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Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study.

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ABSTRACT

Objective: To determine the potential differences in both scapular positioning and scapular movement between the symptomatic and asymptomatic contralateral shoulder, in patients with unilateral subacromial pain syndrome (SAPS), and in comparison with those of participants free of shoulder pain.

Setting: Three different primary care centres.

Participants: A sample of seventy-three patients with SAPS in their dominant arm was recruited, with a final sample size of fifty-four participants.

Primary outcome measures: The scapular upward rotation (SUR), the pectoralis minor and the levator scapulae muscles length tests were carried out.

Results: We found a decreased SUR in symptomatic shoulder compared to contralateral asymptomatic at 45 degrees of shoulder elevation. When symptomatic shoulders and control subjects are compared, an increased SUR at all positions (45, 90 and 135 degrees) was obtained in symptomatic shoulders. These differences in SUR did surpass

the minimal detectable change (MDC95). A greater pectoral minor index was found in symptomatic shoulders when compared with control subjects but differences were smaller than MDC95. For the rest of the comparisons, no significant differences were found.

Conclusions: Scapular upward rotation is greater in patients with chronic SAPS compared with control volunteers at different angles of shoulder elevation. Furthermore, a difference of 1, 15 degrees of SUR between symptomatic and asymptomatic shoulder in those with chronic SAPS when comparing both at 45° of shoulder elevation may indicate shoulder dysfunction.

Keywords: scapular kinematic; shoulder pain; chronic pain

Strengths and limitations of this study

The intra-rater reliability obtained in all the measurements was excellent.

An exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff tears was carried out.

The examiner who assessed all the measurements had an extensive clinical experience. The inter-rater reliability was not calculated, so this could introduce bias.

The minimal clinically importance difference for SUR is unknown, thus we cannot make a conclusion to whether the differences found in this study mean a clinical importance or not.

INTRODUCTION

Shoulder pain is the most common musculoskeletal condition after neck pain and low back pain[1]. Shoulder pain point prevalence figures range from 6.9 to 26%, from 18.6 to 31% for 1-month prevalence, from 4.7 to 46.7% for 1-year prevalence, and from 6.7 to 66.7% for lifetime prevalence[2]. Furthermore, shoulder pain prevalence is even higher in women[3], in the working population[4], and increases with age[5].

Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain[6],[7]. The best therapeutic approach in SAPS is still under debate. Half of the patients with shoulder pain who present in primary care do not completely recover after 6 months from their first episode[8], so there is a need to explore different strategies in these patients. One of the approaches that can be beneficial for the patient is focused on the scapulothoracic joint. To date, there is inconsistent evidence to support a relationship between shoulder symptoms and scapular orientation[9][6]. The most common causative mechanisms of an altered scapular positioning involves the soft tissue, such as inflexibility (tightness) and alterations in the periscapular muscles[10]. The pectoralis minor index (PMI) and the levator scapulae index (LSI) [11][12] have been traditionally used to assess the muscles that can potentially influence scapular positioning.

Previous studies have reported normative values on PMI in the dominant and non-dominant side in both symptomatic and control populations.[13][14] However differences between groups were not calculated. To the best of our knowledge, differences in LSI between symptomatic and control populations have not been determined. With regard to patterns of movement, a reduced scapular upward rotation (SUR) and an increased scapular anterior tilt have been found in patients with SAPS when compared to asymptomatic subjects[15],[16].

Advanced equipment to assess scapular positioning and kinematics exist, nevertheless, most of them are very technical and highly expensive, which makes them almost unattainable in the clinical practice[17]. In this regard, research states that the SUR seems suitably evidence-based for clinical use, while the pectoralis minor length test should be used as a supplementary clinical assessment method in addition to other assessment methods[18][19]. Likewise, the levator scapulae muscle length test has been shown to be a reliable tool, and it has been proposed as part of the scapula assessment because the levator scapulae directly attaches in the superior angle of the scapula[12] and thus it is another possible cause of scapular dysfunction[20].

There is lack of evidence on the potential differences in PMI, LSI and SUR, between painful and contralateral non-painful shoulders, and controls subjects. The existence of differences in scapular positioning and pattern of movement could contribute to steer physiotherapy treatments towards a scapular focused treatment approach.

Hence, the aim of this study was to analyse the differences in scapular positioning and pattern of movement, between the symptomatic and asymptomatic shoulder, in patients with unilateral chronic SAPS, and in control subjects, using three different tests: i) scapular upward rotation, ii) pectoral minor muscle length and, iii) levator scapulae muscle length.

METHOD

Study design

This was a cross-sectional, observational study, carried out in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Health Care District where the primary care centres were located (PI9/012014). The

study has been reported following the recommendations of the STROBE statement for observational studies.

Patient and Public Involment

General practitioners (GPs) carried out the recruitment, and all participants, who had to sign an informed consent, were screened for eligibility and informed about the research project by a research assistant. The participation of all subjects was voluntary,

and no incentives were given to encourage enrollment. All measurements were taken by a physiotherapist with more than 25 years of experience, including height which was necessary to calculate PMI and LSI values. Height was measured with the patient in a standing position, by using a calliper placed at the top of the head and marking a point on a scale placed on the wall. This physiotherapist was blinded to the fact of participants having shoulder pain or not.

The results of the present study were sent by e-mail to those participants who wanted to be informed.

Participants

A sample of seventy-three patients with chronic unilateral shoulder pain in their dominant arm was recruited from three different primary care centres, with a final sample size of fifty-four participants obtained after applying the inclusion criteria. Participants had to meet the following inclusion criteria: (i) men or women aged between 18 to 55 years; (ii) unilateral pain located in the anterior and/or lateral shoulder region; (iii) 2 out of 3 positive clinical tests (Hawkins-Kennedy; Jobe; Neer)[21]; (iv) pain with normal activity $\geq$ 4/10 on a visual analogue scale; (v) shoulder pain lasting

more than three months; (vi) a history of nontraumatic onset of shoulder pain. Participants were ineligible to participate in this study if any of these conditions were present: (i) history of significant shoulder trauma, such as fracture or ultrasonography-clinically suspected full thickness cuff tear; (ii) recent shoulder dislocation on the last two year; (iii) systemic illnesses such as rheumatoid arthritis; (iv) adhesive capsulitis; (v) shoulder pain originating from the neck or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies.

A sample of 54 participants with both shoulders free of pain for the last year was selected. They were recruited from the same three primary care centres as the participants with shoulder pain. Furthermore, to participate in the study, they had to present: (i) a SPADI score ≤ 15 points, based on the minimal clinically detectable change for this tool[22] (Ekeberg et al, 2010); (ii) negative results for Neer test, Hawkins-Kennedy test and Jobe test; iii) no painful arc present during flexion or abduction; iv) no pain during resisted lateral rotation and/or abduction. Asymptomatic participants were specifically age and gender matched to the symptomatic group.

Outcome measurements

Scapular upward rotation

The measurement of SUR was performed using two Plurimeter-V gravity reference inclinometers[23]. One inclinometer was Velcro taped perpendicular to the humeral shaft, just above the humeral epicondyle. At resting position, the humeral inclinometer was calibrated as 0 degrees. Next, the patients were instructed to perform shoulder abduction in the coronal plane with full elbow extension and 45° of external humeral rotation, with the thumb abducted. The patients were asked to stop at 45º, 90º and 135º

degrees of humeral abduction, where the SUR was measured with a second inclinometer, manually aligned along the scapular spine (Figure 1). Three measurements were collected at each position and then the mean was obtained.

#FIGURE 1

Pectoralis minor length

The measurement of the pectoral minor length was carried out with the participant in the supine position. A small pillow was placed under the participant's head for comfort. The participant's arm was passively placed along the side of the body in the neutral position resting on the table[24]. Because of the variability among subjects this measurement was best normalized creating a pectoralis minor index (PMI), which was calculated by dividing the resting muscle length measurement by the subject height and multiplying by 100, as previously described [11]. The resting muscle length was measured from the caudal edge of the 4th rib to the inferomedial aspect of the coracoid process with a sliding calliper (Figure 2). Pectoralis minor index values less than 7.65 have been identified as a shortened pectoralis minor[11]. The measurement was taken during inspiration. [13]

#FIGURE 2

Levator scapulae length

Participants were standing with their arms relaxed at their sides. The subjects were asked to look directly ahead without craniocervical movement[12]. The instruction was to palpate two anatomical reference points in line that represent levator scapulae length: (1) the dorsal tubercles of the transverse processes of the second cervical vertebrae and (2) the superior angle of the medial borders of the scapula. The assessor used a skin-marker pencil to mark the reference points. The marks were cleaned immediately after each test session. The distance between these two bony reference points was measured

with a sliding calliper (Figure 3). By creating an LSI (levator scapulae length [cm]/subjects' height [cm]*100), the subjects' variability in body height was normalized[12]. The LSI was expressed as a percentage of the subjects' height.

FIGURE 3

The Shoulder Pain and Disability Index (SPADI) was assessed in all participants. The SPADI is composed of 13 questions and contains two domains: pain and disability. The score of the questionnaire ranges from 0 to 100, with very high scores indicating worse function. The numeric pain scale runs from 0 to 10, with 0 indicating no pain and 10 representing the worst pain.[25] The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time.[26] A Spanish version of the SPADI was used since English was not the native language for all the participants.[27]

Data analysis

The Statistical Package for the Social Sciences (version 23.0 for Mac; SPSS Inc. Chicago, IL) was used to analyses the collected data. Normality for all variables was explored using the Kolmogorov Smirnov test for the group of participants with shoulder pain (affected and non-affected), and for the control subjects. Comparisons for all the variables between the affected and non-affected groups were calculated using paired sample t-tests. Comparisons between affected group and controls were calculated using independent sample t-tests. When normality was violated, comparisons were made using non-parametric tests for related and/or independent samples. A p-value < 0.05 was considered statistically significant.

RESULTS

Participants

Sample characteristics are shown in Table 1

	Patients	Healthy subjects	p-value
Age (yrs; CI)	46.39 (43.67 to 49.11)	46.42 (44.1 to 48.67)	0.98
Women	33	33	1
Men	21	21	1
SPADI (CI)	56,37 (17,69 to 100)	2,66 (1,73 to 3,60)	N/A
Chronicity of symptoms	3-6months: 18 6-12 months: 5 More than one year: 31	N/A	N/A

Table 1: Sample characteristics; Mean (95% CI); N/A: non-applicable

$p<0.05$: statistically significant; CI= confidence interval

Although it was not a purpose of this study, we calculated intraclass correlation coefficient (ICC), in order to determine the minimal detectable change at 95% (MDC95) for all the outcome measures, which were measured by the same assessor. For the calculation of intrarater reliability of SUR, PMI and LSI, the 3,1 model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. A reliability

coefficient less than 0.50 was an indication of "poor" reliability; "moderate" being between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90[28]. The Standard Error of Measurement (SEM), which was computed as SEM = SD ($\sqrt{1} - ICC$), and the MDC95 was calculated using the formula MDC95 = 1.96* $\sqrt{2} * SEM$. The ICC was greater than 0.90 for all the tests, which means an excellent reliability, except for LSI (0, 87). The MDC95 was as follows: SUR45º= 0, 91; SUR90º= 1, 55; SUR135º= 2, 83; PMI= 0, 80; LSI= 1, 08.

Descriptive data

Mean values of scapular upward rotation, levator scapulae and pectoralis minor index in different groups are presented in Table 2.

	Symptomatic shoulder	Asymptomatic shoulder	Control shoulder
SUR			
At 45° GH abduction	4,55 (3,79 to 5,32)	5,71 (4,82 to 6,60)	2,55 (1,81 to 3,29)
At 90° GH abduction	20,75 (18,81 to 22,69)	21,42 (19,88 to 22,96)	16,77 (15,49 to 18,04)
	45,18 (42,76 to	44,16 (42,20 to	36,22 (34,34 to

At 135° GH abduction	47,59)	46,12)	38,09)
PMI	10,52%(10,27 to 10,76%)	10,86% (10.26 to 11,46%)	10,07% (9,73 to 10,42%)
LSI	7,81% (7,42 to 8,20%)	7,81% (7,53 to 8,30)	7,76% (7,42 to 8,11%)

Table 2: Mean values of pectoralis minor and levator scapulae indexes (%), and scapular upward rotation expressed in degrees in different groups. Abbreviations: GH = glenohumeral; SUR = scapular upward rotation; PMI = pectoralis minor index; LSI = levator scapulae index:

The mean differences between groups regarding SUR, PMI and LSI are shown in Table 3. There were statistically significant differences between the symptomatic and control shoulders for all the measurements, except for LSI. There was a statistically significant difference in SUR at 45 degrees between symptomatic and asymptomatic shoulders. For the rest of variables there were no significant differences.

	Symptomatic-Asymptomatic shoulder	p	Symptomatic-Control shoulder	p
SUR At 45°GH	-1,15 (-2,26 to	0.04*	2,00 (0,96 to	<0.001*

abduction	-0,04)		3,05)	
At 90° GH abduction	-0,67 (-1,90 to 3,94)	0.56	3,98 (1,68 to 6,27)	0.001*
At 135° GH abduction	1,02 (-1,90 to 3,94)	0.70	8,96 (5,94 to 11,98)	<0.001*
PMI	-0,34% (-0,97 to 0,29%)	0.28	0,44% (0,04 to 0,85%)	0.03*
LSI	0,00% (-0,35 to 0,35%)	0.99	0.05% (-0,49 to 0,58%)	0.86

Table 3: Between-group mean differences

*: statistically significant ($p < .05$)

DISCUSSION

This study aimed to explore potential differences in scapular positioning and scapular pattern of movement between the symptomatic shoulder in patients with chronic SAPS, compared with the contralateral asymptomatic, and control shoulders. We found a decreased SUR in symptomatic shoulder compared to asymptomatic at 45 degrees within the patient group. When comparing symptomatic and control participants, an increased SUR at all positions (45, 90 and 135 degrees) and PMI were found in the symptomatic shoulders. For the rest of comparisons, no significant differences were found.

This is the first study that compares SUR, PMI and LSI between both symptomatic and asymptomatic shoulders in patients with SAPS, and the symptomatic shoulder from

patients with control subjects. Previous studies have reported differences in SUR during arm elevation between the symptomatic and the asymptomatic shoulder [29],[16],[15], showing a decreased SUR in the symptomatic shoulders, mainly within the first degrees of elevation in the scapular plane. This is in line with the present study. Furthermore, a significantly increased SUR in the symptomatic shoulder of patients when compared with control subjects was obtained. These differences did surpass the MDC95 of all the positions (45, 90 and 135 degrees of shoulder elevation). This is not in supported by current literature, which suggests the presence of a decreased SUR in shoulders with subacromial symptoms compared with healthy controls[30],[29],[15]. This can be explained by the fact that patients that were included in our study showed long duration of shoulder pain, meaning chronicity of symptoms. In this context, the firing pattern of scapular muscle units can change, generating an early SUR in an attempt to avoid pain, as has been found in a recent study[31] . It can be hypothesized that early stages of SAPS could present a deficit in SUR while more advanced stages can develop a compensatory increased SUR. As this was not measured in this study, further investigation is needed. In others shoulder conditions, current research analysing SUR in both symptomatic and pain-free shoulders does not sustain strong conclusions. Kijima et al.[32] showed absence of differences in SUR, measured by a 3-dimesional scapular kinematic analysis, between symptomatic, asymptomatic rotator cuff tears and healthy shoulders. Furthermore, Hung et al.[33] reported no differences in SUR, measured by 3-dimensional analysis, between patients with glenohumeral instability and healthy controls.

With regard to the pectoralis minor length, there was an absence of statistically significant difference between the symptomatic and the asymptomatic shoulders,

whereas a longer pectoralis minor was found in symptomatic shoulder patient when compared to control shoulders, but differences were smaller than the MDC95 (0,80). This finding was contrary to what was expected, since a more anterior tilted positioning of the scapula is thought to be correlated with a potential risk of SAPS. Our results are in line with those obtained by Struyf et al.[13] The aforementioned study showed PMI values of 9.17 (0.54) in the dominant side in the control group, 9.66 (0.68) in the symptomatic side and 9.64 (0.72) in the asymptomatic side in the patient group, but they did not study the statistical differences between groups. On the other hand, Lewis et al. [14]also reported values that analysed pectoral minor length, but comparisons with the present study are not possible as the test used was different (acromion-table distance test). To our knowledge there are no studies investigating these potential differences.

Previous studies[11] have found, in healthy subjects with a shortened pectoralis minor, a similar scapular behaviour to those suffering from SIS. Likewise, pectoral minor length has a weak positive correlation with the acromiohumeral distance in healthy male athletes[24], which means that the pectoralis minor could have a slight influence in the scapular positioning in the case of shortening. However, based on the results obtained in the present study, and also on previous inconsistent evidence along this line[6][9], the pectoral minor does not seem to play a key role in patients with chronic SAPS, when compared to contralateral non-affected shoulders and control subjects.

In relation to LS length, there was an absence of differences between symptomatic and asymptomatic shoulder in patients, and between symptomatic shoulder and controls in this study. To the best of our knowledge, this is the first study that analyses such differences between subjects with shoulder symptoms and controls, so comparisons with others are difficult. It is thought that a shortened LS can produce a scapula more

downwardly rotated[12] and, hence, a greater compromise of the subacromial space during overhead movements. As we did not determine the scapular position in this study, a conclusion on the absence of differences in levator scapulae length between different groups cannot be made, thus further studies are needed in this field.

Some strong points from this study need to be mentioned. First, the intra-rater reliability obtained in all the measurements was excellent. Second, an exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff tears was carried out. Third, the examiner who assessed all the measurements had an extensive clinical experience.

On the contrary, some limitations need to be recognized. As only one examiner assessed all the outcome measures, inter-rater reliability was not calculated, so this could introduce bias. Moreover, as the minimal clinically importance difference for SUR is unknown, we cannot make a conclusion to whether the differences found in this study mean a clinical importance or not. Lastly, our results should be taken with caution when interpreted, as a sample with chronic SAPS was studied, so we do not know if these results can be extrapolated to other populations, e.g. acute shoulder pain.

The present results could have clinical implications, and contribute to increase the body of knowledge in the field of scapular biomechanics tests. First, it seems that pectoral minor and/or levator scapulae are not distinguishing factors when comparing the symptomatic and the contralateral asymptomatic shoulder in subjects suffering from SAPS. Second, a difference of 1, 15 degrees of SUR between symptomatic and asymptomatic shoulder in those with chronic SAPS when comparing both at 45° of shoulder elevation may indicate shoulder dysfunction, and third, the use of the SUR test

at 45°, 90° and 135° of shoulder elevation may be useful in the assessment of shoulder conditions when compared to values from control subjects.

Further research that analyses levator scapulae length and scapular positioning, and the minimal clinically importance difference in SUR, would contribute to enhance knowledge in this field. Moreover, studies analysing changes in SUR and pectoral minor length after application of physical therapies are necessary to corroborate their contribution, as indicators of improvement, when patients with chronic SAPS are treated.

In conclusion, SUR is greater in patients with chronic SAPS when compared with control volunteers at different angles of shoulder elevation, and is also greater regarding PMI values at rest position. The usefulness of the present findings is theorized, but further studies to confirm this in clinical practice are needed.

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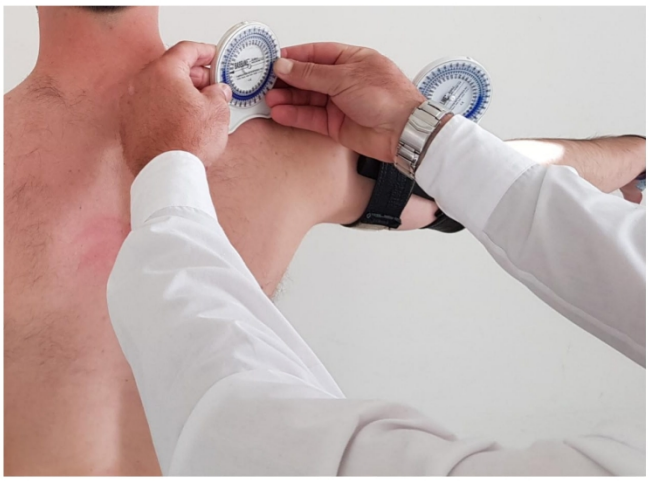
LEGENDS

Figure 1: Scapular upward rotation measurement.

Figure 2: Pectoral minor length measurement.

Figure 3: Levator scapulae length measurement.



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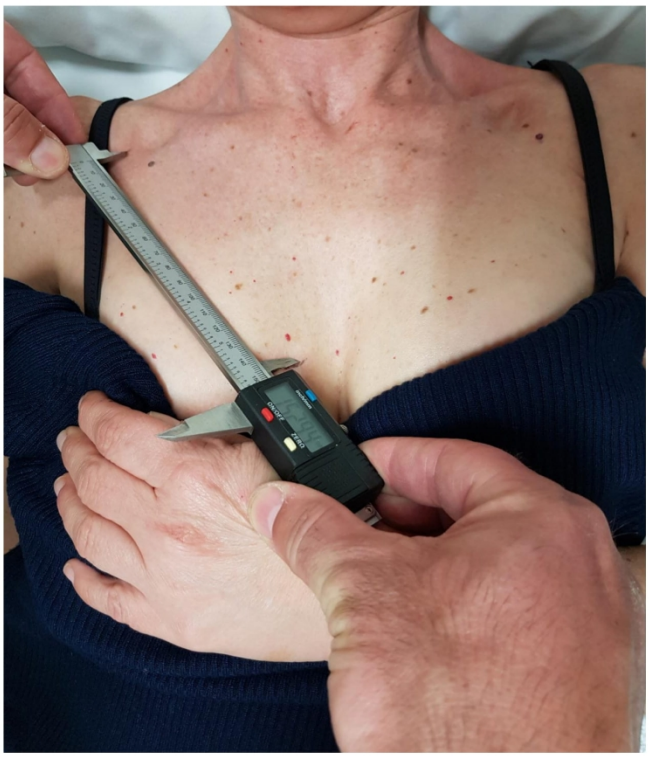

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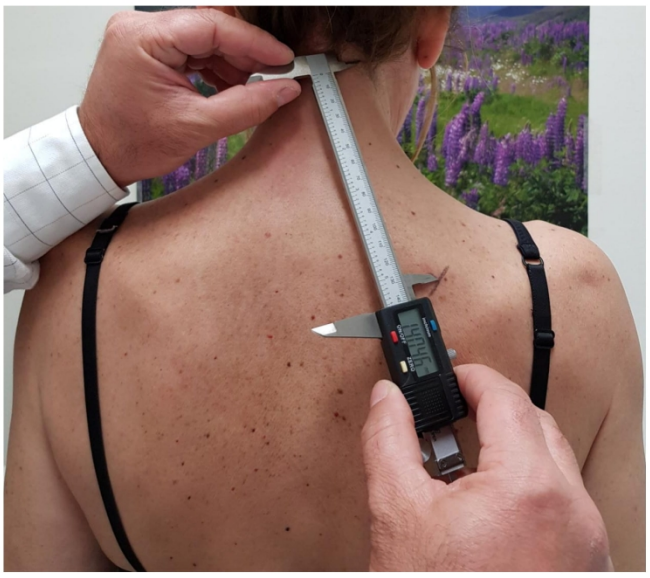

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **PAGE 1**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **PAGE 3**
Objectives	3	State specific objectives, including any prespecified hypotheses **PAGE 4**
Methods		
Study design	4	Present key elements of study design early in the paper **PAGE 4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **PAGE 4**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **PAGE 5**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **PAGE 6-7-8**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **PAGE 6-7-8**
Bias	9	Describe any efforts to address potential sources of bias **PAGE 8**
Study size	10	Explain how the study size was arrived at **PAGE 9**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **PAGE 9**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions **PAGE 9**
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **PAGE 9-12**
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **PAGE 10**
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure **PAGE 9-12**
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **PAGE 11-12**
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **PAGE 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **PAGE 15**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **PAGE 12-14**
Generalisability	21	Discuss the generalisability (external validity) of the study results **PAGE 15-16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **NON APPLICABLE**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study

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Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study.

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Keywords: scapular kinematic; shoulder pain; chronic pain

Word count: 3523

ABSTRACT

Objective: To determine the potential differences in both scapular positioning and scapular movement between the symptomatic and asymptomatic contralateral shoulder, in patients with unilateral subacromial pain syndrome (SAPS), and in comparison with those of participants free of shoulder pain.

Setting: Three different primary care centres.

Participants: A sample of seventy-three patients with SAPS in their dominant arm was recruited, with a final sample size of fifty-four participants.

Primary outcome measures: The scapular upward rotation (SUR), the pectoralis minor and the levator scapulae muscles length tests were carried out.

Results: We found a decreased SUR in symptomatic shoulder compared to contralateral asymptomatic at 45 degrees of shoulder elevation (-1,15 degrees). When symptomatic shoulders and control subjects were compared, an increased SUR at all positions (45, 90 and 135 degrees) was obtained in symptomatic shoulders (2/ 3,98/ 8,96 degrees respectively). These differences in SUR did surpass the minimal detectable change

(MDC95) (0,91/1,55/2,83 degrees at 45/90/135 degrees of shoulder elevation). For the rest of the comparisons, no significant differences were found.

Conclusions: Scapular upward rotation is greater in patients with chronic SAPS compared with control volunteers at different angles of shoulder elevation, while is decreased when compared to asymptomatic shoulder at 45° of shoulder elevation. No differences were found in both pectoralis minor and levator scapulae muscle length between all the groups.

Keywords: scapular kinematic; shoulder pain; chronic pain

Strengths and limitations of this study

The intra-rater reliability obtained in all the measurements was excellent.

An exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff tears was carried out.

The examiner who assessed all the measurements had an extensive clinical experience. The inter-rater reliability was not calculated, so this could introduce bias.

The minimal clinically importance difference for SUR is unknown, thus we cannot make a conclusion to whether the differences found in this study mean a clinical importance or not.

INTRODUCTION

Shoulder pain is the most common musculoskeletal condition after neck pain and low back pain[1]. Shoulder pain point prevalence figures range from 6.9 to 26%, from 18.6 to 31% for 1-month prevalence, from 4.7 to 46.7% for 1-year prevalence, and from 6.7 to 66.7% for lifetime prevalence[2]. Furthermore, shoulder pain prevalence is even higher in women[3], in the working population[4], and increases with age[5].

Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain[6,7]. It is defined as a non-traumatic, usually unilateral, shoulder problem that causes pain localized around the acromion, often worsening during or subsequent to lifting of the arm[8]. The best therapeutic approach in SAPS is still under debate. Half of the patients with shoulder pain who present in primary care do not completely recover after 6 months from their first episode[9], so there is a need to explore different non-invasive strategies in these patients. One of the approaches that can be beneficial for the patient is focused on the scapulothoracic joint. To date, there is inconsistent evidence to support a relationship between SAPS symptoms and scapular orientation[10][6]. The most common causative mechanisms of an altered scapular positioning involves the soft tissue, such as inflexibility (tightness) and alterations in the periscapular muscles[11]. Specifically, both a decreased activation and strength of serratus anterior, as well as alterations in upper trapezius/lower trapezius couple force, can alter scapular upward rotation and posterior tilt [11]. Likewise, pectoralis minor and levator scapulae muscles [12,13], and biceps short head [11] have been traditionally assessed as their shortening may potentially influence scapular positioning.

Previous studies have reported normative values on pectoralis minor length in the dominant and non-dominant side in both symptomatic and control populations, by using the pectoralis minor index [14], and the acromion-table distance test [15]. Recently, pectoralis minor length and its shortening have received remarkable empirical attention,

in terms of reliability study[16], association with shoulder external rotation[17], and as an outcome measurement after a stretching program in participants with shoulder pain[18]. However, differences between symptomatic groups and healthy controls were not calculated. To the best of our knowledge, differences in levator scapulae index (LSI) between symptomatic and control populations have not been determined. With regard to patterns of movement, there is conflicting evidence. While some studies have shown association between a reduced both scapular upward rotation (SUR) and scapular posterior tilt in SAPS [19,20], others did attain inconclusive findings[6,10].

Advanced equipment to assess scapular positioning and kinematics exist, nevertheless, most of them are very technical and highly expensive, which makes them almost unattainable in the clinical practice[21]. In this regard, research states that the SUR seems suitably evidence-based for clinical use, while the pectoralis minor length test should be used as a supplementary clinical assessment method in addition to other assessment methods[22,23]. Likewise, the levator scapulae muscle length test has been shown to be a reliable tool, and it has been proposed as part of the scapula assessment because the levator scapulae directly attaches in the superior angle of the scapula[13] and thus it is another possible cause of scapular dysfunction[24].

There is lack of evidence on the potential differences in PMI, LSI and SUR, between painful and contralateral non-painful shoulders, and controls subjects. The existence of differences in scapular positioning and pattern of movement could contribute to steer physiotherapy treatments towards a scapular focused treatment approach.

Hence, the aim of this study was to analyse the differences in scapular positioning and pattern of movement, between the symptomatic and asymptomatic shoulder, in patients with unilateral chronic SAPS, and in control subjects, using three different tests: i)

scapular upward rotation, ii) pectoralis minor muscle length and, iii) levator scapulae muscle length. The null hypothesis (H_0) was that there are no differences in these three different tests between groups. The alternative hypothesis (H_a) was that there are significant differences in these three tests between groups.

METHOD

Study design

This was a cross-sectional, observational study, carried out in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Health Care District where the primary care centres were located (PI9/012014). The study has been reported following the recommendations of the STROBE statement for observational studies.

Patient and Public Involment

General practitioners (GPs) carried out the recruitment, and all participants, who had to sign an informed consent, were screened for eligibility and informed about the research project by a research assistant. The participation of all subjects was voluntary,

and no incentives were given to encourage enrollment. All measurements were taken by a physiotherapist with more than 25 years of experience, including height which was necessary to calculate PMI and LSI values. This physiotherapist was blinded to the fact of participants having shoulder pain or not.

The results of the present study were sent by e-mail to those participants who wanted to be informed.

Participants

A sample of seventy-three patients with chronic SAPS in their dominant arm was recruited from three different primary care centres, with a final sample size of fifty-four participants obtained after applying the inclusion criteria. Participants had to meet the following inclusion criteria: (i) men or women aged between 18 to 55 years; (ii) unilateral pain located in the anterior and/or lateral shoulder region[8]; (iii) 2 out of 3 positive clinical tests (Hawkins-Kennedy; Jobe; Neer)[25]; (iv) pain with normal activity ≥ 4/10 on a visual analogue scale; (v) shoulder pain lasting more than three months; (vi) a history of nontraumatic onset of shoulder pain. Participants were ineligible to participate in this study if any of these conditions were present: (i) history of significant shoulder trauma, such as fracture or ultrasonography-clinically suspected full thickness cuff tear, following the classification of Wiener and Seitz, 1993[26]; (ii) recent shoulder dislocation in the past two years; (iii) systemic illnesses such as rheumatoid arthritis; (iv) adhesive capsulitis; (v) shoulder pain originating from the neck or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies.

A sample of 54 participants with both shoulders free of pain for the last year was selected. They were recruited from the same three primary care centres as the participants with shoulder pain. Furthermore, to participate in the study, they had to present: (i) a SPADI score ≤ 15 points, based on the minimal clinically detectable change for this tool[27]; (ii) negative results for Neer test, Hawkins-Kennedy test and Jobe test; iii) no painful arc present during flexion or abduction; iv) no pain during resisted lateral rotation and/or abduction. Asymptomatic participants were specifically age and gender matched to the symptomatic group.

Outcome measurements

Scapular upward rotation

The measurement of SUR was performed using two Plurimeter-V gravity reference inclinometers[28]. One inclinometer was Velcro taped perpendicular to the humeral shaft, just above the humeral epicondyle. At resting position, the humeral inclinometer was calibrated as 0 degrees. Next, the patients were instructed to perform shoulder abduction in the coronal plane with full elbow extension and 45° of external humeral rotation, with the thumb abducted. The patients were asked to stop at 45º, 90º and 135º degrees of humeral abduction, where the SUR was measured with a second inclinometer, manually aligned along the scapular spine (Figure 1). Three measurements were collected at each position and then the mean was obtained. The arm was repositioned between measurements.

#FIGURE 1

Pectoralis minor length

The measurement of the pectoral minor length was carried out with the participant in the supine position. A small pillow was placed under the participant's head for comfort. The participant's arm was passively placed along the side of the body in the neutral position resting on the table[29]. Because of the variability among subjects this measurement was best normalized creating a pectoralis minor index (PMI), which was calculated by dividing the resting muscle length measurement by the subject height and multiplying by 100, as previously described by Borstad et al [12]. Heigth was measured with the patient in a standing position, by using a calliper placed at the top of the head and marking a point on a scale placed on the wall. The resting muscle length was measured from the caudal edge of the 4th rib to the inferomedial aspect of the coracoid process with a sliding calliper (Figure 2). Pectoralis minor index values less than 7.65

have been identified as a shortened pectoralis minor[12]. The measurement was taken during inspiration[14].

#FIGURE 2

Levator scapulae length

Participants were standing with their arms relaxed at their sides. The subjects were asked to look directly ahead without craniocervical movement[13]. The instruction was to palpate two anatomical reference points in line that represent levator scapulae length: (1) the dorsal tubercles of the transverse processes of the second cervical vertebrae and (2) the superior angle of the medial borders of the scapula. The assessor used a skin-marker pencil to mark the reference points. The marks were cleaned immediately after each test session. The distance between these two bony reference points was measured with a sliding calliper (Figure 3). By creating an LSI (levator scapulae length [cm]/subjects' height [cm]*100), the subjects' variability in body height was normalized[13]. The LSI was expressed as a percentage of the subjects' height.

FIGURE 3

The Shoulder Pain and Disability Index (SPADI) was assessed in all participants. The SPADI is composed of 13 questions and contains two domains: pain and disability. The score of the questionnaire ranges from 0 to 100, with very high scores indicating worse function. The numeric pain scale runs from 0 to 10, with 0 indicating no pain and 10 representing the worst pain[30]. The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time[31]. A Spanish version of the SPADI was used since English was not the native language for all the participants[32].

Data analysis

The Statistical Package for the Social Sciences (version 23.0 for Mac; SPSS Inc. Chicago, IL) was used to analyses the collected data. Normality for all variables was explored using the Kolmogorov Smirnov test for the group of participants with shoulder pain (affected and non-affected), and for the control subjects. To determine whether there were differences between groups for all the outcome measurements, Kruskal-Wallis test was calculated. A p-value < 0.05 was considered statistically significant. Subsequently, mean differences for all the variables between the affected and non-affected groups were calculated using paired sample t-tests. Comparisons between affected group and controls were calculated using independent sample t-tests. When normality was violated, comparisons were made using non-parametric tests for related and/or independent samples. Based on

Although it was not a purpose of this study, we calculated the intra-rater reliability for all the outcome measurements by using the intraclass correlation coefficient (ICC), in order to determine the minimal detectable change at 95% (MDC95), which were measured by the same assessor as previously described. For the calculation of intrarater reliability of SUR, PMI and LSI, the 3,1 model or a 2-way mixed consistency intraclass correlation coefficient (ICC) model was used. A reliability coefficient less than 0.50 was an indication of "poor" reliability; "moderate" being between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90[33]. The Standard Error of Measurement (SEM), which was computed as SEM = SD x (square root of $(1-ICC)$), and the MDC95 was calculated using the formula MDC95 = 1.96* $\sqrt{2} * SEM$.

RESULTS

Demographic characteristics are shown in Table 1

	Patients	Healthy subjects	p-value
Age (yrs; CI)	46.39 (43.67 to 49.11)	46.42 (44.1 to 48.67)	0.98
Women	33	33	1
Men	21	21	1
SPADI (CI)	56,37 (17,69 to 100)	2,66 (1,73 to 3,60)	N/A
Chronicity of symptoms	3-6months: 18 6-12 months: 5 More than one year: 31	N/A	N/A

Table 1: Demographic characteristics; Mean (95% CI); N/A: non-applicable

$p<0.05$: statistically significant; CI= confidence interval

The ICC was greater than 0.90 for all the tests, which means an excellent reliability, except for LSI (0, 87). The MDC95 was as follows: SUR45º= 0, 91; SUR90º= 1, 55; SUR135º= 2, 83; PMI= 0, 80; LSI= 1, 08.

Mean values for the outcome measures and inter-rate reliability data

Mean values of scapular upward rotation, levator scapulae and pectoralis minor index for all the groups are presented in Table 2, as well as intra-rater reliability data calculated by ICC, and MDC95.

	Symptomatic shoulder	Asymptomatic shoulder	Healthy subject	ICC	MDC95
SUR (degrees)					
At 45° GH abduction	4,55 (3,79 to 5,32)	5,71 (4,82 to 6,60)	2,55 (1,81 to 3,29)	> 0.9	0,91
At 90° GH abduction	20,75 (18,81 to 22,69)	21,42 (19,88 to 22,96)	16,77 (15,49 to 18,04)	> 0.9	1,55
At 135° GH abduction	45,18 (42,76 to 47,59)	44,16 (42,20 to 46,12)	36,22 (34,34 to 38,09)	> 0.9	2,83
LSI	7,81 (7,42 to 8,20)	7,81 (7,53 to 8,30)	7,76 (7,42 to 8,11)	0.87	1,08
PMI	10,52 (10,27 to 10,76)	10,86 (10.26 to 11,46)	10,07 (9,73 to 10,42)	> 0.9	0,80

Table 2: Mean values of pectoralis minor and levator scapulae index, and scapular upward rotation expressed in degrees in different groups. Abbreviations: GH = glenohumeral; SUR = scapular upward rotation; LSI = levator scapulae index: PMI = pectoralis minor index; ICC= intraclass correlation coefficient; MDC95= minimal detectable change

Differences in SUR, PMI and LSI between groups

The mean differences between groups regarding SUR, PMI and LSI are shown in Table 3. There were statistical significant differences between groups in SUR at 45, 90 and 135 degrees of shoulder elevation. Comparisons between groups are described in detail in Table 3. There were not statistically significant differences between groups for both PMI and LSI (see Table 3).

	Symptomatic-Asymptomatic shoulder	p	Symptomatic-Control shoulder	p	H	p
SUR At 45°GH abduction	-1,15 (-2,26 to -0,04)	0.04*	2,00 (0,96 to 3,05)	<0.001*	26,48	< .001*
At 90° GH abduction	-0,67 (-1,90 to 3,94)	0.56	3,98 (1,68 to 6,27)	0.001*	18,48	< .001*
At 135° GH abduction	1,02 (-1,90 to 3,94)	0.70	8,96 (5,94 to 11,98)	<0.001*	35,04	< .001*
PMI	-0,34% (-0,97 to 0,29%)	0.28	0,44% (0,04 to 0,85%)	0.03	3,37	0.18
LSI	0,00% (-0,35 to 0,35%)	0.99	0.05% (-0,49 to 0,58%)	0.86	0,11	0.95

Table 3: Between-group mean differences

*: statistically significant ($p < .025$)

H: Kruskal-Wallis test

DISCUSSION

This study aimed to explore potential differences in scapular positioning and scapular pattern of movement between the symptomatic shoulder in patients with chronic SAPS, compared with the contralateral asymptomatic, and control shoulders. We found statistical significant differences between the three groups in SUR at 45, 90 and 135 degrees of shoulder elevation. Specifically, a decreased SUR in symptomatic shoulder compared to contralateral asymptomatic shoulder at 45 degrees, was achieved. When comparing symptomatic and control participants, an increased SUR at all positions (45, 90 and 135 degrees) was found in the symptomatic shoulders. Regarding PMI and LSI, there were not significant differences between all the groups.

This is the first study that compares SUR, PMI and LSI between both symptomatic and asymptomatic shoulders in patients with SAPS, and the symptomatic shoulder from patients with control subjects, using accessible and low-cost tools. Previous studies have reported differences in SUR during arm elevation between the symptomatic and the asymptomatic shoulder [34],[20],[19], showing a decreased SUR in the symptomatic shoulders, mainly within the first degrees of elevation in the scapular plane. This is in line with the present study. Furthermore, a significantly increased SUR in the symptomatic shoulder of patients when compared with control subjects was obtained. These differences did surpass the MDC95 of all the positions (45, 90 and 135 degrees of shoulder elevation). This is not in supported by current literature, which suggests the presence of a decreased SUR in shoulders with subacromial symptoms compared with

healthy controls[35],[34],[19]. This can be explained by the fact that patients that were included in our study showed long duration of shoulder pain, meaning chronicity of symptoms. In this context, the firing pattern of scapular muscle units can change, generating an early SUR in an attempt to avoid pain, as has been found in a recent study[36] . It can be hypothesized that early stages of SAPS could present a deficit in SUR while more advanced stages can develop a compensatory increased SUR. As this was not measured in this study, further investigation is needed. In others shoulder conditions, current research analysing SUR in both symptomatic and pain-free shoulders does not sustain strong conclusions. Kijima et al.[37] showed absence of differences in SUR, measured by a 3-dimesional scapular kinematic analysis, between symptomatic, asymptomatic rotator cuff tears and healthy shoulders. Furthermore, Hung et al.[38] reported no differences in SUR, measured by 3-dimensional analysis, between patients with glenohumeral instability and healthy controls.

With regard to the pectoralis minor length, there was an absence of statistically significant difference between the symptomatic and the asymptomatic shoulders, whereas a longer pectoralis minor was found in symptomatic shoulder patient when compared to control shoulders, but differences were smaller than the MDC95 (0,80). This finding was contrary to what was expected, since a more anterior tilted positioning of the scapula is thought to be correlated with a potential risk of SAPS. Our results are in line with those obtained by Struyf et al.[14] The aforementioned study showed PMI values of 9.17 (0.54) in the dominant side in the control group, 9.66 (0.68) in the symptomatic side and 9.64 (0.72) in the asymptomatic side in the patient group, but they did not study the statistical differences between groups. On the other hand, Lewis et al. [15]also reported values that analysed pectoral minor length, but comparisons with the

present study are not possible as the test used was different (acromion-table distance test). To our knowledge there are no studies investigating these potential differences.

Previous studies[12] have found, in healthy subjects with a shortened pectoralis minor, a similar scapular behaviour to those suffering from SIS. Likewise, pectoral minor length has a weak positive correlation with the acromiohumeral distance in healthy male athletes[29], which means that the pectoralis minor could have a slight influence in the scapular positioning in the case of shortening. However, based on the results obtained in the present study, and also on previous inconsistent evidence along this line[6][10], the pectoral minor does not seem to play a key role in patients with chronic SAPS, when compared to contralateral non-affected shoulders and control subjects.

In relation to LS length, there was an absence of differences between symptomatic and asymptomatic shoulder in patients, and between symptomatic shoulder and controls in this study. To the best of our knowledge, this is the first study that analyses such differences between subjects with shoulder symptoms and controls, so comparisons with others are difficult. It is thought that a shortened LS can produce a scapula more downwardly rotated[13] and, hence, a greater compromise of the subacromial space during overhead movements. As we did not determine the scapular position in this study, a conclusion on the absence of differences in levator scapulae length between different groups cannot be made, thus further studies are needed in this field.

Some strong points from this study need to be mentioned. First, the intra-rater reliability obtained in all the measurements was excellent. Second, an exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff tears was carried out. Third, the examiner who assessed all the measurements had an extensive clinical

experience.

On the other hand, some limitations need to be recognized. As only one examiner assessed all the outcome measures, inter-rater reliability was not calculated, so this could introduce bias. Moreover, as the minimal clinically importance difference for SUR is unknown, we cannot make a conclusion to whether the differences found in this study mean a clinical importance or not. Our results should be taken with caution when interpreted, as a sample with chronic SAPS was studied, so we do not know if these results can be extrapolated to other populations, e.g. acute shoulder pain. Lastly, including healthy controls by using a SPADI score below 15 points could mean bias.

The present results could have clinical implications, and contribute to increase the body of knowledge in the field of scapular biomechanics tests. First, it seems that pectoral minor and/or levator scapulae are not distinguishing factors when comparing the symptomatic and the contralateral asymptomatic shoulder in subjects suffering from SAPS. Second, a difference of 1, 15 degrees of SUR between symptomatic and asymptomatic shoulder in those with chronic SAPS when comparing both at 45° of shoulder elevation may indicate shoulder dysfunction, and third, the use of the SUR test at 45°, 90° and 135° of shoulder elevation may be useful in the assessment of shoulder conditions when compared to values from control subjects.

Further research that analyses levator scapulae length and scapular positioning, and the minimal clinically importance difference in SUR, would contribute to enhance knowledge in this field. Moreover, studies analysing changes in SUR and pectoral minor length after application of physical therapies are necessary to corroborate their

contribution, as indicators of improvement, when patients with chronic SAPS are treated.

In conclusion, SUR is greater in patients with chronic SAPS when compared with control volunteers at different angles of shoulder elevation, and is also greater regarding PMI values at rest position. The usefulness of the present findings is theorized, but further studies to confirm this in clinical practice are needed.

Contributor ship statement

The presented work follows the ICMJE recommends for authorship, based on the following 4 criteria:

All authors have made substantial contributions to the conception or design of the work (SNL and ALS); or the acquisition (SNL, MFS and ALS), analysis (SNL and ALS), or interpretation of data for the work (SNL, and ALS); AND

Drafting the work or revising it critically for important intellectual content (SNL, MFS, FS, JMC and ALS); AND

Final approval of the version to be published (SNL, MFS, FS, JMC and ALS); AND

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition, authors have confidence in the integrity of the contributions of their co-authors.

Competing interests

All authors state that the founders had no role in the study and they have no conflicts of interest to declare. All authors have made a substantial scientific contribution to the study and they are thoroughly familiar with the primary data. All authors have read the

complete manuscript and take responsibility for the content and completeness of it and understand that if the paper, or any part of it, is found to be faulty or fraudulent, all authors share responsibility.

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Data sharing statement

The data sharing statement is currently not available due to a secondary analysis is being made. However, the available data can be obtained by contacting the corresponding author when the whole work is finished.

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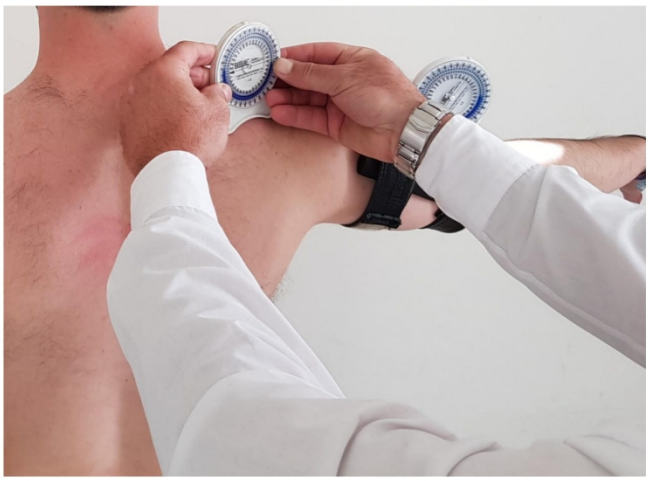
LEGENDS

Figure 1: Scapular upward rotation measurement.

Figure 2: Pectoral minor length measurement.

Figure 3: Levator scapulae length measurement.



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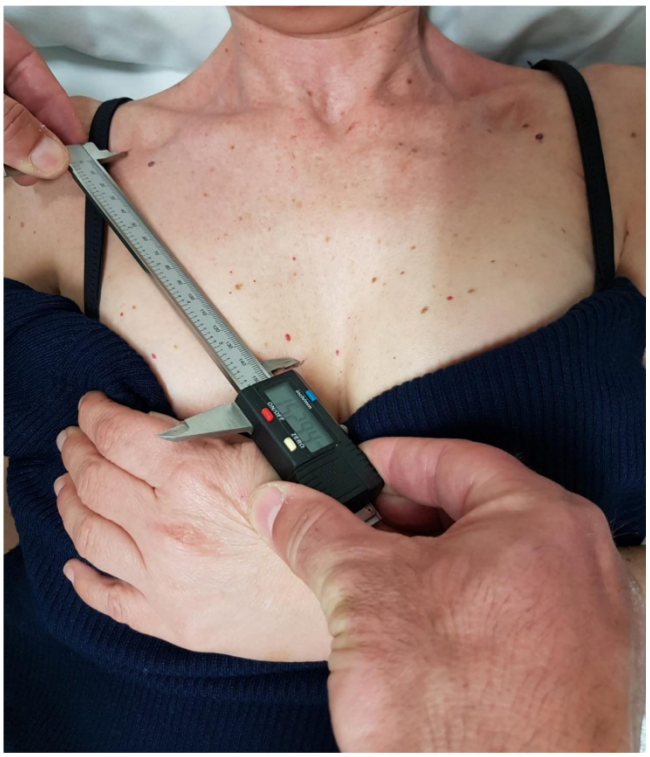

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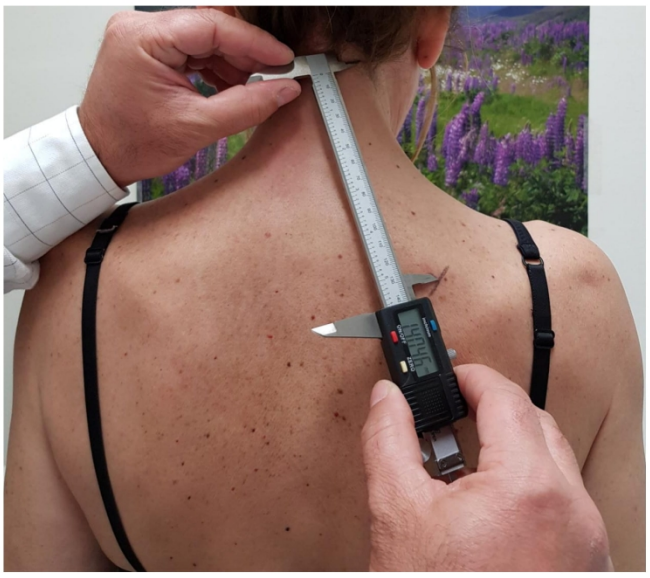

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **PAGE 1**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **PAGE 3**
Objectives	3	State specific objectives, including any prespecified hypotheses **PAGE 4**
Methods		
Study design	4	Present key elements of study design early in the paper **PAGE 4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **PAGE 4**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **PAGE 5**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **PAGE 6-7-8**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **PAGE 6-7-8**
Bias	9	Describe any efforts to address potential sources of bias **PAGE 8**
Study size	10	Explain how the study size was arrived at **PAGE 9**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **PAGE 9**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions **PAGE 9**
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **PAGE 9-12**
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **PAGE 10**
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure **PAGE 9-12**
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **PAGE 11-12**
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **PAGE 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **PAGE 15**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **PAGE 12-14**
Generalisability	21	Discuss the generalisability (external validity) of the study results **PAGE 15-16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **NON APPLICABLE**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study in a Spanish primary care setting.

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Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study in a Spanish primary care setting.

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ABSTRACT

Objective: To determine the potential differences in both scapular positioning and scapular movement between the symptomatic and asymptomatic contralateral shoulder, in patients with unilateral subacromial pain syndrome (SAPS), and when compared to participants free of shoulder pain.

Setting: Three different primary care centres.

Participants: A sample of seventy-three patients with SAPS in their dominant arm was recruited, with a final sample size of fifty-four participants.

Primary outcome measures: the scapular upward rotation (SUR), the pectoralis minor and the levator scapulae muscles length tests were carried out.

Results: When symptomatic shoulders and controls were compared, an increased SUR at all positions (45, 90 and 135 degrees) was obtained in symptomatic shoulders (2/ 3,98/ 8,96 degrees respectively). These differences in SUR surpassed the minimal detectable change (MDC95) (0,91/1,55/2,83 degrees at 45/90/135 degrees of shoulder elevation). No differences were found in SUR between symptomatic and contralateral shoulders. No differences were found in either pectoralis minor or levator scapulae muscle length in all groups.

Conclusions: scapular upward rotation was greater in patients with chronic SAPS compared to controls at different angles of shoulder elevation.

Keywords: scapular kinematic; shoulder pain; chronic pain

Strengths and limitations of this study

An exhaustive ultrasound and clinical assessment was carried out to avoid the inclusion of patients with rotator cuff tears.

The examiner who assessed all the measurements was an experience clinical professional.

The inter-rater reliability was not calculated, so this could introduce bias.

The minimal clinically important difference for SUR is unknown, thus we cannot make a conclusion as to whether the differences found in this study reached clinical importance or not.

INTRODUCTION

Shoulder pain is the most common musculoskeletal condition after neck pain and low back pain[1]. Shoulder pain point prevalence figures range from 6.9 to 26%, from 18.6 to 31% for 1-month prevalence, from 4.7 to 46.7% for 1-year prevalence, and from 6.7 to 66.7% for lifetime prevalence[2]. Furthermore, shoulder pain prevalence is even higher in women[3], in the working population[4], and increases with age[5].

Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain[6,7]. It is defined as a non-traumatic, usually unilateral, shoulder disorder that causes localized pain around the acromion, often worsening during or subsequent lifting the arm[8]. The best therapeutic approach in SAPS is still under debate. Half of the patients with shoulder pain being attended in primary care do not completely recover after 6 months from their initial episode[9]. Thus, there is a need to explore different non-invasive strategies in these patients. One of the approaches that can be beneficial for the patient is to focus on the scapulothoracic joint. To date, there is inconsistent evidence to support a relationship between SAPS symptoms and scapular orientation[10][6]. The most common causative mechanism of an altered scapular positioning involves the soft tissue, such as inflexibility (tightness) and alterations in the periscapular muscles[11]. Specifically, both a decreased activation and strength of the serratus anterior, as well as alterations in upper/lower trapezius couple forces, can alter scapular upward rotation and posterior tilt [11]. Likewise, pectoralis minor, levator scapulae muscles[12,13] and biceps short head[11]have been traditionally assessed as their shortening may potentially influence scapular positioning.

Previous studies have reported normative values on pectoralis minor length in the dominant and non-dominant side in both symptomatic and control populations, by using the pectoralis minor index (PMI)[14] and the acromion-table distance test[15].Recently,

pectoralis minor length and its shortening have received remarkable empirical attention, in terms of studies of its reliability [16], its association with shoulder external rotation[17], and as an outcome measure after a stretching program in participants with shoulder pain[18]. However, differences between symptomatic groups and healthy controls were not calculated. To the best of our knowledge, differences in the levator scapulae index (LSI) between symptomatic and control populations have not been determined yet. With regard to patterns of movement, there is conflicting evidence. While some studies have shown association between a reduced scapular upward rotation (SUR) and scapular posterior tilt in SAPS [19,20], others attained inconclusive findings[6,10].

Advanced equipment exists to assess scapular positioning and kinematics. However, most of them are very technical and highly expensive, which makes them almost unattainable in the clinical practice[21]. In this regard, research states that the SUR seems suitably evidence-based for clinical use, while pectoralis minor length measurements should be used as supplementary clinical assessment methods in addition to others[22,23].Additionally, the levator scapulae muscle length measurement has been shown to be a reliable tool, and it has been proposed as part of the scapula assessment because the levator scapulae directly attaches in the superior angle of the scapula[13] and thus it is another possible cause of scapular dysfunction[24].

Specifically, there is a lack of evidence on the potential differences in PMI, LSI and SUR, between painful and contralateral non-painful shoulders, and control subjects. The existence of differences in scapular positioning and pattern of movement could contribute to steer physiotherapy treatments towards a scapular focused treatment approach.

Hence, the aim of this study was to analyse the differences in scapular positioningand pattern of movement, between the symptomatic and asymptomatic shoulder, in patients with unilateral chronic SAPS, and in controls, using three different tests: i) scapular upward rotation, ii) pectoralis minor muscle length and, iii) levator scapulae muscle length. The null hypothesis (H_0) was that there are no differences in the groups in these three different tests. The alternative hypothesis (H_a) was that there is an increased SUR in painful shoulder when comparing with contralateral and control shoulder, as well as a decreased both pectoralis minor and levator scapulae length in painful shoulder.

METHOD

Study design

This was a cross-sectional, observational study, carried out in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Health Care District where the primary care centres were located (PI9/012014). The study has been reported following the recommendations of the STROBE statement for observational studies. All the participants signed an informed consent.

Participants

A sample of seventy-three patients with chronic SAPS in their dominant arm was recruited from three different primary care centres, with a final sample size of fifty-four participants obtained after applying the inclusion criteria. General practitioners (GPs) recruited the participants who were screened for eligibility by a research assistant.Participants had to meet the following inclusion criteria: (i) men or women aged between 18 to 55 years; (ii) unilateral pain located in the anterior and/or lateral shoulder region[8]; (iii) 2 out of 3 positive clinical tests (Hawkins-Kennedy; Jobe; Neer)[25]; (iv) pain with normal activity ≥ 4/10 on a visual analogue scale; (v) shoulder

pain lasting more than three months; (vi) a history of nontraumatic onset of shoulder pain. Participants were ineligible to participate in this study if any of these conditions were present: (i) history of significant shoulder trauma, such as fracture or ultrasonography-clinically suspected full thickness cuff tear, following the classification of Wiener and Seitz, 1993[26]; (ii) recent shoulder dislocation in the past two years; (iii) systemic illnesses such as rheumatoid arthritis; (iv) adhesive capsulitis; (v) shoulder pain originating from the neck or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies.

A sample of 40 participants with both shoulders free of pain for the last year was selected. They were recruited from the same three primary care centres as the participants with shoulder pain. Furthermore, to participate in the study, they had to present: (i) a SPADI score ≤ 15 points, based on the minimal clinically detectable change for this tool[27]; (ii) negative results for Neer test, Hawkins-Kennedy test and Jobe test; iii) no painful arc present during flexion or abduction; iv) no pain during resisted lateral rotation and/or abduction. Asymptomatic participants were specifically age and gender matched to the symptomatic group.

Outcome measurements

All measurements were taken by a physiotherapist with more than 25 years of experience, including height which was necessary to calculate PMI and LSI values. This physiotherapist was blinded to the fact of participants having shoulder pain or not.

Scapular upward rotation (SUR)

The measurement of SUR was performed using two Plurimeter-V gravity reference inclinometers[28]. One inclinometer was Velcro taped perpendicular to the humeral shaft, just above the humeral epicondyle. At resting position, the humeral inclinometer was calibrated as 0 degrees. Next, the patients were instructed to perform shoulder

abduction in the coronal plane with full elbow extension and 45° of external humeral rotation, with the thumb abducted. The patients were asked to stop at 45º, 90º and 135º degrees of humeral abduction, where the SUR was measured with a second inclinometer, manually aligned along the scapular spine (Figure 1). Three measurements were collected at each position and then the mean was obtained. The arm was repositioned between measurements.

#FIGURE 1

Pectoralis minor length

The measurement of the pectoralis minor length was carried out with the participant in the supine position. A small pillow was placed under the participant's head for comfort. The participant's arm was passively placed along the side of the body in the neutral position resting on the table[29]. Because of the variability among subjects this measurement was best normalized creating a pectoralis minor index (PMI), which was calculated by dividing the resting muscle length measurement by the subject height and multiplying by 100, as previously described by Borstad et al[12]. Height was measured with the patient in a standing position, by using a calliper placed at the top of the head and marking a point on a scale placed on the wall. The resting muscle length was measured from the caudal edge of the 4th rib to the inferomedial aspect of the coracoid process with a sliding calliper (Figure 2). Pectoralis minor index values less than 7.65 have been identified as a shortened pectoralis minor, measured in standing position[12]. The measurement was taken during inspiration[14].

#FIGURE 2

Levator scapulae length

Participants were standing with their arms relaxed at their sides. The subjects were asked to look directly ahead without any craniocervical movement[13]. The instruction

was to palpate two anatomical reference points in line that represent levator scapulae length: (1) the dorsal tubercles of the transverse processes of the second cervical vertebrae and (2) the superior angle of the medial borders of the scapula. The assessor used a skin-marker pencil to mark the reference points. The marks were cleaned immediately after each test session. The distance between these two bony reference points was measured with a sliding calliper (Figure 3). By creating a LSI (levator scapulae length [cm]/subjects' height [cm]*100), the subjects' variability in body height was normalized[13]. The LSI was expressed as a percentage of the subjects' height.

FIGURE 3

The Shoulder Pain and Disability Index (SPADI) was assessed in all participants. The SPADI is composed of 13 questions and contains two domains: pain and disability. The score of the questionnaire ranges from 0 to 100, with very high scores indicating worse function. The numeric pain scale runs from 0 to 10, with 0 indicating no pain and10 representing the worst pain[30].The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time[31]. A Spanish version of the SPADI was used since English was not the native language for all the participants[32].

Data analysis

The Statistical Package for the Social Sciences (version 23.0 for Mac; SPSS Inc. Chicago, IL) was used to analyses the collected data.Normality for all variables was explored using the Kolmogorov Smirnov test for the group of participants with shoulder pain (affected and non-affected), and for the control subjects. Two different analysis strategies were carried out: first, to determine differences in SUR at different degrees of abduction,a repeated measures ANOVA was developed in every group. For this

analysis, F statistic was adjusted in case of non-sphericity (tested by Mauchly's test), with the Greenhouse-Geissner correction. Second, to determine between-groups differences for all the outcome measurements, one-way ANOVA test was calculated with Bonferroni and Tukey post-hoc estimations. A p-value less than 0.05 was considered statistically significant.

Although it was not a purpose of this study, we calculated the intra-rater reliability for all the outcome measurements by using the intraclass correlation coefficient (ICC), in order to determine the minimal detectable change at 95% (MDC95), which were measured by the same assessor as previously described. For the calculation of intrarater reliability of SUR, PMI and LSI, the 3,1 model or a 2-way mixed consistency ICC model was used. A reliability coefficient less than 0.50 was an indication of "poor" reliability; "moderate" being between 0.50 and 0.75, "good" between 0.76 and 0.90; and "excellent" over 0.90[33]. The Standard Error of Measurement (SEM), which was computed as SEM = SD x (square root of $(1 - ICC)$), and the MDC95 was calculated using the formula MDC95 = 1.96*$\sqrt{2} * SEM$.

Patient and Public Involvement

The participation of all subjects was voluntary, and no incentives were given to encourage enrollment. Patients with shoulder pain from each primary care center were not involved neither in the design of the study nor in the recruitment of the participants.The results of the present study were sent by e-mail to those participants who wanted to be informed.

RESULTS

Sample characteristics

Demographic characteristics are shown in Table 1. There were not significant differences between groups in terms of gender and age.

	Patients (mean and SD)	Healthy subjects (mean and SD)
Age (yrs; CI)	46.39 (9.96)	46.42 (7.02)
Women	33 (61.1%)	23 (57.5 %)
Men	21 (38.9%)	17 (42.5 %)
SPADI (CI)	56.37 (20.01)	2.66 (2.88)
Chronicity of symptoms	3-6months: 18 6-12 months: 5 More than one year: 31	N/A

Table 1: Demographic characteristics; Mean (95% CI); N/A: non-applicable; CI= confidence interval; SPADI: shoulder pain and disability index

Mean values for the outcome measures and intra-rater reliability data

Mean values of scapular upward rotation (expressed in degrees), levator scapulae index (LSI) and pectoralis minor index (PMI)for all the groups are presented in Table 2.There were statistically significant differences in SUR when comparing the three groups, while no differences were found for the rest of the outcome measurements (LSI and PMI) (see Table 2). Furthermore, there was an increase in SUR from 45 to 90 and 135 degrees of shoulder abduction for all the groups, analysed by repeated measures ANOVA, with the following results:

Symptomatic shoulder: F (1.51, 80.05) = 1009.22; p<0.001

Asymptomatic shoulder: F (1.46, 77.37) = 1356.57; p<0.001

Healthy controls: F (1.46, 56.89) = 1196.18; p<0.001

	Symptomatic shoulder	**Asymptomatic shoulder**	**Healthy controls**	**F**	**p**
SUR					
45° of GH abduction	4.55 (3.79 to 5.32)	5.71 (4.82 to 6.60)	2.55 (1.81 to 3.29)	F(2,145)=14.14	<0.001*
90°of GH abduction	20.75 (18.81 to 22.69)	21.42 (19.88 to 22.96)	16.77 (15.49 to 18.04)	F(2,145)=8.08	<0.001*
135° of GH abduction	45.18 (42.76 to 47.59)	44.16 (42.20 to 46.12)	36.22 (34.34 to 38.09)	F(2,145)=18.64	<0.001*
LSI	7.81 (7.42 to 8.20)	7.81 (7.53 to 8.30)	7.76 (7.42 to 8.11)	F(2,145)=0.02	0.978
PMI	10.52 (10.27 to 10.76)	10.86 (10.26 to 11.46)	10.07 (9.73 to 10.42)	F(2,145)=2.97	0.054

Table 2: Mean values (95%CI: confidence interval) of pectoralis minor index (PMI), levator scapulae index (LSI), and scapular upward rotation expressed in degrees (SUR) in different groups; F: One-factor ANOVA for differences in symptomatic, asymptomatic and healthy controls.

*: statistically significant.

The ICC was greater than 0.90 for all the tests, which means an excellent reliability, except for LSI (0.87). The MDC95 was as follows: SUR45º= 0.91; SUR90º= 1.55; SUR135º= 2.83; PMI= 0.80; LSI= 1.08.

Differences in SUR, PMI and LSI between groups

Comparisons between groups are described in detail in Table 3.There were statistical significant differences in SUR between symptomatic and control groups at 45, 90 and 135 degrees of shoulder elevation, while no differences between symptomatic and asymptomatic group were found. There were not statistically significant differences between groups for both PMI and LSI (see Table 3).

	Symptomatic vs Asymptomatic shoulder differences (95%CI)	p	Symptomatic vs Control shoulder differences (95%CI)	p
SUR				
At 45°GH abduction	-1,15 (-2,46 to -0,15)	0.09	2,01 (0,59 to 3,42)	0.003*
At 90° GH abduction	-0,67 (-3,35 to 2)	0.82	3,98 (1,08 to 6,88)	0.004*
At 135° GH abduction	1,02 (-2,41 to 4,45)	0.76	8,96 (5,24 to 12,6)	<0.001*
PMI	-0,34 (-1,04 to 0,36)	0.49	0,45 (-0,32 to 1,21)	0.351
LSI	0,00 (-0,55 to 0,55)	1	0.05 (-0,55 to 0,64)	0.98

Table 3: Between-group differences (Bonferroni and Tukey multiple comparisons)

CI: confidence interval; SUR: scapular upward rotation; GH: glenohumeral; PMI: pectoralis minor index; LSI: levator scapulae index

*: statistically significant ($p<0.05$)

DISCUSSION

This study aimed to explore potential differences in scapular positioning and scapular pattern of movement between the symptomatic shoulder in patients with chronic SAPS, compared to the contralateral asymptomatic, and control shoulders. We found statistical significant differences in the three groups in SUR at 45, 90 and 135 degrees of shoulder elevation. Specifically, an increased SUR at all positions (45, 90 and 135 degrees) was found in favour of the symptomatic shoulders when symptomatic and control participants were compared. No differences were found between symptomatic and asymptomatic groups. Hence, our hypothesis was only partially confirmed. Regarding PMI and LSI, there were no significant differences in the groups, thus, our hypothesis was not confirmed.

This is the first study that compares SUR, PMI and LSI between both symptomatic and asymptomatic shoulders in patients with SAPS, and between symptomatic shoulder with control subjects, using accessible and low-cost tools. Previous studies have reported differences in SUR during arm elevation between the symptomatic and the asymptomatic shoulder[19,20,34], showing a decreased SUR in the symptomatic shoulders, mainly within the first degrees of elevation in the scapular plane. We found a significantly increased SUR in the symptomatic shoulder of patients when compared with control subjects. These differences surpassed the MDC95 in all the positions (45, 90 and 135 degrees of shoulder elevation). This is not supported by current literature, which suggests the presence of a decreased SUR in shoulders with subacromial

symptoms compared to healthy controls[19,34,35]. This can be explained by the fact that patients that were included in our study experienced shoulder pain of a long duration, meaning chronicity of symptoms. In this context, the firing pattern of scapular muscle units can change, generating an early SUR in an attempt to avoid pain. This altered pattern has been found in a recent study[36] . It can be hypothesized that early stages of SAPS could present a deficit in SUR while more advanced stages can develop a compensatory increased SUR. As this was not measured in this study, further investigation is needed to confirm that. In other shoulder conditions, current research analysing SUR in both symptomatic and pain-free shoulders does not sustain strong conclusions. Kijima et al.[37] showed an absence of differences in SUR, measured by a 3-dimensional scapular kinematic analysis, in symptomatic rotator cuff tears, contralateral shoulder and healthy shoulders. Furthermore, Hung et al.[38]reported no differences in SUR, measured by 3-dimensional analysis, in patients with glenohumeral instability and healthy controls.

With regard to the pectoralis minor length, there was an absence of statistical significant difference between the symptomatic and the asymptomatic shoulders, as well as in symptomatic shoulder patients when compared with controls. This finding was contrary to what was expected, since a more anterior tilted positioning of the scapula is thought to be correlated with a potential risk of SAPS. Our results are in line with those obtained by Struyf et al.[14] The aforementioned study showed PMI values of 9.17 (SD 0.54) in the dominant side in the control group,9.66 (SD 0.68) in the symptomatic side and 9.64 (SD 0.72) in the asymptomatic side in the patient group, but they did not study the statistical differences between groups. On the other hand, Lewis et al. [15]also reported values that analysed pectoralis minor length. Nevertheless, comparisons with the

present study are not possible as the used test was different (acromion-table distance test). To our knowledge there are no studies investigating these potential differences. Previous studies[12]have found a similar scapular behaviour to those suffering from SIS, in healthy subjects with a shortened pectoralis minor. Likewise, pectoralis minor length presents a weak positive correlation with the acromiohumeral distance in healthy male athletes[29], which means that the pectoralis minor could have a slight influence in the scapular positioning in the case of shortening. However, based on the results obtained in the present study, and also on previous inconsistent evidence on this topic [6][10],a shortened pectoralis minor does not seem to play a key role in patients with chronic SAPS, when compared to contralateral non-affected shoulders and control subjects.

In relation to levator scapulae length, there was an absence of differences between symptomatic and asymptomatic shoulder in patients, and between symptomatic shoulder and controls in this study. As far as we know, this is the first study that analyses such differences between subjects with shoulder symptoms and controls, so comparisons with others are difficult. It is thought that a shortened levator scapulae can produce a scapula more downwardly rotated[13] and, hence, a greater compromise of the subacromial space during overhead movements. As we did not determine the scapular position in this study, a conclusion on the absence of differences in levator scapulae length in different groups cannot be made, thus further studies are needed in this field.

Some strong points from this study need to be mentioned. First, an exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff

tears, was carried out. Second, the examiner who assessed all the measurements had extensive clinical experience.

On the other hand, some limitations need to be recognized. As only one examiner assessed all the outcome measures, inter-rater reliability was not calculated, so this could introduce bias. Moreover, as the minimal clinically important difference of SUR is unknown, we cannot make a conclusion as to whether the differences found in this study have clinical importance or not. Our results should be taken with caution when interpreted, as a sample with chronic SAPS was studied, so we do not know if these results can be extrapolated to other populations, e.g. acute shoulder pain. Lastly, including healthy controls by using a SPADI score below 15 points could mean bias.

The present results could have clinical implications, and could contribute to increase the body of knowledge in the field of scapular biomechanic tests. First, it seems that pectoralis minor and/or levator scapulae are not distinguishing factors when comparing the symptomatic and the contralateral asymptomatic shoulder in subjects suffering from SAPS. Second, the use of the SUR test at 45°, 90° and 135° of shoulder elevation may be useful in the assessment of shoulder conditions when compared to values from control subjects.

Further research that analyses levator scapulae length and scapular positioning, and the minimal clinical important difference in SUR, would contribute to enhance knowledge in this field. Moreover, studies analysing changes in SUR and pectoralis minor length after application of physical therapies are necessary to corroborate their contribution, as indicators of improvement, when patients with chronic SAPS are treated.

In conclusion, SUR is greater in patients with chronic SAPS when compared with controls at different angles of shoulder elevation, and is also greater in PMI values at rest position. The usefulness of the present findings is theorized, but further studies to confirm this in clinical practice are needed.

Contributor ship statement

The presented work follows the ICMJE recommends for authorship, based on the following 4 criteria:

All authors have made substantial contributions to the conception or design of the work (SNL and ALS); or the acquisition (SNL, MFS and ALS), analysis (JMMA and ALS), or interpretation of data for the work (SNL, and ALS); AND

Drafting the work or revising it critically for important intellectual content (SNL, MFS, FS, JMC, JMMA and ALS); AND

Final approval of the version to be published (SNL, MFS, FS, JMC, JMMA and ALS); AND

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition, authors have confidence in the integrity of the contributions of their co-authors.

Competing interests

All authors state that the funders had no role in the study and they have no conflicts of interest to declare. All authors have made a substantial scientific contribution to the study and they are thoroughly familiar with the primary data. All authors have read the complete manuscript and take responsibility for the content and completeness of it and

understand that if the paper, or any part of it, is found to be faulty or fraudulent, all authors share responsibility.

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Data sharing statement

The data sharing statement is currently not available due to a secondary analysis is being made. However, the available data can be obtained by contacting the corresponding author when the whole work is finished.

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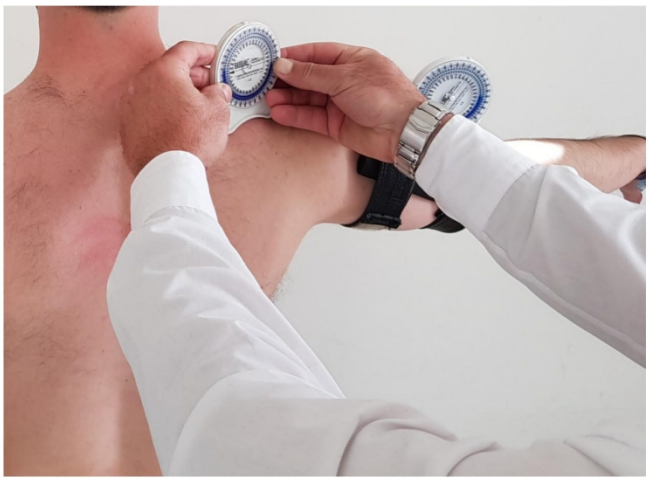
LEGENDS

Figure 1: Scapular upward rotation measurement.

Figure 2: Pectoralis minor length measurement.

Figure 3: Levator scapulae length measurement.



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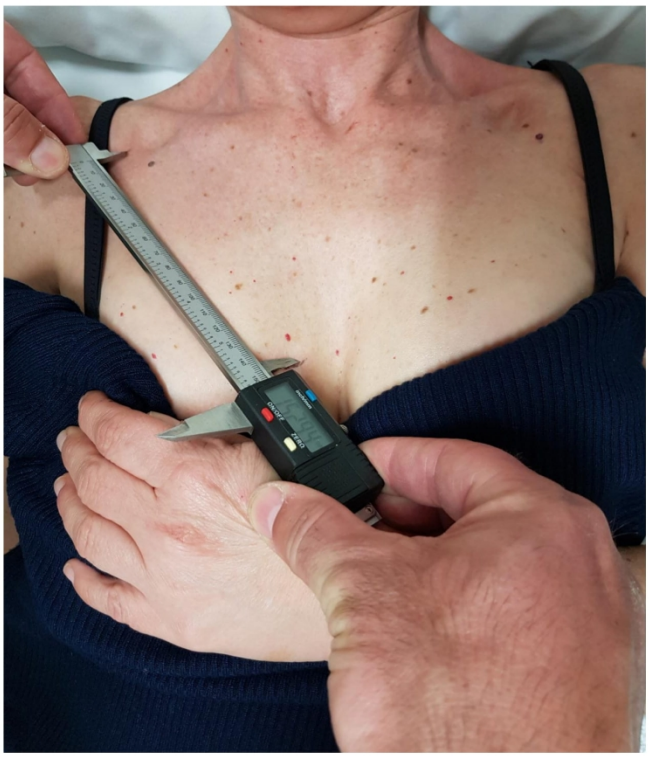

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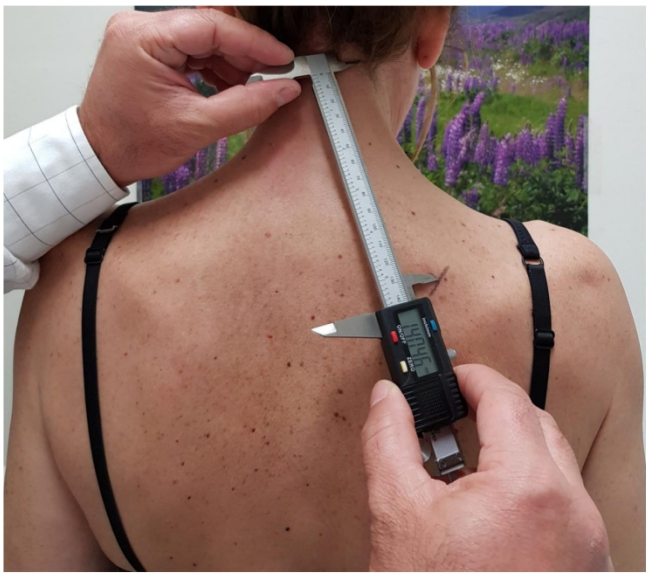

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **PAGE 1**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **PAGE 3**
Objectives	3	State specific objectives, including any prespecified hypotheses **PAGE 4**
Methods		
Study design	4	Present key elements of study design early in the paper **PAGE 4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **PAGE 4**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **PAGE 5**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **PAGE 6-7-8**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **PAGE 6-7-8**
Bias	9	Describe any efforts to address potential sources of bias **PAGE 8**
Study size	10	Explain how the study size was arrived at **PAGE 9**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **PAGE 9**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions **PAGE 9**
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **PAGE 9-12**
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **PAGE 10**
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure **PAGE 9-12**
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **PAGE 11-12**
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **PAGE 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **PAGE 15**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **PAGE 12-14**
Generalisability	21	Discuss the generalisability (external validity) of the study results **PAGE 15-16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **NON APPLICABLE**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study in a Spanish primary care setting.

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Differences in scapular upward rotation, pectoralis minor and levator scapulae muscle length between the symptomatic, the contralateral asymptomatic shoulder and control subjects: A cross-sectional study in a Spanish primary care setting.

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ABSTRACT

Objective: To determine the potential differences in both scapular positioning and scapular movement between the symptomatic and asymptomatic contralateral shoulder, in patients with unilateral subacromial pain syndrome (SAPS), and when compared to participants free of shoulder pain.

Setting: Three different primary care centres.

Participants: A sample of seventy-three patients with SAPS in their dominant arm was recruited, with a final sample size of fifty-four participants.

Primary outcome measures: The scapular upward rotation (SUR), the pectoralis minor and the levator scapulae muscles length tests were carried out.

Results: When symptomatic shoulders and controls were compared, an increased SUR at all positions (45, 90 and 135 degrees) was obtained in symptomatic shoulders (2/ 3,98/ 8,96 degrees respectively). These differences in SUR surpassed the minimal detectable change (MDC95) (0,91/1,55/2,83 degrees at 45/90/135 degrees of shoulder elevation). No differences were found in SUR between symptomatic and contralateral shoulders. No differences were found in either pectoralis minor or levator scapulae muscle length in all groups.

Conclusions: Scapular upward rotation was greater in patients with chronic SAPS compared to controls at different angles of shoulder elevation.

Keywords: scapular kinematic; shoulder pain; chronic pain

Strengths and limitations of this study

An exhaustive ultrasound and clinical assessment was carried out to avoid the inclusion of patients with rotator cuff tears.

The examiner who assessed all the measurements was an experience clinical professional.

The inter-rater reliability was not calculated, so this could introduce bias.

The minimal clinically important difference for SUR is unknown, thus we cannot make a conclusion as to whether the differences found in this study reached clinical importance or not.

INTRODUCTION

Shoulder pain is the most common musculoskeletal condition after neck pain and low back pain[1]. Shoulder pain point prevalence figures range from 6.9 to 26%, from 18.6 to 31% for 1-month prevalence, from 4.7 to 46.7% for 1-year prevalence, and from 6.7 to 66.7% for lifetime prevalence[2]. Furthermore, shoulder pain prevalence is even higher in women[3], in the working population[4], and increases with age[5].

Subacromial pain syndrome (SAPS) is the most common cause of shoulder pain[6,7]. It is defined as a non-traumatic, usually unilateral, shoulder disorder that causes localized pain around the acromion, often worsening during or subsequent lifting the arm[8]. The best therapeutic approach in SAPS is still under debate. Half of the patients with shoulder pain being attended in primary care do not completely recover after 6 months from their initial episode[9].Thus, there is a need to explore different non-invasive strategies in these patients. One of the approaches that can be beneficial for the patient is to focus on the scapulothoracic joint. To date, there is inconsistent evidence to support a relationship between SAPS symptoms and scapular orientation[6,10]. The most common causative mechanism of an altered scapular positioning involves the soft tissue, such as inflexibility (tightness) and alterations in the periscapular muscles[11]. Specifically, both a decreased activation and strength of the serratus anterior, as well as alterations in upper/lower trapezius couple forces, can alter scapular upward rotation and posterior tilt [11]. Likewise, pectoralis minor, levator scapulae muscles[12,13] and biceps short head [11] have been traditionally assessed as their shortening may potentially influence scapular positioning.

Previous studies have reported normative values on pectoralis minor length in the dominant and non-dominant side in both symptomatic and control populations, by using the pectoralis minor index (PMI)[14] and the acromion-table distance test[15]. Recently,

pectoralis minor length and its shortening have received remarkable empirical attention, in terms of studies of its reliability [16], its association with shoulder external rotation[17], and as an outcome measure after a stretching program in participants with shoulder pain[18]. However, differences between symptomatic groups and healthy controls were not calculated. To the best of our knowledge, differences in the levator scapulae index (LSI) between symptomatic and control populations have not been determined yet. With regard to patterns of movement, there is conflicting evidence. While some studies have shown association between a reduced scapular upward rotation (SUR) and scapular posterior tilt in SAPS [19,20], others attained inconclusive findings[6,10].

Advanced equipment exists to assess scapular positioning and kinematics. However, most of them are very technical and highly expensive, which makes them almost unattainable in the clinical practice[21]. In this regard, research states that the SUR seems suitably evidence-based for clinical use, while pectoralis minor length measurements should be used as supplementary clinical assessment methods in addition to others[22,23]. Additionally, the levator scapulae muscle length measurement has been shown to be a reliable tool, and it has been proposed as part of the scapula assessment because the levator scapulae directly attaches in the superior angle of the scapula[13] and thus it is another possible cause of scapular dysfunction[24].

Specifically, there is a lack of evidence on the potential differences in PMI, LSI and SUR, between painful and contralateral non-painful shoulders, and control subjects. The existence of differences in scapular positioning and pattern of movement could contribute to steer physiotherapy treatments towards a scapular focused treatment approach.

Hence, the aim of this study was to analyse the differences in scapular positioning and pattern of movement, between the symptomatic and asymptomatic shoulder, in patients with unilateral chronic SAPS, and in controls, using three different tests: i) scapular upward rotation, ii) pectoralis minor muscle length and, iii) levator scapulae muscle length. The null hypothesis (H_0) was that there are no differences in the groups in these three different tests. The alternative hypothesis (H_a) was that there is an increased SUR in painful shoulder when comparing with contralateral and control shoulder, as well as a decreased both pectoralis minor and levator scapulae length in painful shoulder.

METHOD

Study design

This was a cross-sectional, observational study, carried out in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the Health Care District where the primary care centres were located (PI9/012014). The study has been reported following the recommendations of the STROBE statement for observational studies. All the participants signed an informed consent.

Participants

A sample of seventy-three patients with chronic SAPS in their dominant arm was recruited from three different primary care centres, with a final sample size of fifty-four participants obtained after applying the inclusion criteria. General practitioners (GPs) recruited the participants who were screened for eligibility by a research assistant. Participants had to meet the following inclusion criteria: (i) men or women aged between 18 to 55 years; (ii) unilateral pain located in the anterior and/or lateral shoulder region[8]; (iii) 2 out of 3 positive clinical tests (Hawkins-Kennedy; Jobe; Neer)[25]; (iv) pain with normal activity ≥ 4/10 on a visual analogue scale; (v) shoulder pain lasting

more than three months; (vi) a history of nontraumatic onset of shoulder pain. Participants were ineligible to participate in this study if any of these conditions were present: (i) history of significant shoulder trauma, such as fracture or ultrasonography-clinically suspected full thickness cuff tear, following the classification of Wiener and Seitz, 1993[26]; (ii) recent shoulder dislocation in the past two years; (iii) systemic illnesses such as rheumatoid arthritis; (iv) adhesive capsulitis; (v) shoulder pain originating from the neck or if there was a neurological impairment, osteoporosis, haemophilia and/or malignancies.

A sample of 40 participants with both shoulders free of pain for the last year was selected. They were recruited from the same three primary care centres as the participants with shoulder pain. Furthermore, to participate in the study, they had to present: (i) a SPADI score ≤ 15 points, based on the minimal clinically detectable change for this tool[27]; (ii) negative results for Neer test, Hawkins-Kennedy test and Jobe test; iii) no painful arc present during flexion or abduction; iv) no pain during resisted lateral rotation and/or abduction. Asymptomatic participants were specifically age and gender matched to the symptomatic group.

Outcome measurements

All measurements were taken by a physiotherapist with more than 25 years of experience, including height which was necessary to calculate PMI and LSI values. This physiotherapist was blinded to the fact of participants having shoulder pain or not.

Scapular upward rotation (SUR)

The measurement of SUR was performed using two Plurimeter-V gravity reference inclinometers[28]. One inclinometer was Velcro taped perpendicular to the humeral shaft, just above the humeral epicondyle. At resting position, the humeral inclinometer was calibrated as 0 degrees. Next, the patients were instructed to perform shoulder

abduction in the coronal plane with full elbow extension and 45° of external humeral rotation, with the thumb abducted. The patients were asked to stop at 45º, 90º and 135º degrees of humeral abduction, where the SUR was measured with a second inclinometer, manually aligned along the scapular spine (Figure 1). Three measurements were collected at each position and then the mean was obtained. The arm was repositioned between measurements.

#FIGURE 1

Pectoralis minor length

The measurement of the pectoralis minor length was carried out with the participant in the supine position. A small pillow was placed under the participant's head for comfort. The participant's arm was passively placed along the side of the body in the neutral position resting on the table[29]. Because of the variability among subjects this measurement was best normalized creating a pectoralis minor index (PMI), which was calculated by dividing the resting muscle length measurement by the subject height and multiplying by 100, as previously described by Borstad et al[12]. Heigth was measured with the patient in a standing position, by using a calliper placed at the top of the head and marking a point on a scale placed on the wall. The resting muscle length was measured from the caudal edge of the 4th rib to the inferomedial aspect of the coracoid process with a sliding calliper (Figure 2). Pectoralis minor index values less than 7.65 have been identified as a shortened pectoralis minor, measured in standing position[12]. The measurement was taken during inspiration[14].

#FIGURE 2

Levator scapulae length

Participants were standing with their arms relaxed at their sides. The subjects were asked to look directly ahead without any craniocervical movement[13]. The instruction

was to palpate two anatomical reference points in line that represent levator scapulae length: (1) the dorsal tubercles of the transverse processes of the second cervical vertebrae and (2) the superior angle of the medial borders of the scapula. The assessor used a skin-marker pencil to mark the reference points. The marks were cleaned immediately after each test session. The distance between these two bony reference points was measured with a sliding calliper (Figure 3). By creating a LSI (levator scapulae length [cm]/subjects' height [cm]*100), the subjects' variability in body height was normalized[13]. The LSI was expressed as a percentage of the subjects' height.

FIGURE 3

The Shoulder Pain and Disability Index (SPADI) was assessed in all participants. The SPADI is composed of 13 questions and contains two domains: pain and disability. The score of the questionnaire ranges from 0 to 100, with very high scores indicating worse function. The numeric pain scale runs from 0 to 10, with 0 indicating no pain and10 representing the worst pain[30].The SPADI has shown a good internal consistency with a Cronbach's alpha of 0.95 for the total score, 0.92 for the pain subscale and 0.93 for the disability subscale as well as the ability to detect change over time[31].A Spanish version of the SPADI was used since English was not the native language for all the participants[32].

Data analysis

The Statistical Package for the Social Sciences (version 23.0 for Mac; SPSS Inc. Chicago, IL) was used to analyses the collected data.Normality for all variables was explored using the Kolmogorov Smirnov test for the group of participants with shoulder pain (affected and non-affected), and for the control subjects. Two different analysis strategies were carried out: first, to determine differencesin SUR at different degrees of abduction, a repeated measures ANOVA was developed in every group. For this

analysis, F statistic was adjusted in case of non-sphericity (tested by Mauchly's test), with the Greenhouse-Geissner correction. Second, to determine between-groups differences for all the outcome measurements, one-way ANOVA test was calculated with Bonferroni and Tukey post-hoc estimations. A p-value less than 0.05 was considered statistically significant.

The intraclass correlation coefficient was greater than 0.90 for all the tests, which means an excellent reliability[33], except for LSI (0.87). The MDC95 was as follows: SUR45º= 0.91; SUR90º= 1.55; SUR135º= 2.83; PMI= 0.80; LSI= 1.08.

Patient and Public Involvement

The participation of all subjects was voluntary, and no incentives were given to encourage enrollment. Patients with shoulder pain from each primary care center were not involved neither in the design of the study nor in the recruitment of the participants.The results of the present study were sent by e-mail to those participants who wanted to be informed.

RESULTS

Sample characteristics

Demographic characteristics are shown in Table 1. There were not significant differences between groups in terms of gender and age.

	Patients (mean and SD) (dominant and non dominant shoulder)	Healthy subjects (mean and SD) (dominant shoulder)
Age (yrs; CI)	46.39 (9.96)	46.42 (7.02)
Women	33 (61.1%)	23 (57.5 %)

Men	21 (38.9%)	17 (42.5 %)
SPADI (CI)	56.37 (20.01)	2.66 (2.88)
Chronicity of symptoms	3-6months: 18 6-12 months: 5 More than one year: 31	N/A

Table 1: Demographic characteristics; Mean (95% CI); N/A: non-applicable; CI= confidence interval; SPADI: shoulder pain and disability index

Mean values for the outcome measures and intra-rater reliability data

Mean values of scapular upward rotation (expressed in degrees), levator scapulae index (LSI) and pectoralis minor index (PMI)for all the groups are presented in Table 2. There were statistically significant differences in SUR when comparing the three groups, while no differences were found for the rest of the outcome measurements (LSI and PMI) (see Table 2). Furthermore, there was an increase in SUR from 45 to 90 and 135 degrees of shoulder abduction for all the groups, analysed by repeated measures ANOVA, with the following results: (i) symptomatic shoulder: $F(1,51; 80.05) = 1009.22$; $p<0.001$; (ii) asymptomatic shoulder: $F(1,46; 77.37) = 1356.57$; $p<0.001$; (iii) healthy controls: $F(1,46; 56.89) = 1196.18$; $p<0.001$

	Symptomatic shoulder	Asymptomatic shoulder	Healthy controls	F	p
SUR					
45° of GH abduction	4.55 (3.79 to 5.32)	5.71 (4.82 to 6.60)	2.55 (1.81 to 3.29)	F(2,145)=14.14	<0.001*
90°of GH abduction	20.75 (18.81 to 22.69)	21.42 (19.88 to 22.96)	16.77 (15.49 to 18.04)	F(2,145)=8.08	<0.001*
135° of GH abduction	45.18 (42.76 to 47.59)	44.16 (42.20 to 46.12)	36.22 (34.34 to 38.09)	F(2,145)=18.64	<0.001*
LSI	7.81 (7.42 to 8.20)	7.81 (7.53 to 8.30)	7.76 (7.42 to 8.11)	F(2,145)=0.02	0.978
PMI	10.52 (10.27 to 10.76)	10.86 (10.26 to 11.46)	10.07 (9.73 to 10.42)	F(2,145)=2.97	0.054

Table 2: Mean values (95%CI: confidence interval) of pectoralis minor index (PMI),levator scapulae index (LSI), and scapular upward rotation expressed in degrees (SUR) in different groups; F: One-factor ANOVA for differences in symptomatic, asymptomatic and healthy controls. Bonferroni post-hoc analysis were carried out.

*: statistically significant (p< .01).

Differences in SUR, PMI and LSI between groups

Comparisons between groups are described in detail in Table 3.There were statistical significant differences in SUR between symptomatic and control groups at 45, 90 and 135 degrees of shoulder elevation, while no differences between symptomatic and asymptomatic group were found. There were not statistically significant differences between groups for both PMI and LSI (see Table 3).

	Symptomatic vs Asymptomatic shoulder differences (95%CI)	p	Symptomatic vs Control shoulder differences (95%CI)	p
SUR				
At 45°GH abduction	-1,15 (-2,46 to -0,15)	0.09	2,01 (0,59 to 3,42)	0.003*
At 90° GH abduction	-0,67 (-3,35 to 2)	0.82	3,98 (1,08 to 6,88)	0.004*
At 135° GH abduction	1,02 (-2,41 to 4,45)	0.76	8,96 (5,24 to 12,6)	<0.001*
PMI	-0,34 (-1,04 to 0,36)	0.49	0,45 (-0,32 to 1,21)	0.351
LSI	0,00 (-0,55 to 0,55)	1	0.05 (-0,55 to 0,64)	0.98

Table 3: Between-group differences (Tukey post-hoc analysis)

CI: confidence interval; SUR: scapular upward rotation; GH: glenohumeral; PMI: pectoralis minor index; LSI: levator scapulae index

*: statistically significant ($p<0.05$)

DISCUSSION

This study aimed to explore potential differences in scapular positioning and scapular pattern of movement between the symptomatic shoulder in patients with chronic SAPS,

compared to the contralateral asymptomatic, and control shoulders. We found statistical significant differences in the three groups in SUR at 45, 90 and 135 degrees of shoulder elevation. Specifically, an increased SUR at all positions (45, 90 and 135 degrees) was found in favour of the symptomatic shoulders when symptomatic and control participants were compared. No differences were found between symptomatic and asymptomatic groups. Hence, our hypothesis was only partially confirmed. Regarding PMI and LSI, there were no significant differences in the groups, thus, our hypothesis was not confirmed.

This is the first study that compares SUR, PMI and LSI between both symptomatic and asymptomatic shoulders in patients with SAPS, and between symptomatic shoulder with control subjects, using accessible and low-cost tools. Previous studies have reported differences in SUR during arm elevation between the symptomatic and the asymptomatic shoulder[19,20,34], showing a decreased SUR in the symptomatic shoulders, mainly within the first degrees of elevation in the scapular plane. We found a significantly increased SUR in the symptomatic shoulder of patients when compared with control subjects. These differences surpassed the MDC95 in all the positions (45, 90 and 135 degrees of shoulder elevation). This is not supported by current literature, which suggests the presence of a decreased SUR in shoulders with subacromial symptoms compared to healthy controls[19,34,35] This can be explained by the fact that patients that were included in our study experienced shoulder pain of a long duration, meaning chronicity of symptoms. In this context, the firing pattern of scapular muscle units can change, generating an early SUR in an attempt to avoid pain. This altered pattern has been found in a recent study[36] . It can be hypothesized that early stages of SAPS could present a deficit in SUR while more advanced stages can develop a compensatory increased SUR. As this was not measured in this study, further

investigation is needed to confirm that. In other shoulder conditions, current research analysing SUR in both symptomatic and pain-free shoulders does not sustain strong conclusions. Kijima et al.[37] showed an absence of differences in SUR, measured by a 3-dimensional scapular kinematic analysis, in symptomatic rotator cuff tears, contralateral shoulder and healthy shoulders. Furthermore, Hung et al.[38]reported no differences in SUR, measured by 3-dimensional analysis, in patients with glenohumeral instability and healthy controls.

With regard to the pectoralis minor length, there was an absence of statistical significant difference between the symptomatic and the asymptomatic shoulders, as well as in symptomatic shoulder patients when compared with controls. This finding was contrary to what was expected, since a more anterior tilted positioning of the scapula is thought to be correlated with a potential risk of SAPS. Our results are in line with those obtained by Struyf et al.[14] The aforementioned study showed PMI values of 9.17 (SD 0.54) in the dominant side in the control group, 9.66 (SD 0.68) in the symptomatic side and 9.64 (SD 0.72) in the asymptomatic side in the patient group, but they did not study the statistical differences between groups. On the other hand, Lewis et al. [15]also reported values that analysed pectoralis minor length. Nevertheless, comparisons with the present study are not possible as the used test was different (acromion-table distance test). To our knowledge there are no studies investigating these potential differences. Previous studies[12]have found a similar scapular behaviour to those suffering from SIS, in healthy subjects with a shortened pectoralis minor. Likewise, pectoralis minor length presents a weak positive correlation with the acromiohumeral distance in healthy male athletes[29], which means that the pectoralis minor could have a slight influence in the scapular positioning in the case of shortening. However, based on the results

obtained in the present study, and also on previous inconsistent evidence on this topic [6,10],a shortened pectoralis minor does not seem to play a key role in patients with chronic SAPS, when compared to contralateral non-affected shoulders and control subjects.

In relation to levator scapulae length, there was an absence of differences between symptomatic and asymptomatic shoulder in patients, and between symptomatic shoulder and controls in this study. As far as we know, this is the first study that analyses such differences between subjects with shoulder symptoms and controls, so comparisons with others are difficult. It is thought that a shortened levator scapulae can produce a scapula more downwardly rotated[13] and, hence, a greater compromise of the subacromial space during overhead movements. As we did not determine the scapular position in this study, a conclusion on the absence of differences in levator scapulae length in different groups cannot be made, thus further studies are needed in this field.

Some strong points from this study need to be mentioned. First, an exhaustive ultrasound and clinical assessment to avoid the inclusion of patients with rotator cuff tears, was carried out. Second, the examiner who assessed all the measurements had extensive clinical experience.

On the other hand, some limitations need to be recognized. As only one examiner assessed all the outcome measures, inter-rater reliability was not calculated, so this could introduce bias. Moreover, as the minimal clinically important difference of SUR is unknown, we cannot make a conclusion as to whether the differences found in this study have clinical importance or not. Our results should be taken with caution when

interpreted, as a sample with chronic SAPS was studied, so we do not know if these results can be extrapolated to other populations, e.g. acute shoulder pain. Lastly, including healthy controls by using a SPADI score below 15 points could mean bias.

The present results could have clinical implications, and could contribute to increase the body of knowledge in the field of scapular biomechanic tests. First, it seems that pectoralis minor and/or levator scapulae are not distinguishing factors when comparing the symptomatic and the contralateral asymptomatic shoulder in subjects suffering from SAPS. Second, the use of the SUR test at 45°, 90° and 135° of shoulder elevation may be useful in the assessment of shoulder conditions when compared to values from control subjects.

Further research that analyses levator scapulae length and scapular positioning, and the minimal clinical important difference in SUR, would contribute to enhance knowledge in this field. Moreover, studies analysing changes in SUR and pectoralis minor length after application of physical therapies are necessary to corroborate their contribution, as indicators of improvement, when patients with chronic SAPS are treated.

In conclusion, SUR is greater in patients with chronic SAPS when compared with controls at different angles of shoulder elevation, and is also greater in PMI values at rest position. The usefulness of the present findings is theorized, but further studies to confirm this in clinical practice are needed.

Contributor ship statement

The presented work follows the ICMJE recommends for authorship, based on the following 4 criteria:

All authors have made substantial contributions to the conception or design of the work (SNL and ALS); or the acquisition (SNL, MFS and ALS), analysis (JMMA and ALS), or interpretation of data for the work (SNL, and ALS); AND

Drafting the work or revising it critically for important intellectual content (SNL, MFS, FS, JMC, JMMA and ALS); AND

Final approval of the version to be published (SNL, MFS, FS, JMC, JMMA and ALS); AND

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition, authors have confidence in the integrity of the contributions of their co-authors.

Competing interests

All authors state that the funders had no role in the study and they have no conflicts of interest to declare. All authors have made a substantial scientific contribution to the study and they are thoroughly familiar with the primary data. All authors have read the complete manuscript and take responsibility for the content and completeness of it and understand that if the paper, or any part of it, is found to be faulty or fraudulent, all authors share responsibility.

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Data sharing statement

The data sharing statement is currently not available due to a secondary analysis is being made. However, the available data can be obtained by contacting the corresponding author when the whole work is finished.

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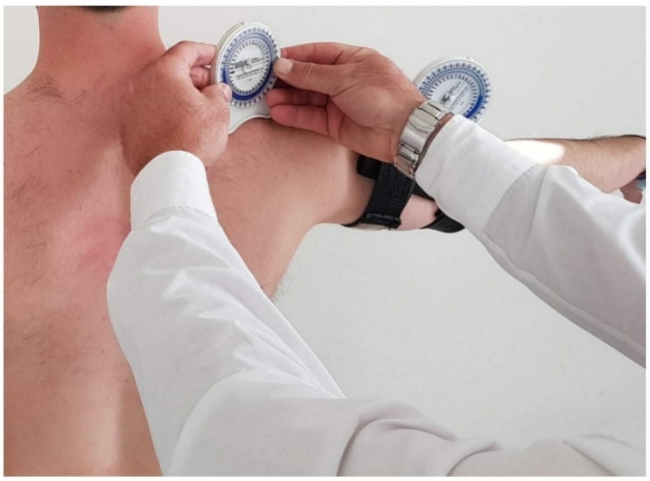
LEGENDS

Figure 1: Scapular upward rotation measurement.

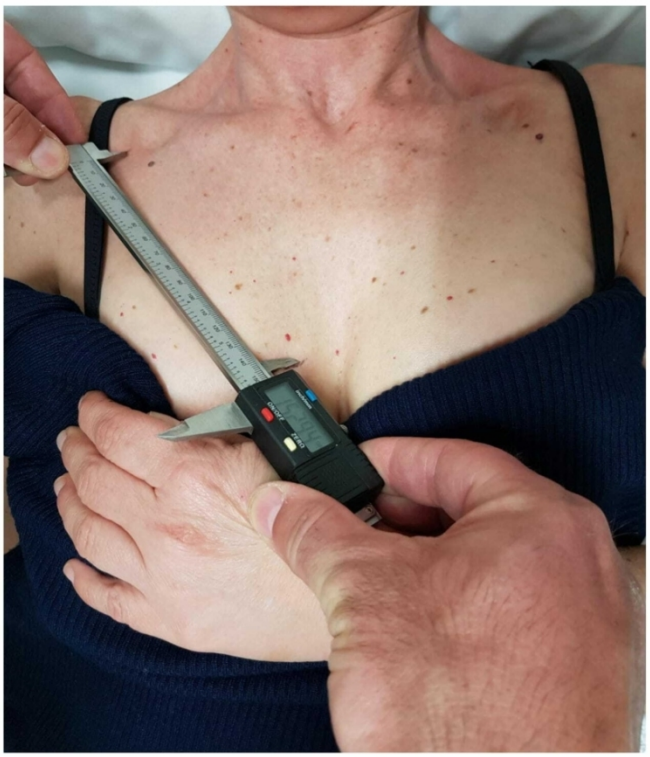
Figure 2: Pectoralis minor length measurement.

Figure 3: Levator scapulae length measurement.



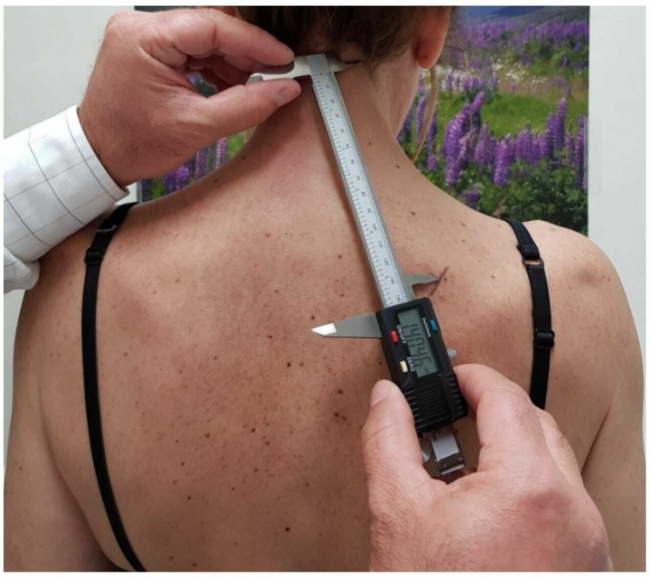
Scapular upward rotation measurement.

90x127mm (300 x 300 DPI)



Pectoralis minor length measurement.

90x127mm (300 x 300 DPI)



Levator scapulae length measurement

90x127mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **PAGE 1**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **PAGE 3**
Objectives	3	State specific objectives, including any prespecified hypotheses **PAGE 4**
Methods		
Study design	4	Present key elements of study design early in the paper **PAGE 4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **PAGE 4**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **PAGE 5**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **PAGE 6-7-8**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **PAGE 6-7-8**
Bias	9	Describe any efforts to address potential sources of bias **PAGE 8**
Study size	10	Explain how the study size was arrived at **PAGE 9**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **PAGE 9**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions **PAGE 9**
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **PAGE 9-12**
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **PAGE 10**
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure **PAGE 9-12**
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included **PAGE 11-12**
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **PAGE 12**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **PAGE 15**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **PAGE 12-14**
Generalisability	21	Discuss the generalisability (external validity) of the study results **PAGE 15-16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **NON APPLICABLE**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.