7

The effect of conservative therapies on proprioception in subacromial pain syndrome: a narrative synthesis

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ABSTRACT

Background

Physical exercises targeting proprioception are part of conservative therapy for Subacromial Pain Syndrome (SAPS). However, the effect of such exercises on proprioception itself has not been orderly established, hampering the advancement of treatment protocols and implementation. We summarised the evidence for a loss of proprioception in SAPS and defined the type of interventions that target and improve proprioception in SAPS.

Methods

Two reviewers independently analysed 12/761 articles that evaluated joint position, kinaesthetic or force sense in patients with SAPS.

Results

Patients with SAPS had reduced joint position sense during abduction. There was no evidence for a loss of kinesthetic sense or force sense. Stretching, strengthening and stabilisation exercises improved joint position and kinaesthetic sense in SAPS. Microcurrent electrical stimulation and kinesiotaping did not improve proprioception in SAPS.

Conclusions

The lack of evidence on proprioception in SAPS is striking. We found limited evidence for a loss of joint position sense in the higher ranges of abduction in SAPS. Active training programs including strengthening and stabilisation exercises showed superiority in terms of enhancing proprioception relative to passive methods like kinesiotaping. The results of this narrative synthesis should be used as a base for providing value-based and data-driven treatment solutions to SAPS.

PROSPERO

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Key words

shoulder pain; position sense; physical therapy; rehabilitation; systematic review.

INTRODUCTION

Chronic shoulder pain is the second most common musculoskeletal disorder in the general population, with prevalence rates ranging between 15% and 22%[1-3]. In approximately 29% to 34% of all patients with chronic shoulder pain a specific anatomical explanation (e.g. acromioclavicular osteoarthritis, calcific tendinitis, or full-thickness rotator cuff tears) is not present, and the condition of these patients is described as Subacromial Pain Syndrome (SAPS)[4,5]. This prevalent condition becomes chronic frequently and the associated pain, sleep disturbance and restrictions in activities of daily living have a substantial impact on an individual's quality of life[6]. Recent studies suggest that surgical treatment provides no significant benefit over non-surgical intervention and while conservative management is effective, more targeted approaches are warranted[4,5,7-9].

A systematic review dating from 2015 showed evidence for a loss of proprioception in SAPS and studies have demonstrated a clinical benefit of exercises targeting proprioception in SAPS[10-12]. Hence, conservative management aimed at improving shoulder proprioception and active joint stabilisation is suggested as a viable targeted treatment approach in SAPS[13-15]. The effect of exercises on proprioception itself has however not been orderly established, which hampers the advancement of treatment protocols and clinical implementation.

We were interested in defining the type of interventions that target proprioception in patients with SAPS and assessing whether these interventions improve proprioception. Because there has been an expansion of research on the loss of proprioception in SAPS since a systematic review in 2015[10], we first re-evaluated the evidence for a loss of proprioception in SAPS[16-19]. Then, we summarised the effectiveness of different types of intervention on proprioception and symptoms in SAPS.

MATERIAL AND METHODS

Protocol and registration

We conducted this review following the published guidelines by the International Committee of Medical Journal Editors (ICMJE) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[20,21]. The protocol was published (PROSPERO: No. CRD42017055520, registered 10/02/2017) prior to conducting the search[22].

Information sources and search strategy

We performed the search with support from an expert librarian using PubMed, Embase, CINAHL, Web of Science, Cochrane Library, CENTRAL, Academic Search Premier, Emcare and ScienceDirect from inception to February 27th, 2019. Search terms included text words and controlled vocabulary i.e. Medical Subheadings (MeSH) and equivalents related to 1) subacromial pain syndrome and 2) proprioception[23]. These components were combined with the operator, "AND" and the search was performed without any limits (**Appendix 1**). We also included relevant articles from the reference lists of included articles and reference lists of systematic reviews on similar topics.

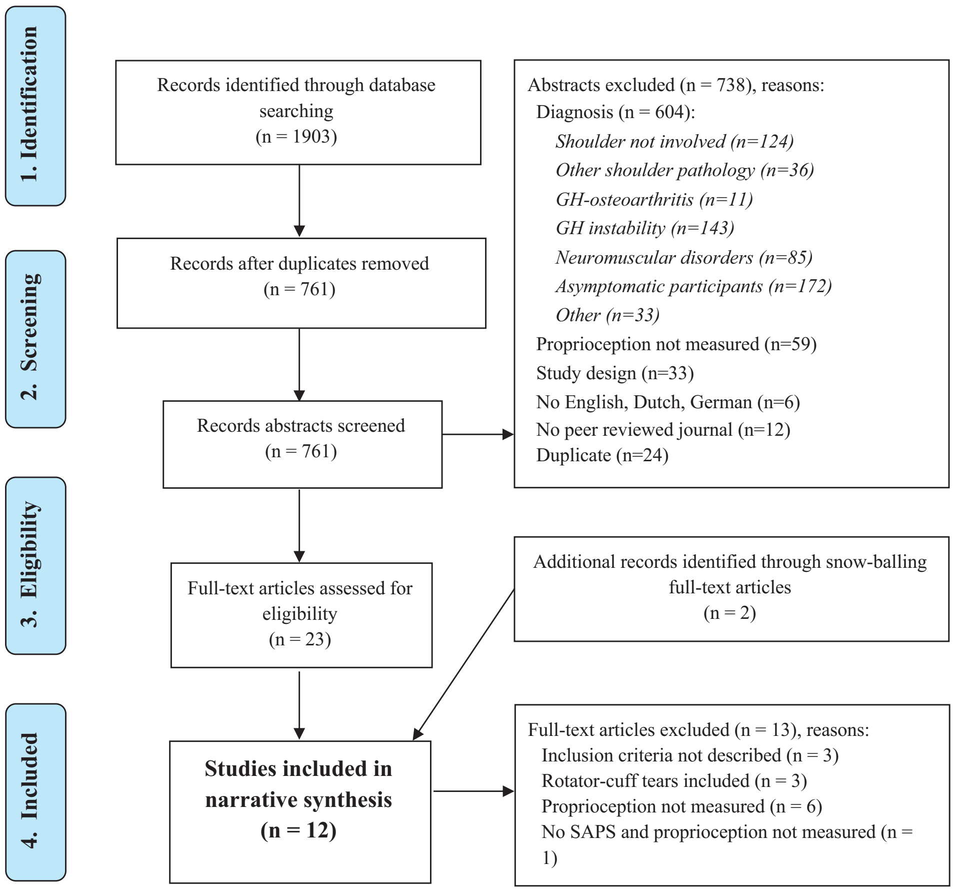

Figure 1 | Flowdiagram

Study selection

We managed search data using a reference manager (EndNote X7.7.1. 2016; Thomson

Reuters). Duplicates were removed and titles and abstracts were individually screened for eligibility by two researchers (C.L.O, MD, H.G., MD). SAPS was defined as shoulder pain that exacerbated by abduction, with at least one positive clinical test for SAPS (e.g. Neer test, Hawkins test, Jobe test)[24]. Articles had to furthermore measure aspects of proprioception, including joint position sense, kinaesthetic sense and force sense. These aspects of proprioception can be measured with good reliability using joint reproduction testing, measurement of the threshold to detection of passive movement and force steadiness testing, repsectively[14-16,22,23]. Exclusion criteria included signs of other shoulder pathology (e.g. acromioclavicular osteoarthritis, massive tears, isolated subscapularis tears, frozen shoulder), primary or secondary glenohumeral osteoarthritis, glenohumeral instability disorder, neuromuscular disorder (e.g. cerebral ischemic attack, muscular dystrophy), no measurement of proprioception, surgical intervention, inappropriate study design (e.g. systematic review, letters to the editor), non-peer reviewed articles in languages other than Dutch, German or English language. We accessed the full-text in cases of uncertainty regarding the eligibility of an article and disagreements were solved by means of discussion with a third reviewer (J.N., MD) until consensus was reached.

Assessment of methodological quality

The full-text of all included articles were assessed for methodological quality for each research question separately. We used the validated Effective Public Health Practice Project (EPHPP) instrument, which scores six components (i.e. selection bias, study design, confounders, blinding, data collection method and withdrawals/drop-outs) on an ordinal scale, i.e. 1) strong, 2) moderate and 3) weak[25,26]. This grading system allows for the assessment of both observational, non-randomised studies as well as interventional, randomised or clinical controlled trials[25]. An additional quality assessment of two components (intervention integrity and assessment of analyses) was performed for studies related to our second research question i.e. interventions targeting proprioception, using the same ordinal scale[25]. We then assigned a rating for overall methodological quality for each study (i.e. 1) strong, 2) moderate or 3) weak global rating[25]. A strong rating was given if there were no weak ratings in any components, moderate if there was one weak rating, and weak if there are two or more weak ratings[25]. Two researchers (C.L.O, H.G.) assessed the quality of the articles independently and disagreements were solved via discussion with a third reviewer (J.N.) and reaching consensus.

Data collection and abstraction

We extracted the following data using a standardised data-abstraction sheet: 1) author, year of publication and country; 2) study design, study populations, demographics (age/gender); 3) intervention, if applicable; 4) duration of follow-up, if applicable;

5) measurement method of joint position sense, kinaesthetic sense and force sense and; 6) other reported outcome measures: e.g. clinical symptoms, patient reported outcome measures, if applicable. Due to the heterogeneity of studies in terms of the outcome measures and measurement methods, statistical pooling was not considered feasible or appropriate and thus, our conclusions were based on a narrative synthesis of study results and methodological quality.

RESULTS

The search yielded 761 unique articles. After screening for eligibility, 738 studies were excluded, leaving 23 articles of which the full-text articles were screened for eligibility (flow diagram, **Figure 1**). Two additional articles were retrieved from the reference lists of included studies. Thirteen full-text articles were excluded, resulting in 12 articles for the final analysis (**Figure 1**)[16-18,27-35]. One study performed both a comparison of proprioception between patients with SAPS and controls and assessed the efficacy of an intervention in SAPS, and was therefore used for both study questions (**Table 1**)[36].

Loss of proprioception in SAPS

Joint Position Sense

Three studies compared Joint Position Sense between a total of 73 patients with SAPS and 92 controls (**Table 1**)[16,18,34]. Joint Position Sense was tested using Joint Position Reproduction tasks (JPR) in scapular plane abduction (scaption)[16] and axial humerus rotation[18,34]. Active JPR testing in scaption showed that patients with SAPS have a higher Degree of Mismatch (MM_{degree}) compared to controls at 100°, indicating reduced Joint Position Sense, which was not present during testing in 40° scaption (**Table 3**)[16]. During the testing in 100° scaption, patients experienced significantly more pain (3.4 cm on 10 cm Visual Analogue Scale) compared to testing in 40° scaption (1.8 cm on 10 cm Visual Analogue Scale), which may be associated with the observed reduction in Joint Position Sense[16]. The risk of bias in this study was low, and a reliability assessment showed that measurements were performed with good reliability during testing in 40° and moderate reliability during testing in 100° (**Table 2**)[16]. During both passive and active axial humerus rotation testing neither of the two studies found a difference in MM_{degree} between patients with SAPS and controls[18,34]. Thus, Joint Position Sense in patients with SAPS may be affected during high scaption[16], but seems to be preserved during axial humerus rotation[18,34]. It is yet unclear whether declined Joint Position Sense during high scaption is influenced by associated pain (or vice versa)[16].

Table 1 | Study characteristics

Author (year)	Country	1st question (case-control comparison)	2nd question (interventional study)	Populations	Selectioncriteria SAPS	Age±SD	M/F
Anderson et al. (2011)[16]	Australia	X		26 patients	- Positive Neer test. - Pain >3months, >3/10 on VAS, exacerbated by abduction or external rotation.	56±11	15/11
				30 matched controls		56±4.5	17/13
Atya (2012)[27]	Egypt		X	19 patients with intervention	- Symptoms >3 months. - Shoulder pain >5/10 VAS. - 2/4 positive tests: e.g. Neer test, Hawkins test, painful arc. - Pain during 1/4 resistance test.	49±6	10/9
				21 patients without intervention		49±3.3	9/12
Bandholm et al. (2006)[28]	Denmark	X		9 patients	- Recurrent unilateral shoulder pain in dominant shoulder > 2 months. - Positive painful arc, Hawkins test.	28±5.3	NA
				9 matched asymptomatic controls		28±4.2	NA
Baskurt et al. (2011)[29]	Turkey		X	20 patients with intervention	- Positive Neer, Hawkins, and Jobe test. - Consistent radio- and ultrasonography.	52±8.4	13/27[e]
				20 patients without intervention		51±12	13/27[e]
Camargo et al. (2009)[31]	Brazil	X		27 patients	- At least 3 positive tests: e.g. Neer, Hawkins, Jobe test. - Consistent ultrasonography.	33±9.9	18/9
				23 matched asymptomatic controls		32±9.0	15/8
De Oliviera (2019)[35]	Canada		X	22 patients	- Painful arc - Positive Neer or Hawkins test - Resistence tests painful (e.g. empty can test).	29±6.7	14-sep
Gomes et al. (2019)[34]	Brazil	X		32 patients	- Unliateral pain during abduction, Hawkins, Neer and Drop Arm test.	33±6.9	22/10
				32 matched asymptomatic controls		33±6.9	22/10
Haik et al. (2013)[18]	Brazil	X		15 patients (ALW)	- At least 3 positive tests: e.g. Neer, Hawkins, Jobe test. - Consistent ultrasonography.	36±5.8	0/15
				15 matched asymptomatic controls (ALW)		34±5.5	0/15
				15 matched asymptomatic controls (no ALW)		33±6.2	0/15

7

Table 1 | Continued

Author (year)	Country	1st question (case-control comparison)	2nd question (interventional study)	Populations	Selectioncriteria SAPS	Age±SD	M/F
Jerosch and Wüstner (2002)[33]	Germany		X	32 patients	- Symptoms >3 months. - Positive Jobe, painful arc, Neer test and pain during palpation of tuberculum majus. - Consistent radio- and ultrasonography.	37 (range 25-56)	NA
Keenan et al. (2017)[32]	USA	X	X	10 patients with intervention	- Pain ≥ 2 weeks. - Positive Neer, Hawkins and Painful Arc Test.	25±5.1	5/5
				10 patients without intervention		24±3.2	8/2
				10 asymptomatic controls		26±3.8	3/7
Maenhout et al. (2012)[17]	Belgium	X		36 patients	- Unilateral pain ≥ 3 months (≥3 VAS). - Painful arc, 2/3 positive tests (Hawkins, Jobe, Neer), 2/4 resistance tests painful (e.g. full can test). - Palpation pain at SSP/ISP insertion. - Consistent ultrasonography or MRI.	43±14	14/22
				30 matched asymptomatic controls		41±13	15/15
Zanca et al. (2010)[30]	Brazil	X		14 patients (ALW)	- At least three positive test: e.g. Neer, Hawkins, Jobe test.	37±5.2	0/14
				15 matched asymptomatic controls (ALW)		36±5.5	0/15

1[st] study question: Is there a loss of proprioception in paitnets with Subacromial Pain Syndrome (SAPS)?
2[nd] study question: What is the effect of conservative interventions on proprioception in SAPS?
ALW, Assembly Line Workers; NA, not available in original article.[a] Originally referred to as chronic rotator cuff pathology (CRCP). [b] Originally referred to as subacromial impingement, subacromial impingement syndrome, impingement syndrome, shoulder impingement syndrome. [c]Originally referred to as rotator cuff tendinopathy. [d] Originally referred to as unspecific shoulder pain. [e] Not described per group.

Table 2| Quality assessment of included full-text articles

Author (year)	Selection bias	Study design	Confounders	Data collection method	Blinding	Withdrawals and dropout	Intervention integrity	Assessment of analyses	Global rating 1st study question	Global rating 2nd study question
Anderson et al. (2011)[16]	2	2	1	2	2	-	-	-	Strong	NA
Atya et al. (2012)[27]	2	1	2	3	1	3	2	1	NA	Weak
Bandholm et al. (2006)[28]	2	2	1	3	2	-	-	-	Moderate	NA
Baskurt et al. (2011)[29]	2	1	2	3	3	1	2	1	Moderate	Weak
Camargo et al. (2009)[31]	2	2	1	2	2	-	-	-	Strong	NA
De Oliviera et al. (2019)[35]	2	2	1	2	2	1	2	1	NA	Strong
Gomes et al. (2019)[34]	3	2	1	2	2	-	-	-	Moderate	NA
Haik et al. (2013)[18]	3	2	1	2	2	-	-	-	Moderate	NA
Jerosch and Wüstner (2002)[33]	2	2	1	2	2	3	2	1	Moderate	Moderate
Keenan et al. (2017)[32]	2	1	1	2	2	1	2	1	Strong	Strong
Maenhout et al. (2012)[17]	2	2	1	2	2	-	-	-	Strong	NA
Zanca et al. (2010)[30]	3	2	1	3	2	-	-	-	Weak	NA

1st study question: Is there a loss of proprioception in paitnets with Subacromial Pain Syndrome (SAPS)?
2nd study question: What is the effect of conservative interventions on proprioception in SAPS?
Assessment of methodological quality using the validated Effective Public Health Practice Project (EPHPP) tool (Deeks et al., 2003; Thomas et al., 2004)[25,26]. Each component was scored as strong (1), moderate (2) or weak (3). The global rating of an article is strong if there are no components rated as weak, moderate if there is one weak rating and weak if there are two or more weak ratings.

Kinaesthetic sense

Using the Threshold to Detection of Passive Motion (TTDPM) testing method, the two case-control comparisons, which were of moderate[34] and strong[32] methodological quality (**Table 2**), showed no differences in MM_{degree} between patients with SAPS and controls in adduction and 60° scaption, thus Kinaesthetic Sense seems preserved in patients with SAPS (**Table 3**).

Force sense

Only one of four studies found a deficit in Force Sense[28], and this was only in one of three tasks (concentric contraction, **Table 3**), which suggests that Force Sense is not affected in patients with SAPS[17,28,30,31].

7

Table 3 | Summary of results – loss of proprioception in SAPS

Author (year)	JPS	Kinaesthetic sense	Force sense	Device	Outcome measure	Task	Statistic	SAPS ± SD	Controls ± SD	Proprioception reduced in SAPS?	p-value
Anderson et al. (2011)[16]	X			Optic 3D motion tracker	Active JPR	Scaption 40°	MM_{degree}	4.2 ± 3.1	3.4 ± 1.8		0.289
						Scaption 100°	MM_{degree}	5.2 ± 3.7	2.8 ± 1.7	X	**0.003**
Gomes et al. (2019)[34]	X	X		Dynamometer	Active and passive JPR	IR from 50° to 0°, in 60° scaption	$MM_{degree\ (passive)}$	3.8 ± 3.6	3.8 ± 5.1		0.75
							$MM_{degree\ (active)}$	2.6 ± 2.1	2.8 ± 1.8		0.93
						ER from 0° to 50°, in 60° scaption	$MM_{degree\ (passive)}$	7.9 ± 7.3	8.1 ± 7.7		0.88
							$MM_{degree\ (active)}$	7.7 ± 7.3	9.5 ± 7.3		0.96
					TTDPM	IR in 60° scaption	MM_{degree}	2.5 ± 2.8	2.1 ± 2.0		0.38
						ER in 60° scaption	MM_{degree}	2.8 ± 3.4	2.1 ± 3.2		0.27
Haik et al. (2013)[18]	X			Dynamometer	Active and passive JPR	IR from 90° to 30°, in 90° scaption	$MM_{degree\ (passive)}$[a]	8.4 ± 4.9	8.4 ± 5.7[b]		>0.05
							$MM_{degree\ (active)}$[a]	9.9 ± 7.4	13 ± 8.6[b]		>0.05
						ER from 0° to 75°, in 90° scaption	$MM_{degree\ (passive)}$[a]	9.8 ± 6.5	9.9 ± 6.1[b]		>0.05
							$MM_{degree\ (active)}$[a]	15 ± 11	14 ± 11[b]		>0.05
Keenan et al. (2017)[32]		X		Dynamometer	TTDPM	IR	MM_{degree}	2.9 ± 1.5[c]	3.9 ± 4.9		0.315
						ER	MM_{degree}	2.0 ± 1.0[c]	3.7 ± 5.1		0.436
Bandholm et al. (2006)[28]			X	Dynamometer	Force steadiness	Abduction 90°	SD	NA	NA		>0.05
							CV	NA	NA		>0.05
						Abduction from 120° to 30°	SD	NA	NA		>0.05
							CV	NA	NA		>0.05
						Abduction from 30° to 120°	SD	3.6 ± 0.86	2.7 ± 1.1	X	**0.05**
							CV	6.7 ± 2.3	4.5 ± 1.3	X	**0.03**
Camargo et al. (2009)[31]			X	Dynamometer	Force steadiness	Scaption 80°	SD	1.6 ± 0.68[d]	1.4 ± 0.40[d]		>0.05
							CV	4.3 ± 1.4[d]	4.1 ± 1.2[d]		>0.05

Table 3 | Continued

Author (year)	JPS	Kinaesthetic sense	Force sense	Device	Outcome measure	Task	Statistic	SAPS ± SD	Controls ± SD	Proprioception reduced in SAPS?	p-value
Maenhout et al. (2012)[17]			X	Dynamometer	Force reproduction	IR	MM_{degree}	15	13		0.17[e]
						ER	MM_{degree}	21	15		
					Force steadiness	IR	CV	6.4	10		0.478[e]
						ER	CV	12	11		
Zanca et al. (2010)[30]			X	Dynamometer	Force steadiness	IR at 45° and 75° ER in 90° scaption	SD	NA	NA		>0.05
							CV	NA	NA		>0.05
						ER at 45° and 75° ER in 90° scaption	SD	NA	NA		>0.05
							CV	NA	NA		>0.05

JPS, Joint Position Sense; JPR, Joint Position Reproduction; TTDPM, Threshold to Detection of Passive Motion; IR, Internal Rotation; ER, External Rotation; $MM_{degree,}$ Degree of Mismatch between target and reproduced position (JPR) or between start of motion and perception of motion (TTDPM); SD, standard deviation; CV, Coefficient of Variation, i.e. (SD/mean force) * 100; NA, not available in original article.
[a] Standard errors converted to standard deviations following [$SD = SE \times \sqrt{n}$]. [b] Data from one of both control-groups presented (assymbly line workers without SAPS). [c] Data from one of both SAPS-groups presented (flexible foil group). [d] Data from one of both SAPS-groups presented (kinesiotape). [e] Values averaged over dominant and nondominant sides, for SD with formula [$\sqrt{((SD_1^2+SD_2^2)/2)}$]. [f] Test for group-difference in MM_{degree}, not taking task direction (IR/ER) into account

7

The effect of conservative interventions on proprioception in SAPS

There were five studies that assessed the effect of an active (e.g. strengthening exercises)[29,33] or passive (e.g. kinesiotape or microcurrent electrical stimulation)[27,32,35] training program on proprioception in a total of 103 patients with SAPS (10 to 32 per study)[27,29,32,35,36].

Active training programs

The 6-weeks training program of Baskurt et al. consisted of standardised flexibility exercises, strengthening, Codman exercises and scapular stabilisation exercises[29]. Flexibility exercises focused on anterior, posterior and inferior capsule stretching, next to forward flexion, abduction and internal rotation stretching. The subscapularis, infraspinatus, supraspinatus, and anterior part of deltoid and posterior part of deltoid were strengthened. Scapular stabilisation exercises consisted of scapular proprioceptive neuromuscular facilitation (PNF) exercises, scapular clock exercise, standing weight shift, double arm balancing, scapular depression, wall push up, wall slide exercises[29].

The 4-weeks training program of Jerosch and Wüstner consisted of standardised sensorimotor training for the glenohumeral joint, using proprioceptive exercise tools (body-blade, BOING), next to Tai Chi and aquatic gymnastic[33].

Both studies showed that the active training programs improved Joint Position Sense (and Kinaesthetic Sense[33]) with a moderate[33] and large[29] risk of bias (**Table 4**). These studies also showed significant reduced pain (assessed with the Visual Analogue Scale[29], Constant Score[33] and University of California Los Angeles score[33]) and reduced impairment or disability (assessed with the Constant Score[33], Western Ontario Rotator Cuff index[29] and University of California Los Angeles score[33]) after intervention.

Passive training programs

No improvement in proprioception was observed using micro-current electrical stimulation, while symptoms did improve (weak methodological quality)[27]. Both studies assessing the effect of kinesiotaping on proprioception, used the taping methods suggested by Kase et al. with slight differences[37]. Next to a Y-strip covering the deltoid and a I-strip horizontally crossing the glenohumeral joint, De Oliveira applied a I-strip crossing the glenohumeral joint vertically[35], while Keenan et al.[32] applied a Y-strip from the insertion to the origin of the supraspinatus. Both studies showed no effect of kinesiotaping on proprioception (both strong methodological quality)[32,35]. The effect of these taping methods on symptoms was not assessed[32,35]. Altogether, passive methods including micro-current electrical stimulation[27] or kinesiotaping[32,35] had no effect on proprioception.

Table 4 | Summary of results – effect of intervention

Author (year)	JPS	Kinaesthetic sense	Outcome measure	Follow up	Device	Task	Intervention	MM_{degree} at baseline	MM_{degree} at follow-up	Sensory feedback improved?	p-value
Atya (2012)[27]	X		Active JPR	6 weeks	Dynamometer	IR/ER in 90° scaption, averaged	Microcurrent electrical stimulation	11 (SD 0.65)	10 (SD 1.3)		0.067
							Placebo microcurrent stimulation	11 (SD 0.95)	10 (SD 1.1)		0.231
Baskurt et al. (2011)[29]	X		Passive JPR	6 weeks	Inclinometer	IR in 90° abduction	Stretching, strengthening & scapular stabilisation	4.5 (SD 2.9)	1.5 (SD 1.3)	X	**<0.05**
						ER in 90° abduction		4.7 (SD 2.6)	2.1 (SD 1.5)	X	**<0.05**
						IR in 90° abduction	Stretching, strengthening	4.6 (SD 2.8)	3.3 (SD 1.4)	X	**<0.05**
						ER in 90° abduction		4.3 (SD 2.2)	3.3 (SD 1.4)	X	**<0.05**
De Oliviera (2019)[35]	X		Active JPR	Immediate	Inertial measurement unit sensor	Anteversion (45°-65°)	Kinesiotape	3.48 (SD 2.2)	3.0 (SD 2.6)		0.427
						Anteversion (80°-100°)		2.9 (SD 2.2)	3.3 (SD 2.1)		0.448
						Abduction (45°-65°)		2.7 (SD 2.4)	3.2 (SD 3.2)		0.497
						Abduction (80°-100°)		2.0 (SD 1.3)	2.8 (SD 1.8)		0.140
Jerosch and Wüstner (2002)[33]	X		Active JPR	4 weeks	Optic 3D motion tracker	Anteversion (50°)	Proprioceptive exercises, glenohumeral stabilisation, tai-chi, aqua-gymnastics	8.4[a]	7.0[a]	X	**<0.05**
						Anteversion (100°)		5.4[a]	4.9[a]		>0.05
						Abduction (50°)		7.1[a]	5.9[a]		>0.05
						Abduction (100°)		5.2[a]	3.6[a]	X	**<0.05**
						IR in 90° abduction		5[a]	4.6[a]		>0.05
						ER in 90° abduction		4.2[a]	4[a]		>0.05
		X	TTDPM	4 weeks	Dynamometer	Abduction	Proprioceptive exercises, glenohumeral stabilisation, tai-chi, aqua-gymnastics	12[a]	6.4[a]	X	**<0.05**
						Adduction		9.8[a]	5.6[a]	X	**<0.05**
						IR		12[a]	9.2[a]	X	**<0.05**
						ER		12[a]	8.9[a]	X	**<0.05**

Table 4 | Continued

Author (year)	JPS	Kinaesthetic sense	Outcome measure	Follow up	Device	Task	Intervention	MM_{degree} at baseline	MM_{degree} at follow-up	Sensory feedback improved?	p-value
Keenan et al. (2017)[32]		X	TTDPM	Immediate	Dynamometer	IR	Kinesiotape in SAPS	2.9 (SD 1.5)	2.2 (SD 1.9)		0.333
						ER		2.0 (SD 1.0)	1.9 (SD 1.1)		0.444
						IR	Placebo Tape in SAPS	1.3 (SD 0.84)	1.4 (SD 0.81)		0.721
						ER		3.0 (SD 2.7)	2.1 (SD 1.0)		0.333
						IR	Kinesiotape in controls	3.9 (SD 4.9)	4.4 (SD 6.0)		0.767
						ER		3.7 (SD 5.1)	3.9 (SD 4.3)		0.721

JPS, Joint Position Sense; JPR, Joint Position Reproduction; TTDPM, Treshold to Detection of Passive Motion; IR, Internal Rotation; ER, External Rotation; SAPS, subacromial pain syndrome; $MM_{degree,}$ Degree of Mismatch between target and reproduced position (JPR) or between start of motion and perception of motion (TTDPM).
[a] Interpreted from figure 1 in the concerning article(Machner et al., 2003). [b] Dispersion measures not described in original article.

DISCUSSION

We included twelve studies in a narrative analysis on the loss of proprioception in SAPS and the effect of interventions targeting proprioception in SAPS. Although two components of proprioception (kinaesthetic sense and force sense) seem to remain intact in SAPS, joint position sense in higher angles of scapular plane elevation may be compromised. Passive therapeutic strategies, such as kinesiotape, did not yield an improvement in proprioception, whereas active training with strengthening and stabilisation exercises improved proprioception in SAPS.

Loss of proprioception in SAPS

We found no evidence for a loss of kinaesthetic or force sense in patients with SAPS[17,28,30,31,36]. The well-powered, strong methodological quality study by Anderson and Wee[16] suggests that patients with SAPS do have a loss of joint position sense manifesting at higher scapular plane elevation angles, but not during axial humerus rotation.

It has been suggested that impaired joint position sense present in patients with SAPS during abduction, but not during axial humerus rotation, means that glenohumeral proprioception is preserved and pain is the explanation for observed deficits during abduction[34]. This explanation is contradicted by two experimental studies that showed reduced joint position sense and increased asymmetry of scapular kinematics in response to pain relief with subacromial anaesthetics in patients with SAPS[38,39]. We therefore suggest an alternative line of reasoning. Electromyography studies have shown that patients with SAPS exhibit reduced co-contraction of shoulder girdle muscles during abduction, which is also related to excessive upward migration of the humerus during this movement[40-42]. Subsequent reduced muscle tonus of antagonists (e.g. infraspinatus and teres major) results in reduced excitability of muscle spindles and this may explain impaired joint position sense in patients with SAPS during abduction[43].

Effect of interventions targeting proprioception

Based on consistent findings in two studies of moderate and weak methodological quality, it may be suggested that proprioception (joint position sense[29,33] and kinaesthetic sense[33]) in SAPS can be improved with exercise therapy aimed at enhancing shoulder stability[29,33] and strength[29], either or not also aimed at enhancing range of motion[29]. Additional well designed studies are warranted to confirm these findings.

Previous studies have suggested impaired active joint stabilisation as a causal factor in SAPS [40-42] and the goal of exercises targeting proprioception would be to enhance joint stability[40-42,44,45]. We suggest that effective exercises may accomplish enhanced joint stability in two ways. First, exercises may result in increased co-contraction of agonists and antagonists at the glenohumeral and scapulothoracal joint, which directly results in increased active stabilisation[40-42]. Second, consequent increased tonus of antagonistic muscles may lower the excitation threshold of muscle spindles, enhancing joint position sense, and thus active joint stabilisation[43]. Considering also that muscle spindle information is the main source of input for joint position sense, this would explain why passive strategies such as kinesiotape are less effective in improving joint position sense in patients with SAPS[27,35,36,46].

This study had a number of limitations. First, we found only few relevant articles on the topic and therefore our conclusions should only serve as guidance for future studies and not for direct clinical interpretation. Second, due to inconsistency in diagnostic criteria for SAPS, variability in population characteristics may have occurred[47]. In order to enhance the generalisability of our findings, we handled strict inclusion criteria. Third, sample sizes were low in five studies (≤20 participants per group). Four of these studies had negative results, and it cannot be made sure that there indeed was no effect, or that negative results may be explained by underpowering. Nevertheless, the findings of studies with low power were consistent with other higher powered studies and therefore we do not think that underpowering affected our conclusions. Fourth, regarding our second study question, the studies that showed a positive effect of active training programs on proprioception did not include control groups without therapy and thereby did not account for a bias of time or natural regression to the mean[29,33]. In one of these, the follow-up duration was 4 weeks, while the pre-existent duration of complaints was minimal 3 months (mean 6.2 months)[37]. Considering this pre-existent duration of complaints it seems unlikely that the observed improvement in proprioception would have also occurred without the intervention.

In patients with SAPS, it has been shown that surgical treatment provides no significant benefit over non-surgical intervention and physical therapy is preferable[7-9]. We believe that physical therapy programs can be improved with targeted approaches[7]. Generally, the goal of these programs is to enhance proprioception and active joint stabilisation[40-42] through stability[29,33] and strength exercises[29]. It has been suggested that increasing cocontraction of the arm adductors (teres major and latissimus dorsi) is a viable treatment option for patients with SAPS to enhance stability[41,48,49]. In future clinical assessments, it may be assessed whether enhancing proprioception and stability in patients with SAPS, for instance by training adductor co-contraction is effective. To gain insight into causal relationships, EMG monitoring, kinematic assessments to monitor excessive upward migration of the humerus during abduction and clinical evaluations may be used[50-52].

CONCLUSION

For the prevalent condition SAPS, physical treatment is the treatment of choice, with exercise therapy focusing on proprioception and stability being cornerstone[4,5,7-9]. In this narrative review we found a striking lack of evidence on proprioception in patients with SAPS. There was limited evidence for a reduction of joint position sense during arm elevation (not during axial humerus rotation) in patients with SAPS[16]. No evidence was found for a loss of kinaesthetic sense or force sense in patients with SAPS[17,28,30,31,33,36]. It showed that active treatment programs targeting proprioception, such as stability[29,33] and strength exercises [29], enhance joint position and kinaesthetic sense, while passive strategies, such as kinesiotaping, do not improve proprioception in patients with SAPS[27,35,36]. Providing value-based and data driven solutions to common shoulder problems such as SAPS should be the goal of practicing orthopaedic surgeons, general practitioners and physical therapists. The findings of this review may serve as a base for further studies into the development of targeted conservative treatment approaches in SAPS.

DISCLOSURE OF INTEREST

The authors report no conflict of interest.

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SUPPLEMENTARY MATERIAL | SEARCH STRATEGY

The search strategy was built up from two components, i.e. one component describing sensory feedback and one component describing SAPS, combined with “AND”. This search was altered to match the search engines of several databases:

Component 1 *Subacromial Pain Syndrome*	(“Shoulder Impingement Syndrome”[Mesh] OR “Subacromial Impingement Syndrome”[tw] OR “Subacromial pain syndrome”[tw] OR “Subacromial Impingement”[tw] OR “Subacromial pain”[tw] OR “Sub-acromial Impingement”[tw] OR “Sub-acromial pain”[tw] OR “SAIS”[tw] OR “SAPS”[tw] OR “SIS”[tw] OR “shoulder pain”[tw] OR ((“Rotator Cuff”[mesh] OR “rotator cuff”[tw]) AND (“Tendinopathy”[mesh] OR “tendinopathy”[tw] OR tendinopath*[tw] OR tendin*[tw] OR partial tear*[tw] OR degenerat*[tw])) OR “tendinitis calcarea”[tw] OR calcific tend*[tw] OR calcified tend*[tw] OR “supraspinatus tendinopathy”[tw] OR “subacromial bursitis”[tw] OR ((“Bursitis”[mesh] OR “bursitis”[tw]) AND (subacromial*[tw] OR subdeltoid*[tw])) OR “subacromial bursitis”[tw] OR “tendinosis calcarea”[tw] OR “biceps tendinitis”[tw] OR “shoulder injury”[tw] OR “shoulder injuries”[tw] OR “Shoulder Joint/injuries”[mesh] OR “chronic rotator cuff pathology”[tw] OR “Rotator Cuff Injuries”[Mesh] OR “rotator cuff injury”[tw] OR “rotator cuff injuries”[tw] OR “rotator cuff pain”[tw] OR “rotator cuff disease”[tw] OR “rotator cuff diseases”[tw])
Component 2 *Sensory feedback*	(“Proprioception”[Mesh] OR propriocep*[tw] OR “joint sense”[tw] OR “position sense”[tw] OR kinesthe*[tw] OR kinaesthe*[tw] OR “Postural Balance”[tw] OR “Position Senses”[tw] OR “Sense of Position”[tw] OR “Sensorimotor alteration”[tw] OR “Sensorimotor factor”[tw] OR “Sensorimotor alterations”[tw] OR “Sensorimotor factors”[tw] OR “neuromuscular control”[tw] OR “sensorimotor control”[tw] OR “sense of effort”[tw] OR “sense of balance”[tw] OR “sense of tension”[tw] OR “sense of resistance”[tw] OR “sense of strength”[tw] OR “joint position sense”[tw] OR “movement sense”[tw] OR “sensory motor control”[tw] OR “time-to-peak torque”[tw] OR “force sensation”[tw] OR “sensory-motor control”[tw] OR “force sense”[tw] OR “force steadiness”[tw] OR “torque steadiness”[tw] OR “force reproduction”[tw] OR “joint position reproduction”[tw] OR (“joint position”[tw] AND “reproduction”[tw]) OR “Treshold to detect passive movement”[tw] OR (threshold*[tw] AND detect*[tw] AND “passive movement”[tw]))
Combined search strategy *(component 1+2)*	(((“Shoulder Impingement Syndrome”[Mesh] OR “Subacromial Impingement Syndrome”[tw] OR “Subacromial pain syndrome”[tw] OR “Subacromial Impingement”[tw] OR “Subacromial pain”[tw] OR “Sub-acromial Impingement”[tw] OR “Sub-acromial pain”[tw] OR “SAIS”[tw] OR “SAPS”[tw] OR “SIS”[tw] OR “shoulder pain”[tw] OR ((“Rotator Cuff”[mesh] OR “rotator cuff”[tw]) AND (“Tendinopathy”[mesh] OR “tendinopathy”[tw] OR tendinopath*[tw] OR tendin*[tw] OR partial tear*[tw] OR degenerat*[tw])) OR “tendinitis calcarea”[tw] OR calcific tend*[tw] OR calcified tend*[tw] OR “supraspinatus tendinopathy”[tw] OR “subacromial bursitis”[tw] OR ((“Bursitis”[mesh] OR “bursitis”[tw]) AND (subacromial*[tw] OR subdeltoid*[tw])) OR “subacromial bursitis”[tw] OR “tendinosis calcarea”[tw] OR “biceps tendinitis”[tw] OR “shoulder injury”[tw] OR “shoulder injuries”[tw] OR “Shoulder Joint/injuries”[mesh] OR “chronic rotator cuff pathology”[tw] OR “Rotator Cuff Injuries”[Mesh] OR “rotator cuff injury”[tw] OR “rotator cuff injuries”[tw] OR “rotator cuff pain”[tw] OR “rotator cuff disease”[tw] OR “rotator cuff diseases”[tw]) AND (“Proprioception”[Mesh] OR propriocep*[tw] OR “joint sense”[tw] OR “position sense”[tw] OR kinesthe*[tw] OR kinaesthe*[tw] OR “Postural Balance”[tw] OR “Position Senses”[tw] OR “Sense of Position”[tw] OR “Sensorimotor alteration”[tw] OR “Sensorimotor factor”[tw] OR “Sensorimotor alterations”[tw] OR “Sensorimotor factors”[tw] OR “neuromuscular control”[tw] OR “sensorimotor control”[tw] OR “sense of effort”[tw] OR “sense of balance”[tw] OR “sense of tension”[tw] OR “sense of resistance”[tw] OR “sense of strength”[tw] OR “joint position sense”[tw] OR “movement sense”[tw] OR “sensory motor control”[tw] OR “time-to-peak torque”[tw] OR “force sensation”[tw] OR “sensory-motor control”[tw] OR “force sense”[tw] OR “force steadiness”[tw] OR “torque steadiness”[tw] OR “force reproduction”[tw] OR “joint position reproduction”[tw] OR (“joint position”[tw] AND “reproduction”[tw]) OR “Treshold to detect passive movement”[tw] OR (threshold*[tw] AND detect*[tw] AND “passive movement”[tw]))) OR ((“Shoulder”[majr] OR “Shoulder Joint”[majr] OR Shoulder*[ti]) AND (“Proprioception”[majr] OR propriocep*[ti] OR “joint sense”[ti] OR “position sense”[ti] OR kinesthe*[ti] OR kinaesthe*[ti] OR “Postural Balance”[ti] OR “Position Senses”[ti] OR “Sense of Position”[ti] OR “Sensorimotor alteration”[ti] OR “Sensorimotor factor”[ti] OR “Sensorimotor alterations”[ti] OR “Sensorimotor factors”[ti] OR “neuromuscular control”[ti] OR “sensorimotor control”[ti] OR “sense of effort”[ti] OR “sense of balance”[ti] OR “sense of tension”[ti] OR “sense of resistance”[ti] OR “sense of strength”[ti] OR “joint position sense”[ti] OR “movement sense”[ti] OR “sensory motor control”[ti] OR “time-to-peak torque”[ti] OR “force sensation”[ti] OR “sensory-motor control”[ti] OR “force sense”[tw] OR “force steadiness”[tw] OR “torque steadiness”[tw] OR “force reproduction”[tw] OR “joint position reproduction”[tw] OR (“joint position”[tw] AND “reproduction”[tw]) OR “Treshold to detect passive movement”[tw] OR (threshold*[tw] AND detect*[tw] AND “passive movement”[tw]))))