: 15 Iat: 5 Idi: 8	100	NR	Indirect	Semitendinosus (autograft)	21	RoM VAS ASES	0	Frozen shoulder (4) Seroma (1)

Surgical (trapezius palsy)

Study (year)	Shoulders (n)	Mean age in years (range)	% Female	Mean follow-up in months (range)	Etiology	% EMG-proven	% Previous surgery	Intervention	Version	Mean time to surgery in months	Reported outcome measures	%Persistent winging	Complications (n)
Bigliani (1996)[3]	22	32 (8-74)[*]	73	90 (24-168)	Tra: 7 Iat: 15	Unclear	32	Eden-Lange	Modified	34	ASES (pain)	27	Neurologic (1)
Romero (2003)[35]	12	25 (11-43)[*]	75	408 (348-456)	Tra: 1 Iat: 14 Oth: 1	33	67	Eden-Lange	-	NR	CS	NR	None
Teboul (2004)[42]	7	39 (25-65)	NR	29 (14-54)	Iat: 5 Idi: 2	NR	NR	Eden-Lange	-	28	RoM	NR	NR

(*continued on next page*)

Table II Study characteristics and outcomes (*continued*)

Surgical (trapezius palsy)

Study (year)	Shoulders (n)	Mean age in years (range)	% Female	Mean follow-up in months (range)	Etiology	% EMG-proven	% Previous surgery	Intervention	Version	Mean time to surgery in months	Reported outcome measures	%Persistent winging	Complications (n)
Galano (2008)[13]	6	40 (18-54)	50	47 (11-89)	Tra: 3 Iat: 3	100	17	Eden-Lange	Modified	54	RoM VAS ASES	0	Infection (2)
Elhassan (2015)[9]	22	NR	41	35 (13-26)	Tra: 8 Iat: 11 Oth: 3	NR	NR	Eden-Lange	Modified	48	RoM CS SSV DASH	5	Transfer rupture (2)
Amroodi (2018)[2]	11	41 (25-59)	27	34 (24-48)	Tra: 2 Iat: 9	100	NR	Eden-Lange	-	10	RoM VAS ASES	NR	NR

EMG-proven, diagnosis confirmed with electromyography; *NR*, not reported; *Tra*, traumatic; *NA*, not applicable; *Iat*, Iatrogenic; *RoM*, range of motion; *Idi*, idiopathic; *Oth*, other; *NAM*, neuralgic amyotrophy; *WORC*, Western Ontario Rotator Cuff Index; *VAS*, visual analog scale for pain; *ASES*, American Shoulder and Elbow Surgeons score; *SSV*, subjective shoulder value; *CS*, Constant score; *DASH*, Disabilities of the Arm, Shoulder and Hand Questionnaire.

* Some cases were under 18 years of age and therefore did not meet the inclusion criteria.

† Average mean from larger cohort including patients with scapular winging due to myopathy. Follow-up of conservative treatment: starting from first presentation in hospital; follow-up of surgical treatment: starting from the day of surgery.

providing sufficient information, mostly because the SD was not reported and could not be calculated, showed comparable improvements in means as included studies and were mostly older studies. Six studies (4 MQ and 2 LQ) presented pre- and postoperative visual analog scale (VAS) scores for pain, of which 4 MQ studies contributed data to the overall effect in a forest plot (Fig. 2, *b*).[6,22,40,41] Overall, VAS scores for pain were significantly lower postoperatively (mean difference: −3.0, 95% CI: −4.9 to −1.0, $P = .003$, $I^2 = 88\%$). Pooled estimates also showed significant improvements in both American Shoulder and Elbow Surgeons (4 studies, mean difference: 24, 95% CI: 9-39, $P = .002$, $I^2 = 90\%$) (Fig. 2, *c*)[6,13,22,40] and Constant scores (3 studies, mean difference: 45, 95% CI: 39-51, $P \leq .001$, $I^2 = 0\%$) (Fig. 2, *d*).[8,31,41] Across all studies, residual winging was observed in 16% of patients who underwent PM transfer. The overall complication rate was 20%, which included infection (3%), failure of the transferred tendon (3%), neurological complaints (4%), and postoperative frozen shoulders (5%) as the most frequently reported. All reported study outcomes can be found in Supplementary Appendix S3.

Surgical management of TP palsy

There were 6 studies (80 shoulders; 1 MQ and 5 LQ studies) that investigated the clinical outcomes after a tendon transfer for TP paralysis with a median follow-up of 41 months (Table I).[2,3,9,13,35,42]

Preoperative and postoperative active forward flexion were reported in 1 MQ and 2 LQ studies.[2,9,13] Forward flexion improved significantly after the Eden-Lange procedure with a mean improvement of 36° (95% CI: 21-51, $P \leq .001$), but substantial heterogeneity was present ($I^2 = 73\%$) (Fig. 2, *e*). Statistical pooling was not possible for other outcome measures (pain and shoulder scores) as insufficient data were available. Two LQ studies showed improvements in VAS scores for pain from 7.8 and 7.0 to 1.6 and 2.3, respectively.[2,13] In addition, substantial improvements in both American Shoulder and Elbow Surgeons (2 LQ studies) and Constant scores (1 MQ study) were described after surgery.[2,9,13] Across all studies, residual winging was seen in 15% of patients who underwent the Eden-Lange procedure, whereas 4 complications (8%) were reported. All reported study outcomes can be found in Supplementary Appendix S3.

Discussion

The present review found that only few studies reported on nonsurgical management for scapular winging due to SA palsy. In most of these nonsurgical management studies, there was no specific intervention but only observation of the natural course. Scapular winging, functional limitations, and pain persisted in a substantial percentage of these patients, which is indicative that the recovery of scapular winging due to SA palsy after nonsurgical management is often only partial. The latter may also reflect that patients included in these studies may have had a more severe clinical presentation, but data on background characteristics were often not presented within studies; thus, this remains unclear. No study reported on nonsurgical management for scapular winging due to TP palsy. For tendon transfer surgery, significant improvements in function, pain scores, and shoulder scores were shown for both SA and TP palsy, suggesting that a tendon transfer is a viable option for patients not recovering after initial nonsurgical management. However, substantial heterogeneity in reported outcomes was found, which can likely (at least in part) be explained by the variety in the diagnostic criteria of scapular winging and the difference in quality between studies. Therefore, the overall effect estimates should be interpreted with caution, when discussing this with patients in clinical practice. Nevertheless, this review compiles the best available data on this low prevalent entity of scapular winging due to SA or TP palsy.

This study had some limitations. First, as with any systematic review, the inherent weaknesses of individual studies translate into limitations of this review. In this systematic review, only noncontrolled case series were included. Noncontrolled studies are prone to potential bias, although they can still offer useful information about the effectiveness of an intervention aiming to improve patient safety if the risk of bias is low. None of the studies met the mandatory criteria of the ICROMS tool for noncontrolled studies, whereas only 10 studies (43%) met the minimum score of 22 points and mostly concerned the more recent studies. All included studies were therefore labeled as MQ at best. Secondly, a clear description of the diagnostic criteria for scapular wining due to SA or TP palsy was often lacking within studies, and not all studies confirmed the diagnosis by electromyography and not in all of the patients. Electromyography, however, is considered of crucial importance to confirm the diagnosis of scapular winging originating from neurologic abnormalities.[38] Therefore, the diagnostic accuracy of scapular winging due to SA or TP palsy may be questioned in several studies, and it is possible that some of the included patients might have been misdiagnosed as scapular winging may have been secondary to other causes than SA or TP palsy.[37] Furthermore, scapular winging is only a symptom and does not specify the nature of the disorder that has a large variety in etiology (eg, traumatic, inflammatory, iatrogenic, and myopathic). Both the potentially misdiagnosed patients and the variety in etiologic factors may be (partially) responsible for the heterogeneity in the overall effect estimates. Third, it is possible that publication bias contributed to the relative paucity of studies investigating the outcomes of nonsurgical management in comparison with studies evaluating the outcomes of surgical treatment. Also, we did not evaluate

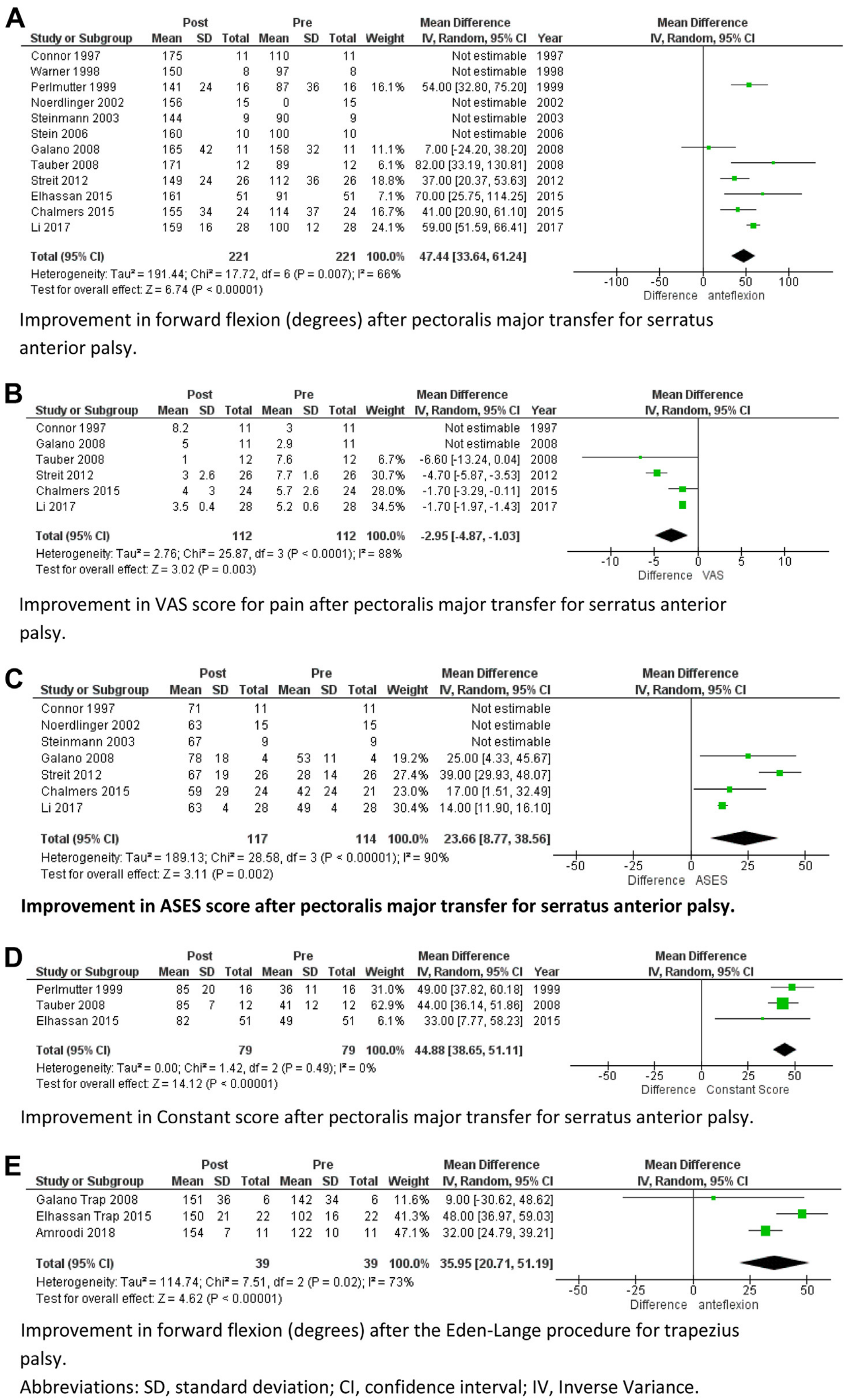

Figure 2 Forest plots. (**A**) Improvement in forward flexion (degrees) after pectoralis major transfer for serratus anterior palsy. (**B**) Improvement in VAS score for pain after pectoralis major transfer for serratus anterior palsy. (**C**) Improvement in ASES score after pectoralis major transfer for serratus anterior palsy. (**D**) Improvement in Constant score after pectoralis major transfer for serratus anterior palsy. (**E**) Improvement in forward flexion (degrees) after the Eden-Lange procedure for trapezius palsy. *SD*, standard deviation; *IV*, inverse variance; *CI*, confidence interval.

the effect of other surgical procedures, such as nerve surgery and scapulothoracic fusion, as this was beyond the scope of this review. Lastly, although we used a systematic methodology, it is possible that different search terms would have resulted in additional studies meeting our inclusion criteria. On the other hand, no additional records were added by checking references of included studies, suggesting that the search strategy has comprehensively captured all studies.

To our knowledge, this is the first systematic review that summarized the existing evidence on outcomes after both nonsurgical and surgical treatment for scapular winging caused by SA or TP palsy. Only Elsawi et al[10] performed a systematic review on the clinical outcomes after surgical treatment (ie, nerve surgery or Eden-Lange procedure) of TP palsy. However, 3 studies reporting on the outcomes of the Eden-Lange procedure for TP palsy were added by the present study, thereby giving a more complete overview.[3,9,35] Chalmers et al[6] performed a systematic review on the clinical outcomes of PM transfer for SA palsy, but only compared direct with indirect PM transfer and did not assess the risk of bias of the included studies. The present systematic review therefore adds to the literature by providing a more complete overview on the overall evidence available of both nonsurgical management and tendon transfer surgery for scapular winging, while taking the quality of studies into account, which can be used to inform patients during a shared decision-making process with their physician in clinical practice.

In literature, there is general consensus that scapular winging should be treated nonsurgically for at least 24 months, consistent with the average time to recover reported by 3 studies in the present review.[11,28,32] A variety of nonsurgical intervention options (eg, physical therapy, bracing) have been suggested to relieve symptoms and maintain shoulder function, but no therapy is universally accepted as being effective.[14,25] Only 1 study investigated the efficacy of a specific physical therapy program and reported a significant improvement in the Western Ontario Rotator Cuff score after treatment, but did not report on other clinical outcome scores (eg, persistent winging, function, or pain) and did not have a control group.[43] Other studies investigating bracing therapy have reported conflicting results and low patient compliance.[11,24,46,49] Some authors advice to start corticosteroid treatment to alleviate symptoms and stimulate recovery in case of scapular winging secondary to neuralgic amyotrophy.[44] Despite nonsurgical management being the first treatment option, surprisingly few studies were identified reporting on its outcomes. Only 2 of these studies reported on objective clinical outcome measures (ie, range of motion), but not on pain and/or shoulder scores. Consequently, the optimal nonsurgical management strategy of scapular winging remains unclear, and many interventions are applied without clear evidence.

Although it must be noted that most included nonsurgical management studies only described the natural cause of scapular winging without a specific intervention, the present study showed that a substantial part of nonsurgically managed patients with scapular winging keep experiencing winging, functional limitations, and/or pain in the long run. Therefore, it is possible that some patients with scapular winging would benefit from surgical treatment at an earlier stage. Unfortunately, this population cannot yet be identified as little is known about prognostic factors or the role of etiology that may predict sufficient spontaneous recovery of scapular winging.[47] Initial electromyographic examination does not seem to predict clinical outcomes.[12,48] Only few studies investigated the influence of SA palsy etiology on the outcomes of spontaneous recovery and suggested that a traumatic or iatrogenic etiology carry a poorer prognosis in treatment outcomes, whereas palsies caused by infection recovered better.[12,15,47] Future studies are warranted to identify prognostic variables that may help predict (non) recovery after nonsurgical management and thus identify those patients who might benefit from surgical treatment at an earlier stage.

Treatment of scapular winging should be individualized and based on severity and chronicity of the patients' symptoms. As a variety of disorders can cause scapular winging, it is important that the correct diagnosis be established as the basis for any type of intervention.[20,23] Nonsurgical management is always warranted in the beginning of the pathology as many patients will experience resolution without the need of surgery, as shown in this systematic review. However, because a substantial part of patients keep experiencing residual complaints, this should also be part of the information provided to patients. The same is true for tendon transfer surgery, for which the present review showed substantial heterogeneity in outcomes that can be used to inform patients so that they have reasonable expectations on surgical treatment. The provided estimated treatment effects of the best available evidence may thus guide clinicians and patients in treatment decisions, but given the overall low-to-moderate quality of evidence, the results should be interpreted with caution.

Higher quality evidence is needed to supplement this evidence base and enable stronger recommendations. This review showed that diagnostic criteria for scapular winging varied widely between studies. In addition, large variability in reported outcome measures was present between studies that were often subjective (eg, degree of winging), and therefore made it difficult to evaluate and compare treatment effects. Until a more precise and widespread method of classification and categorization of scapular winging is established, little meaningful information can be accumulated to help guide clinical decision-making. Future studies should establish clear criteria for the diagnosis of scapular winging and report on standardized (objective) outcomes so that data can be pooled across studies. In particular, this review shows a research gap regarding the outcomes of nonsurgical management of scapular winging. Furthermore, more knowledge of prognostic factors that predict poor outcome after nonsurgical management may help to identify patients who would benefit from surgical treatment at an earlier stage. As scapular winging is a rare entity, this will likely not be feasible for a single institution or country, so that large (inter)national collaboratives are needed to further substantiate these findings and guide clinical decision-making.

Conclusion

This systematic review compiles the best available evidence on nonsurgical management and tendon transfer surgery for scapular winging caused by SA and TP palsy. This review showed that scapular winging, functional limitations, and pain persisted in a substantial percentage of nonsurgically managed patients, indicating that spontaneous recovery of scapular winging is often only partial. For tendon transfer surgery, significant improvements in function, pain scores, and shoulder scores were shown for both SA and TP palsy, suggesting that a tendon transfer is a viable option for patients not recovering after initial nonsurgical management. Higher quality evidence is needed to further substantiate these findings and further guide clinical treatment.

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Supplementary data

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