IJSPT

ORIGINAL RESEARCH

POSTURAL ALTERATIONS IN PATIENTS WITH SUBACROMIAL IMPINGEMENT SYNDROME

Omid Alizadehkhaiyat[1]
Margaret M. Roebuck[2]
Ahmed T. Makki[2]
Simon P. Frostick[2]

ABSTRACT

Background: An aberrant upper body posture has been proposed as one of the etiological factors contributing to the development of subacromial impingement syndrome (SAIS). Clinicians have translated this supposition into assessment and rehabilitation programs despite insufficient and conflicting evidence to support this approach.

Purpose: The purpose of this study was to compare several postural variables between the SAIS patients and asymptomatic healthy controls.

Study Design: Case-Control Study

Methods: A total of 75 participants including 39 patients (20 females; 19 males) and 36 healthy controls (15 females; 21 males) participated in the study. Study evaluated several postural variables including forward head posture (FHP), forward shoulder posture (FSP), thoracic kyphosis index (TKI), scapular index (SI), normalized scapular protraction (NSP), and the lateral scapular slide test (LSST). The variables were compared between patient and control groups according to sex.

Results: Significant differences were observed in the female patients compared to asymptomatic controls for the FHP (49.3° + 9.6o vs 55.5o + 8.3°, $p = 0.03$), FSP (45.5° + 10.1o vs 53.6° + 7.0°, $p = 0.02$), and LSST in third position (10.2 + 2.1cm vs 11.5 + 0.7cm, $p = 0.01$). Male patients showed a significant difference only in the FSP compared to controls (61.9o + 9.4o vs 49.7° + 9.2°, $p < 0.001$).

Conclusions: While inadequate data on the relationship between dysfunctional posture and SAIS has led to broad variations in current rehabilitation strategies, the results of the present study revealed different patterns of postural aberrations in female and male patients with SAIS. This clarifies the need to develop individualized or sex-specific approaches for assessing posture in men and women with SAIS and rehabilitation programs based on the assessment results.

Level of Evidence: 3b

Key words: Forward head posture, forward shoulder posture, movement system, postural assessment, scapular positioning, shoulder impingement, thoracic kyphosis

[1] School of Health Sciences (Sport and Exercise Science), Liverpool Hope University, Liverpool, UK
[2] Musculoskeletal Science Research Group, Institute of Translational Medicine, University of Liverpool, Liverpool, UK

Laboratory: MARIARC, University of Liverpool

This study received no external funding. Authors disclose no conflict of interest. Study received ethical approval from the NRES Committee North West – Liverpool Central (08/1005/117)

CORRESPONDING AUTHOR
Dr Omid Alizadehkhaiyat
School of Health Sciences, Liverpool Hope University
Hope Park, Liverpool L16 9JD, UK
Tel: 0044 151 291 3262
E-mail: alizado@hope.ac.uk

PBACKGROUND

Subacromial Impingement Syndrome (SAIS) is one of the most common causes of shoulder pain affecting manual and sedentary workers as well as athletes.[1,2] Individuals with SAIS present with insidious pain during overhead movements and arm elevation within the painful arc (70°-120° of abduction), leading to considerable functional incapacity. The underlying etiology of SAIS is multifactorial with symptoms triggered by both extrinsic and intrinsic factors including inflammation of the subacromial bursa, rotator cuff tendon degeneration, weak or dysfunctional rotator cuff and scapular musculature (muscle imbalances), aberrant activation patterns of shoulder girdle muscles, and postural dysfunction of the spinal column and scapula.[1-3] The condition is more common in athletes where altered activation patterns, scapular dyskinesis, and muscle imbalances involving key postural muscles (upper, middle, lower trapezius and serratus anterior) are frequently observed.[4,5]

Upper body postural dysfunction (i.e. alteration in the alignment of the head, neck, shoulders and thoracic spine) has been suggested as one of the key underlying factors in association with the SAIS. Previous authors have suggested that aberrant upper body posture (i.e. increased thoracic kyphosis together with a forward shoulder posture) results in the narrowing of subacromial space and prompts tendon inflammation/tendon degeneration and upper limb movement dysfunction due to mechanical compression.[6-11] Hence, assessment of upper body posture has received considerable attention in order to facilitate developing enhanced management strategies for the SAIS.[7,12,13] While postural alterations can occur independently within thoracic and cervical spine, shoulder, and scapula, they are typically linked together leading to aberrant and dysfunctional upper body alignments. Common postural alterations within the sagittal plane include increased forward head posture (FHP), forward shoulder posture (FSP), and thoracic spine kyphosis. Figure1 provides a schematic presentation of potential pathways through which an aberrant posture may progressively contribute to the development of SAIS. These aberrant alignments are suggested to particularly influence scapular kinematics and produce dysfunctional postural adjustments with detrimental effect on the pressure and dimensions of the subacromial space.[11,14-16]

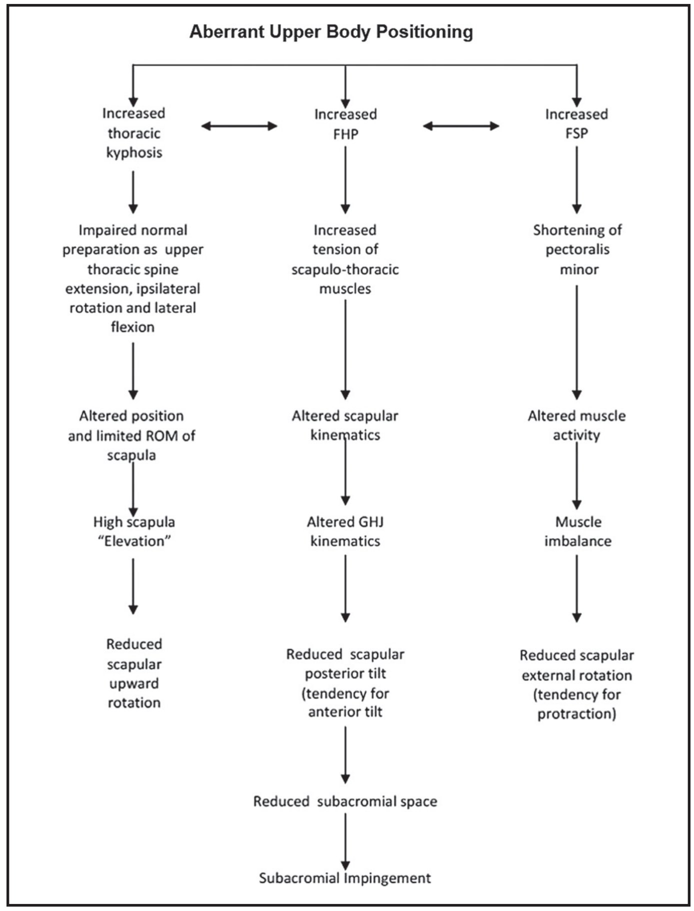

Figure 1. *Summary of proposed relationships between aberrant upper body posture and subacromial impingement syndrome.*
**FHP: forward head posture; FSP: forward shoulder posture; ROM: range of motion; GHJ: glenohumeral joint.*

The majority of researchers have used common methods, accessible in clinical practice, for fast yet reliable quantitative assessment of static upper body posture in SAIS patients. The results have however been conflicting. Using bony landmarks as reliable markers and taking into account the physical appearance of the head, neck and shoulders as principal characteristic of human posture, several researchers have identified postural differences between patients with asymptomatic and symptomatic shoulders.[9,17,18] Despite these reports of differences in upper body posture between asymptomatic and symptomatic subjects, it is not possible to determine whether these altered postures have an etiological relationship with the SAIS or occur as consequences of underlying pathology. Lewis et al, evaluated postural variables including FHP, FSP and scapular protraction in 60 asymptomatic subjects and 60 subjects with SAIS and highlighted limited role of these factors in the clinical decision-making process.[7,8] Ratcliffe et al, conducted a systematic review and reported insufficient evidence to support the role of aberrant posture in the pathogenesis of SAIS potentially due to the complex and multifactorial nature of SAIS and lack of consistency between study methodologies.[10]

Considering contradictory reports, more research is needed for the identification of aberrant postural adaptations in SAIS patients in order to facilitate the implementation of assessment-driven targeted interventions. Hence, the purpose of this study was to compare several postural variables between the SAIS patients and asymptomatic healthy controls.

METHODS

Participants

The study received ethical approval from a local research ethics committee and all participants gave their written consent prior to participation. A total of 75 controls and patients with SAIS participated in the study: 1) the control Group included 36 healthy volunteers (15 female, 21 males); with normal upper limb clinical assessment and no history of upper extremity painful conditions or surgery; 2) the patient group was comprised of 39 participants (20 females, 19 males) who were diagnosed and recruited through a specialized Upper Limb Orthopaedic Unit overseen by a leading orthopaedic surgeon. Participant demographics are summarized in Table 1. All patients presented with persistent shoulder pain for at least 12 weeks (average pain duration: 15 months, range 7 – 30 months) and a range of positive clinical tests.[19] Patients with at least three positive tests (3/5) were included in the SAIS groups.[20] The patient exclusion criteria included receiving treatment other than pain relief medication during the last three months, positive imaging (rotator cuff tear, instability, and osteoarthritis), hypermobility syndrome, and systemic diseases affecting the function of neck, back, or upper extremity. The same experienced clinician (senior orthopaedic surgeon/PhD fellow) located the specific bony landmarks during postural measures, and performed all assessments in order to enhance the measurement accuracy.[21]

POSTURAL MEASUREMENTS

Measurement Protocol

Subjects stood 30cm in front of a plumb line hanging from the ceiling and 20cm away from a wall on their side while assuming their normal posture. Non-allergenic adhesive markers were placed on following bony prominences (Figure 2): 1) posterolateral angle of the acromion (A); 2) root of the spine of the scapula (B); 3) inferior angle of the scapula (C); 4) thoracic spinous process levelled with acromion's posterior-lateral angle (D); 5) thoracic spinous process corresponding to the root of scapula spine (E); 6) thoracic spinous process corresponding to the scapula's inferior angle (F); 7) ear tragus (G); 8) C7 spinous process (H); 9) mid-point of the humeral head half-way between the acromion process and posterior acromial angle and 4 cm downward on the lateral aspect of the shoulder (I); 10) mid-point of the sternal notch (J); and 11) tip of the coracoid process (K). Five postural variables were measured for each participant: 1) forward head posture (FHP); 2) forward shoulder posture (FSP); 3) normalized scapular protraction (NSP); 4) scapular index (SI); 5) lateral scapular slide test (LSST); and 6) the thoracic kyphosis index (TKI). All measurements were repeated three times and average calculated and used during analysis.

Table 1. *Participant demographics presented as Mean (SD) for Control and Patient Groups*

	Control Group			Patient Group		
	Male N=21	Female N=15	All N=36	Male N=19	Female N=20	All N=39
Age	47.6 (10.3)	42.9 (9.3)	45.8 (10)	54.2 (8.1)	55.5 (5.3)	54.9 (6.7)
Height	172.4 (10)	168.4 (7)	170.9 (9)	173.8 (9.7)	161.3 (7.1)	167.4 (10.5)
Weight	76.8 (12.6)	69.1 (8.6)	73.9 (11.7)	83.6 (11.7)	78.0 (15.6)	80.7 (13.9)

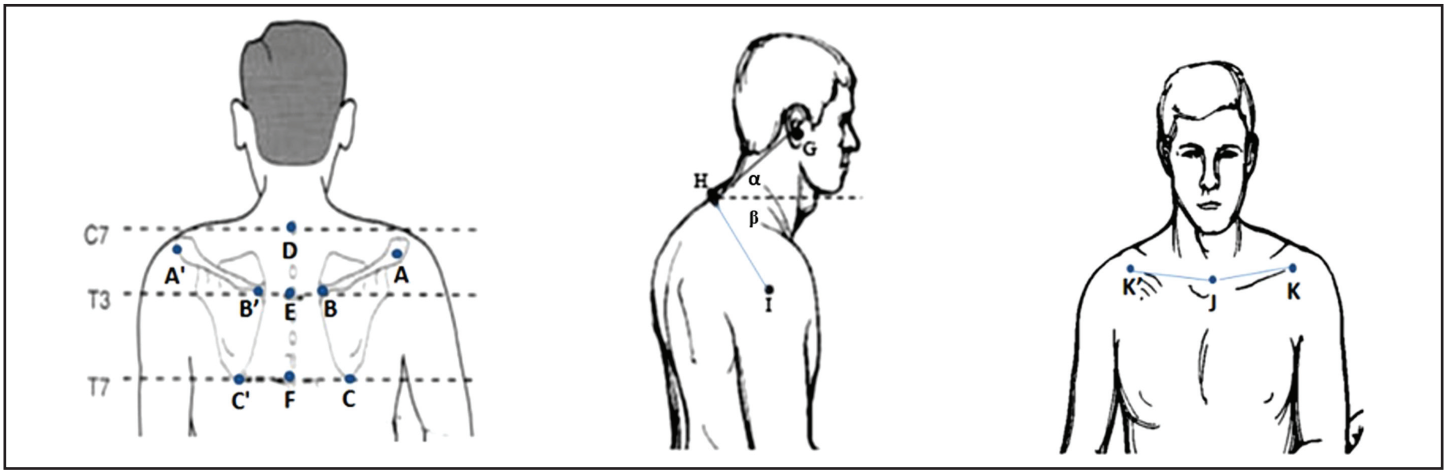

Figure 2. *Reference points (bony landmarks) for upper body postural measurements.*

FHP and FSP

A lateral photograph was taken from the cervicothoracic region using a digital Sony Camera with a 28- to 50-mm adjustable lens and set at 100 ASA mounted on a levelled tripod placed two meters from the participant. The C7 marker was placed approximately in the centre of the lens to eliminate lens error. The base and front of the camera were parallel to the ground and the facing wall, respectively to minimise parallax error. FHP and FSP angles were determined as the angle between the ear tragus and the midpoint of the shoulder with the C7 spinous process (α and β, respectively) (Figure 2-middle).[7,9] A high intratester reliability has been reported for this measurement method.[8]

Thoracic Kyphosis Index (TKI)

Thoracic spine curvature was measured in standing position by placing the flexible ruler between C7 and T12 aligned to the curve of the spine. The ruler was then marked at C7 and T12 and placed flat on paper: a straight line was drawn from the ruler position of C7 to T12 to determine the length of thoracic kyphosis and a perpendicular line from the highest point in the thoracic curve to the point at which it intersected the straight line drawn from C7 to T12 to determine the height of thoracic kyphosis. The depth of the curve was divided by the height of the curve to determine the TKI (%) (Figure 3).[22,23] Both high intrarater and interrater reliability have been reported in association with the TKI.[24,25]

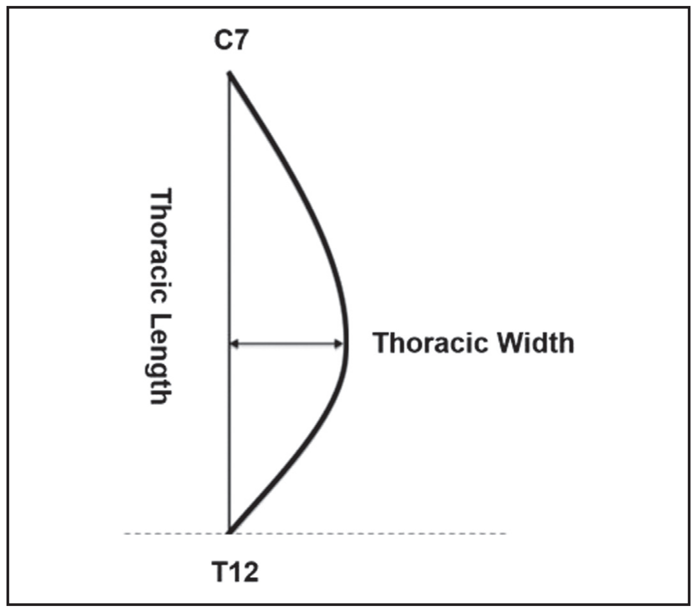

Figure 3. *Schematic drawing of thoracic kyphosis measurement by flexible ruler.*

Normalized Scapular Protraction (NSP) and Scapular Index (SI)

Using a measuring tape, the distances AE and A'E then AB and A'B' were measured and the NSP at each side was calculated as AE/AB and A'E/A'B' (Figure 2). This normalization process reduced the impact of individual body size on results. A larger NSP value indicates a more protracted scapula. The SI or also referred to as pectoralis minor index (PMI) was measured as the distance from the mid-point of the sternal notch (J) to the medial aspect of the coracoid process on each side (K, K') and the horizontal distance from the posterolateral angle of the acromion on each side (A, A') to the thoracic spine (D) were measured (Figure 2). The SI was calculated as a potential clinical indicator of pectoralis minor influence on scapular position, using the equation:

$$[(J) \text{ to } (K)/(A) \text{ to } (D) \times 100]$$

$$\text{and } [(J) \text{ to } (K')/(A') \text{ to } (D) \times 100]$$

on the right and left sides, respectively.[26] Both tests have been associated with sufficient reliability in human cadavers, but their in-vivo reliability has not yet been addressed.[27]

The Lateral Scapular Slide Test (LSST)

LSST is a reliable objective measure of scapular position[28,29] determined as the distance between the inferior angle of each scapula (points C, C') and the nearest thoracic spinous process (point F) (Figure 2). Measures were taken in three different positions: 1) LSST1: arms placed at sides in resting anatomical position (Figure 4A); 2) LSST2: hands resting on hips with the fingers pointing anterior and the thumbs pointing posterior (Figure 4B); and 3) LSST3: arms abducted 90° with full shoulder internal rotation (thumb to floor) (Figure 4C).[28,30]

Data Analysis and Statistics

Descriptive statistics for six postural variables (FHP, FSP, TKI, NSP, SI, LSST) are reported separately for female and male groups of patient and controls as mean ± standard deviation (SD). The Shapiro–Wilk's test was applied to determine normal distribution assumption of the quantitative variables. To determine differences between patient and healthy groups, variables with a normal distribution were analyzed with parametric independent sample t-test, whereas data without a normal distribution were analyzed with the nonparametric Mann-Whitney U test. The level of significance was set at $p < 0.05$. The SPSS statistical package (Version 20.0; IBM, Armonk, NY, USA) was used for analysis and modeling of the data.

RESULTS

Postural variables were measured in 36 healthy volunteers and 39 SAIS patients during this study. There was no difference in the demographics between controls and patients for either gender. All patients had at least three positive tests: Painful arc, Neer's, Hawkin's, Empty Can, and Full Can tests were positive in 95%, 86%, 81%, 71%, and 52% of female patients; and 88%, 81%, 81%, 73%, and 46% of male patients, respectively. Table 2 presents and compares the values of all of the postural measurements in the female and male patients and controls. In females, significant differences ($p < 0.05$) were detected between SAIS patients and controls for FHP, FSP, and LSST3. Regarding males, a significant difference was observed only for the FSP ($p < 0.05$). The differences in the majority of postural

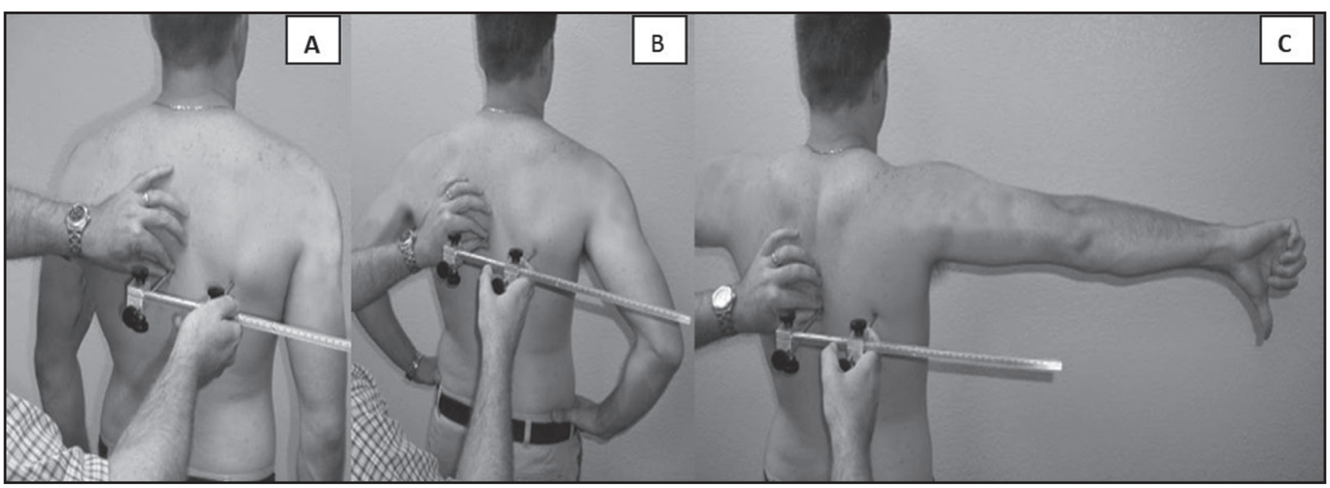

Figure 4. *Measurements of Lateral Scapular Sliding Test. A) Arm at the side standing in dependent position; (B) Arm abducted with hand resting at hip with thumbs posterior; (C) Arm abducted 90° with full shoulder internal rotation. "Used with permission of The International Journal of Sports Physical Therapy, formerly known as The North American Journal of Sports Physical Therapy".*[28]

Table 2. *Comparison of Postural Measurements between Patients and Controls.*

Postural Measurement	SAIS Patients		p- value	Controls	
	Mean	SD		Mean	SD
Females					
FHP (°)	49.3	9.6	**0.03**	55.5	8.3
FSP (°)	45.5	10.1	**0.02**	53.6	7.0
NSP (%)	161.0	8.7	1.00	162.0	5.5
SI (%)	70.5	6.7	0.47	72.1	6.7
TKI (%)	10.4	2.9	0.93	10.1	1.3
LSST (cm)					
- LSST1 (Position 1)	8.8	2.0	0.61	9.0	0.9
- LSST2 (Position 2)	9.6	1.9	0.14	10.3	0.9
- LSST3 (Position 3)	10.2	2.1	**0.01**	11.5	0.7
Males					
FHP (°)	52.5	5.9	0.10	47.0	11.4
FSP (°)	61.9	9.4	**P<0.00**	49.7	9.2
NSP (%)	157.0	9.9	0.13	161.5	13.4
SI (%)	75.6	8.3	0.34	73.5	6.1
TKI (%)	11.8	2.1	0.14	10.5	2.4
LSST (cm)					
- LSST1 (Position 1)	9.7	1.5	0.75	9.6	1.2
- LSST2 (Position 2)	10.9	2.0	0.40	10.4	1.3
- LSST3 (Position 3)	11.6	1.2	0.35	11.9	1.0

FHP= Forward Head Posture; FSP= Forward Shoulder Posture; NSP= Normalized Scapular Protraction; SI= Scapular Index; LSST= Lateral Scapular Slide Test; TKI= Thoracic Kyphosis Index.

Bolded values indicate statistically significant differences.

measurements between the compared male groups were generally small and not significant.

DISCUSSION

Despite over 90% of SAIS patients being managed conservatively, the broad variation in the existing therapeutic strategies indicates a need for more individualized and tailored approaches.[19] Clinicians commonly believe that aberrant upper body posture potentially leads to the impingement of supraspinatus tendon against the anterior portion of the acromion process. This has been widely translated into clinical practices to inform patients of the role of poor posture in the development of SAIS, to underpin postural assessments, and to rationalize rehabilitation strategies.[3,5,31] Unfortunately, research studies investigating postural alterations in SAIS have reported conflicting findings.[14,26,32,33]

The results of the present study identified multiple postural alterations in female patients with SAIS, including greater FHP, FSP, and LSST (LSST3) compared to only greater FSP in male patients. Increased FHP and FSP are considered potential clinical indicators of faulty posture due to altered scapular positioning. The scapula provides a stable base for efficient function of the rotator cuff and other muscles crossing the glenohumeral joint in individuals with good upper body posture.[34,35] Furthermore, altered scapular kinematics and muscle activation patterns reported by motion analysis and EMG studies in asymptomatic individuals with increased FHP and FSP have suggested a subsequent mechanical impact on subacromial space.[36] Persistent FHP leads to shortening of the posterior neck extensors, tightening of the anterior neck and shoulder muscles with subsequent impact on normal scapular position and kinematics.[16,37-39] Abnormal scapular orientations can then alter the activation of the stabilizing muscles such as levator scapulae and upper trapezius muscles as well as the mobilizing muscles such as pectoralis minor. Continuous FSP causes adaptive shortening and tightness of the anterior musculature such as the pectoralis minor resulting in increased scapular anterior tilt, internal rotation, and downward rotation These scapular patterns associated with FSP would depress the acromion, restrict clearance of subacromial space, and increase the pressure on subacromial soft tissues leading to painful shoulder elevation, restricted motion, weakness, and functional disability.[7,15,35]

Other researchers have reported opposing results. In a study of 60 controls and 60 SAIS patients, Lewis et al,[7] reported no relationships between various postural components including FHP and FSP. They attributed this to large individual variations and challenged the hypothesis that posture and resultant muscle imbalance play an etiologic role in the pathogenesis of SAIS. McClure et al,[40] assessed FSP using goniometrical indicators of scapular posture combined with electromagnetic motion analysis of the shoulder kinematics in 45 patients with SAIS and 45 asymptomatic participants and found no correlation between SAIS and FSP. However, none of above studies, reported gender-specific results.

Despite suggestions from the biomechanical studies that increased thoracic kyphosis may increase compression under the acromion and subacromial tissues due to scapular dyskinesis,[41,42] no differences in thoracic spine curvature and TKI were found in the present study between SAIS patients and controls. This is agreement with the results of previous studies which failed to establish a direct etiological link between increased thoracic kyphosis and development of SAIS even in the presence of altered FHP and FSP.[7] A study of 160 asymptomatic subjects failed to support an association between increased FHP and FSP and increased thoracic curvature.[33] The results of an epidemiologic study of 2144 normal participants did not demonstrate a direct association between thoracic curvature and SAIS, and the authors of that study suggested that thoracic kyphosis may only play an indirect role in the development of SAIS by reducing shoulder elevation which would be induced by restriction in thoracic spine extension and scapular dyskinesis.[43] A strong correlation reported between thoracic kyphosis and age[43] suggests that kyphosis may have a more prominent role in the development of SAIS in during aging, particularly in females due to their anatomical and physiological disadvantages.[44]

The present study evaluated scapular positioning in the coronal plane by means of SI, NSP, and LSST. The SI and NSP are related to anterior/posterior tilting of the scapula and provide helpful information regarding scapular protraction and function of surrounding muscles.[26] Scapular protraction is indicative of alterations in pectoralis minor length and individuals with a shortened muscle demonstrate scapular kinematics similar to those seen in SAIS patients.[16,45,46] It has been theorized that shortening of the pectoralis minor could lead to the narrowing of the subacromial space due to lack of posterior tilting.[45] Consistent with previous studies, the current results indicated no difference in the SI and NSP of SAIS patients of either gender.[26,32]

Current research on LSST has challenged the reliability and specificity of the original technique described by Kibler.[5,47] Hence, the present study used a more reliable measure compared to the original technique by means of the distance between inferior angle of the scapula and thoracic spinous process at the same level for comparisons with controls at each position.[28,30] The only significant alteration in LSST was observed in female patients when the affected arm was abducted to 90^{o} (LSST3). Among the three LSST positions with graded functional difficulty, only LSST3 provides an active challenge for the muscles involved in stabilizing the scapula.[5] EMG studies report a small number of scapular muscles (serratus and lower trapezius) being activated at low levels during the first two positions, but LSST3 is associated with a noticeable activation of the upper and lower trapezius, serratus, and rhomboids.[48,49] Thus, the LSST3 utilizes a more functional (although still static) position of the shoulder complex in which a major contribution from the scapular stabilizers is crucial for the stabilizing and accurate positioning of the scapula. Hence, in SAIS patients with underlying scapular dyskinesis it could be expected that scapula positioning would change when going from the first to the third position due to an increasing demand for the contribution of stabilizing muscles in controlling the retraction and upward rotation of the scapula. It is also possible that excessive scapular protraction combined with other postural abnormalities in female patients (i.e. increased FSP and FHP) could restrict scapular upward rotation during shoulder abduction in the range of 60^{o}-90^{o} and reduces subacromial space clearance. Lewis et al,[6] evaluated the impact of scapular taping in SAIS patients and reported a significant effect on glenohumeral range of motion but not on pain experience. While it has been suggested that maintaining the shoulder position at around 90°would minimize the effect of pain-related muscle inhibition by avoiding the position of impingement,[5] it is still likely that LSST3 alterations could be partially the result of pain-avoidance phenomenon as the arm is abducted in an internally rotated position.[3] This finding in female patients again emphasizes the importance of categorizing postural assessments according to the gender. While male patients had a significant increase in the FSP, it may have had less detrimental effects on the LSST3 than in female patients who had both FHP and FSP.

Methodological Considerations and Study Limitations

The present study compared several postural variables in female and male SAIS patients and healthy controls to identify potential postural abnormalities that may contribute to the development of or coexist with the condition. The postural measures chosen were undertaken using methodologies consistent with previous studies in which the reliability and practicality of the techniques were detailed. Furthermore, upper extremity/shoulder pain is more prevalent in females compared to men (22.8%-30.9% vs 13.3%-21.4%) between the ages of 25–64[50] and a significant association exists between SAIS and female gender.[51] Judging the posture of men and women by the same standards may also affect group comparisons.[52] Hence the authors reported group results separately by sex and some findings of this study may be attributed to this approach.

Finally, while there were no statistically significant differences in the demographics between controls and patients for either sex, the relatively higher age in patient groups (female patients in particular) compared to the healthy participants could have partly attributed to the study findings. There is a growing body of literature suggesting complex structural age-related changes in body posture and physiological curvature of the spine due to reduced efficiency of central and peripheral mediation, gradual decrease in skeletal muscle function and connective tissue elasticity, and regressive changes in ligaments and articular cartilage (reduced flexibility). However, such changes start with a slow progression between the ages of 40–50 years and increase mainly after 60 years of age.[53,54] Large studies have reported marked postural changes occurring in men and women, above 59 and 60 years of age respectively.[54,55]

The selection of patients through a single upper limb unit overseen by an orthopaedic surgeon could have caused selection bias (spectrum bias) depending on the chosen clinical tests as well as accuracy and expertise in performing the tests.[56] The sample size was relatively small mainly due to focusing on separate data reporting for female and male groups of patients and controls. This approach was taken based on the evidence suggesting a significant association between SAIS and female sex[32] and higher prevalence of upper extremity/shoulder pain in females compared to men.[31] While the use of a single assessor to perform all tests could have enhanced the internal validity of study reliability, it may limit the external validity and generalizability of findings particularly when combined with a small sample size. The study examined and compared the outcome measures only in patients with active SAIS symptoms and future studies are needed to evaluate the changes in outcome following common surgical and conservative interventions for SAIS.

CONCLUSION

Earlier understanding of the crucial elements influencing the relationship between dysfunctional posture and SAIS has not been rigorously examined. While studies of asymptomatic subjects established the likelihood of a connection between SAIS and posture; studies involving SAIS patients have largely failed to clarify this relationship. Female SAIS patients in the current study exhibited abnormal FHP, FSP, and LSST3 as compared to controls, while male patients presented only with an increased FSP. Randomized controlled trials of rehabilitation interventions addressing defined postural alterations, particularly in female patients, are needed to support their integration into prevention and intervention programs. Further research should explore whether a common gender-related pattern in scapular positioning exists in SAIS patients or whether subgroups of patients with common patterns can be identified to facilitate the development of tailored interventions.

REFERENCES

1. de Witte PB, Nagels J, van Arkel ER, et al. Study protocol subacromial impingement syndrome: the identification of pathophysiologic mechanisms (SISTIM). *BMC Musculoskelet Disord.* 2011; 12:1-12.

2. Seitz AL, McClure PW, Finucane S, et al. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? *Clin Biomech.* 2011; 26:1-12.
3. Ellenbecker TS, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med.* 2010; 44:319-327.
4. Cools AM, Declercq GA, Cambier DC, et al. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports.* 2007; 17:25-33.
5. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998; 26:325-337.
6. Neer CS. Impingement lesions. *Clin Orthop Relat Res.* 1983; 173.
7. Lewis JS, Green A, Wright C. Subacromial impingement syndrome: the role of posture and muscle imbalance. *J Shoulder Elbow Surg.* 2005; 14:385-392.
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. Raine S, Twomey L. Posture of the head, shoulders and thoracic spine in comfortable erect standing. *Aust J Physiother.* 1994; 40:25-32.
10. Ratcliffe E, Pickering S, McLean S, et al. Is there a relationship between subacromial impingement syndrome and scapular orientation? A systematic review. *Br J Sports Med.* 2014; 48:1251-1256.
11. Solem-Bertoft E, Thuomas KA, Westerberg CE. The influence of scapular retraction and protraction on the width of the subacromial space. An MRI study. *Clin Orthop Relat Res.* 1993:99-103.
12. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Phys Ther.* 2006; 86:549-557.
13. Braun BL, Amundson LR. Quantitative assessment of head and shoulder posture. *Arch Phys Med Rehabil.* 1989; 70:322-329.
14. Culham E, Peat M. Functional anatomy of the shoulder complex. *J Orthop Sports Phys Ther.* 1993; 18:342-350.
15. 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.
16. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther.* 2000; 80:276-291.
17. Struyf F, Nijs J, Baeyens JP, et al. Scapular positioning and movement in unimpaired shoulders, shoulder impingement syndrome, and glenohumeral instability. *Scand J Med Sci Sports.* 2011; 21:352-358.
18. Timmons MK, Thigpen CA, Seitz AL, et al. Scapular kinematics and subacromial-impingement syndrome: a meta-analysis. *J Sport Rehabil.* 2012; 21:354-370.
19. Diercks R, Bron C, Dorrestijn O, et al. Guideline for diagnosis and treatment of subacromial pain syndrome: a multidisciplinary review by the Dutch Orthopaedic Association. *Acta Orthop.* 2014; 85:314-322.
20. Park HB, Yokota A, Gill HS, et al. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. *J Bone Joint Surg Am.* 2005; 87:1446-1455.
21. Thigpen CA, Padua DA. Assessment of shoulder-girdle posture in overhead athletes. *Athl Ther Today.* 2006; 11:42-46.
22. Dunleavy K, Mariano H, Wiater T, et al. Reliability and minimal detectable change of spinal length and width measurements using the Flexicurve for usual standing posture in healthy young adults. *J Back Musculoskelet Rehabil.* 2010; 23:209-214.
23. Yanagawa TL, Maitland ME, Burgess K, et al. Assessment of thoracic kyphosis using the flexicurve for individuals with osteoporosis. *Hong Kong Physiother J.* 2000; 18:53-57.
24. Barret E, McCreesh K, Lewis J. Intrarater and interrater reliability of the flexicurve index, flexicurve angle, and manual inclinometer for the measurement of thoracic kyphosis. *Rehabil Res Pract.* 2013; 2013:1-7.
25. Teixeira F, Carvalho G. Confiabilidade e validade das medidas da cifose torácica através do método flexicurva. *Braz J Phys Ther.* 2007; 11:199-204.
26. DiVeta J, Walker ML, Skibinski B. Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther.* 1990; 70:470-476.
27. Struyf F, Nijs J, Mottram S, et al. Clinical assessment of the scapula: a review of the literature. *Br J of Sports Med.* 2014; 48:883-890.
28. Curtis T, Roush JR. The lateral scapular slide test: A reliability study of males with and without shoulder pathology. *N Am J Sports Phys Ther.* 2006; 1:140-146.
29. Shadmehr A, Sarafraz H, Heidari Blooki M, et al. Reliability, agreement, and diagnostic accuracy of the modified lateral scapular slide test. *Man Ther.* 2016; 24:18-24.
30. Odom CJ, Taylor AB, Hurd CE, et al. Measurement of scapular asymetry and assessment of shoulder

dysfunction using the lateral scapular slide test: a reliability and validity study. *Phys Ther.* 2001; 81:799-809.

31. Kendall FP, McCreary EK, Provance PG, et al. *Muscles, Testing and Function With Posture and Pain 5th edition.* . Baltimore: Williams & Wilkins; 2005.
32. Greenfield B, Catlin PA, Coats PW, et al. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther.* 1995; 21:287-295.
33. Raine S, Twomey LT. Head and shoulder posture variations in 160 asymptomatic women and men. *Arch Phys Med Rehabil.* 1997; 78:1215-1223.
34. Paine RM, Voight M. The role of the scapula. *J Orthop Sports Phys Ther.* 1993; 18:386-391.
35. Grimsby O, Gray JC. Interrelationship of the spine to the shoulder girdle. In: Donatelli RA, ed. *Clinics in Physical Therapy of the Shoulder*. New York: Churchill Livingstone; 1997:95-129.
36. Thigpen CA, Padua DA, Michener LA, et al. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *J Electromyogr Kinesiol.* 2010; 20:701-709.
37. Ludewig PM, Braman JP. Shoulder impingement: biomechanical considerations in rehabilitation. *Man Ther.* 2011; 16:33-39.
38. Ludewig PM, Phadke V, Braman JP, et al. Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Joint Surg Am.* 2009; 91:378-389.
39. Im B, Kim Y, Chung Y, et al. Effects of scapular stabilization exercise on neck posture and muscle activation in individuals with neck pain and forward head posture. *J Phys Ther Sci.* 2016; 28:951-955.
40. McClure PW, Michener LA, Karduna AR. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther.* 2006; 86:1075-1090.
41. Gray J, Grimsby O. Interrelationship of the spine, rib cage, and shoulder. In: R D, ed. *Physical therapy of the shoulder*. Edinburgh: Churchill Livingstone; 2004:133-185.
42. Schenkman M, Rugo de Cartaya V. Kinesiology of the shoulder complex. *J Orthop Sports Phys Ther.* 1987; 8:438-450.
43. 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.
44. Nishiwaki Y, Kikuchi Y, Araya K, et al. Association of thoracic kyphosis with subjective poor health, functional activity and blood pressure in the community-dwelling elderly. *Environ Health Prev Med.* 2007; 12:246-250.
45. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther.* 2005; 35:227-238.
46. Nijs J, Roussel N, Vermeulen K, et al. Scapular positioning in patients with shoulder pain: a study examining the reliability and clinical importance of 3 clinical tests. *Arch Phys Med Rehabil.* 2005; 86:1349-1355.
47. Gibson MH, Goebel GV, Jordan TM, et al. A reliability study of measurement techniques to determine static scapular position. *J Orthop Sports Phys Ther.* 1995; 21:100-106.
48. Escamilla RF, Yamashiro K, Paulos L, et al. Shoulder muscle activity and function in common shoulder rehabilitation exercises. *Sports Med.* 2009; 39:663-685.
49. Struyf F, Cagnie B, Cools A, et al. Scapulothoracic muscle activity and recruitment timing in patients with shoulder impingement symptoms and glenohumeral instability. *J Electromyogr Kinesiol.* 2014; 24:277-284.
50. Pribicevic M. The epidemiology of shoulder pain: A narrative review of the literature. In: S G, ed. *Pain in perspective*. Rijeka: InTech; 2012.
51. Tangtrakulwanich B, Kapkird A. Analyses of possible risk factors for subacromial impingement syndrome. *World J Orthop.* 2012; 3:5-9.
52. Hanten WP, Lucio RM, Russell JL, et al. Assessment of total head excursion and resting head posture. *Arch Phys Med Rehabil.* 1991; 72:877-880.
53. Drzał-Grabiec J, Rykała J, Podgórska J, et al. Changes in body posture of women and men over 60 years of age. *Ortopedia, traumatologia, rehabilitacja.* 2012; 14: 467-75.
54. Drzał-Grabiec J, Snela S, Rykała J, et al. Changes in the body posture of women occurring with age. *BMC Geriatr.* 2013; 13:108.
55. Milne JS, Lauder IJ. Age effects in kyphosis and lordosis in adults. *Ann Hum Biol.* 1974; 1:327-337.
56. Lambert J. Statistics in brief: how to assess bias in clinical studies? *Clin Orthop Relat Res.* 2011; 469:1794-1796.