Electromyographic activity of the shoulder muscles during rehabilitation exercises in subjects with and without subacromial pain syndrome: a systematic review

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Abstract

Background: Subacromial pain syndrome (SPS) is a common cause of shoulder pain and muscle activity deficits are postulated to contribute to the development and progression of the disorder. The purpose of this systematic review was to definitively determine whether evidence exists of differences in electromyography (EMG) characteristics between subjects with and without SPS.

Methods: Six key databases were searched: MEDLINE, EMBASE, CINAHL, SPORTdiscus, PEDro and The Cochrane Library (inception to May 2016). The search yielded 1414 records using terms relating to shoulder impingement, EMG, scapular and rotator cuff muscles. Twenty-two papers remained once duplicates were removed and selection criteria applied. Data extraction, quality assessment and data synthesis were performed. Effect sizes and 95% confidence intervals were calculated.

Results: There was limited evidence that serratus anterior has lower amplitude, delayed activation and earlier termination in SPS participants. For the majority of muscles, regardless of task, load or arm position, significant differences were not demonstrated or results were contradictory.

Conclusions: The understanding of SPS is changing and EMG appears unable to capture the complexities associated with this condition. Addressing aberrant movement patterns and facilitating balanced activation of all shoulder muscles may be a more appropriate treatment direction for the future.

Keywords

subacromial pain syndrome, electromyography, rehabilitation, rotator cuff, scapular muscles

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Introduction

Shoulder disorders are a leading cause of pain and disability in our society with incidence reported as 5–47% in the general population¹ and prevalence associated with age^{1–3} and female gender.^{2–4} Recurrence is common and symptoms often persistent, with ongoing morbidity beyond 2 years reported by 14% of patients in general practice.⁴ Subacromial impingement syndrome, including rotator cuff pathology, is the most common of all shoulder diagnoses reported to general practitioners³ and has been shown to be the most common upper extremity disorder seen in working populations.⁵

The term ‘subacromial impingement syndrome’ as a useful diagnosis is increasingly questioned in the

literature with an emerging consensus that the symptoms ascribed to this disorder may arise from a number of shoulder pathologies associated with the soft tissues occupying the subacromial space.⁶ Traditionally, extrinsic factors were proposed as causing compression and abrasion of the bursal side of the rotator cuff,

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mechanically encroached between the acromion (or coracoid) and humeral head.⁷ Increasingly, this model is being challenged with intrinsic rotator cuff pathology suggested as more causative of symptoms,^{8,9} particularly since cadaver studies have demonstrated that rotator cuff pathology occurs more frequently within the internal substance or on the joint side of the tendon.¹⁰

The authors of this systematic review acknowledge the significant evidence base that has fostered a greater understanding of rotator cuff tendinopathy and a departure from the traditionally held view of subacromial impingement syndrome. For the purposes of this review, though much of the relevant literature is described in terms of subacromial or shoulder impingement, the term subacromial pain syndrome (SPS) has been used.

Electromyography (EMG) studies have demonstrated the important role of the scapular muscles for optimal scapular motion during arm movements with the relative contributions of the serratus anterior and trapezii muscles in normal shoulder motion demonstrated.^{11,12} Alterations in the activation of these muscles in patients presenting with SPS have been described¹³ and are proposed to result in the aberrant scapular position and motion frequently seen clinically and associated with this diagnosis.^{13,14}

Alterations in the activity of the rotator cuff have also been implicated in the development of SPS due to a reduced ability to centralize the humeral head and prevent superior migration.^{15–20} Despite these notions, consistent deviations in shoulder muscle activity and timing have not been identified.²¹

Two previous systematic reviews have attempted to synthesize muscle activity data in SPS populations.^{21,22} One review²¹ included nine studies across 11 papers published up until 2008 that investigated differences in EMG activity of all shoulder muscles between subjects with and without SPS during various tasks. The other²² included nine papers published until 2012 and only examined scapulothoracic muscles in subjects with SPS compared to controls. The two reviews differed in their conclusions on scapulothoracic muscle activity, with Chester et al.²¹ reporting no difference in serratus anterior activity, limited or conflicting evidence of a difference for upper, middle and lower trapezius, and more consistent evidence for differences in recruitment timing with a delay shown in upper and lower trapezius as well as serratus anterior. In contrast, Struyf et al.²² reported moderate evidence that the upper trapezius shows increased activity and the lower trapezius and serratus anterior decreased activity in SPS subjects, and they did not reach consensus regarding scapular muscle recruitment patterns. Only Chester et al.²¹ reported on rotator cuff and other shoulder muscles and found no evidence of a difference in EMG

amplitude between subjects with SPS and controls in supraspinatus, teres minor, biceps, anterior and posterior deltoid, and only limited or conflicting evidence of a difference during some tasks for infraspinatus, subscapularis, middle deltoid and latissimus dorsi.

Understanding whether differences in shoulder muscle function exist in people with SPS remains an important question because all of the muscles about the shoulder complex are potential targets for clinical intervention in this complex and often difficult to treat condition. A synthesis of available current literature in this area is warranted since the previous reviews are either dated²¹ or limited in their search breadth and muscles evaluated.²²

The aim of this systematic review was therefore to (i) present a comparison of mean EMG differences [$\pm$ 95% confidence intervals (CIs)] in amplitude and timing identified among the scapular, rotator cuff and other synergistic muscles in subjects with SPS compared to controls and thus (ii) determine whether more definitive evidence of differences in EMG characteristics between subjects with and without SPS during rehabilitation type exercises has emerged.

Methods

Search strategy

The databases searched included MEDLINE, EMBASE, CINAHL, SPORTdiscus, PEDro and The Cochrane Library from inception to May 2016 using MeSH terms, keywords, and Boolean operators. The search was based on three concept headings: *population* (shoulder pain, shoulder impingement, subacromial impingement syndrome); *outcome* (electromyography, EMG) and *muscles* (muscle activity, peak amplitude, scapular muscles, rotator cuff). PubMed and Google Scholar were searched for articles not yet indexed in the above databases. The reference lists of included studies were reviewed and citation tracking undertaken via Web of Knowledge. All yielded articles were imported into Endnote (version X7) and duplicates deleted.

Two reviewers (RK and TP) independently evaluated all identified titles and abstracts against predetermined eligibility criteria. Full-text articles of those potentially meeting the criteria were screened independently for inclusion (RK and TP) with agreement for inclusion reached by consensus.

Eligibility criteria

Studies were eligible for inclusion in the review if they evaluated EMG activity of the scapula and/or rotator cuff muscles in subjects diagnosed with SPS compared to controls during rehabilitation based activities.

Subjects. To be eligible, studies should have recruited subjects with a confirmed diagnosis of SPS based on relevant imaging and clinical tests. To isolate the pathology specifically to SPS, studies were excluded if they used subjects with any other existing or previous shoulder pathology or injury, cervical referred pain including upper limb radiculopathy and/or neurological disorders.

Outcomes. EMG is considered the gold standard method of measuring muscle activity²³ and studies that used either surface EMG (sEMG) or intramuscular EMG (iEMG) to analyze timing and intensity of muscle activation were eligible for inclusion.

Muscles analyzed. Studies that investigated the following muscles were eligible for inclusion: all portions of the trapezius complex; serratus anterior; the four rotator cuff muscles. Where studies also evaluated other synergistic muscles, the activity of these muscles was included in the review but such studies were not otherwise sought.

Data extraction

A range of methodological details including EMG analysis methods, normalization procedures and raw EMG data were extracted by a single investigator (RK) with re-evaluation by a second reviewer (TP). Where insufficient data were provided to make study comparisons possible, the authors were contacted by e-mail. If this process did not yield the required information, where studies presented data in clear graph form, an estimation of the data was made using specialized software.²⁴ Chester et al.²¹ kindly provided raw data for one study after permission from the original author²⁵ was obtained.

Data analysis

Methodological differences across the studies, including tasks performed, muscles tested and load applied as well as EMG procedures used, precluded a full meta-analysis.²⁶ However where studies provided appropriate raw data for each group, standardized mean differences (SMD) with $\pm 95\%$ CIs were calculated using Review Manager.²⁷ In the studies where sufficient raw data were not available,^{28,29} the reported EMG results have been presented in a narrative format.

Quality assessment

A quality assessment tool was developed, based on the standardized form for observational studies devised by Siegfried et al.³⁰ This tool evaluates external validity, detection bias and performance bias and was readily adaptable to address the requirements of this review.

The Non-Randomised Studies Methods Group of The Cochrane Collaboration has commended this as a quality assessment tool³¹ and it has recently been used in a similar systematic review estimating shoulder muscle activity during therapeutic exercises in normals.³² Included studies were independently assessed for methodological validity by two reviewers (RK and TP).

Results

Study selection and characteristics

In total, 22 studies were included that evaluated a total of 342 subjects with a diagnosis of SPS and 334 healthy controls. Figure 1 illustrates the number of references considered at each stage of the review.

All studies were comparative cross-sectional designs with some utilizing the same subjects but presenting different EMG characteristics in separate papers.^{29,33–35} Of the 22 studies, two used companion studies for

Figure 1. Study selection.

control data: Reddy et al.²⁰ with data from Alpert et al.³⁶ and Clisby et al.³⁷ with data from Bitter et al.³⁸

The mean age across the SPS subjects ranged from 21.0 years to 53.5 years and the control group mean age ranged from 19.3 years to 46.9 years. For the 20 studies that provided gender information, 196 were men and 127 women (61% male) in the SPS population and 177 were men and 139 women (56% male) in the controls.

Of the 22 studies, 17 investigated EMG amplitude and/or co-activation ratios,^{14,19,20,25,28,34,35,37,39–47} five investigated only muscle recruitment timing^{29,33,48–50} and two investigated both amplitude and timing^{28,41} during a variety of tasks with differing applications of load under isotonic, isometric or isokinetic conditions. Characteristics of the included studies are summarized in Supplementary File 1.

Quality assessment

The included studies showed variable methodological quality. Control-matching generally occurred except in one study where the control group contained twice as many subjects⁴⁴ and two others where a large mean age discrepancy was seen.^{20,37} Six studies recruited from young athletic populations involved in overhead sports^{33,34,42,43,46,48} and another excluded patients aged above 34 years,⁴⁹ potentially limiting the generalizability of the results to typical subacromial pain syndrome patients. Patients aged under 35 years are considered more likely to have 'secondary impingement' symptoms arising from dynamic glenohumeral instability^{51,52} rather than the primary subacromial pain presentation^{3,5} more often seen in clinical practice. Four studies only investigated subjects of single gender^{14,42,46,47} with two others not reporting gender details.^{25,48}

Based on the available evidence at each study's publication date, appropriate EMG electrodes were generally employed, with infraspinatus the only rotator cuff muscle that was investigated with sEMG.⁵³ Cross-talk from adjacent muscles with sEMG is well documented^{54,55} and there is emerging evidence that challenges the validity of sEMG in sampling muscle activity in the shoulder complex.^{56–58}

Most of the amplitude and co-activation studies undertook normalization using maximum isometric voluntary contraction (MVIC) except three^{19,44,46} where potential validity issues associated with pain inhibition or fear avoidance were addressed by averaging activation amplitudes across task repetitions and/or using co-activation ratios. Of the studies that normalized data to MVIC, randomization was only undertaken in one²⁵ with others reporting the use of rest breaks to minimize subject fatigue. Most of the studies adopted some form of randomization during

movement testing except seven^{25,33,37,39–41,49} where this was either not done or not documented. Blinding of assessors to raw EMG data was poorly addressed in all of the studies and only four studies provided data relating to within- or between-day reliability of testing.^{14,33,40,50}

Determination of latency varied across the timing studies with some using computer software to detect changes in EMG activity [two to three standard deviations from baseline^{28,29,50} or muscle activation reaching 5% to 10% of peak maximum voluntary contraction (MVC) recorded],^{33,48} while others used visual inspection of filtered and rectified EMG signals.^{41,49} Although a high correlation between computer and visual based determination of onset has been shown,⁵⁹ direct comparison between studies is potentially impeded where differing methods have been used. The full quality assessment is documented in Table 1.

Comparative muscle analysis

The following comparison of mean ($\pm 95\%$ CI) EMG differences in amplitude, timing and co-activation ratios identified among the scapular, rotator cuff and other synergistic muscles between subjects with SPS and controls is presented in conjunction with Supplementary File 1, Table 1 and Figures 2 to 6.

Scapular muscle amplitude and co-activation ratios. Twelve studies^{14,25,28,34,35,39–43,46,47} investigated mean differences in scapular muscle amplitude between subjects with and without SPS, using sEMG.

Upper trapezius was the most frequently analyzed scapular muscle with all 12^{14,25,28,34,35,39–43,46,47} studies investigating amplitude differences between groups. For almost all studies, significant SMDs were not demonstrated between groups for upper trapezius activity, regardless of task, load or arm position (Fig. 2). Significantly lower mean amplitude in subjects with SPS was reported in another study, not included in the effect-size calculations, during frontal plane reaching tasks.²⁸

Eleven studies evaluated differences in lower trapezius amplitude in subjects with SPS compared to controls.^{14,25,28,34,35,39,41–43,46,47} A significant SMD was not demonstrated between groups for the majority of studies regardless of task, load or arm position (Fig. 3). In three studies,^{14,34,42} significant but inconsistent SMDs were demonstrated in lower trapezius activity.

EMG amplitude of serratus anterior was evaluated in ten studies.^{14,25,28,35,39,41–43,46,47} Figure 4 highlights that three studies showed a lower mean serratus anterior amplitude in subjects with SPS observed during isotonic scapular plane elevation with and without load^{14,42} and during midrange isotonic external

Table 1. Quality assessment.

Study	External validity			Performance		Detection		Internal validity				
	Representative	Participation rate	Control matched	Direct observation	Blinding of assessors	Appropriate electrode choice	Appropriate normalization procedures	Selection bias and control of confounding				
								Randomization of MVICs	Randomization of trials	Appropriate data analysis and synthesis	Trial to trial reliability	
Alves di Oliveira et al. [46]	X	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Bandholm et al. [25]	X	✓	✓	✓	X	✓	✓	✓	X	✓	X	
Brox et al. [40]	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	
Castelain et al. [47]	X	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Clisby et al. [37]	✓	✓	X	X	X	✓	✓	X	X	✓	X	
Cools et al. [33]	X	✓	✓	✓	X	✓	✓	X	X	✓	✓	
Cools et al. [34]	X	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Diederichsen et al. [39]	✓	✓	✓	✓	X	✓	✓	X	X	✓	X	
Huang et al. [45]	✓	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Larson et al. [41]	✓	✓	✓	✓	X	✓	✓	X	X	✓	X	
Lin et al. [42]	X	✓	✓	✓	X	✓	✓	X	NA	✓	X	
Ludewig & Cook [14]	X	✓	✓	✓	X	✓	✓	X	✓	✓	✓	
Moraes et al. [29]	✓	✓	✓	✓	X	✓	✓	X	NA	X	X	
De Moraes Faria et al. [35]	✓	✓	✓	✓	X	✓	✓	X	NA	✓	X	
Myers et al. [19]	✓	✓	✓	✓	X	✓	✓	X	NA	✓	X	
Phadke & Ludewig [50]	✓	✓	✓	✓	X	✓	✓	X	✓	✓	✓	
Reddy et al. [20]	✓	✓	X	X	X	✓	✓	X	NA	✓	X	
Roy et al. [28]	✓	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Smith [44]	✓	X	X	✓	X	✓	✓	X	NA	✓	X	
Tucker et al. [43]	✓	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Wadsworth & Bullock-Saxton [48]	X	✓	✓	✓	X	✓	✓	X	✓	✓	X	
Worsley et al. [49]	X	✓	✓	✓	X	✓	✓	X	X	✓	X	

Note: ✓ measure adequately addressed; X measure not adequately addressed; representative: ✓ both groups representative of SPS population; participation rate: ✓ if all eligible volunteers were allowed to participate; control matched: ✓ if control subjects were matched for demographics (mean age difference ≤ 7 years) and number; direct observation: ✓ if stated or implied; appropriate EMG: ✓ if surface electrodes were used on serratus anterior, trapezius, infraspinatus; ✓ if intramuscular electrodes were used on supraspinatus, subscapularis or teres minor; N/A: not applicable.

Figure 2. Standardized mean differences (with 95% confidence intervals) for upper trapezius amplitude in subjects with and without subacromial pain syndrome (SPS).

rotation.³⁹ No significant effect-size differences were observed among the other studies.

EMG amplitude of middle trapezius was investigated in six studies^{28,34,35,43,46,47} with significantly lower mean amplitude demonstrated in one only,

during isokinetic external rotation³⁴ (Supplementary File 2).

Six studies^{34,35,41,44-46} investigated scapular muscle amplitude, using co-activation ratios to analyze force couples. Although firm conclusions were difficult to

Lower trapezius

Figure 3. Standardized mean differences (with 95% confidence intervals) for lower trapezius amplitude in subjects with and without subacromial pain syndrome (SPS).

draw, the most consistent finding was of a higher ratio of upper trapezius compared to both the middle and lower trapezius fibres (Supplementary File 3).

Scapular muscle activation timing. Seven studies^{28,29,33,41,48–50} investigated differences in scapular

muscle recruitment timing between subjects with and without SPS. Effect-size calculations were undertaken in all except two^{28,29} with Fig. 5 illustrating those for lower trapezius and serratus anterior.

All seven studies^{28,29,33,41,48–50} investigated upper trapezius and almost all demonstrated no significant

Figure 4. Standardized mean differences (with 95% confidence intervals) for serratus anterior amplitude in subjects with and without subacromial pain syndrome (SPS).

between-group differences for upper trapezius activation or termination timing. Earlier activation was demonstrated in upper trapezius (relative to anterior deltoid) in subjects with SPS during unloaded unrestrained plane elevation.⁵⁰

All seven studies^{28,29,33,41,48–50} investigated lower trapezius recruitment timing with significant (but conflicting) results identified in three.^{33,49,50} Delayed mean activation and earlier termination was demonstrated in

subjects with SPS during scapular and sagittal plane elevation⁴⁹ but earlier activation was shown in elevation in an unrestrained plane.⁵⁰ Delayed activation (relative to middle deltoid) was also seen during an unexpected drop from frontal plane elevation.³³ One study, not included in the effect-size calculations, reported significantly earlier onset of lower trapezius during frontal plane reaching at natural speeds but reported delayed activation during scapular plane reaching at fast speeds.²⁸

Lower trapezius

Serratus anterior

Figure 5. Standardized mean differences (with 95% confidence intervals) for lower trapezius and serratus anterior recruitment timing in subjects with and without subacromial pain syndrome (SPS).

Serratus anterior timing was investigated in six^{28,29,41,48–50} of the seven studies. A general trend of later activation and earlier termination of serratus anterior was demonstrated across the studies and significant SMDs demonstrated in two.^{49,50}

Middle trapezius timing was investigated in three^{28,29,33} studies with a significant delay (relative to middle deltoid) demonstrated in one study in subjects with SPS during an unexpected drop from frontal plane elevation.³³

Rotator cuff muscle amplitude and co-activation ratios. Seven studies^{19,20,25,28,37,39,40} investigated differences in amplitude, including co-activation ratios, of the rotator cuff muscles between subjects with and without SPS. The results are illustrated in Fig. 6.

Infraspinatus was the most frequently analyzed rotator cuff muscle with all seven studies^{19,20,25,28,37,39,40} investigating amplitude differences between groups. Although four studies^{19,20,39,40} demonstrated significant SMDs between groups for infraspinatus activity, the results were not consistent across the majority of tasks or loads investigated with lower amplitude identified in the SPS group during elevation in the scapular plane in one study,²⁰ while greater amplitude was demonstrated during isometric abduction at 45° in another.⁴⁰ One study reported a trend of lower infraspinatus amplitude in subjects with SPS when analyzed across the whole movement cycle but not when analyzed by phase.³⁹

Five studies^{19,20,25,39,40} investigated supraspinatus amplitude. Significant SMDs were not demonstrated between groups regardless of task, load or arm position except for one study, where lower amplitude was demonstrated in subjects with SPS below 60° and greater amplitude above 60° during scapular plane elevation.¹⁹

Subscapularis was investigated in two studies^{19,20} during isotonic scapular plane elevation with lower amplitude demonstrated in subjects with SPS in loaded conditions between 0° and 30°¹⁹ and 30° and 60°²⁰ and greater amplitude between 90° and 120°¹⁹. Teres minor was investigated in just one study with no SMDs demonstrated.²⁰

Rotator cuff co-activation ratios were investigated in one study¹⁹ and showed decreased rotator cuff co-activation between 0° and 60° and increased co-activation between 90° and 120°.

Overall, any between-group differences in the rotator cuff muscles are identified primarily in just two studies during scapular plane elevation^{19,20} with both suggestive of reduced rotator cuff activation in subjects with SPS in the early part of range and increased activation later in range.

Other synergistic muscles. Eight studies investigated amplitude differences in middle deltoid^{19,20,25,28,33,37,39,40}

with significant SMDs identified in three: greater amplitude was demonstrated in subjects with SPS during external rotation at low load with a corresponding lower amplitude at high load;³⁷ two others demonstrating lower amplitude during elevation in the scapular plane between 30° and 90°.^{19,20} Two studies investigated amplitude differences for latissimus dorsi^{25,39} with one demonstrating significantly greater amplitude in subjects with SPS during isokinetic scapular plane elevation between 95° and 110° at 20% MVC²⁵ and the other, reporting a trend of greater amplitude in subjects with SPS when analyzed across the whole movement cycle.³⁹ No other significant SMDs were seen for any of the other synergistic muscles investigated.

Discussion

Summary of evidence

This systematic review provides a comprehensive evaluation of the literature investigating EMG differences in scapular and rotator cuff muscle activation in subjects with SPS compared to controls. The results of this systematic review suggest that subjects with SPS demonstrate a trend towards decreased serratus anterior amplitude with differences between upper, lower and middle trapezius less consistent. Where co-activation ratios were used to analyze amplitude differences between muscles, significant differences are observed particularly for upper trapezius relative to both lower and middle trapezius: higher ratios were demonstrated in subjects with SPS but not across all studies, again making it difficult to draw definitive conclusions. For recruitment timing of the scapular muscles, though not across all studies, there was a trend of delayed activation and earlier termination of serratus anterior. Significant SMDs for recruitment timing across the other scapular muscles were not consistently observed. For EMG amplitude of the rotator cuff muscles, significant between-group differences were demonstrated in supraspinatus, infraspinatus and subscapularis primarily during scapular plane elevation although only in two studies, making it difficult to draw firm conclusions. Of the other synergistic muscles, there is some limited evidence to show greater amplitude in subjects with SPS for latissimus dorsi.

Interpretation of evidence

This systematic review highlights the difficulties in comparing studies that have investigated differences in EMG muscle activity between subjects with and without SPS. The calculation of SMDs undertaken in this review has enabled trends of muscle activity to be more easily identified despite the obvious study

Figure 6. Standardized mean differences (with 95% confidence intervals) for amplitude of the rotator cuff muscles in subjects with and without subacromial pain syndrome (SPS).

heterogeneity. Relatively consistent trends have been presented for a minority of muscles with inconsistencies seen in the results of the majority of muscles investigated.

While some studies did demonstrate significant between-group differences in amplitude for the scapular muscles, the quality assessment process identified varying methodological flaws. For example, although Lin et al.⁴² demonstrated significant SMDs in upper and lower trapezius, as well as serratus anterior, in their study, the all-male overhead athletes were classified into severe and less severe SPS groups based on their sporting participation with subjects excluded from either SPS group if they had a painful arc or pain on isometric abduction. It is difficult to generalize the results of this study to the wider SPS population. Despite performing well overall in the quality assessment, both Ludewig and Cook¹⁴ and Cools et al.³⁴ demonstrated conversely significant SMDs for lower trapezius amplitude. This inconsistency is difficult to explain, although Cools et al.³⁴ evaluated athletes involved in overhead sports, whereas Ludewig and Cook¹⁴ evaluated relatively older construction workers exposed to overhead manual tasks.

In the co-activation studies, a trend of increased upper trapezius co-activation relative to the middle and lower portions was identified. Smith et al.⁴⁴ provided much of the evidence in support of this. However, their control group had twice as many subjects as the SPS group potentially biasing the results.

Although delayed onset and earlier termination of serratus anterior was demonstrated by Phadke and Ludewig⁵⁰ and Worsley et al.⁴⁹ in subjects with SPS, Phadke and Ludewig⁵⁰ excluded patients with a body mass index above 28 and Worsley et al.⁴⁹ excluded patients older than 34 years, potentially making the results of both studies difficult to fully generalize to the SPS population. The studies by Wadsworth and Bullock-Saxton⁴⁸ and Moraes et al.²⁹ are frequently cited since they both reported increased variance in recruitment timing in SPS subjects compared to controls but these studies were low powered, with somewhat arbitrary determination of latency and Wadsworth and Bullock-Saxton⁴⁸, in particular, performing poorly in the external validity section of the quality assessment undertaken in this systematic review.

For the rotator cuff muscles, differences in amplitude and/or co-activation ratios were primarily demonstrated in two studies during scapular plane elevation.^{19,20} Myers et al.¹⁹ normalized their data to the mean activation of the entire series of 10 elevation–depression cycles, potentially making it difficult to compare against other rotator cuff studies. In their study, Reddy et al.²⁰ compared their data derived from a SPS group with mean age of 53 years against controls with a mean age of 29 years.

Given the influence of age, amongst other factors, on tendon health,⁶⁰ a more equally matched age group may have produced very different results.

Indeed, the results of this systematic review should be read with the caveat that many of the included studies investigated participants drawn from young athletic populations, more likely to have symptoms arising from dynamic instability rather than what may be considered primary subacromial pain.^{51,52}

Importantly, accumulating evidence challenges the sensitivity and specificity of sEMG when used even in the larger, superficial muscles for which it has been traditionally advocated^{54,55} with recent studies demonstrating under- or over-estimation of muscle activity due to electrode displacement during limb excursion^{58,61}, as well as cross-talk from adjacent muscles during isometric^{57,58,62} and dynamic^{53,56,58} exercise testing in scapular, rotator cuff and other synergistic shoulder muscles, including serratus anterior, infraspinatus, deltoid and latissimus dorsi.

Moreover, recent research questions the accuracy of traditionally used infraspinatus and subscapularis EMG sampling methods: the two parts of infraspinatus have been shown to exhibit differing activity levels during resisted shoulder external rotation in normals,⁶³ and independent innervation of both upper and lower portions of subscapularis has been described, with each portion demonstrating a variable role.⁶⁴

The detailed SMD calculations undertaken for this review permit the most definitive answer to date regarding differences in shoulder EMG activity in people with SPS. Importantly, this review suggests that, although differences may exist in some muscles in subjects with SPS during various rehabilitation tasks, a uniform pattern of alteration is lacking. Much of this inconsistency may relate to the heterogeneity, low study power and other highlighted flaws in methodology, as well as the multifactorial nature of SPS and rotator cuff pathology. Equally, the unique and individualized complexity of pain and its impact on motor output may also be a critical factor.

Although it was hoped that this comprehensive review would provide a reference base from which further research into rehabilitation programs tailored for this specific subgroup of patients with shoulder pain could be developed, the results suggest that although EMG may be considered the gold standard in muscle analysis, it might not readily capture all of the complexities associated with SPS even when used in high quality, well powered studies alongside kinematic analysis. Furthermore, although EMG findings have been used as a basis for many shoulder rehabilitation protocols, including strength training, EMG data relates to muscle activation and is not necessarily directly correlated with muscle force or torque production.⁶⁵

This highlights some important implications for current clinical management of this subgroup of patients. Protocols incorporating rehabilitation exercises that focus on decreasing the activity of upper trapezius while increasing that of lower trapezius and serratus anterior may not be as effective as expected. Since this systematic review suggests that alterations in muscle activity in subjects with SPS are not uniform, it is reasonable to expect that rehabilitation may need to be similarly individualized. Furthermore, whether the significant between-group EMG differences observed within these studies equate to clinically observable differences is also questionable and it may be that addressing aberrant movement patterns and facilitating balanced activation of all of the scapular muscles is a more appropriate treatment direction.

Review limitations

Due to resource constraints, only English-language papers were included in this review.

Conclusions

This systematic review identified limited evidence of significant differences in EMG activity in subjects with SPS compared to controls for the scapular, rotator cuff and other synergistic muscles. For the majority of muscles, regardless of task, load or arm position, significant differences were not demonstrated. Inconclusive results were observed for upper, middle and lower trapezius with respect to amplitude and timing, although there appeared to be a trend in the co-activation studies of a higher ratio of upper trapezius relative to both middle and lower portions. More consistent evidence was demonstrated for differences in amplitude and recruitment timing of serratus anterior, with lower amplitude, delayed activation and earlier termination demonstrated in some of the included studies. Evidence of significant differences in amplitude and co-activation ratios of the rotator cuff and other shoulder muscles was identified, although this was across relatively few studies, with the results, inconclusive overall.

In concurrence with the move away from the traditionally held view and terminology of SPS, these review findings reinforce the potential limitations of prescriptive rehabilitation protocols and support treating SPS patients based on their unique presentation, be that manifested as altered movement patterns, postural adaptations or muscle strength deficits in the shoulder region or elsewhere in the kinetic chain.

Supplementary material

Supplementary files are available at: sel.sagepub.com/supplemental.

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