Original Research

Relationship Between Shoulder Impingement Syndrome and Thoracic Posture

Donald J. Hunter, Darren A. Rivett, Sharmain McKeirnan, Lyn Smith, Suzanne J. Snodgrass

Background. Shoulder impingement syndrome (SIS) is the most common form of shoulder pain and a persistent musculoskeletal problem. Conservative and invasive treatments, aimed at the shoulder joint, have had limited success. Research suggests shoulder function is related to thoracic posture, but it is unknown whether thoracic posture is associated with SIS.

Objective. The objective of this study was to investigate whether there is a relationship between SIS and thoracic posture.

Design. This was a case control study.

Methods. Thoracic posture of 39 participants with SIS and 39 age-, gender-, and dominant arm-matched controls was measured using the modified Cobb angle from a standing lateral radiograph. Thoracic range of motion (ROM) was also measured using an inclinometer. Between-group differences were compared using t tests. The relationship between thoracic posture and thoracic ROM was determined with linear regression.

Results. Twenty women and 19 men with SIS (mean age = 57.1 years, SD = 11.1) and 39 age-matched, gender-matched, and dominant arm-matched controls (mean age = 55.7 years, SD = 10.6) participated. Individuals with SIS had greater thoracic kyphosis (mean difference = 6.2°, 95% CI 2.0–10.4) and less active thoracic extension (7.8°, 95% CI = 2.2–13.4). Greater thoracic kyphosis was associated with less extension ROM (ie, more flexion when attempting full extension: $\beta = 0.71$, 95% CI = 0.45–0.97).

Limitations. These cross-sectional data can only demonstrate association and not causation. Both radiographic measurements and inclinometer measurements were not blinded.

Conclusion. Individuals with SIS had a greater thoracic kyphosis and less extension ROM than age- and gender-matched healthy controls. These results suggest that clinicians could consider addressing the thoracic spine in patients with SIS.

D.J. Hunter, BAppSc(Osteo), MOsteo, Discipline of Physiotherapy, School of Health Sciences, The University of Newcastle, Callaghan, NSW 2308, Australia. Address all correspondence to Mr Hunter at: Donald.hunter@uon.edu.au.

D.A. Rivett, BAppSc(Phty), MAppSc(ManipPhty), PhD, Discipline of Physiotherapy, School of Health Sciences, The University of Newcastle.

S. McKiernan, BAppSc(MedRadTech), Hons, PhD, Discipline of Physiotherapy, School of Health Sciences, The University of Newcastle.

L. Smith, MB BCh, Discipline of Physiotherapy, School of Health Sciences, The University of Newcastle.

S.J. Snodgrass, BSc(PhysTher), MMedSc(Physio), PhD, Discipline of Physiotherapy, School of Health Sciences, The University of Newcastle.

[Hunter DJ, Rivett DA, McKiernan S, Smith L, Snodgrass SJ. Relationship between shoulder impingement syndrome and thoracic posture. *Phys Ther.* 2020;100:677–686.]

Published Ahead of Print: December 11, 2019
Accepted: August 21, 2019
Submitted: December 17, 2018

Shoulder pain and dysfunction is a common and costly problem.[1–3] The estimated cost of treatment of shoulder dysfunction in the United States in 2000 was $7 billion.[1] In a study in the Netherlands conducted over 10 years, Greving et al[4] found shoulder complaints to be the third most common musculoskeletal cause of visitation to general practice, with an average incidence of 29.3 per 1000 person-years and an annual prevalence of 41.2 to 48.4 per 1000 person-years.[4]

Shoulder impingement syndrome (SIS) is the most common cause of shoulder pain.[5] SIS is a diagnosis that relates to pain from pathologies within the subacromial space above the glenohumeral joint. Different authors have used alternative, but synonymous, names for SIS, including outlet impingement syndrome[6] and subacromial impingement syndrome.[7,8] Pathologies related to SIS include subacromial bursitis, tendonitis of the rotator cuff, partial thickness and/or full thickness rotator cuff tears, and rotator cuff degeneration.[9,10] Two observational studies[11,12] and a systematic review[13] of rotator cuff disease all reported a minimal presence of SIS younger than the age of 40 years, with prevalence consistently increasing with age over 40 years.[14]

A recent systematic review of interventions for SIS concluded the effectiveness of surgical or conservative therapies targeting the shoulder joint was limited.[15] Though approximately 23% of all new episodes of shoulder pain resolve within 6 months, at least one-half persist beyond 12 months.[16] Hence, SIS is a common and costly problem for which current treatments are not often effective. This suggests that new strategies should be explored to better understand and manage this condition.

The thoracic spine is an anatomical area that has been suggested to influence the function of the shoulder. Research evidence, using both people with shoulder pain and asymptomatic participants, suggests that decreasing thoracic kyphosis may increase shoulder range of motion (ROM).[8,17,18] Hence, increased thoracic kyphosis may be related to decreased shoulder ROM, which may lead to SIS. Given thoracic kyphosis progressively increases with age[19–21] and the prevalence of SIS steadily increases from age 40 years,[14] the relationship between thoracic posture and SIS is worth investigating.

Several authors have investigated possible associations between thoracic posture and SIS.[6,22–25] However, Alizadehkhaiyat et al[25], Lewis et al,[22] and McClure et al[24] all included participants in their twenties, while Alizadehkhaiyat et al[25] and McClure et al[24] used thoracic kyphosis measures not yet validated. Only 2 studies (Otoshi et al[23] and Theisen et al[6]) have focused on individuals over 40 years despite the presence of SIS being much greater in this age group.[11–13] Otoshi et al[23] found a significant association between thoracic posture and SIS, while Theisen et al[6] did not. Both studies used measures of thoracic kyphosis that were not validated.

The gold standard for measuring thoracic kyphosis is the modified Cobb angle from a lateral radiograph (termed "modified" as the original Cobb angle was designed for coronal plane radiographs).[26] Theisen et al[6] did find a significant association between a restriction in thoracic spine ROM (a measure combining both thoracic flexion and extension ROM) and the presence of SIS.

The gold standard for diagnosing the pathologies related to SIS is arthroscopic or open surgery.[27–29] However, given surgery is not often required for people with SIS, imaging techniques such as magnetic resonance imaging (MRI) and ultrasound are commonly used to diagnose the presence of SIS.[30,31] Ultrasound is noninvasive and has no side effects; it is also easily and quickly performed in the clinic and costs less than MRI.[30] Early studies questioned the accuracy of ultrasound in detecting partial rotator cuff tears.[32] However, recent advances in technology have improved ultrasound diagnosis of all types of pathologies associated with SIS.[33] Vlychou et al[34] compared the findings of ultrasound and MRI to surgery for the detection of partial rotator cuff tears and reported ultrasound had a sensitivity of 95.6%, specificity of 70%, accuracy of 91%, and a positive predictive value of 93.6% (better than MRI).[34] Another recent study found ultrasound to be significantly more specific than MRI (specificity: ultrasound 90.1%, MRI 72.6%) in the detection of partial thickness rotator cuff tears, with the authors recommending ultrasound as the investigation of choice in the diagnosis of rotator cuff tears.[35] Similarly, Kayser et al[36] evaluated the diagnosis of calcific tendinitis compared with surgery and found ultrasound had a sensitivity of 1.0, specificity of 0.98, and accuracy of 98.3%.[36]

One limitation of ultrasound is it is somewhat operator dependent; it is desirable that an experienced musculoskeletal ultrasonographer performs the ultrasound imaging and an experienced musculoskeletal radiologist interprets the ultrasound findings.[30,37] This is highlighted in the study by Kayser et al[36] in which they evaluated the accuracy of ultrasound against surgery in diagnosing subacromial bursitis. The study averaged the findings of 2 ultrasonographers, one much more experienced, in diagnosing subacromial bursitis and found a mean sensitivity of 0.79, with a specificity of 0.98.[36] However, the more experienced examiner had a sensitivity of 0.92 with a specificity of 0.99.[36] In summary, given ultrasound image quality has greatly improved with advancements in technology,[33] more recent studies now recommend ultrasound as the best imaging option for people with shoulder pain provided it is performed by a qualified musculoskeletal ultrasonographer experienced in shoulder imaging.[27,28,30,33,38] Hence, ultrasound was selected as the recommended and noninvasive method to be used in the current study for diagnosing the presence of SIS.

This study therefore investigates whether there is an association between SIS and increased thoracic kyphosis and decreased thoracic spine ROM using appropriately aged participants, a valid measure of thoracic kyphosis, and a valid tool for the diagnosis of SIS.

Method and Materials

Participants

Participants recruited were between 40 and 80 years of age, given the increase in prevalence of SIS from the age of 40 years.[11–13] One group were people who had shoulder pain lasting at least 3 months and diagnosed by a radiologist using ultrasound as having SIS. The second group were age-, gender-, and dominant arm-matched asymptomatic participants confirmed as not having SIS by a radiologist using ultrasound. Both groups had not sought treatment for symptoms in their shoulder, back, or neck within the previous 3 months. The asymptomatic participants had never had shoulder symptoms lasting longer than 3 weeks.

Exclusion criteria for both groups included any condition where undertaking a radiograph was contraindicated (eg, pregnancy); any history of previous traumatic injury or surgery to the shoulder, neck, or back; and any known, diagnosed malignancy, infectious disease, inflammatory disease, or neurological condition (eg, multiple sclerosis or stroke) that could affect the shoulder or spine.

Potential participants were sourced using community advertising and a volunteer research register maintained by a local research institute. Advertising within the general community was in the form of a flyer advertisement displayed on noticeboards throughout a university campus, on local public noticeboards in shopping centers, on private health professional practice noticeboards, and on local radio online noticeboards. The volunteer research register was a list of individuals in the community who had previously agreed to have their contact details listed as being potential participants in research. Potential participants contacted the primary researcher, and a telephone screening for inclusion and exclusion criteria was performed before attendance at the data collection session.

This study complies with the Declaration of Helsinki. Human ethics approval was obtained from the University of Newcastle Human Research Ethics Committee (H-2014-0192), and all participants provided written informed consent before their commencement in the study.

Participant Characteristics

The participant's age, height, and weight were recorded using a stadiometer (Health-o-meter, Bridgeview, IL, USA) and standard analogue scales (A & D, Seven Hills, NSW, Australia).[39] From the height and weight measurements, a score for body mass index (BMI) was obtained. Shoulder pain and disability were quantified using 2 questionnaires: the Disabilities of the Arm Shoulder and Hand (DASH; minimal detectable change [MDC] 7.9–14.8 points[40]; minimal clinically important difference [MCID] 10.2 points[40]; test-retest reliability, intraclass correlation coefficient [ICC] 0.93–0.98[40]) and the Shoulder Pain and Disability Index (SPADI; MDC 18.0 points[41]; MCID 8–13.2 points[41]; test-retest reliability, ICC = 0.84–0.95[40]). The DASH and SPADI have both been shown to be valid and have excellent reliability relating to a number of shoulder complaints, including SIS.[41,42] Pain intensity was also measured using a visual analogue scale (MDC 11 mm[43]; MCID 14 mm[44]; test-retest reliability, ICC = 0.71–0.99[45]) anchored by "no pain" on the left and "worst pain imaginable" on the right, where participants were asked to rate their average shoulder pain over the previous 4 weeks.

Thoracic Posture Measurement

To compare the thoracic posture of each group, the modified Cobb angle for each participant was recorded. To measure the modified Cobb angle, a single standing lateral x-ray of the thoracic spine was taken. Participants stood with their left side to the x-ray bucky and were aligned with the x-ray field. They were given the single instruction "leave your arms by your sides and face the wall," and they could breathe normally while the x-ray was taken. These instructions were used to capture their normal resting posture, without adjustments that might be made if additional instructions were provided. A digital image of the thoracic spine was recorded. From this image, the modified Cobb angle was automatically calculated using the "Cobb" tool of the Merge PACS software package (Merge PACS, version 3.6, Merge Healthcare, Hartland, WI, USA). The greater the angle calculated for the modified Cobb angle, the greater the thoracic kyphosis (the more hunched an individual). For the current study, the modified Cobb angle measured from the lateral thoracic spine radiograph was the angle created by the intersection of the lines formed from the extension of the top endplate of T1 and the extension of the top endplate of T10 (Fig. 1). The top endplate of T10 was used due to it being the most inferior vertebral endplate able to be seen on every participant's radiograph (due to other anatomy obscuring the vertebrae below). By using a radiographic computer package to calculate the angle, a consistent and accurate value for the modified Cobb angle was obtained.[46] Reliability for measuring the modified Cobb angle from T1 to T10 from digital radiographs using the same Merge PACS software has already been established as good to excellent for both intra- and interrater measures (intrarater reliability ICC[2,1] = 0.99, 95% CI = 0.98–1.00 and ICC[2,1] = 0.88, 95% CI = 0.71–0.95; interrater reliability ICC[2,1] = 0.89, 95% CI = 0.73–0.96).[47]

Thoracic ROM Measurements

For accuracy, participants were asked to remove all upper body clothing, with women wearing a gown open at the back. Two pencil marks were placed on the skin over the spine on the C7 and T12 spinous processes. The C7

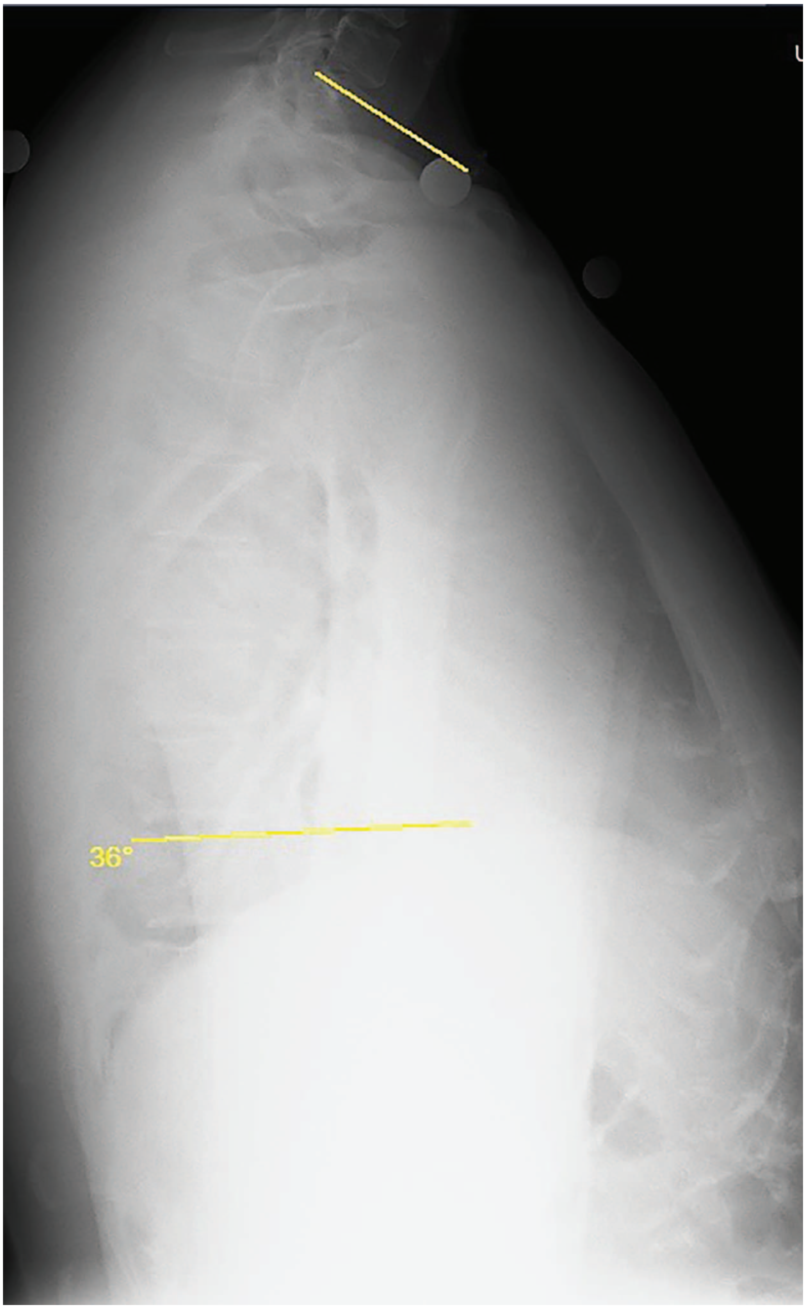

Figure 1.
The modified Cobb angle is the angle created by the intersection of the lines formed from the extension of the top endplate of T1 and the extension of the top endplate of T10.

spinous process was found using palpation, as the C7 spinous process is the most prominent at the cervico-thoracic junction.[48] To ensure the researcher was at the anatomically correct location, the participant was instructed to extend their neck and head. During cervical extension, the C7 spinous process should not move while the C6 spinous process moves anteriorly.[49] Shin et al[49] found this technique to be more accurate than simply relying on the C7 spinous process to be the most prominent.[49]

Lumley[48] has stated the most precise spinal landmark in the lower thoracic and lumbar spine is found by identifying L4 using a line drawn between the iliac

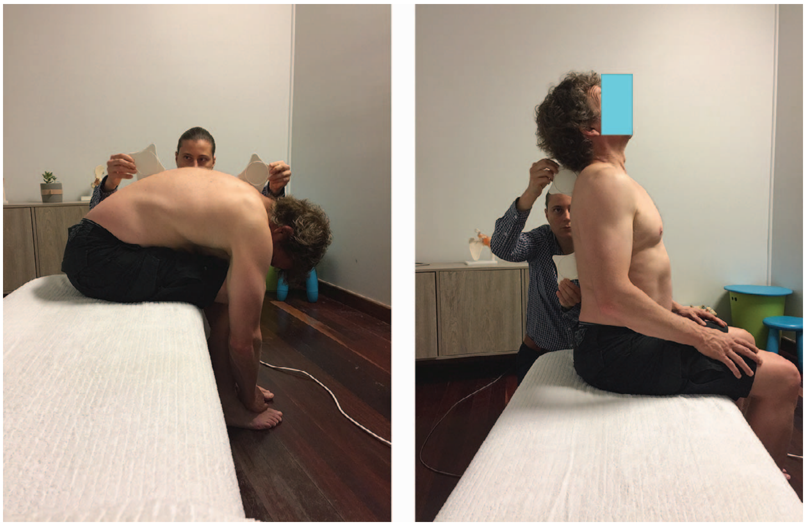

Figure 2.
The cephalad and caudal inclinometer placements for the participant flexed (A) and extended (B). The inclinometer measurement was obtained by subtracting the inclinometer reading on the lower part of the spine from the inclinometer reading from the upper part of the spine. Positive angles represented any angle in the direction of forward flexion away from the vertical.

crests.[48] Hence, T12 was identified in the current study by first locating L4 using the technique described by Lumley[48] and then counting up the spinous processes to T12 using palpation.

A clinical measure for assessing the ROM in flexion, and extension of the thoracic spine was performed using an inclinometer.[50] The intrarater and interrater reliability of this measurement have previously been found to be good to excellent.[51,52] Participants were seated on a bench, feet flat on the floor, and instructed to sit comfortably and look straight ahead to the wall in front of them. A gravity-dependent (analogue) bubble inclinometer (Baseline bubble inclinometer, Fabrication Enterprises Inc., White Plains, NY, USA) was zeroed on a vertical wall prior to measuring this neutral seated position. Using the standard clinical procedure, the cephalic foot of the inclinometer was placed on the pencil mark on the C7 spinous process.[50] This procedure was repeated for the lower thoracic spine, with the caudal foot of the inclinometer placed on the pencil mark made for T12. Both inclinometer angles were recorded, taking care to minimize parallax error with each measurement, by ensuring eye level was in the same horizontal plane as the inclinometer.

First, the thoracic kyphosis measure (in degrees) for this neutral seated position was obtained by taking the difference between the 2 inclinometer measurements. From this natural sitting position and without removing the inclinometers from their position on the spine, participants were then asked to bend forward from the waist as far forward as possible (Fig. 2A). Inclinometer readings were again taken with the participant in this position. The result of subtracting the caudal inclinometer reading from the cephalad inclinometer reading represented the participant's maximum thoracic flexion ROM. To calculate the maximum extension thoracic ROM, the participant was asked to sit upright, then extend their thoracic spine as far as possible, taking their head back as far as comfortable (Fig. 2B). The inclinometer measurements were made and recorded in the same manner. Any inclinometer measurement recorded forward of vertical was a positive angle, and any measure backward of vertical was recorded as a negative angle. All measurements were made by a registered and experienced osteopath.

Ultrasound

As discussed earlier, ultrasound is recommended as a valid tool in diagnosing the various pathologies of SIS. Hence, ultrasound was utilized to ensure each participant in both groups fulfilled the relevant inclusion criteria. To confirm a participant was suffering from SIS, the ultrasound was performed by an experienced ultrasonographer on the affected shoulder of participants in the SIS group and the shoulder of the matched asymptomatic participant. SIS was confirmed if any evidence existed of bursitis or any rotator cuff abnormality, including tears, tendonitis, or degeneration. The diagnosis of SIS could also be dynamic if the sonographer noticed signs of complete or partial blocking of humeral head motion, or bunching of the bursa and/or tendon at the acromion during shoulder abduction.[53–56] The ultrasound images were then read by an experienced radiologist and the diagnosis of SIS confirmed for participants suspected of having SIS and the absence of SIS confirmed for the healthy participants.

Statistical Analysis

To estimate the number of participants necessary for this study, a sample size calculation was performed using the STATA statistical package (version 13, College Station, TX, USA). To detect a 5-degree difference in modified Cobb angles between groups with a standard deviation of 10 degrees (estimated from Katzman et al[19] and Fon et al[20]), it was determined that 34 participants would be required for each group to detect a difference in the thoracic posture measure with a power of 80% and a 5% level of significance. A target sample size of 40 participants per group was selected to ensure adequate power.

Descriptive statistics were calculated for participant characteristics (age, height, and weight), shoulder disability questionnaires (DASH, SPADI), and pain (visual analogue scale) scores.

T tests were then used to determine differences in age and BMI between groups and to compare the mean modified Cobb angles from the digital radiographic images and the measures of thoracic ROM from the inclinometer readings between groups. A linear regression analysis with thoracic extension as the dependent variable and modified Cobb angle as the independent variable was performed to assess whether a participant's ability to extend their spine was related to their degree of thoracic kyphosis.

Results

Ninety-one potential participants attended for data collection following telephone screening. Five of the potential participants provisionally thought to have SIS were subsequently deemed not to have SIS because there was no evidence of SIS on ultrasound. A further 6 participants were not included due to acromio-clavicular joint abnormalities observed on ultrasound (acromio-clavicular joint injuries were excluded due to the potential of the injury being caused by trauma, one of the exclusion criteria). A further 2 participants (one from the SIS group and one from the healthy group) were also excluded on examination of the ultrasound images by the radiologist, because they were found not to meet the inclusion criteria. Hence, 78 individuals participated, with 39 asymptomatic individuals (20 females) and 39 (19 females) with SIS (Fig. 3 depicts a flowchart of recruitment). Age, height, weight, shoulder disability (DASH and SPADI), and pain scores are reported in Table 1.

The groups were well matched for age with no significant differences between groups. Participants with SIS had significantly higher BMI than those without shoulder symptoms (mean difference 3.53, 95% CI = 1.49–5.57, $P < .001$). Hence, a linear regression was utilized to assess whether BMI was related to static thoracic posture. With modified Cobb angle as the dependent variable and BMI as the independent variable, it was established there was no significant relationship between BMI and an individual's thoracic posture ($\beta = 0.12$, 95% CI −0.33 to 0.58, $P = .60$, $R^2 = 0.00$). Performing the same regression analysis but only for participants with SIS established a negative relationship ($\beta = -0.53$, 95% CI = −1.12 to 0.07, $P < .001$, $R^2 = 0.05$). That is, as an individual's BMI increased, their thoracic kyphosis decreased.

Comparisons between the SIS and asymptomatic control groups for thoracic posture from the lateral radiograph, and thoracic ROM, from the inclinometer measurements, are listed in Table 2.

There was a statistically significant mean increase (6.2°, 95% CI = 2.0–10.4) in thoracic kyphosis (modified Cobb angle) in participants with SIS compared with the healthy controls. Participants with SIS were also significantly less able to extend their thoracic spines (mean 7.8°, 95% CI = 2.2–13.4) and had decreased mean total thoracic spine ROM (6.1°, 95% CI = 0.86–11.41) compared with asymptomatic participants. Only 3 of the 78 participants were able to move their thoracic spine into extension past the vertical (ie, there were only 3 negative values for thoracic extension). Thus, all participants were still in some degree of flexion when they attempted to extend their thoracic spines as far as possible (as illustrated in Fig. 2). The mean thoracic extension value for the SIS group participants was 24.2° (SD = 13.2), meaning they were flexed by a mean of 24.2° when they attempted full extension, whereas the asymptomatic group controls were flexed by a mean of 16.4° (SD = 11.6) when they attempted full extension. Hence, the SIS group participants were less extended (ie, more flexed), on average, than the asymptomatic group controls when they tried to extend their thoracic spines as far as possible.

There was a significant association between the modified Cobb angle and thoracic extension ROM ($\beta = 0.71$, 95% CI = 0.45–0.97, $P < .001$, $R^2 = 0.28$). That is, as thoracic kyphosis increased, thoracic spine extension decreased (positive β denotes an amount of flexion as thoracic kyphosis angle increased).

Discussion

To the best of the authors' knowledge, this is the first study to investigate a possible relationship between thoracic posture and SIS using the gold standard of a lateral thoracic spine radiograph for measuring thoracic posture and a valid diagnosis of SIS by radiologist-confirmed ultrasonography. The results of this study indicate that participants with SIS had significantly greater thoracic kyphosis (6.2° on average, as measured by modified Cobb angle on radiograph while standing in a relaxed posture) compared with asymptomatic participants matched by age, gender, and dominant arm. Because thoracic kyphosis may be potentially modifiable

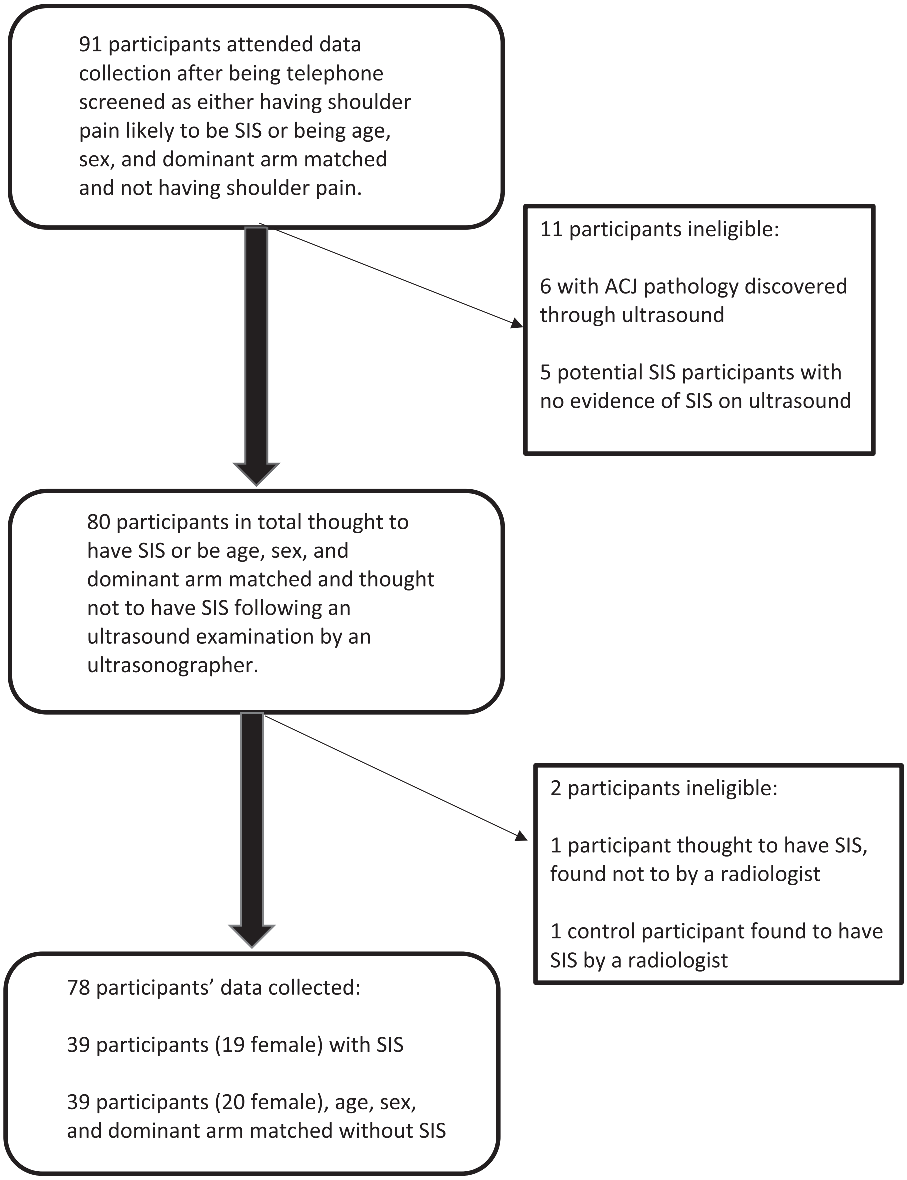

Figure 3.
Flowchart of recruitment.

with physical interventions (such as manual therapy or exercise), clinicians may consider this in their management of patients with SIS.

Otoshi et al[23] in a sample of 2144 participants over 40 years of age also found a significant relationship between SIS and participants with increased thoracic kyphosis.[23] Otoshi et al[23] used the wall-occiput test to compare participants' thoracic kyphosis. This test is considered positive if a participant is unable to put their occiput against a wall when their back and heels are already contacting the wall, but there was no calculation of an actual angle of kyphosis.[23] Theisen et al,[6] in a similar age sample to the current study, did not find a significant relationship between SIS and static seated thoracic kyphosis as measured by ultrasound topometry, though they did find that participants with SIS had significantly decreased thoracic mobility (a summation of both flexion and extension measurements) compared with participants without SIS. Further, their definition of SIS excluded any rotator cuff lesion and had to involve an abnormality of the acromion as defined by Bigliani.[57] Hence, SIS participants in the Theisen et al[6] study somewhat differed from participants in the present study. Theisen et al[6] also used ultrasound for their seated static thoracic posture measure, which the authors reported had not been tested

Table 1.
Mean Characteristics of Participants With SIS (N = 39) and Age-, Gender-, and Dominant Arm-Matched Healthy Control Participants (N = 39)[a]

Characteristic	SIS Group (SD)	Control Group (SD)
Age, y	57.1 (11.1)	55.7 (10.6)
Height, cm	170.0 (8.0)	166.8 (9.3)
Weight, kg	84.8 (17.6)	71.9 (13.3)
BMI, kg/m^2	29.3 (5.3)	25.7 (3.5)
SPADI, /100	43.3 (11.5)	——
DASH, /100	26.7 (12.5)	——
VAS, average over 4 wk	3.8 (1.8)	——

[a]BMI = body mass index; DASH = Disabilities of the Arm Shoulder and Hand questionnaire; SIS = shoulder impingement syndrome; SPADI = Shoulder Pain and Disability Index questionnaire; VAS = visual analogue scale.

for reliability or validity in measuring posture of the thoracic spine. It is therefore difficult to compare the current study's findings with those of other studies using participants of similar ages considering the differences in measurement methods for thoracic kyphosis.

Other previous studies that did not find any relationship between thoracic kyphosis and SIS[22,24,25] used samples involving participants in their teens, 20s, and 30s. The current study excluded individuals younger than 40 years of age, because the presence of SIS is much greater in individuals older than 40 years,[11–13] suggesting a potentially different etiology of SIS compared with investigations of SIS in participants of younger ages.

The ability of all participants to extend their thoracic spine in the current study was shown to decrease as participants' modified Cobb angle increased. This was not unexpected, because when the spine is naturally positioned in greater flexion for long periods of time, it may be expected to have more difficulty moving into extension. Previous studies[8,17,18,58] in participants with and without SIS have also shown decreased shoulder ROM to be associated with decreased thoracic extension. Perhaps clinicians should thus consider measuring thoracic extension in patients with SIS and possibly provide interventions to increase thoracic extension, though further research would be needed to determine the efficacy of such interventions.

Limitations

This was a cross-sectional study investigating posture at 1 point in time; thus, only associations between thoracic kyphosis and SIS are demonstrated, and findings do not imply causation. Although it appears that thoracic kyphosis may be a risk factor for SIS, given this is a cross-sectional study, it is possible this is not true. Further, it is unclear whether a greater thoracic kyphosis from a young age or an increased rate of the development of thoracic kyphosis would increase the risk for developing SIS. A large longitudinal study following, initially younger, people over several decades would be required to confirm whether increased thoracic kyphosis is indeed a risk factor for SIS.

Another limitation of this study was the lack of blinding for the researcher measuring the modified Cobb angle and for the researcher measuring the thoracic ROM with the inclinometer. However, the radiologist diagnosing SIS was blinded to symptomatic status.

Mean BMI significantly differed between groups and might be hypothesized to affect the inclinometer measurements, where the instruments are placed on the skin along the spine. However, it would have been very difficult and potentially unethical to match participants for BMI.

Table 2.
Mean (SD) Values and T Test Results of Comparisons Between Individuals with SIS (N = 39) and Healthy Age-, Gender-, and Dominant Arm-Matched Controls (N = 39) for Modified Cobb Angle and Thoracic ROM Measures[a]

Measure	Group	Mean (SD)	Mean Difference	*P*	95% CI
Modified Cobb angle (degrees)	SIS	42.2 (10.0)	6.2	.004	2.0 to 10.4
	Control	36.0 (8.5)			
Thoracic Extension (degrees)[b]	SIS	24.2 (13.2)	7.8	.007	2.2 to 13.4
	Control	16.4 (11.6)			
Thoracic Flexion (degrees)	SIS	59.2 (9.2)	1.7	.41	−2.3 to 5.7
	Control	57.6 (8.5)			
Total thoracic ROM (degrees)[b]	SIS	35.0 (13.1)	6.1	.023	0.86 to 11.41
	Control	41.2 (10.1)			

[a]CI = confidence interval; ROM = range of motion; SIS = shoulder impingement syndrome.
[b]Positive values for flexion and extension represent some degree of flexion forward of the vertical (negative values would represent extension past the vertical).

Conclusion

This study has demonstrated an association between thoracic posture and SIS. Individuals with SIS had greater thoracic kyphosis and a decreased ability to extend their thoracic spines compared with matched asymptomatic individuals. Longitudinal studies are required to determine whether thoracic kyphosis is a cause or effect of having SIS. These results suggest that treatment protocols for SIS should be investigated that address thoracic spine kyphosis and thoracic extension ROM in addition to treating the shoulder joint.

Author Contributions and Acknowledgments

Concept/idea/research design: D.J. Hunter, D.A. Rivett, S. McKiernan, L. Smith, S.J. Snodgrass
Writing: D.J. Hunter, D.A. Rivett, S. McKiernan, S.J. Snodgrass
Data collection: D.J. Hunter, S. McKiernan
Data analysis: D.J. Hunter, L. Smith
Project management: D.J. Hunter, S. McKiernan, L. Smith
Providing facilities/equipment: S. McKiernan, L. Smith
Consultation (including review of manuscript before submitting): D.A. Rivett, S. McKiernan, L. Smith, S.J. Snodgrass

The authors thank the Hunter Medical Research Institute for assisting with participant recruitment.

Ethics Approval

The University of Newcastle Human Research Ethics Committee approved this study (H-2014-0192), and all participants provided written informed consent before their commencement in the study. This study complies with the Declaration of Helsinki.

Funding

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure and Presentations

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

DOI: 10.1093/ptj/pzz182

References

1 Meislin RJ, Sperling JW, Stitik TP. Persistent shoulder pain: epidemiology, pathophysiology, and diagnosis. *Am J Orthop.* 2005;34:5–9.

2 Serrano-Aguilar P, Kovacs FM, Cabrera-Hernández JM, Ramos-Goñi JM, García-Pérez L. Avoidable costs of physical treatments for chronic back, neck and shoulder pain within the Spanish National Health Service: a cross-sectional study. *BMC Musculoskelet Disord.* 2011;12:287.

3 Virta L, Joranger IB, Eriksson R. Costs of shoulder pain and resource use in primary health care: a cost-of-illness study in Sweden. *BMC Musculoskelet Disord.* 2012;13:17–27.

4 Greving K, Dorrestijn O, Winters JC, et al. Incidence, prevalence, and consultation rates of shoulder complaints in general practice. *Scand J Rheumatol.* 2012;41:150–155.

5 Mayerhoefer ME, Breitenseher MJ, Wurnig C, Roposch A. Shoulder impingement: relationship of clinical symptoms and imaging criteria. *Clin J Sport Med.* 2009;19:83–89.

6 Theisen C, van Wagensveld A, Timmesfeld N, et al. Co-occurrence of outlet impingement syndrome of the shoulder and restricted range of motion in the thoracic spine—a prospective study with ultrasound-based motion analysis. *BMC Musculoskelet Disord.* 2010;11:135–135.

7 Kelly S, Brittle N. The value of physical tests for subacromial impingement syndrome: a study of diagnostic accuracy. *Clin Rehabil.* 2010;24:149–158.

8 Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *J Orthop Sports Phys Ther.* 2005;35:72–87.

9 Rumack CM, Levine D. *Diagnostic Ultrasound*. 5th ed. St Louis, MO, USA:Elsevier/Mosby; 2018.

10 Harvey D. The diagnosis of subacromial impingement syndrome and associated pathology in the primary care setting. In: *Masters Thesis.* Auckland University of Technology, Auckland 1142 , New Zealand, 2009.

11 Tekavec E, Joud A, Rittner R, et al. Population-based consultation patterns in patients with shoulder pain diagnosis. *BMC Musculoskelet Disord.* 2012;13:238.

12 Minagawa H, Yamamoto N, Abe H. Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: from mass-screening in one village. *J Ortho.* 2013;10:8–12.

13 Teunis T, Lubberts B, Reilly BT, Ring D. A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. *J Shoulder Elbow Surg.* 2014;23: 1913–1921.

14 Linsell L, Dawson J, Zondervan K, et al. Prevalence and incidence of adults consulting for shoulder conditions in UK primary care; patterns of diagnosis and referral. *Rheumatology.* 2006;45:215–221.

15 Saltychev M, Aarima V, Virolainen P, Laimi K. Conservative treatment or surgery for shoulder impingement: systematic review and meta-analysis. *Disabil Rehabil.* 2015;37:1–8.

16 Van der Heijden GJ. Shoulder disorders: a state-of-the-art review. *Bailliere's Clin Rheumatol.* 1999;13:287–309.

17 Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 1999;80:945–950.

18 Bullock MP, Foster NE, Wright CC. Shoulder impingement: the effect of sitting posture on shoulder pain and range of motion. *Man Ther.* 2005;10:28–37.

19 Katzman WB, Huang MH, Lane NE, Ensrud KE, Kado DM. Kyphosis and decline in physical function over 15 years in older community-dwelling women: the study of osteoporotic fractures. *J Gerontol A Biol Sci Med Sci.* 2013; 68:976–983.

20 Fon GT, Pit MJ, Thies AC. Thoracic kyphosis: range in normal subjects. *Am J Roentgenol*. 1980;134:979–983.

21 Boyle J, Milne N, Singer KP. Influence of age on cervicothoracic spinal curvature: an ex vivo radiographic survey. *Clin Biomech*. 2002;17:361–367.

22 Lewis JS, Green A, Wright C. Subacromial impingement syndrome: the role of posture and muscle imbalance. *J Shoulder Elbow Surg.* 2005;14:385–392.

23 Otoshi K, Takegami M, Sekiguchi M, et al. Association between kyphosis and subacromial impingement syndrome: LOHAS study. *J Shoulder Elbow Surg.* 2014;23: e300–307.

24 McClure P, Michener L, Karduna A. Shoulder function and 3-dimensional scapula kinematics in people with and without shoulder impingement syndrome. *Phys Ther.* 2006;86:1075–1088.

25 Alizadehkhaiyat O, Roebuck MM, Makki AT, Frostick SP. Postural alterations in patients with subacromial impingement syndrome. *Int J of Sports Phys Ther.* 2017;12:1111–1120.

26 Harrison DE, Harrison DD, Cailliet R, Janik TJ, Holland B. Radiographic analysis of lumbar lordosis: centroid, cobb, TRALL, and Harrison posterior tangent methods. *Spine.* 2001;26:E235–E242.

27 de Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. *Am J Roentgenol.* 2009;192:1701–1707.

28 Beggs I. Shoulder ultrasound. *Semin Ultrasound CT MR.* 2011;32:101–113.

29 Alqunaee M, Galvin R, Fahey T. Diagnostic accuracy of clinical tests for subacromial impingement syndrome: a systematic review and meta-analysis. *Arch Phys Med Rehabil.* 2012;93:229–236.

30 Saraya S, El Bakry R. Ultrasound: can it replace MRI in the evaluation of the rotator cuff tears? *The Egyptian Journal of Radiology and Nuclear Medicine.* 2016;47:193–201.

31 Tuite MJ, Small KM. Imaging evaluation of nonacute shoulder pain. *Am J Roentgenol.* 2017;209:525–533.

32 Moosmayer S, Heir S, Smith HJ. Sonography of the rotator cuff in painful shoulders performed without knowledge of clinical information: results from 58 sonographic examinations with surgical correlation. *J Clin Ultrasound.* 2007;35:20–26.

33 Singh JP. Shoulder ultrasound: what you need to know. *Indian J Radiol Imaging.* 2012;22:284–292.

34 Vlychou M, Dailiana Z, Fotiadou A, Papanagiotou M, Fezoulidis IV, Malizos K. Symptomatic partial rotator cuff tears: diagnostic performance of ultrasound and magnetic resonance imaging with surgical correlation. *Acta Radiologica.* 2009;50:101–105.

35 Elmorsy A, Keightley A, Flannery M. Accuracy of ultrasonography (US) and magnetic resonance imaging (MRI) in detection of rotator cuff tears in district general hospital. *Pol J Radiol.* 2017;82:634–637.

36 Kayser R, Hampf S, Pankow M, Seeber E, Heyde CE. Validity of ultrasound examinations of disorders of the shoulder joint. *Ultraschall Med.* 2005;26:291–298.

37 Okoroha KR, Fidai MS, Tramer JS, Davis KD, Kolowich PA. Diagnostic accuracy of ultrasound for rotator cuff tears. *Ultrasonography.* 2018;38:215–220.

38 Singh AP. Rao a, Devaru S, Amithavikrama. Role of ultrasound in evaluation of shoulder injuries: a comparative study of ultrasound and MRI. *Int J Anat Radiol Surg.* 2017;6:R012–R018.

39 Pennell PN, Sizer PS, Owens SC, Brismee JM, Dedrick GS, James CR. Inter-tester and intra-tester reliability of measuring spinal height changes using a stadiometer. *J Man Manip Ther.* 2008;16:166.

40 Angst F, Schwyzer HK, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: disabilities of the arm, shoulder, and hand questionnaire (DASH) and its short version (QuickDASH), shoulder pain and disability index (SPADI), American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, constant (Murley) score (CS), simple shoulder test (SST), Oxford shoulder score (OSS), shoulder disability questionnaire (SDQ), and Western Ontario shoulder instability index (WOSI). *Arthritis Care Res.* 2011;63: S174–S188.

41 Roy JS, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis Rheum.* 2009;61:623–632.

42 Bot SDM. Clinimetric evaluation of shoulder disability questionnaires: a systematic review of the literature. *Ann Rheum Dis.* 2004;63:335–341.

43 Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: visual analog scale for pain (VAS pain), numeric rating scale for pain (NRS pain), McGill pain questionnaire (MPQ), short-form McGill pain questionnaire (SF-MPQ), chronic pain grade scale (CPGS), short Form-36 bodily pain scale (SF-36 BPS), and measure of intermittent and constant osteoarthritis pain (ICOAP). *Arthritis Care Res.* 2011;63: S240–S252.

44 Tashjian RZ, Deloach J, Porucznik CA, Powell AP. Minimal clinically important differences (MCID) and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease. *J Shoulder Elbow Surg*. 2009;18:927–932.

45 Kahl C, Cleland JA. Visual analogue scale, numeric pain rating scale and the McGill pain questionnaire: an overview of psychometric properties. *Phys Ther Rev.* 2013;10:123–128.

46 Min He X, Jung K, Ham H, Kim Ham J, Kim S. A comparison of the validity and reliability between a digital radiographic imaging system and manual method in measuring the cobb angle. *Scoliosis (17487161).* 2013;8:O20–O21.

47 Hunter DJ, Rivett DA, McKiernan S, Weerasekara I, Snodgrass SJ. Is the inclinometer a valid measure of thoracic kyphosis? A cross-sectional study. *Braz J Phys Ther.* 2018;22:310–317.

48 Lumley JSP. *Surface Anatomy*. 3rd ed. Edinburgh, Scotland: Churchill Livingstone; 2002.

49 Shin S, Yoon DM, Yoon KB. Identification of the correct cervical level by palpation of spinous processes. *Anesth Analg.* 2011;112:1232–1235.

50 Clarkson HM. *Musculoskeletal Assessment: Joint Motion and Muscle Testing*. 3rd ed. Philadelphia, PA, USA: Lippincott Williams & Wilkins; 2013.

51 Fleiss JL. *The Design and Analysis of Clinical Experiments*. New York, NY: John Wiley & Sons; 1986.

52 Lee CN, Robbins DP, Roberts HJ, et al. Reliability and validity of single inclinometer measurements for thoracic spine range of motion. *Physiother Can.* 2003;55:73–78.

53 Read JW, Perko M. Ultrasound diagnosis of subacromial impingement for lesions of the rotator cuff. *Australas J Ultrasound Med.* 2010;13:11–15.

54 Farin PU, Jaroma H, Harju A, Soimakallio S, Soimakallio S. Shoulder impingement syndrome: sonographic evaluation. *Radiology.* 1990;176:845–848.

55 Bureau NJ, Beauchamp M, Cardinal E, Brassard P. Dynamic sonography evaluation of shoulder impingement syndrome. *Am J Roentgenol.* 2006;187:216–220.

56 Wang SJ, Wang HK, Chen WS, Wang TG. Dynamic visualisation of the coracoacromial ligament by ultrasound. *J Ultrasound Med Biol.* 2009;35:1242–1248.

57 Bigliani LU, Morrison DS, April EW. The morphology of the acromion and its relationship to rotator cuff tears. *Orthop Trans.* 1986;10:228.

58 Barrett E, O'Keeffe M, O'Sullivan K, Lewis J, McCreesh K. Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. *Man Ther.* 2016;26:38–46.