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Therapeutic Interventions for Scapular Kinematics and Disability in Patients With Subacromial Impingement: A Systematic Review

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Context: Impaired scapular kinematics are commonly reported in patients with subacromial impingement syndrome (SIS). Various therapeutic interventions designed to improve scapular kinematics and minimize pain and disability have been described in the literature. However, the short- and long-term benefits of these interventions are unclear.

Objective: To determine the effects of specific short- and long-term therapeutic interventions on scapular kinematics and disability in patients with SIS.

Data Sources: We searched PubMed, CINAHL, and SPORTDiscus databases from their origins to January 2018 using a combination of the key words *scapular kinematics* AND (*shoulder dysfunction* OR *subacromial impingement*) and conducted a manual search by reviewing the references of the identified papers.

Study Selection: Studies were included if (1) preintervention and postintervention measures were available; (2) patient-reported outcomes were reported; (3) scapular kinematics measures at 90° of ascending limb elevation in the scapular plane were included; (4) SIS was diagnosed in participants or participants self-reported symptoms of SIS; (5) they were original clinical studies published in English; and (6) the sample sizes, means, and measure of variability for each group were reported.

Data Extraction: Seven studies were found. Sample sizes, means, and standard deviations of scapular upward rotation, posterior tilt, and internal rotation at 90° of ascending limb elevation on the scapular plane and the Disabilities of the Arm, Shoulder and Hand scores were extracted.

Data Synthesis: Standardized mean differences between preintervention and postintervention measures with 95% confidence intervals (CIs) were calculated. We observed that the Disabilities of the Arm, Shoulder and Hand scores improved (mean difference = 0.85; 95% CI = 0.54, 1.16) but did not observe changes in scapular upward rotation (mean difference = –0.04; 95% CI = –0.31, 0.22), posterior tilt (mean difference = –0.09; 95% CI = –0.32, 0.15), or internal rotation (mean difference = 0.06; 95% CI = –0.19, 0.31).

Conclusions: The short- and long-term therapeutic interventions for SIS improved patient-reported outcomes but not scapular kinematics. The identified improvements in shoulder pain and function were not likely explained by changes in scapular kinematics.

Key Words: shoulder pathology, scapular dysfunction, patient-reported outcomes, 3-D motion analysis

Key Points

- Various therapeutic interventions for subacromial impingement syndrome (SIS), in both the short and long term, are intended to correct improper scapular kinematics.
- Those proposed interventions effectively reduced pain and disability in individuals with SIS.
- Therapeutic interventions did not change scapular kinematics in individuals with SIS.
- Improvements in shoulder pain and function were not likely explained by changes in scapular kinematics.
- Future studies that include scapular kinematics in other planes of elevation at angles other than 90° of ascending limb elevation may provide alternative results.

Shoulder pain is one of the most common musculoskeletal conditions encountered in general medical practices, with an estimated prevalence of 16% to 48%.[1–5] Among painful shoulder conditions, subacromial impingement syndrome (SIS) accounts for 44% to 65% of all shoulder pain.[6,7] Researchers have documented that SIS is associated with repetitive work performed at or above shoulder level[2,4] and participation in sports involving frequent overhead motions, such as baseball pitching, swimming, tennis serving, and volleyball spiking.[8] Symptoms of SIS include consistent pain in the shoulder, arm, or neck; increased pain in the shoulder during lifting or reaching movements; limited shoulder range of motion; muscle weakness; and joint stiffness or tenderness. These signs and symptoms of SIS may result from multiple underlying pathologic conditions, such as altered scapular kinematics, glenohumeral posterior tightness, faulty posture, acromial arch morphologic or pathologic condition, shoulder instability, rotator cuff weakness, and motor-control deficits.[9–12]

In a recent meta-analysis, Timmons et al[13] identified altered scapular kinematics, specifically more scapular internal rotation and less scapular upward rotation and posterior tilt during upper extremity elevation, in patients with SIS compared with matched healthy individuals. Optimal scapular motion is considered crucial to shoulder function, and any alteration in scapular kinematics is believed to contribute to developing pathologic shoulder conditions. The scapula must upwardly and externally rotate and posteriorly tilt adequately to prevent the humeral head from compressing and shearing against the undersurface of the acromion, one of the proposed mechanisms for producing the syndrome commonly called *subacromial impingement*.[14] Based on this widely held view, the aim of many shoulder rehabilitation programs is to correct aberrant local scapular mechanics.[15] Clinicians often manage SIS with various treatment techniques to address the strength deficits and altered pattern of scapular kinematics that lead to injury and are modifiable characteristics to improve patient outcomes, such as reducing pain and decreasing shoulder dysfunction. These techniques include, but are not limited to, posterior shoulder stretching for capsular abnormalities[16,17]; scapular bracing to correct poor posture[18]; taping that was claimed to correct aberrant kinematic patterns due to poor rotator cuff or scapular muscle function[19–21]; thoracic spine manipulation to readjust the alignment of thoracic vertebrae where important scapular muscles are attached, modify costovertebral mobility, or possibly enhance neuromuscular control of scapulothoracic muscles[22–25]; rotator cuff and other scapular muscle strengthening[8,16,26–29] to stabilize or position the scapula properly[30] during dynamic shoulder movement; neuromuscular reeducation for coordinated activation of scapular muscles during shoulder movement[27,29]; and manual therapy, such as joint mobilization to restore proper joint mobility.[31,32]

The variation in intervention approaches is directly related to various views on the mechanism leading to impingement.[26] Short-term interventions, including manual therapies, taping, and bracing, aim to immediately correct kinetic or kinematic pathologic conditions. Long-term interventions using a therapeutic exercise–oriented approach, such as muscle strengthening, stretching, or neuromuscular reeducation, are intended to correct the underlying mechanism leading to SIS. Given the nature of tissue healing, strength gain, and motor learning, a clinician usually expects progression to require weeks to months.[16,26,27]

Whereas various therapeutic methods, from short- to long-term interventions, are aimed at improving scapular kinematics to effectively decrease pain and disability in individuals with SIS, the association between changes in scapular kinematics and perceived reduction of pain or disability remains unclear, and evaluating the effectiveness of therapeutic interventions on the association is necessary. Knowing the effectiveness of these interventions on scapular kinematics would help clinicians make informed therapeutic decisions. Therefore, the purpose of our study was to perform a systematic review of all published eligible studies to determine the effects of short- and long-term therapeutic interventions on scapular kinematics during 90° of ascending upper extremity elevation in the scapular plane and self-reported pain and disability in patients with SIS by comparing pretreatment and posttreatment outcome measures.

METHODS

Literature Search and Data Sources

We performed a systematic literature search via the PubMed, CINAHL, SPORTDiscus, and Scopus databases from their origin to January 4, 2018, using a combination of the key words *scapular kinematics* AND (*shoulder dysfunction* OR *subacromial impingement*) to find all relevant published articles. After retrieving the relevant articles, we conducted a manual search by reviewing the reference sections of the papers to identify additional eligible studies that might not have appeared in the online search.

Study Selection and Inclusion Criteria

We identified 307 records through the initial database search and manual search of the reference sections of eligible articles (Figure 1). For this systematic review, studies were included if the following criteria were met:

- Specific outcome measures were reported at any time before and after the intervention or the original data were available upon request from the corresponding author.
- The intervention(s) reported in the study was (were) intended to improve pain, disability, and altered scapular kinematics due to SIS.
- The patient-reported outcome measures for pain and disability were included.
- Scapular kinematics measures were included as range of motion in degrees, specifically upward rotation, posterior tilt, and internal (or external) rotation at 90° of ascending limb elevation in the scapular plane.
- Participants had a diagnosis of or reported experiencing signs and symptoms of subacromial impingement.
- The original clinical studies were published in English.
- Point estimates (mean differences between pretreatment and posttreatment) along with a measure of variability and the sample size of each group were reported.

Studies were excluded if they were reviews, letters, editorials, meeting abstracts, or case reports. We did not identify duplicated samples in the selected studies.

After removing 282 papers based on the exclusion criteria, 25 studies remained for full evaluation. Subsequently, 18 articles in which the authors examined samples from a healthy population only, did not report specific data, provided only incomplete data, or provided data sets for different kinematic measurements (ie, anatomic planes, joint angles) were also excluded. Therefore, 7 observational studies (4 randomized controlled trials, 1 quasi-experimental study, and 2 case-control studies) were identified as suitable for subsequent systematic review. These 7 studies consisted of 4 on the effects of short-term interventions (2 on manual therapy and 2 on taping) and 3 on the effects of long-term interventions (1 on muscle strengthening and stretching, 1 on neuromuscular reeducation, and 1 on dynamic scapular stabilization). All studies included in this review were published from 2009 to 2017.

Data Extraction

Two evaluators (K.T., N.R.G.) independently graded each study using the Physiotherapy Evidence Database (PEDro) scale for quality assessment. The PEDro scale is a 10-point assessment tool comprising an 11-item checklist.

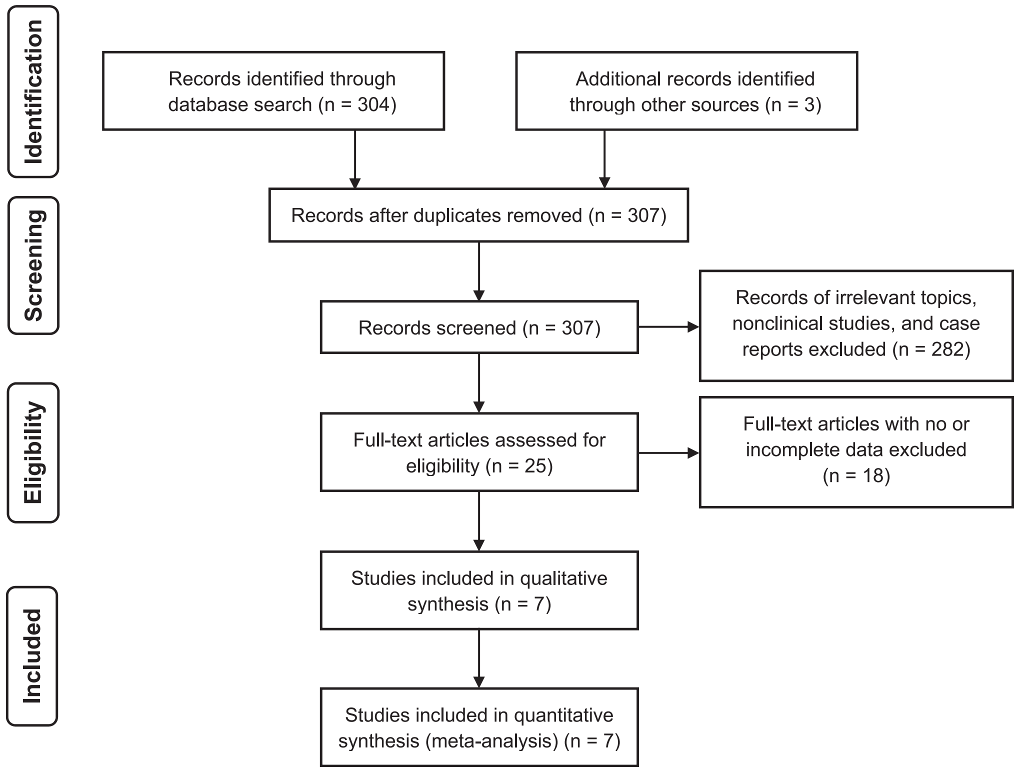

Figure 1. Flow diagram of study selection.

The reliability of the PEDro score has been documented[33] as fair to good at evaluating clinical interventions, with an intraclass correlation coefficient (ICC [1,1]) for the total score of 0.56 (95% confidence interval [CI] = 0.47, 0.65) for rating by individuals and an ICC for consensus rating of 0.68 (95% CI = 0.57, 0.76). Discrepancies were resolved by consensus. A third evaluator (G.E.N.) was consulted if any discrepancy in a PEDro score could not be resolved by consensus. The 7 studies (n = 153) had an average PEDro score of 6.3 (highest score = 9, lowest score = 4). Four of the 7 studies were deemed high quality based on the research objectives, experimental protocol, results of concurrent validity, interpretation of the results, and conclusions. Three of the 7 studies had PEDro scores of less than 6 because of nonrandomized experimental designs. Therefore, caution should be taken when interpreting their results, especially when they conflict with the results of the higher-quality studies. The PEDro score and critiques for each study included in our review are presented in Table 1. Among the 7 studies, 1 included 2 treatment groups (exercise alone and exercise plus manual therapy) to assess the effect of therapeutic exercises with and without manual therapy.[16] Consequently, we obtained a total of 8 data sets for this systematic review.

We included the studies that reported Disabilities of the Arm, Shoulder and Hand (DASH) scores (score range, 0–100)[16,22,29] as the patient-reported outcome measures. Although we examined studies of other patient-reported outcome measures, such as the Shoulder Pain and Disability Index (score range, 0%–100%),[20] Numeric Pain Rating Scale (score range, 0–10),[24] and Shoulder Disability Questionnaire (score range, 0–100),[28] only for kinematic variable comparison for more consistent assessment, we did not include them in the comparison of the patient-reported outcome measures because of the different rating scales and types of questions used. Therefore, from 3 studies, 4 data sets of DASH scores (sample sizes, means, and standard deviations) were extracted as patient-reported outcomes for preintervention and postintervention comparison. Eight, 7, and 6 sets of kinematic measures were also extracted for scapular upward rotation, posterior tilt, and internal rotation at 90° of ascending limb elevation in the scapular plane, respectively. We defined *upward/downward rotation of the scapula* as the rotation around the anterior-posterior axis of the thorax, *scapular anterior/posterior tilt* as the rotation around the medial-lateral axis of the thorax, and *internal/external rotation of the scapula* as the rotation around the superior-inferior axis of the thorax.[34] The positive directions of the 3 kinematic variables were scapular upward rotation, scapular posterior tilt, and scapular internal rotation.

We reviewed these scapular kinematic measures to assess the effectiveness of therapeutic interventions because more scapular internal rotation and less scapular upward rotation and posterior tilt during limb elevation have been documented in patients with SIS than in asymptomatic individuals.[23] In addition, the ascending phase of 90° of limb elevation is included in the "painful arc," and all included studies measured scapular kinematics at this angle, which allowed us to accumulate a reasonable number of studies and sample sizes for analysis. In addition, beyond 90° of limb elevation, less accurate

Table 1. Description and Critiques of Reviewed Studies

Study	Patient Group	Design	Physiotherapy Evidence Database Score[a]	Comments	Critique
Hsu et al[19] (2009)	Subacromial impingement syndrome	Randomized controlled clinical trial	6	Kinesiology taping versus placebo	No blinding of patients or therapists and no numeric patient-reported outcome
Keenan et al[20] (2017)	Subacromial impingement syndrome	Quasi-experimental study	4	Kinesiology taping Subacromial impingement syndrome versus healthy control group Kinesiology taping versus placebo	No random allocation, no concealed allocation, blinding of therapist not specified, blinding of assessors not specified, and treatment applied to the allocated group not explicitly reported
Muth et al[22] (2012)	Rotator cuff tendinopathy	Case-control study	5	Thoracic spine manipulation	No control group and no blinding of patients, therapists, or examiners
Kardouni et al[24] (2015)	Subacromial impingement syndrome	Randomized controlled clinical trial	9	Thoracic spine manipulation versus sham	No blinding of therapists
Struyf et al[28] (2013)	Subacromial impingement syndrome	Randomized controlled clinical trial	8	12-wk dynamic scapular stabilization	No blinding of patients or therapists
Worsley et al[29] (2013)	Subacromial impingement syndrome	Case-control study	4	10-wk motor-control retraining	Control group results not fully reported and no blinding of patients, therapists, or examiners
Camargo et al[16] (2015)	Subacromial impingement syndrome	Randomized controlled clinical trial	8	Stretching and strengthening exercises with versus without manual therapy	No blinding of patients or therapists

[a] Points awarded for randomization of groups, concealed allocation, similarity of groups at baseline, blinding of participants, high percentage of follow-up, participants received the treatment or control condition as allocated or analyzed by intention to treat when indicated, reporting of between-groups comparison, and reporting of variability. Maximum possible score = 10.

tracking of sensors for 3-dimensional (3-D) kinematic measurement has been reported.[35]

When preintervention and postintervention data were partially or not presented in the literature, we contacted the authors via e-mail and obtained the original data.

Data Synthesis

To evaluate the therapeutic effects on scapular kinematics and pain and disability in the shoulder, we calculated the standardized mean differences using 95% CIs between preintervention and postintervention for each outcome measure (eg, scapular upward rotation, posterior tilt, and internal rotation in degrees and subjective ratings of disability in numeric DASH score) in each study by intervention type as subgroup comparisons (ie, short-term intervention, long-term intervention) and calculated the overall difference with random effects using the weighted means of each outcome measure. We assessed the consistency of the studies using τ^2, χ^2, and I^2. The τ^2 values that were greater than 1.0 suggested large between-studies variability, and χ^2 values that were different ($P <$ .10) and I^2 values greater than 50% suggested that heterogeneity was present among the included studies. We performed data synthesis using Review Manager (version 5.3; The Cochrane Collaboration, Cambridge, United Kingdom).

RESULTS

From the 7 selected studies and 8 data sets, 4 studies provided a total of 4 sets of outcomes for short-term interventions,[19,20,22,24] and 3 studies provided a total of 4 sets of outcomes for long-term interventions.[16,28,29] An overview of the reviewed studies and summaries of their main findings are presented in Table 2. We observed τ^2 tests for between-studies variability ($\tau^2 < 1.0$) that were not different and did not detect overall heterogeneity ($\chi^2 \geq$ 0.43, $P >$ .10, $I^2 <$ 50%) across the included studies in each comparison of scapular kinematics and DASH scores. A summary of statistical analyses for each outcome measure is presented in Figures 2 through 5.

Scapular Upward Rotation

The 8 data sets for changes in scapular upward rotation at 90° of ascending limb elevation in the scapular plane between preintervention and postintervention are provided in Figure 2.[16,19,20,22,24,28,29] In a total of 153 patients, the overall standardized mean difference was –0.04 (95% CI = –0.31, 0.22). Our subgroup analysis showed that patients with SIS exhibited a standardized mean difference of –0.03 (95% CI = –0.48, 0.42), with only 1 set of authors reporting improvement (mean difference = –0.75; 95% CI = –1.45, –0.05) after short-term interventions (n = 83)[19,20,22,24] and –0.07 (95% CI = –0.43, 0.29) after long-term interventions

	Preintervention		Postintervention				
Study or Subgroup	Mean ± SD, °	Total No. of Participants	Mean ± SD, °	Total No. of Participants	Weight, %	Standard Mean Difference Inverse Variance, Random (95% CI)	Standard Mean Difference Inverse Variance, Random (95% CI)
Short-term interventions							
Hsu et al[19] (2009)	18.0 ± 1.3	17	19.0 ± 1.3	17	11.3	−0.75 (−1.45, −0.05)[c]	
Kardouni et al[24] (2015)	40.4 ± 10.3	26	40.3 ± 9.9	26	16.1	0.01 (−0.53, 0.55)	
Keenan et al[20] (2017)	31.0 ± 7.7	10	27.0 ± 7.7	10	7.6	0.50 (−0.40, 1.39)	
Muth et al[22] (2012)	24.7 ± 10.1	30	22.8 ± 11.7	30	17.6	0.17 (−0.34, 0.68)	
Subtotal		83		83	52.6	−0.03 (−0.48, 0.42)	
Heterogeneity: χ^2_3 = 6.06, *P* = .11, τ^2 = 0.11, I^2 = 50%							
Test for overall effect: *Z* = 0.14, *P* = .89							
Long-term interventions							
Camargo et al[16] (2015)[a]	20.1 ± 13.5	22	21.3 ± 15.2	22	14.4	−0.08 (−0.67, 0.51)	
Camargo et al[16] (2015)[b]	20.5 ± 15.2	22	21.9 ± 15.1	22	14.4	−0.09 (−0.68, 0.50)	
Struyf et al[28] (2013)	4.9 ± 7.0	10	1.4 ± 3.0	10	7.5	0.62 (−0.28, 1.53)	
Worsley et al[29] (2013)	14.1 ± 5.9	16	16.7 ± 5.1	16	11.2	−0.46 (−1.16, 0.24)	
Subtotal		70		70	47.4	−0.07 (−0.43, 0.29)	
Heterogeneity: χ^2_3 = 3.45, *P* = .33, τ^2 = 0.02, I^2 = 13%							
Test for overall effect: *Z* = 0.37, *P* = .71							
Total		153		153	100.0	−0.04 (−0.31, 0.22)	
Heterogeneity: χ^2_7 = 9.56, *P* = .22, τ^2 = 0.04, I^2 = 27%							
Test for overall effect: *Z* = 0.33, *P* = .74							
Test for subgroup differences: χ^2_1 = 0.02, *P* = .90, I^2 = 0%							

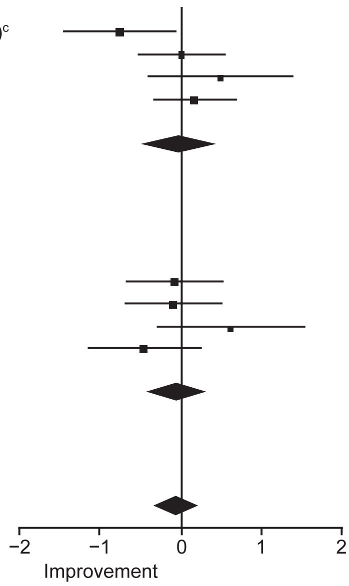

Figure 2. Scapular upward rotation at 90° of ascending limb elevation in the scapular plane. Abbreviation: CI, confidence interval. [a] Exercise-alone group. [b] Exercise-plus-manual-therapy group. [c] Difference in scapular upward rotation between preintervention and postintervention ($P < .05$).

(n = 70)[16,28,29] for changes in scapular upward rotation. Extrapolating data from the graphs demonstrated that the therapeutic interventions did not change scapular upward rotation in patients with SIS, and observed differences were not clinically meaningful.

Scapular Posterior Tilt

The 7 data sets for scapular posterior tilt at 90° of ascending limb elevation in the scapular plane between preintervention and postintervention are provided in Figure 3.[16,19,20,22,24,29] In a total of 143 patients, the overall

	Preintervention		Postintervention				
Study or Subgroup	Mean ± SD, °	Total No. of Participants	Mean ± SD, °	Total No. of Participants	Weight, %	Standard Mean Difference Inverse Variance, Random (95% CI)	Standard Mean Difference Inverse Variance, Random (95% CI)
Short-term interventions							
Hsu et al[19] (2009)	−5.5 ± 1.3	17	−5.1 ± 1.3	17	11.8	−0.30 (−0.98, 0.38)	
Kardouni et al[24] (2015)	−10.8 ± 7.5	26	−10.6 ± 7.7	26	18.3	−0.03 (−0.57, 0.52)	
Keenan et al[20] (2017)	−11.8 ± 9.4	10	−10.0 ± 8.4	10	7.0	−0.19 (−1.07, 0.69)	
Muth et al[22] (2012)	−6.9 ± 8.4	30	−6.4 ± 8.6	30	21.1	−0.06 (−0.56, 0.45)	
Subtotal		83		83	58.3	−0.11 (−0.42, 0.19)	
Heterogeneity: χ^2_3 = 0.47, *P* = .93, τ^2 = 0.00, I^2 = 0%							
Test for overall effect: *Z* = 0.73, *P* = .47							
Long-term interventions							
Camargo et al[16] (2015)[a]	1.6 ± 7.3	22	1.9 ± 8.3	22	15.5	−0.04 (−0.63, 0.55)	
Camargo et al[16] (2015)[b]	−0.1 ± 8.1	22	−2.2 ± 7.0	22	15.3	0.27 (−0.32, 0.87)	
Worsley et al[29] (2013)	−5 ± 5.1	16	−2.2 ± 5.5	16	10.9	−0.51 (−1.22, 0.19)	
Subtotal		60		60	41.7	−0.06 (−0.49, 0.37)	
Heterogeneity: χ^2_2 = 2.80, *P* = .25, τ^2 = 0.04, I^2 = 29%							
Test for overall effect: *Z* = 0.27, *P* = .78							
Total		143		143	100.0	−0.09 (−0.32, 0.15)	
Heterogeneity: χ^2_6 = 3.34, *P* = .76, τ^2 = 0.00, I^2 = 0%							
Test for overall effect: *Z* = 0.72, *P* = .47							
Test for subgroup differences: χ^2_1 = 0.04, *P* = .84, I^2 = 0%							

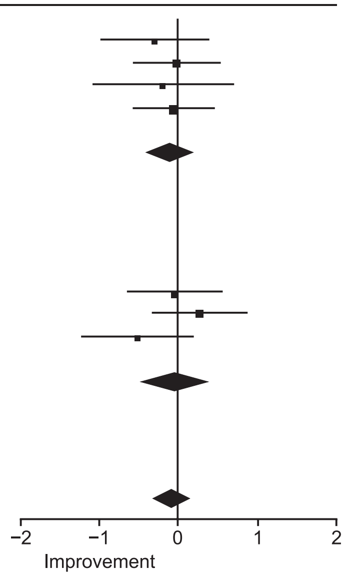

Figure 3. Scapular posterior tilt at 90° of ascending limb elevation in the scapular plane. Abbreviation: CI, confidence interval. [a] Exercise-alone group. [b] Exercise-plus-manual-therapy group.

Table 2. Overview of Reviewed Studies and Findings Continued on Next Page

Study	Sample	Inclusion Criteria	Instrument Used	Mean Difference (95% CI)		Comments on Results
				Experimental Group	Control Group	
Hsu et al[19] (2009)	Subacromial impingement syndrome (n = 17 male baseball players)	>2 subacromial impingement syndrome symptoms and >1 positive subacromial impingement syndrome test	Electromagnetic tracking system	Scapular upward rotation: −1.0° (−1.9°, −0.1°) Scapular posterior tilt: −0.4° (−1.3°, 0.5°) Scapular internal rotation: −0.6° (−1.7°, 0.5°)	Scapular upward rotation: −0.8° (−1.7°, 0.1°) Scapular posterior tilt: 0.1° (−0.8°, 0.9°) Scapular internal rotation: 1.1° (−0.5°, 2.8°)	No therapeutic effect on kinematics No numeric patient-reported outcomes reported
Keenan et al[20] (2017)	Subacromial impingement syndrome (n = 10 active individuals; 5 males, 5 females)	>2 wk of symptoms and positive Neer test, Hawkins-Kennedy test, and painful arc	3-dimensional motion capture with retroreflective markers and Shoulder Pain and Disability Index[a]	Scapular upward rotation: 4.0° (−2.8°, 10.8°) Scapular posterior tilt: −1.8° (−9.6°, 6.0°) Scapular internal rotation: −0.9° (−10.3°, 8.5°)	Healthy control group Scapular upward rotation: 4.0° (−1.5°, 9.5°) Scapular posterior tilt: −4.0° (−9.2°, 1.2°) Scapular internal rotation: −0.5° (−5.3°, 4.4°) Placebo group Scapular upward rotation: 1.2° (−5.3°, 7.7°) Scapular posterior tilt: −0.7° (−7.8°, 6.4°) Scapular internal rotation: −2.8° (−10.6°, 5.1°)	No between-groups difference in scapular kinematics No within-group difference in scapular kinematics Patient-reported outcomes reported for baseline comparison only
Muth et al[22] (2012)	Rotator cuff tendinopathy (n = 30; 16 males, 14 females)	>3/10 on the NPRS and >1 positive subacromial impingement syndrome test	Electromagnetic tracking system and DASH[b]	Scapular upward rotation: 1.9° (−3.6°, 7.4°) Scapular posterior tilt: −0.5° (−4.8°, 3.8°) Scapular internal rotation: 3.0° (−4.7°, 10.7°) DASH: 16.8 (5.1, 28.5)	No control group	No therapeutic effect on kinematics Improved patient-reported outcomes
Kardouni et al[24] (2015)	Subacromial impingement syndrome (n = 26; 11 males, 15 females)	>6 wk of pain, >2/10 on the NPRS, and >3 positive subacromial impingement syndrome tests	Electromagnetic tracking system, NPRS,[c] and PSS[b]	Scapular upward rotation: 0.1° (−5.4°, 5.6°) Scapular posterior tilt: −0.2° (−4.3°, 4.0°) Scapular internal rotation: −0.9° (−4.7°, 2.9°) NPRS: 0.9 (0.0, 1.8) PSS: 9.1 (6.5, 11.7)	Scapular upward rotation: 0.7° (−3.1°, 4.5°) Scapular posterior tilt: 0.0 (−4.5°, 4.5°) Scapular internal rotation: −1.1° (−6.0°, 3.8°) NPRS: 1.2 (0.2, 2.2) PSS: not reported	No therapeutic effect on kinematics Improved patient-reported outcomes
Struyf et al[28] (2013)	Subacromial impingement syndrome (n = 10; 5 males, 5 females)	>2 positive subacromial impingement syndrome tests and no biceps tendinopathy	Gravity-referenced inclinometer and SDQ[b]	Scapular upward rotation: 3.5 (−1.2°, 8.2°) SDQ: 20.9 (7.5, 34.3)	Scapular upward rotation: 1.7° (−2.7°, 6.2°) SDQ: 2.2 (−8.7, 13.1)	No therapeutic effect on kinematics Improved patient-reported outcomes
Worsley et al[29] (2013)	Subacromial impingement syndrome (n = 16; 11 males, 5 females)	>2 positive subacromial impingement syndrome tests	3-dimensional motion capture with retroreflective markers and DASH[b]	Scapular upward rotation: −2.6° (−6.4°, 1.2°) Scapular posterior tilt: −2.8° (−6.5°, 0.9°) DASH: 9.2 (3.0, 15.4)	Healthy control group: reference values only	No therapeutic effect on kinematics Improved patient-reported outcomes

Table 2. **Overview of Reviewed Studies and Findings Continued From Previous Page**

Study	Sample	Inclusion Criteria	Instrument Used	Mean Difference (95% CI)		Comments on Results
				Experimental Group	Control Group	
Camargo et al[16] (2015)	4 wk of therapeutic exercises for shoulder impingement plus manual therapy: subacromial impingement syndrome (n = 23; 10 males, 13 females) 4 wk of therapeutic exercises for shoulder impingement: subacromial impingement syndrome (n = 23; 14 males, 9 females)	Nontraumatic onset of shoulder pain, painful arc with active shoulder elevation, rotator cuff tenderness with palpation, and >1 positive subacromial impingement syndrome test or pain with passive or resisted shoulder external rotation	Electromagnetic tracking system and DASH[b]	4 wk of therapeutic exercises for shoulder impingement plus manual therapy: Scapular upward rotation: −1.4° (−10.4°, 7.6°) Scapular posterior tilt: 2.1° (−2.4°, 6.6°) Scapular internal rotation: 2.1° (−3.3°, 7.5°) DASH: 12.9 (4.4, 21.4) 4 wk of therapeutic exercises for shoulder impingement: Scapular upward rotation: −1.2° (−9.7°, 7.3°) Scapular posterior tilt: −0.3° (−4.9°, 4.3°) Scapular internal rotation: 2.1° (−1.7°, 5.9°) DASH: 9.1 (3.2, 15.0)	The group with exercise alone served as the control group	No therapeutic effect on kinematics Improved patient-reported outcomes

Abbreviation: DASH, Disabilities of the Arm, Shoulder and Hand; NPRS, Numeric Pain Rating Scale; PSS, Penn Shoulder Score; SDQ, Shoulder Disability Questionnaire.

[a] Score range, 0%–100%.

[b] Score range, 0–100.

[c] Score range, 0–10.

Study or Subgroup	Preintervention Mean ± SD, °	Preintervention Total No. of Participants	Postintervention Mean ± SD, °	Postintervention Total No. of Participants	Weight, %	Standard Mean Difference Inverse Variance, Random (95% CI)
Short-term interventions						
Hsu et al[19] (2009)	26.3 ± 1.6	17	26.9 ± 1.6	17	13.2	−0.37 (−1.04, 0.31)
Kardouni et al[24] (2015)	34.4 ± 6.8	26	35.3 ± 7.3	26	20.6	−0.13 (−0.67, 0.42)
Keenan et al[20] (2017)	35.6 ± 11.1	10	36.5 ± 10.3	10	7.9	−0.08 (−0.96, 0.80)
Muth et al[22] (2012)	29.2 ± 5.8	30	26.2 ± 20.7	30	23.7	0.19 (−0.31, 0.70)
Subtotal		83		83	65.5	−0.05 (−0.36, 0.25)
Heterogeneity: χ^2_3 = 1.81, *P* = .61, τ^2 = 0.00, I^2 = 0%						
Test for overall effect: *Z* = 0.34, *P* = .73						
Long-term interventions						
Camargo et al[16] (2015)[a]	38.0 ± 6.4	22	35.9 ± 6.3	22	17.2	0.32 (−0.27, 0.92)
Camargo et al[16] (2015)[b]	36.9 ± 8.3	22	34.8 ± 9.8	22	17.3	0.23 (−0.37, 0.82)
Subtotal		44		44	34.5	0.28 (−0.14, 0.70)
Heterogeneity: χ^2_1 = 0.05, *P* = .82, τ^2 = 0.00, I^2 = 0%						
Test for overall effect: *Z* = 1.29, *P* = .20						
Total		127		127	100.0	0.06 (−0.19, 0.31)
Heterogeneity: χ^2_5 = 3.40, *P* = .64, τ^2 = 0.00, I^2 = 0%						
Test for overall effect: *Z* = 0.48, *P* = .63						
Test for subgroup differences: χ^2_1 = 1.54, *P* = .21, I^2 = 35.0%						

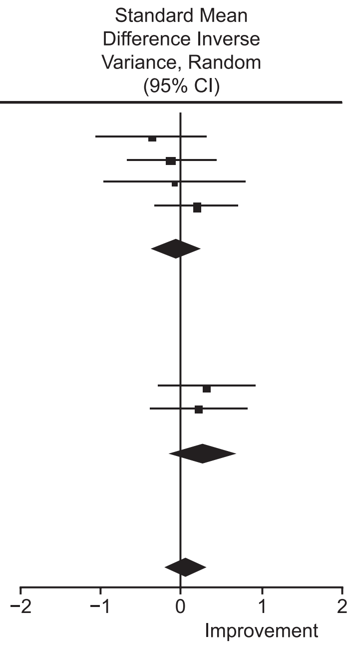

Figure 4. Scapular internal rotation at 90° of ascending limb elevation in the scapular plane. Abbreviation: CI, confidence interval. [a] Exercise-alone group. [b] Exercise-plus-manual-therapy group.

standardized mean difference was –0.09 (95% CI = –0.32, 0.15). Our subgroup analysis showed that patients with SIS exhibited standardized mean differences of –0.11 (95% CI = –0.42, 0.19) after short-term interventions (n = 83)[19,20,22,24] and –0.06 (95% CI = –0.49, 0.37) after long-term interventions (n = 60)[16,29] for changes in scapular posterior tilt. Extrapolating data from the graphs showed that the therapeutic interventions did not change scapular posterior tilt in patients with SIS, and the observed differences were not clinically meaningful.

Scapular Internal Rotation

The 6 data sets for scapular internal rotation at 90° of ascending limb elevation in the scapular plane between preintervention and postintervention are presented in Figure 4.[16,19,20,22,24] In a total of 127 patients, the overall

Study or Subgroup	Preintervention Mean ± SD, °	Preintervention Total No. of Participants	Postintervention Mean ± SD, °	Postintervention Total No. of Participants	Weight, %	Standard Mean Difference Inverse Variance, Random (95% CI)
Short-term interventions						
Muth et al[22] (2012)	37.1 ± 23.1	30	20.3 ± 23.1	30	34.3	0.72 (0.19, 1.24)[c]
Subtotal		30		30	34.3	0.72 (0.19, 1.24)[c]
Heterogeneity: not applicable						
Test for overall effect: *Z* = 2.69, *P* = .007						
Long-term interventions						
Camargo et al[16] (2015)[a]	20.8 ± 10.4	22	11.7 ± 9.5	22	24.2	0.90 (0.27, 1.52)[c]
Camargo et al[16] (2015)[b]	25.3 ± 16.1	22	12.4 ± 12.3	22	24.3	0.88 (0.26, 1.51)[c]
Worsley et al[29] (2013)	17.0 ± 11	16	7.8 ± 6.4	16	17.1	1.00 (0.26, 1.74)[c]
Subtotal		60		60	65.7	0.92 (0.54, 1.30)[c]
Heterogeneity: χ^2_2 = 0.06, *P* = .97, τ^2 = 0.00, I^2 = 0%						
Test for overall effect: *Z* = 4.76, *P* < .001						
Total		90		90	100.0	0.85 (0.54, 1.16)[c]
Heterogeneity: χ^2_3 = 0.43, *P* = .93, τ^2 = 0.00, I^2 = 0%						
Test for overall effect: *Z* = 5.43, *P* < .001						
Test for subgroup differences: χ^2_1 = 0.37, *P* = .54, I^2 = 0%						

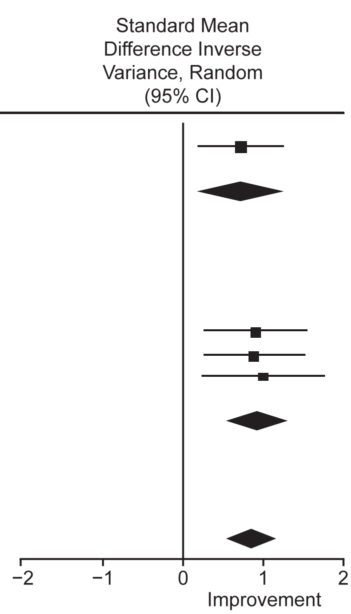

Figure 5. Disability of the Arm, Shoulder and Hand score. Abbreviation: CI, confidence interval. [a] Exercise-alone group. [b] Exercise-plus-manual-therapy group. [c] Improvement in perceived pain and disability after the interventions ($P < .05$).

standardized mean difference was 0.06 (95% CI = –0.19, 0.31). Our subgroup analysis showed that patients with SIS exhibited standardized mean differences of –0.05 (95% CI = –0.36, 0.25) after short-term interventions (n = 83)[19,20,22,24] and 0.28 (95% CI = –0.14, 0.70) after long-term interventions (n = 44) for changes in scapular internal rotation.[16] Extrapolating data from the graphs indicated that the therapeutic interventions did not improve scapular posterior tilt in patients with SIS.

Patient-Reported Outcomes

We included 3 studies (4 data sets) in which patient-reported outcomes measured with DASH scores were evaluated (Figure 5).[16,22,29] In a total of 90 patients, the overall standardized mean difference in DASH scores after therapeutic interventions was 0.85 (95% CI = 0.54, 1.16). Our subgroup analysis showed that only 1 set of authors[22] reported DASH scores after short-term interventions. The standardized mean differences for patients with SIS were 0.72 (95% CI = 0.19, 1.24) after short-term interventions[22] (n = 30) and 0.92 (95% CI = 0.54, 1.30) after long-term interventions (n = 60).[16,29] These findings suggest that current therapeutic interventions effectively reduced perceived pain and disability in patients with SIS, and observed changes were clinically meaningful.

DISCUSSION

Impaired scapular kinematics are commonly reported in patients with SIS.[12,13] A variety of therapeutic interventions designed to improve scapular kinematics and reduce pain and disability have been described in the literature. The objective of our systematic review was to determine the effects of short- and long-term therapeutic interventions on scapular kinematics during 90° of ascending upper extremity elevation in the scapular plane and self-reported pain and disability in patients with SIS by comparing pretreatment and posttreatment outcome measures. Whereas both short- and long-term therapeutic interventions for treating SIS improved subjective ratings of pain and disability with no conflicting result reported by DASH score, we did not find an effect of those interventions to improve scapular kinematics, especially for scapular upward rotation, posterior tilt, and internal rotation at 90° of ascending limb elevation in the scapular plane.

Researchers[12,13] have identified altered scapular kinematics in patients with SIS versus healthy individuals. The differences include more scapular internal rotation and less scapular upward rotation and posterior tilt during limb elevation. Weakness of the scapulohumeral muscles and improper control of glenohumeral and scapulothoracic movement during limb elevation have also been well documented in patients with SIS. Characteristics such as less activity of the serratus anterior and more activity of the upper and lower trapezius have been believed to contribute to these abnormal scapular kinematics.[27] Therefore, it seems reasonable for clinicians to manage SIS by trying to correct altered scapular kinematics. Whereas our systematic review suggested that the current clinical interventions designed to improve scapular kinematics for patients with SIS have limited support from current evidence, close observation of each included study and other relevant studies may suggest a valuable insight regarding the direction of future clinical approaches.

One of our interesting findings was the effect of elastic taping. Some specific elastic-taping techniques have become increasingly popular as clinicians try to solve a variety of musculoskeletal problems. Whereas the underlying mechanisms of taping are still unclear, researchers[21] have proposed that taping works by offering constant proprioceptive feedback or providing alignment correction during dynamic movements. Hsu et al[19] investigated the immediate effects of elastic taping on scapular kinematics, muscle strength, and electromyographic activity in baseball players with shoulder impingement. They demonstrated that a specific taping method improved scapular upward rotation at 90° of ascending limb elevation in the scapular plane in a within-group comparison; however, the difference was not found in a between-groups comparison with the control group. They also reported increased scapular posterior tilt at 30° and 60° during limb raising and increased lower trapezius muscle activity in the 60° to 30° limb-lowering phase compared with the placebo-taping group; however, these changes did not occur simultaneously. Therefore, as they noted, further research focusing on the underlying mechanisms of the effects of taping is warranted. Keenan et al[20] examined the effect of kinesiology taping on shoulder strength, proprioception, and scapular kinematics in healthy participants and patients with SIS. No within-group or between-groups difference was reported for any measure. They concluded that kinesiology taping did not appear to aid or impair scapular kinematics and that researchers should explore whether the effects of specific taping techniques were time dependent and were similar in other pathologic conditions.

A discussion of the studies that were not included in our review is worthwhile. Shaheen et al[21] investigated the effect of rigid- and elastic-taping techniques on scapular kinematics and pain in 11 patients with SIS. They suggested that both taping techniques externally rotate the scapula during sagittal-plane movements by an average of between 30° and 120° of limb elevation compared with baseline and result in reduced pain during limb elevation and lowering. However, they did not find changes in scapular upward rotation, posterior tilt, or internal rotation between preintervention and postintervention during scapular-plane limb elevation. Regardless of the small effects of the 2 taping techniques on scapular kinematics, they concluded these could not be used to indicate an added advantage of the taping technique because of the absence of a concomitant effect on pain and the existing discrepancy in the literature concerning the movements that taping must normalize in patients with SIS.

Thoracic spine manipulation may also be a popular option for those seeking immediate reduction of musculoskeletal pain and dysfunction, but the mechanisms by which the manipulation induces these changes are not well understood. One may suggest that introducing manipulative force results in biomechanical (eg, subtle changes in joint mechanics) and neurophysiological responses (eg, changes in pain perception, altered motor-neuron excitability).[36] Among the studies included in our review, Muth et al[22] and Kardouni et al[24] investigated the immediate effects of thoracic spine manipulation on scapular kinematics and changes in patient-reported outcome measures in individuals with SIS. Both groups reported immediate improvements in shoulder pain and function after the intervention but no clinically meaningful changes in scapular kinematics. They concluded that the improvements in patient-reported outcomes after thoracic spine manipulation were not likely explained by alterations in scapular kinematics. Although not included in our review, Haik et al[23] similarly evaluated the immediate effects of a low-amplitude, high-velocity thrust thoracic spine manipulation on pain and kinematics during the ascending and descending phases of limb elevation in patients with SIS. They reported changes in scapular upward rotation during both ascending and descending phases of sagittal-plane limb elevation at an unspecified humerothoracic angle before and after thoracic spine manipulation but, because of the small effect size, concluded that the observed changes in scapular kinematics after thoracic spine manipulation were not clinically important.

Exercise-centered therapeutic intervention is often the first line of management for SIS. Whereas researchers have reported that therapeutic interventions, including stretching and scapular mobilization techniques,[31,32] strengthening exercises,[26] and motor control,[27] can improve patient-reported outcomes in patients with SIS, their efficacy on kinematic changes has not been fully supported by evidence. Camargo et al[16] reported small, clinically irrelevant changes in scapular kinematics in a group that performed stretching and strengthening exercises with manual therapy after a 4-week intervention and no kinematic changes in a group that did not receive manual therapy. Struyf et al[28] reported no difference in scapular kinematics after a 12-week dynamic scapular stabilization. Worsley et al[29] demonstrated improved scapular upward rotation during sagittal-plane limb elevation and improved scapular posterior tilt during frontal-plane limb elevation after 10 weeks of motor-control scapular retraining. They also reported general trends in increased upward rotation and posterior tilt in scapular-plane limb movement; however, these were not different. In other studies that we did not include in this review, researchers have assessed the mechanistic effects of exercises and stretching on scapular kinematics. Their general findings were comparable with our overall results. Surenkok et al[32] reported an effect of scapular mobilization for improving glenohumeral range of motion, scapular upward rotation at maximal shoulder elevation in the scapular plane, and patient-reported outcomes (Constant Shoulder Score) in patients with SIS compared with placebo and control groups. However, the results can be applied only to the shoulder position at maximal humeral elevation in the scapular plane, and no comparison at the specific thoracohumeral angles (eg, in ascending phase at 90° of shoulder elevation) was reported. McClure et al[26] also assessed the effects of a 6-week exercise program in patients with SIS to identify changes that might occur in 3-D scapular kinematics, physical impairment, and functional limitations. They reported no differences in scapular kinematics during scapular-plane limb elevation, whereas they observed improvements in pain, satisfaction, and shoulder function using the Penn Shoulder Score.

Overall, authors of the studies included in this review[16,22,24,28,29] and most previous clinical studies[23,26,27,31,32] have reported improved patient-reported outcomes after receiving therapeutic interventions in patients with SIS, but the intended effectiveness of those interventions on altered scapular kinematics has not been fully supported by evidence.

To the best of our knowledge, this is the first systematic review of the effectiveness of short- and long-term therapeutic interventions for improving scapular kinematics in patients with SIS. The strength of our study is that all included studies were published in recent years, which could decrease variability in the methods used to collect kinematic data. Improved technologies, such as 3-D motion-capture systems, have made precise measurement of range of motion in the scapular plane during dynamic and coupled movement possible.[35,37] However, caution should be taken when interpreting these results, as we still cannot exclude potential methodologic limitations. Researchers have reported a slight difference in reliability when applying 3-D motion-capture systems to assess shoulder kinematics. Whereas excellent (ICC $>$ 0.75) sensor tracking of scapular upward rotation[38–40] and good (ICC range, 0.60–0.74) tracking of scapular posterior tilt[39] and internal rotation[41] have been demonstrated, less accurate marker tracking above 90° to 120° of limb elevation has been reported.[42] Scapular kinematics are also influenced by the speed of motion, direction, pain, shoulder tightness, and fatigue.[30] In addition, accurate measurement of scapular kinematics is challenging because it depends on the precise notation of movement conditions, coordinate systems, and skill level of examiners.[34] Therefore, researchers should use reliable, high-quality instruments and consistent methods in future studies to examine the effects of various therapeutic interventions on scapular kinematics in order to confirm these associations or lack of associations.

Our study had several limitations. First, possible between-studies heterogeneity may exist in subgroup comparisons because of different study designs, instrumentation variability, differences in sampled populations, and possible differences in criteria for SIS. The analysis of the short-term intervention effect on scapular upward rotation showed possible moderate between-studies heterogeneity ($\chi^2_3 = 6.06$, $P = .11$, $I^2 = 50\%$; Figure 2); therefore, we should evaluate the short-term and overall effects on scapular upward rotation cautiously. Second, our review might be limited because we assessed the intervention effects by comparing within-group changes, which means we did not control for time or therapist-patient nonspecific effects. Between-groups comparisons in future randomized control trials may yield alternative results. We only compared scapular kinematic changes at 90° of ascending limb elevation in the scapular plane. A limited number of researchers have discussed the differences in scapular kinematics between the ascending and descending phases of limb elevation in symptomatic and asymptomatic cohorts or treatment and control groups, and questions remain as to whether clinically meaningful differences exist between those phases.[43,44] However, in an electromyographic study of patients with SIS, de Morais Faria et al[45] suggested altered activation of the trapezius and serratus anterior muscles during the raising and lowering of limbs. Therefore, scapular kinematics in other planes of arm elevation or at angles other than 90° of ascending limb elevation may provide alternative results if we review an adequate number of studies in the future. Third, several subgroup analyses (ie, short- and long-term interventions) of scapular kinematics and patient-reported outcome measures were performed on a relatively small number of studies. An inadequate number of studies or sample sizes may be a reason for the shortcomings of the current body of knowledge regarding therapeutic effects on scapular kinematics in patients with SIS; however, this may be an inherent concern given that measuring 3-D scapular kinematics demands a high level of expertise for accuracy and between-sessions reliability. In the future, more studies with randomized controlled trials and improved measurement properties for 3-D scapular kinematics will provide stronger evidence for characterizing the mechanisms of treatment for SIS. Fourth, we combined long- and short-term interventions in the analyses and did not specifically evaluate the effects of any individual intervention. Perhaps this diminished the effect of an individual intervention when pooled with other interventions.

Despite these study limitations, our review provides valuable insight regarding how future studies should be designed to examine the association between improved patient-reported outcomes and various therapeutic interventions for SIS, which would help to characterize the mechanisms of therapeutic effects on scapular kinematics. Current clinical interventions designed to improve scapular kinematics for patients with SIS have limited support from the available evidence, regardless of their effectiveness in improving patient-reported outcomes. These findings do not necessarily demand a radical change in the therapeutic approach because we still need to accumulate clinical evidence before drawing conclusions. In fact, current therapeutic interventions commonly used to treat SIS improve patient-reported outcomes. Overall, the 10.6-point improvement in the DASH scores (95% CI = 6.9, 14.2) demonstrated after interventions in this review was greater than the minimal clinically important difference (10.2) or minimal detectable change (10.4) for the DASH,[46] which suggests the benefit from the care received. However, given this theoretical departure between improved patient-reported outcomes and intended changes in scapular kinematics, we can speculate whether pain or disability actually causes instead of results from kinematic changes at the onset or whether reduced pain and disability result in kinematic improvement during the recovery process of patients with SIS, as McQuade et al[30] hypothesized. Prospective studies and studies with extended follow-up that include well-matched control groups and reliable kinematic measurement methods should be considered.

The results of our review may also suggest consideration of an alternative clinical approach, such as neuromuscular control (eg, altered spinal and supraspinal levels of motor control),[30] in future research. Traditional therapeutic exercises based on resistance training improve muscle strength; however, those strengthening exercises alone may not be sufficient to address impaired muscle-coordination patterns during functional tasks.[47,48] Therefore, they are often ineffective in achieving expected therapeutic goals. Developing a new therapeutic standard accompanied by evidence would help us understand the mechanisms of altered scapular kinematics in patients with SIS and intended functional improvement, which may enhance patient outcomes.

CONCLUSIONS

The short- and long-term therapeutic interventions we studied for SIS improved patient-reported outcomes, such as reducing disability and pain, but did not change scapular kinematics. The improvements in shoulder pain and disability that we identified are not likely explained solely by changes in scapular kinematics. To further understand the mechanisms that lead to shoulder pathologic conditions or functional improvement in patients with SIS, additional studies are warranted. Randomized controlled trials with adequate sample sizes, well-matched control groups, and blinding, as well as using a sophisticated measure of scapular kinematics, would strengthen the evidence for clinical effectiveness of therapeutic interventions for SIS.

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