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Subacromial Impingement Syndrome: The Effect of Changing Posture on Shoulder Range of Movement

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Study Design: Random allocation of subjects into a placebo-controlled, crossover study.
Objectives: To investigate the effect of changing thoracic and scapular posture on shoulder flexion and scapular plane abduction range of motion in asymptomatic subjects, and in subjects with subacromial impingement syndrome.
Background: Changes in upper body posture and concomitant imbalance of the muscle system have been proposed as one of the etiological mechanisms leading to subacromial impingement syndrome. Although clinicians commonly assess posture and devise rehabilitation programs to correct posture, there is little evidence to support this practice.
Methods and Materials: Selected postural, range of movement, and pain measurements were investigated in 60 asymptomatic subjects and 60 subjects with subacromial impingement syndrome, prior to and following thoracic and scapular taping intended to change their posture.
Results: Changing posture had an effect on all components of posture measured ($P<.001$) and these changes were associated with a significant increase ($P<.001$) in the range of motion in shoulder flexion and abduction in the plane of the scapula. Changing posture was not found to have a significant effect on the intensity of pain experienced by the symptomatic subjects, although the point in the range of shoulder elevation at which they experienced their pain was significantly higher ($P<.001$).
Conclusions: The findings of this investigation suggest that changing 1 or more of the components of posture may have a positive effect on shoulder range of movement and the point at which pain is experienced. *J Orthop Sport Phys Ther 2005;35:72-87.*

Key Words: *pain, scapula, taping, thorax*

Shoulder disorders are considered to be among the most common of musculoskeletal disorders,[48] with 1.1% of patients attending general medical practice each year in Holland for such problems.[98] In a survey of 372 athletes who predominantly use their upper extremity, 43.8% reported shoulder pain.[48] Shoulder pathology is associated with a high morbidity rate, with up to 54% of sufferers reporting ongoing symptoms after 3 years.[53] Subacromial impingement syndrome (SIS) has been considered to be one of the most common forms of shoulder pathology.[35,40,98] The syndrome is associated with pathology of 1 or more of the contents of the subacromial space. Pain and dysfunction occur when the shoulder is placed in positions of elevation, an activity that is commonplace during many sporting and vocational pursuits, and activities involved in daily living. SIS has been associated with shoulder pain in a number of sports, including golf, volleyball, badminton, basketball, tennis, cricket, and baseball.[3,4,37] It has also been reported in competitive as well as noncompetitive swimmers.[7,80,84,103,104] Richardson et al[86] reported a 42% incidence of SIS in 137 elite American swimmers. SIS has a detrimental effect on quality of life, with shoulder elevation, sleeping, throwing, and working activities being most affected.[17]

Notwithstanding the high incidence of SIS, the literature is beset with controversy surrounding its etiology. A number of alternative, often contradictory, hypotheses have been proposed to explain the pathogenesis of the condition, the cause of the pain, and the loss of

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function.[9,12,44,47,56,62,70,78,93,96,101] Although there were earlier references to subacromial pathology,[1,5,20,61,64] Neer[70] was the first to use the term subacromial impingement syndrome. He argued that 100% of SIS and 95% of rotator cuff pathology were caused by impingement of the subacromial contents, principally the supraspinatus tendon, by the anterior one-third of the acromion. Neer[70,71] described a continuum of the pathology, a diagnostic test, conservative management, and an operative procedure, the anterior acromioplasty. This procedure remains the most common surgical technique performed on the shoulder.[22] Neer's model involving acromial irritation of the subacromial tissues has been embraced by physical therapists,[3,6,28,89] who have suggested that an alteration in upper body posture, colloquially known as a forward head posture (FHP), is associated with the impingement process due to changes in the position of the scapula, an increase in the thoracic kyphosis angle, and a concomitant imbalance of the surrounding muscles. These changes are thought to produce a compressive impingement under the acromion, creating a mechanical block to elevation of the humerus and irritation of the subacromial tissues.[3,6,28,89]

As such, considerable importance is placed on the assessment of posture in patients with SIS.[6,14,28,39,41] Identified deviations from an ideal posture then form the basis for rehabilitation programs designed to address imbalances of the musculoskeletal system[15,32,39,67,89,94] and to restore normal postural relationships, with the aim of alleviating the symptoms associated with SIS. Although this is common clinical practice among physical therapists,[3,32,67,94] as well as in other professions,[15,41,42] the evidence to support this practice is largely anecdotal.

The aim of the current study was to investigate the effect of changing posture on the range of movement of shoulder flexion and abduction in the plane of the scapula in asymptomatic subjects, and in subjects with SIS. The influence of changing posture on the intensity of pain was also investigated in the subjects with symptoms. The null hypotheses for this investigation was that changing posture would have no effect on shoulder range of movement in asymptomatic subjects and on shoulder range of movement and pain in subjects with SIS.

METHODS

Subject Information and Consent

Ethical approval for this study was granted by Riverside Research Ethics Committee, London, UK and by the Coventry University School of Health Sciences Ethics Committee, Coventry, UK. Subjects were provided with information booklets explaining the purpose of the study and signed informed consent documents prior to participation. Subjects were free to withdraw from the study at any time.

Power Analysis

The sample size required for a significance level of 0.05 and a power of 0.9 to detect a 10° increase in shoulder flexion and scapular plane abduction, a 5° decrease in the thoracic kyphosis angle, a 5° decrease in the FHP angle, a 2-cm decrease in the sagittal plane displacement of the acromion of the scapula, and a 1-cm decrease in the lateral linear displacement of the scapula, was calculated to be 60 asymptomatic subjects and 60 subjects with SIS. The angular and linear measurements and the standard deviations used in the power analysis were based on the findings of published clinical studies.[19,42,45,50,72,102]

Experimental Design

A placebo-controlled crossover design was employed in this investigation,[91] with subjects randomized into either protocol A or B, using random-number tables. For both protocols postural data were collected during 2 data collection periods (periods 1 and 2), with an intervening 1-hour washout period. The following postural data were collected from subjects randomized to protocol A: period 1, baseline postural data followed by postural data after real postural change; period 2, baseline postural data followed by placebo postural change. Subjects randomized to protocol B followed the same procedure, with the exception that the order of allocation for the placebo and real postural data was reversed. The results of a pilot study had revealed that a 1-hour passive washout period was sufficient time to allow the subjects to return to their natural posture, following the techniques used to change posture.

Inclusion Criteria

The relationship between rotator cuff pathology, identified by diagnostic imaging and symptoms, appears to be equivocal[65,66,92] and, as such, subjects in the SIS group were included on the basis of clinical findings. In an attempt to recruit a homogeneous group of subjects with SIS, a standard set of clinical tests was performed after the subjects gave consent to participate. Table 1 provides the full details of the inclusion criteria for this study.

Neer Impingement Sign This test is performed with the patient in sitting. The examiner stabilizes the clavicle and scapula with one hand and passively flexes the patient's internally rotated arm with the other hand. The purpose of the test is to compress the subacromial contents under the acromion. Reproduction of pain indicates a positive test.[71] This test

TABLE 1. Inclusion and exclusion criteria.

Subjects Without Symptoms
Inclusion criteria
1. Male and female between the ages of 18 to 75 years
Exclusion criteria
1. Health professionals
2. Staff members of the institutions where data were collected
3. Neuromusculoskeletal disorders of the spine and upper limb
4. Spinal pain or upper limb pain in the past year
5. Treatment for any spinal or upper limb pathology in the past year
6. Systemic illnesses and connective tissue disorders
7. Pregnancy
8. Allergy to taping products
Subjects With Symptoms
Inclusion criteria
1. Male and female between the ages of 18 to 75 years
2. Unilateral shoulder pain of more than 1 week localized (anterior and/or anterolateral) to the acromion
3. Pain produced or increased during flexion and/or abduction of the symptomatic shoulder
And at least 4 of the following:
1. Positive Neer impingement sign
2. Positive Hawkins sign
3. Pain reproduced during supraspinatus empty can test
4. Painful arc of movement between 60° to 120°
5. Pain with palpation on the greater tuberosity of the humerus
Exclusion criteria
1. Health professionals
2. Staff members of the institutions where data were collected
3. Systemic illnesses
4. Pregnancy
5. Cervical pain at rest, or cervical pain during active cervical movements
6. Reproduction of shoulder symptoms during active cervical movements
7. Reproduction of shoulder symptoms with the addition of overpressure at the end of range of left and right cervical rotation, and, left rotation combined with left side flexion, and right rotation combined with right side flexion
8. History of cervical pain or treatment to this region over the past 12 months
9. History of spinal or upper limb surgery
10. History of spinal or upper limb fractures
11. Post traumatic onset of symptoms
12. Radiographic evidence of shoulder laxity (if available)
13. Presence of a positive sulcus sign
14. Presence of a positive load and shift test
15. Presence of a positive active compression labral test
16. Presence of clinical signs of acromioclavicular pathology
17. Known allergies to taping
18. Subjects involved in elite levels of sport

has been used widely in both clinical practice and shoulder research.[3,10,13,17,50,54,81,97]

Hawkins and Kennedy Impingement Test This test is performed with the patient either sitting or standing. The examiner flexes the arm to 90° and then internally rotates the shoulder. This procedure may be done at varying degrees of horizontal adduction. Reproduction of pain indicates a positive test. This test has also been used widely in both clinical practice and research into SIS.[3,10,13,54,81,97]

Empty Can Test[36] This test is performed in 2 stages and is used to determine the presence of supraspinatus pathology. The patient's shoulder is abducted to 90° in the plane of the scapula. The humerus is in neutral rotation. Resistance to abduction is applied by the examiner. The humerus is then internally rotated so that the thumb points to the floor and the same resistance is applied. Pain or painful weakness in the second part of the test is a positive finding and indicates supraspinatus pathology[36] and was used in this investigation to support the clinical diagnosis of SIS. The use of this test has been recommended by a number of clinical authorities.[3,10,51,54,81]

Painful Arc of Shoulder Movement Test[40] The patient actively abducts the arm. The presence of a painful arc of movement between 60° and 120° suggests subacromial pathology. This test is recommended by clinical authorities and has been used in research studies.[10,13,17,24,54]

Palpation of the Supraspinatus Tendon Tenderness when palpating the greater tuberosity of the humerus has been described as being indicative of supraspinatus tendon pathology,[10,81] and has been used in clinical research on SIS.[49,50] Mattingly and Mackarey[57] examined 24 shoulders in 12 cadavers and recommended that palpation of the supraspinatus tendon is possible when the hand is placed behind the back with the arm adducted against the chest. In this position, the tendon is palpable from under the acromion to a point anterior to the acromioclavicular joint. Exposure is increased if the arm is then hyperextended. The addition of hyperextension was not considered appropriate in the current investigation due to the potential aggravation of shoulder symptoms it might cause. Although the supraspinatus tendon has been described as being palpable with the forearm on the abdomen,[29] Mattingly and Mackarey[57] described it as being inaccessible in this position.

Exclusion Criteria

The tests used to exclude subjects were performed to identify subjects who clinically presented with shoulder symptoms referred from the cervical spine, shoulder instability, labral lesions, and acromioclavicular joint pathology.

Cervical Spine Tests[55] In sitting, the patient actively (1) flexes the head and neck, (2) extends the head and neck, (3) rotates the head and neck to the left, (4) rotates the head and neck to the right, (5) side flexes the head and neck to the left, and (6) side flexes the head and neck to the right. Reproduction of local and/or shoulder pain during these tests is suggestive of a cervical component to the symptoms. If the active movements did not reproduce local or referred pain, then overpressure, when appropriate, was performed by the examiner at the end of range of the active movements to further stress the cervical structures. In this investigation the overpressures used were left and right rotation, and left rotation combined with left side flexion and right rotation combined with right side flexion. A subject was considered to have a positive response if local shoulder pain was reproduced during any of the cervical testing procedures. A positive finding excluded participation in the study.

Sulcus Sign Test[25] The presence of an excessive sulcus under the acromion following traction to the humerus applied in an inferior direction, with the arm along the trunk, has been suggested to indicate inferior laxity and potentially multidirectional instability of the glenohumeral joint.[25] The traction is applied by the clinician grasping the forearm below the elbow. The patient can stand or sit and should relax the shoulder muscles. The use of this test has been widely reported.[3,50,51,100] In the current investigation potential subjects with a positive finding (presence of a sulcus) were excluded from the study.

Load and Shift Test[31] This procedure is designed to test for the presence of anterior and posterior laxity of the humeral head on the glenoid fossa. The patient sits and the clinician stabilizes the clavicle and scapula with one hand and grasps the head of the humerus with the thumb and fingers of the other hand. The humeral head is gently pushed into the glenoid fossa in order to ''seat'' it against the fossa. Following this, the clinician moves the humeral head anteriorly and posteriorly, noting the amount of translation.[31] The amount of translation is compared with the asymptomatic side. The use of this test has been widely recommended.[3,10,31,54,51,60] In the current investigation a subject with a positive anterior or posterior load and shift test was excluded.

Active Compression Labral Test/Acromioclavicular Joint Test[75] This test is designed to test the integrity of the glenoid labrum and the acromioclavicular joint. The examiner stands behind the patient. The patient is asked to forward flex the affected arm to 90° with the elbow in full extension. The patient then horizontally adducts the arm 10° to 15°. The arm is then internally rotated so that the thumb points downward towards the floor. The examiner then applies a downward force on the forearm. Maintaining the 90° shoulder flexion and 10° to 15° horizontal adduction past midline, the shoulder is externally rotated so that the palm faces upwards towards the ceiling. The same pressure in the same direction is applied. The test is considered to be positive if pain is elicited in the first manoeuvre and reduced or eliminated in the second. Pain or painful clicking described inside the glenohumeral joint is indicative of labral pathology. Pain located to the area of the acromioclavicular joint or to the top of the shoulder is diagnostic of an acromioclavicular pathology. Individuals with a positive test were excluded from the study.

Table 1 details the exclusion criteria for the subjects participating in this study.

Procedure

Postural measurements were made on the painful side of the subjects with symptoms and the dominant arm of the asymptomatic subjects. Male subjects were asked to remove their shirts and female subjects were asked to wear an open-back bathing costume. Subjects stood 30 cm in front of a plumb line hanging from the ceiling, with their nondominant shoulder (asymptomatic subjects), or pain-free shoulder (subjects with symptoms) 20 cm from a plain white wall. Adhesive tape on the floor was used to identify these distances. Following palpation, nonallergenic adhesive markers 6 mm in diameter were attached to the following anatomical points that were designated with an alphabetical reference (Figure 1):

1. The posterior aspect of the acromion (point C)
2. The inferior angle of the scapula (point E)

3. The thoracic spinous process (SP) corresponding with the root of the spine (point A)
4. The thoracic SP corresponding with the inferior angle (point D)
5. The 12th thoracic SP (point F)
6. The lateral midpoint of the humeral head
7. The tragus of the ear
8. A 3-cm straw marker was attached through a hole, the same diameter as the straw, in adhesive felt padding of 3.2-mm width to the seventh cervical (C7) SP. The straw marker was held in place on the C7 SP by sliding the adhesive felt down the straw to secure it in place onto the skin

Subjects were then asked to adopt a comfortable and natural standing position. To facilitate this, each subject was informed that during the investigation it was important that a natural posture be adopted and to pretend that nobody was observing them. The specific postural instructions that were given to each subject, were developed during pilot testing and were standardized for all subjects.

To measure FHP and forward shoulder posture (FSP) angles, a lateral photograph was then taken of the cervicothoracic region, using an Olympus OM2 SLR camera (Olympus Optical Company, London, UK) set at 100ASA, with a 28- to 50-mm adjustable lens. The lens aperture was set at F-stop 8. The camera was placed 2 m from the subject and mounted on a tripod, leveled with a bubble spirit level to control frontal and sagittal angles. One hundred ASA color photographic film (Eastman Kodak Company, Rochester, NY) was used. This procedure has been used in previous published studies.[84,85] The method chosen to measure the FHP and FSP angles for the current investigation was direct measurement from lateral view photographs of head and shoulder posture. To measure the angles, an A4-sized sheet of graph paper was photocopied onto transparency film for photocopiers. The graph paper had vertical and horizontal lines spaced at 1-mm intervals. The transparency film was then placed over the photograph and aligned so that one of the vertical lines was placed over the plumb line and the intersection of 1 vertical and 1 horizontal line coincided with the point the C7 marker came in contact with the skin (Figure 2). To calculate the position of the head in relation to C7 (C7-tragus angle), shown as angle A in Figure 2, the vertical distance and the horizontal distance from the C7 marker to the tragus were measured. The angle was determined by calculating the length of the vertical distance divided by the length of the horizontal distance. The angle was determined by using the $\tan^{-1}$ function key on a pocket calculator. The method used to calculate the angular position of the shoulder in relation to C7 (FSP), involved dividing the vertical distance from the C7 marker to the

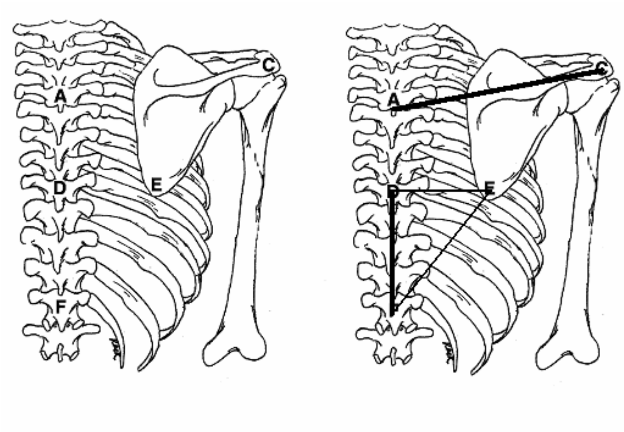

FIGURE 1. Bony landmarks identified by palpation used to investigate resting position of the scapula. The diagram on the left depicts the landmarks and the diagram on the right details the method of measuring the lateral linear displacement of the scapula (distance AC), and the method for calculating the elevation of the scapula above the T12 spinous process (distance DF), after the distances DE and FE were measured.

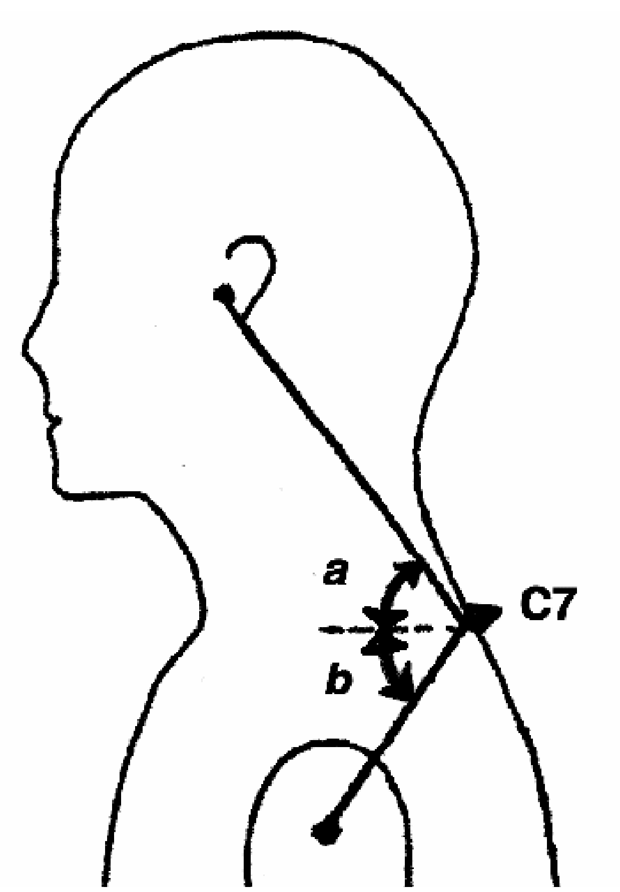

FIGURE 2. Forward head posture determined by calculating the angle (A) made between the horizontal and the tragus of the ear from the C7 spinous process. Forward shoulder posture determined by calculating the angle (B) made between the horizontal and the midpoint of the shoulder

lateral midpoint of the shoulder by the horizontal distance between these points. The angle was determined using the same method as described above. Figure 2 depicts how the FHP and FSP angles were determined from the lateral photograph.

Following the photograph, the following measurements were each made 3 times with the same standard nonstretch measuring tape and recorded to the nearest millimeter on the data collection form. The measurements were the lengths between the landmarks identified in Figure 1, and were AC, DE, and FE. The measurement AC was used to determine the distance between the posterior angle of the acromion and the SP corresponding with the root of the spine of the scapula. The measurements FE and DE were used in Pythagoras' theorem to calculate the vertical displacement of the inferior angle of the scapula above the T12 SP. Although the distance FD could have been measured, during the pilot stages of this investigation it was found that the curvature of the spine made this direct measurement difficult in a number of patients.

Inclinometers (Isomed, Inc, Portland, OR) were then placed with their feet over the T1 and T2 SP, and the T12 and L1 SP, and the angles were recorded. Each measurement was made 3 times. This method of generating a clinical measurement for the thoracic kyphosis has been described previously.[19,77] Figure 3 details how the kyphosis angle was measured.

Two lines marked with tape on the floor served as guides for the direction of shoulder flexion and scapular plane abduction. Flexion was performed in the sagittal plane and abduction was performed in a plane defined as being 30° anterior of the frontal plane (abduction in the plane of the scapula). To standardize the internal/external rotation position of the glenohumeral joint, subjects were requested to perform the movement with their thumbs pointing towards the ceiling. Each movement was performed 3 times. The range of shoulder flexion and scapular plane abduction for the subjects with symptoms was at the first point of pain, or the first increase in their resting pain. The end of available range of movement for this group was not measured to avoid aggravating symptoms. Measurements for the asymptomatic subjects were made at the end of their available range. Shoulder flexion and abduction in the plane of the scapula range of movement was recorded with the inclinometer facing towards the ceiling and with its proximal foot at the insertion of the deltoid. Subjects were asked to record their maximal pain during the movements on a 10-cm horizontal visual analogue scale (VAS) for pain, where the left side (0) was marked as no pain and the right side (10) as the worse pain imaginable.

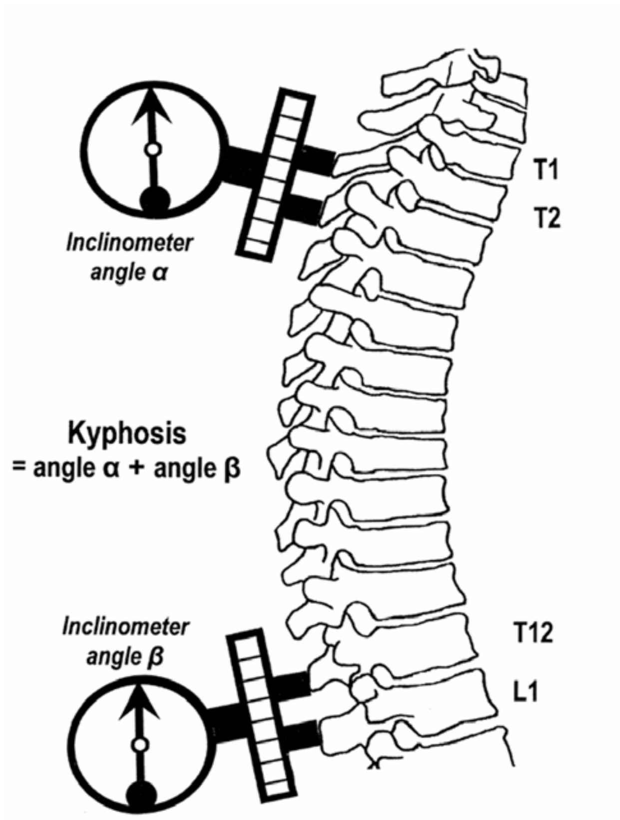

FIGURE 3. Thoracic kyphosis angle calculated by the summation of the inclinometer placed over the spinous process of T1 and T2 (angle α) and the inclinometer placed over the spinous process of T12 and L1 (angle β)

To determine if the taping technique had an influence on the sagittal plane position of the scapula, a nonstretch fiberglass tape measure was attached to a tripod located behind the patient and adjusted to the height of the individual subject's acromion. To measure the linear distance from the tripod to the posterior aspect of the acromion, subjects were asked to sit to the back of an armless office chair with only their lumbar spines supported on a pressure biofeedback device (Stabilizer, Chattanooga, Australia). The tripod was secured to the floor at a fixed distance (60 cm) behind the chair. To facilitate the same sitting position during the 4 data collection phases (no tape, tape, no tape, placebo tape), the subject's lumbar spines were supported on a pressure biofeedback device (Stabilizer, Chattanooga, Australia). The pressure in the device was recorded and, on each occasion that the linear measurement from the tripod to the posterior aspect of the acromion was made, the subjects were required to sit and reproduce the same pressure in the pressure device. The linear distance from the tripod to the posterior aspect of the acromion was the only measurement made in sitting. It was done so, as the results of pilot studies had suggested that because method of measurement produced minimal anteroposterior postural sway of the trunk. Once seated, subjects were asked to let their arms hang to their sides and adopt a comfortable posture. While the subjects remained sitting, the linear measurement from the tripod to the posterior aspect of the acromion was made 3 times on each data collection phase.

To reduce investigator bias, the measurements made by the investigator were reported to an assistant who recorded the measurements on data collection sheets. Four data collection sheets were used for each subject and the investigator was not able to observe the imputed data during data collection. Postural data were collected from other subjects during the 1-hour washout period that separated the 2 data collection phases for each subject, which further reduced investigator bias.

Changing Posture

Taping products were used to change posture and as a placebo procedure. Real postural change was achieved by requesting the subjects to extend their thoracic spines. The investigator demonstrated the movement to each subject and the subjects were allowed to practice this once before the application of 3.8-cm-wide Leukotape (Beiersdorf UK Ltd, Birmingham, UK) which was applied bilaterally from T1 to T12. Subjects were then asked to fully retract and depress their scapula, and tape was applied from the center of the spine of the scapula to the T12 SP in a diagonal fashion. The leukotape was pretensioned prior to application on the subject and the subjects maintained the required postural changes while the tape was applied. Subjects were not required to actively maintain the postural change, as the aim of the tape was to hold each subject in the new posture.

The placebo procedure involved the application of 5-cm-wide Fixomull Tape (Beiersdorf UK Ltd, Birmingham, UK), which was applied over the same locations as the real postural tape. During the application of placebo taping subjects stood in their natural postures with no attempt made to change posture in any way. The placebo taping was not pretensioned and was included in the protocol to determine if any observed changes in the dependent variables had occurred as a result of the postural change and not as a result of another effect of the tape. The use of placebo taping in this fashion has been reported previously.[95] The findings of a pilot study on 5 asymptomatic subjects suggested that the real postural change procedure was able to produce a decrease in the thoracic kyphosis and a more depressed scapula, as well as reductions in the sagittal plane position of the scapula and lateral linear displacement of the scapula. The pilot study also revealed that subjects returned to their baseline posture within 1 hour of removing the taping materials. The taping techniques are depicted in Figure 4, and Figure 5 details a lateral photograph of a subject in the 4 postural measurement phases.

Measurement Reliability

The intrainvestigator reliability, using the measuring devices to produce the measurements of interest, was investigated in a separate study involving 15 asymptomatic and 15 subjects with symptoms who completed informed consent documentation. A 1-hour interval separated each set of measurements, where the subjects were asked to move around, but not adopt, extremes of posture or participate in heavy lifting or any sporting activity. Photographic

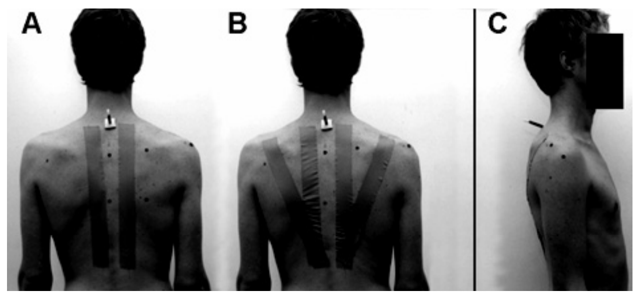

FIGURE 4. Diagram A depicts the application of real postural change thoracic taping followed by the postural change scapular taping (B). Figure C represents a lateral view of a subject with the taping in place.

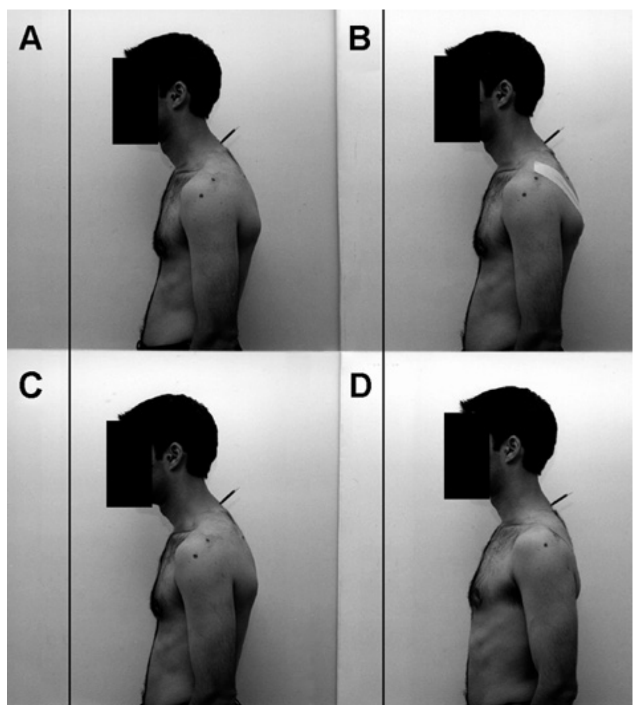

FIGURE 5. The 4 data collection phases for a subject randomized to protocol B. The order of the techniques performed was A→ B→ C→ D: A, first no tape measurements; B, placebo tape measurements; C, second no tape measurements; D, postural correction taping measurements.

TABLE 2. Pilot reliability study.

Measurement	$ICC_{3,1}$	95% CI for $ICC_{3,1}$	SEM
Subjects Without Symptoms			
AC	0.98	0.96 to 0.99	0.3 cm
DE	0.96	0.90 to 0.98	0.3 cm
FE	0.91	0.77 to 0.97	0.7 cm
Scapular elevation (DF)	0.82	0.55 to 0.93	0.9 cm
Kyphosis (T1/2 + T12/L1)	0.96	0.90 to 0.98	1.5°
Sagittal plane position of scapula	0.94	0.84 to 0.98	1.9 cm
Shoulder flexion	0.98	0.95 to 0.99	1.1°
Shoulder abduction	0.98	0.96 to 0.99	1.1°
Subjects With Symptoms			
AC	0.92	0.80 to 0.97	0.5 cm
DE	0.91	0.77 to 0.97	0.4 cm
FE	0.90	0.74 to 0.96	0.5 cm
Scapular elevation (DF)	0.81	0.52 to 0.93	0.7 cm
Kyphosis (T1/2 + T12/L1)	0.94	0.83 to 0.98	2.5°
Sagittal plane position of scapula	0.97	0.94 to 0.99	1.9 cm
Shoulder flexion	0.99	0.97 to 0.99	2.9°
Shoulder abduction	0.98	0.96 to 0.99	3.3°

Abbreviations: AC, distance between spinous process corresponding with the root of the spine of the scapula, and, the posterior aspect of the acromion; CI, confidence interval; DE, distance between spinous process corresponding with the inferior angle of the scapula, and, the inferior angle of the scapula; DF, distance between spinous process corresponding with the root of the spine of the scapula, and, the spinous process of the twelfth thoracic vertebra; FE, distance between spinous process corresponding with the twelfth thoracic spinous process and the inferior angle of the scapula; ICC, intraclass correlation coefficient; SEM, standard error of measurement; T1/2, measurements made at the first and second thoracic vertebrae; T12/L1, measurements made at the 12th thoracic and first lumbar vertebrae.

reliability was tested by (1) measuring the same photograph (intraphotograph reliability) on 2 occasions (C7-tragus angle [$ICC_{3,1}$, 0.98; 95% CI, 0.89-0.99; SEM, 0.5°] and C7-shoulder angle [$ICC_{3,1}$, 0.99; 95% CI, 0.99-1.0; SEM, 0.5°]), (2) taking measurements from 2 photographs (interphotograph reliability) of the same posture with an hour interval between each photograph (C7-tragus angle [$ICC_{3,1}$, 0.93; 95% CI, 0.76-0.98; SEM, 1.1°] and C7-shoulder angle [$ICC_{3,1}$, 0.93; 95% CI, 0.78-0.99; SEM, 1.4°]), and (3) the accuracy of the technique was measured by comparing the method used to measure the angles on the photographs from known angles ($ICC_{3,1}$, 0.99; 95% CI, 0.97-0.99). The other measurements are detailed in Table 2.

The results of the intratester reliability study suggested that the measurement reliability for the outcome measurements of interest would be acceptable for the main investigation.[16,82]

Data Analysis

The measurements available for analysis were: FHP, FSP, thoracic kyphosis angle, lateral linear displacement of the scapula, scapular elevation (above T12), the sagittal plane position of the acromion, the pain-free ranges of sagittal plane shoulder flexion, and abduction in the plane of the scapula, and the VAS pain score during these movements. Data were analyzed using the SPSS, Version 11.5.0. Descriptive statistics (mean, SD, range) were computed for each study variable.

The crossover design allowed postural corrections on each subject to be computed for the real postural change tape (defined as postural measurements after application of the real postural correction taping, minus baseline postural measurements before the application of the real tape), the placebo tape (defined as, postural measurements after the application of placebo postural correction taping, minus baseline postural measurements before the application of placebo tape), and a control (baseline postural measurements for period 2, minus baseline postural measurements for period 1). The postural taping effect on measurements was defined as the comparison of postural corrections for the real tape and the placebo tape, and the placebo taping effect as the comparison of postural corrections for the placebo tape and the control.

Postural and placebo taping effects were tested for statistical significance using a 1-factor repeated-measures analysis of variance. Comparisons of main effects, with a Bonferonni adjustment, were used to produce 99% CIs for the mean postural and taping effects. The levels of the within-subject factor were taken as the postural corrections for real tape, placebo tape, and the control. Homogeneity of variances was tested using Mauchly's test of sphericity.[83] When the sphericity test was significant, the Greenhouse-Geisser correction was applied to adjust the tests, as recommended by Portney and Watkins.[83] All adjusted tests produced the same *P* values as unadjusted tests. There were 10 variables of interest in this study, so the hypothesis tests were conducted at a 0.01 level of significance.

Multiple regression analyses were conducted for improvement in range of movement (shoulder flexion, sagittal plane abduction) following real taping on changes in postural measures (FHP, FSP, thoracic kyphosis angle, lateral linear displacement of the scapula, scapular elevation [above T12], the sagittal plane position of the acromion). Standardized regression coefficients and partial correlation coefficients[83] were computed to consider the relative importance of changes in individual postural measures to the improvement in range of movement.

RESULTS

All 120 subjects completed the study. There were 56 females and 64 males, with ages ranging from 19 to 75 years, heights between 149 to 189 cm, and masses between 43 and 108 kg. Characteristics for the asymptomatic and symptomatic subjects are given in Table 3.

Postural taping effects were statistically significant ($P<.001$) for all postural measures for both symptomatic and asymptomatic subjects (Table 4). For symptomatic subjects, postural taping produced significantly less FHP (mean, 4.1°), less FSP (mean, 3.9°), smaller kyphosis (mean, 5.8°), less lateral scapular displacement (mean, 1.8 cm), less elevated scapula position (mean, 1.7 cm), less forward sagittal position (mean, 2.5 cm), increased pain-free range of shoulder flexion (mean 16.2°), and increased pain-free range of scapular plane abduction (mean 14.7°), as compared to when measured with placebo taping. Similar improvements were found on asymptomatic subjects (Table 4). No significant effects were found on VAS pain score for shoulder flexion ($P = .136$), or VAS pain scores for shoulder scapular plane abduction ($P = .111$), for symptomatic subjects. Ninety-nine percent confidence intervals for effects are given in Table 4.

There were no statistically significant effects of placebo taping for the symptomatic subjects on FHP (mean difference, –1.32°; SE, 0.54°; $P = .05$), FSP (mean difference, 1.65°; SE, 0.97°; $P = .28$), kyphosis (mean difference, 0.43°; SE, 0.40°; $P = .86$), lateral linear displacement of the scapula (mean difference, –0.04 cm; SE, 0.10 cm; $P = 1.00$), scapular elevation (mean difference, 0.09 cm; SE, 0.09 cm; $P = 1.00$), scapular sagittal plane (mean difference, –0.10 cm; SE, 0.19 cm; $P = 1.00$), shoulder flexion (mean difference, –1.52°; SE, 2.18°; $P = 1.00$), and shoulder abduction in the plane of the scapula (mean difference, –3.15°; SE, 2.23°; $P = .49$). In addition, no significant effects of placebo taping were found on VAS pain scores for shoulder flexion (mean difference, 0.28; SE, 0.17; $P = .32$) and scapular plane abduction (mean difference, 0.07; SE, 0.16; $P = 1.00$).

There were no statistically significant effects of placebo taping for the asymptomatic subjects on FHP (mean difference, –0.23°; SE, 0.47°; $P = 1.00$), FSP (mean difference, 2.10°; SE, 0.86°; $P = .05$), kyphosis (mean difference, –0.78°; SE, 0.55°; $P = .48$), scapular elevation (mean difference, 0.02 cm; SE, 0.14 cm; $P = 1.00$), scapular sagittal plane (mean difference, –0.41 cm; SE, 0.24 cm; $P = .26$), shoulder flexion (mean difference, –0.87°; SE, 0.56°; $P = .39$), and shoulder abduction in the plane of the scapula (mean difference, –1.12°; SE, 0.55°; $P = .14$). Mean postural correction of lateral linear displacement of the scapula was significantly smaller for placebo tape than the control (mean difference, –0.33 cm; SE, 0.08 cm; $P = .001$).

TABLE 3. Descriptive statistics.

	Subjects Without Symptoms		Subjects With Symptoms	
	Protocol A	Protocol B	Protocol A	Protocol B
Sex (n)				
Female	17	14	13	12
Male	13	16	17	18
Age (y)*	32.8 ± 9.9 (19.0-59.0)	35.3 ± 10.0 (23.0-65.0)	47.9 ± 15.3 (22.0-72.0)	49.9 ± 15.1 (19.0-75.0)
Height (cm)*	168.5 ± 10.2 (150.0-184.0)	173.3 ± 10.6 (150.0-188.0)	170.9 ± 11.4 (149.0-189.0)	171.4 ± 7.9 (155.0-185.0)
Mass(kg)*	65.9 ± 13.4 (45.0-94.0)	69.7 ± 13.5 (43.0-100.0)	76.3 ± 15.0 (52.0-108.0)	72.6 ± 10.4 (54.0-95.0)
DOS (y)*	-	-	1.5 ± 4.0 (0.1-22.0)	0.8 ± 1.0 (0.4-5.0)
Arm dominance (n)				
Left	1	1	5	3
Right	29	29	25	27
Painful side				
Left	-	-	14	11
Right	-	-	16	19

Abbreviations: DOS, duration of symptoms.
* Data are presented in (means ± SD [range]).

TABLE 4. Effect of taping techniques (compared to placebo taping condition) on postural measurements of interest. With the exception of pain, taping produced a significant change ($P<.001$) for all variables measured.

Outcome Measures	Subjects Without Symptoms Mean (SE)*	99% CI*	DF†	*P* Value‡	Subjects With Symptoms Mean (SE)*	99% CI*	DF†	*P* Value‡§
FHP (°)	2.5 (0.45)	1.1-3.9	2,118	<.001	4.1 (0.66)	2.0-6.1	2,118	<.001
FSP (°)	5.0 (1.12)	1.6-8.4	2,118	<.001	3.9 (1.12)	0.4-7.3	2,118	<.001
Kyphosis (°)	–6.4 (.72)	–8.6- –4.2	2,118	<.001	–5.8 (0.66)	–7.8- –3.7	2,92	<.001
Lateral scapular displacement (cm)	–1.4 (.14)	–1.8- –1.0	2,90	<.001	–1.8 (0.15)	–2.2- –1.3	2,100	<.001
Elevation (cm)	–1.7 (.18)	–2.2- –1.1	2,95	<.001	–1.7 (0.18)	–2.3- –1.2	2,84	<.001
Sagittal position (cm)	–1.8 (.32)	–2.7- –0.8	2,94	<.001	–2.5 (0.25)	–3.3- –1.7	2,118	<.001
Shoulder flexion (°)	8.2 (.69)	6.1-10.3	2,118	<.001	16.2 (2.70)	7.9-24.4	2,118	<.001
Scapular plane abduction (°)	7.0 (.65)	5.0-9.0	2,118	<.001	14.7 (2.92)	5.7-23.6	2,118	<.001
Shoulder flexion VAS (pain)	-	-	-	-	–0.4 (0.23)	–1.1-0.3	2,118	.136
Shoulder abduction VAS (pain)	-	-	-	-	–0.4 (0.20)	–1.0-0.2	2,118	.111

Abbreviations: FHP, forward head posture; FSP, forward shoulder posture; VAS, visual analogue scale.
* SE (standard error) and CI (confidence intervals) from Bonferonni adjusted comparisons of main effects in a repeated measures analysis of variance.
† DF (degrees of freedom) from repeated measures analysis of variance, Greenhouse-Geisser adjusted where appropriate.
‡ *P* value from repeated measures analysis of variance.
§ Significant at the .001 level.

TABLE 5. Standardized regression coefficients and partial correlation coefficients for the prediction of improvement in range of movement from improvements in postural measurements after the application of postural taping.

Improvements on Postural Measure	Subjects Without Symptoms Beta*	Partial Correlation Coefficient†	*P* Value	Subjects With Symptoms Beta*	Partial Correlation Coefficient†	*P* Value
Shoulder flexion						
FHP (°)	.140	.14	.31	.222	.20	.14
FSP (°)	.041	.04	.79	–.029	–.03	.84
Kyphosis (°)	–.199	–.19	.16	–.120	–.13	.39
Lateral scapular displacement (cm)	–.231	–.21	.13	–.042	–.04	.77
Elevation (cm)	.057	.06	.67	–.137	–.14	.33
Sagittal position (cm)	–.008	–.01	.96	–.043	–.04	.78
Scapular plane abduction (°)						
FHP (°)	.315	.32	.02	.200	.18	.18
FSP (°)	.116	.11	.41	–.081	–.08	.57
Kyphosis (°)	–.298	–.30	.03	.031	.03	.82
Lateral scapular displacement (cm)	–.017	–.02	.90	.095	.09	.51
Elevation (cm)	.118	.13	.35	–.102	–.10	.47
Sagittal position (cm)	.019	.02	.90	–.119	–.11	.44

Abbreviations: FHP, forward head posture; FSP, forward shoulder posture.
* Standardized regression coefficient.
† Correlation between measure for the range of movement and improvement in postural measure, adjusting for the influence of improvements on other postural measures.

At a 5% level of significance, changes in postural measures did not individually contribute significantly to improvement in range of movement for subjects with symptoms (Table 5), or to improvement in shoulder flexion for asymptomatic subjects. Improvements on FHP ($\beta = .315$, partial correlation = .32, $P = .02$) and kyphosis ($\beta = -0.298$, partial correlation = –.30, $P = .03$) were related to improvements on range of scapular plane abduction for asymptomatic subjects (Table 5).

DISCUSSION

Clinical authorities have suggested that poor upper body posture and muscle imbalance may cause or perpetuate SIS. The aim of many conservative reha-

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bilitation programs is to correct posture and muscle imbalance using muscle strengthening, muscle stretching, and joint mobilization techniques.[39,68,94,99] The evidence to support the efficacy of these clinical practices is limited. The aim of this study was to contribute to knowledge regarding the influence on changing posture on shoulder range of movement in asymptomatic and symptomatic subjects, as well as pain in subjects with SIS. It was considered important to choose a model of changing posture that could be considered realistic to an extent that it might be achievable as a result of a clinical rehabilitation program. Models that required subjects to be assessed in extremes of inflexible postures[38] were rejected, and the model chosen was the use of taping materials. The application of taping has been recommended for many therapeutic reasons[23,32,52,58,59,68,87,90] and it was necessary to demonstrate that one of the effects of taping, as used in this investigation, was to elicit a change in the static posture of the subjects. Placebo taping, applied over the same area as the postural correction taping, but without requesting the subjects to alter their posture, was also investigated in an attempt to determine if it was the influence of changing posture, or another effect of applying tape, that brought about any observed changes in the outcome measurements of interest. If the postural correction tape influenced the postural and functional measurements of interest and the placebo postural taping did not, it was considered that a change in the postural measurements may be attributable to a change in the static posture of the subject, produced by the subject and maintained by the tape.

The placebo postural correction procedure did not produce a significant change in the static position of the scapula, or on the range of pain-free shoulder flexion and abduction in the plane of the scapula in the symptomatic subjects. With the exception of a significantly smaller lateral linear displacement of the scapula from the thoracic spine (–0.3 cm, $P = .001$), the placebo procedure did not produce a significant effect on any of the measurements of interest in the asymptomatic group. However, the clinical importance of the reduced lateral linear displacement of 3 mm is questionable. In contrast, the findings suggest that the taping technique used to change posture did have a significant effect on all the postural variables measured. There was a significant ($P<.001$) decrease in the FHP angle, FSP angle, thoracic kyphosis angle, amount of lateral linear displacement of the scapula, and elevation and sagittal plane position of the acromion. There was also a significant increase ($P<.001$) in the range of shoulder flexion and scapular plane abduction for both groups of subjects. Although the point at which pain was first experienced or first felt to increase occurred later in the shoulder flexion and scapular plane abduction range in the symptomatic subjects, the intensity of pain was not found to be significantly reduced. The results of multiple regression analysis suggested that there was no predominant postural variable that influenced shoulder flexion and abduction in the plane of the scapula range, and that the subjects responded individually to the effects of postural change. Therefore, it is not possible to determine if a single change, or a combination of changes, in the static posture led to the recorded increased range in shoulder flexion and abduction in the plane of the scapula. It is also not possible to determine if isolated changes had a positive or negative effect on the results. The purpose of the postural change taping was to extend the thoracic spine, and, to retract, depress, and posteriorly tilt the scapula. It is unknown if the addition of either upward or downward rotation would have had a beneficial or detrimental effect on the results. The results from other studies[27,46,84,85] have suggested that upper body posture does not follow the set patterns described in the literature and have challenged the belief that clinicians may assume the presence of a specific changes in posture based on the presence of a FHP. Although the findings from the current study suggest that changing components of posture may lead to an increase in shoulder flexion and scapular plane abduction range of movement, it is important to acknowledge that the findings do not suggest that posture follows set patterns, or that the postural change reported here has functional relevance. This is important to emphasize, as the postural change described in the current investigation, despite an overall mean improvement, had a detrimental effect on shoulder range in a number of subjects in both groups. The findings of this and other studies[27,46,84,85] suggest that it may be more useful clinically to assess the individual components of posture and their effect on range of movement and pain than to examine sagittal plane posture.

Although the clinical and functional implications of an increase mean 8.2° shoulder flexion and 7.0° abduction in the plane of the scapula, as observed in the asymptomatic subjects in this investigation, is unknown, it is comparable to the mean 6.6° increase in shoulder abduction reported by Wang et al,[99] who assessed the effect of a 6-week exercise program aimed at correcting posture on 20 asymptomatic subjects. Subjects exercised 3 times a week, performing pectoral muscle stretches and strengthening exercises for the scapular retractors, glenohumeral external rotators, and abductors. Wang et al[99] also reported that, following the program, the scapula was more downwardly rotated, a finding that contradicts postural theory, due to the belief that a downwardly rotated scapula increases subacromial compression. Wang et al[99] also reported that, following the program, there was a significant reduction in the upper thoracic kyphosis. Roddey et al[88] investigated the short-term effect of a daily pectoralis major stretching program in a control (nonstretching) group, a group with mild FHP, and a group with moderate FHP, on the short-term resting static scapular protraction distance from the spine. No significant change was reported in either the control or the mild FHP groups. A significant decrease in the scapular protraction distance was reported in the moderate FHP group. Although the results presented by Roddey et al[88] suggested that in asymptomatic subjects with moderate FHP a pectoralis major stretching program would lead to a significant decrease in the amount of static scapular protraction, it is not known what effect this had on shoulder range of movement, as it was not investigated, nor was the effect of stretching in subjects with symptoms.

Scapular Elevation

Wang et al[99] reported that the scapula was less elevated following their exercise program. This finding is relevant, as other studies have reported that the scapula is more elevated in slouched postures[38] and in subjects with SIS.[18,50] Warner et al[101] also reported increased scapular elevation in 4 subjects out of a group of 7 with shoulder pathology. It is not known if the scapular elevation reported in these studies was involved in the pathogenesis of the condition or was a secondary compensatory response to the pathology. The results from the current investigation suggest that the mean decrease of resting scapular elevation following the postural correction technique used in the current investigation was 1.7 cm for both the asymptomatic and symptomatic subjects.

Lateral Linear Displacement of the Scapula

As the scapula protracts and retracts around the thorax, its lateral linear distance from the thoracic spine increases and decreases. The mean within-subject decrease in lateral linear displacement of the scapula was found to be 1.4 cm for the asymptomatic subjects and 1.7 cm for those with SIS. This suggests that the scapula was more retracted following the procedure. Although previous research[21] suggests that there is no statistical difference between function and the amount of medial/lateral displacement of the scapula from the thoracic spine, in this study, reducing the amount of resting lateral linear displacement of the scapula as part of a combination of postural changes led to an increase in shoulder flexion and scapular plane abduction range. By itself there was no significant relationship between a change in lateral scapular displacement and shoulder motion (Table 5).

Sagittal Plane Position of the Acromion

Other studies have reported that the scapula is more anteriorly tilted in slouched postures[38] and in subjects with SIS.[49,50] Postural theorists[6,28] and clinical observations[32] have suggested that this may be due to an associated shortening of the pectoralis minor muscle. The taping technique in the current study significantly reduced the sagittal plane position of the acromion by 1.7 cm and 2.5 cm in the asymptomatic and symptomatic subjects, respectively. This reduction potentially reduced the anterior tilt of the scapula and may have contributed to the observed increase in shoulder flexion and scapular plane abduction observed in the current investigation.

Thoracic Kyphosis

The review of the literature failed to identify any studies that had investigated the effect of changing the resting angle of the thoracic kyphosis experimentally in subjects with SIS to determine the effect on shoulder range of movement and pain. The mean decrease in the kyphosis angle of 6.4° and 5.8° in the asymptomatic and symptomatic subjects (in conjunction with other postural changes), respectively, observed in this study, following the postural correction taping, offers some support to the belief that reducing the thoracic kyphosis can contribute to improving arm elevation.[11,28,41]

Shoulder Flexion and Scapular Plane Abduction

The results suggest that the combined effect of changing several components of posture in the symptomatic subjects led to a mean increase of 16.2° shoulder flexion and 14.7° abduction in the plane of the scapula from their respective baseline values (end point of movement defined by the onset or increase in pain). The mean baseline values were 120.1° (SD, 30.8°) and 111.2° (SD, 30.8°), respectively, for these measurements, and the mean values following postural correction were 136.3° (SD, 28.4°) and 125.9° (SD, 31.3°), respectively. Although the large standard deviations reflect considerable variation among the subjects, the increases in shoulder flexion and scapular plane abduction range observed following the taping technique may allow subjects with SIS to perform activities with the upper limb in a greater degree of elevation before experiencing pain, or an increase in pain. A limitation of this study, inherent to investigations involving nonconstrained subjects, is that the method used to measure shoulder flexion and scapular plane abduction could not isolate the movement occurring at the glenohumeral joint, and also involved scapular and trunk movement. This limitation is acknowledged and future research involving nonconstrained subjects should attempt to isolate the humeral, scapular, thoracic, lumbar, and lower limb contribution to the movement of arm elevation.

The Therapeutic Use of Taping

The use of taping has been widely reported in the literature. The therapeutic effects of taping have been hypothesized to include joint stabilization,[52] changing and controlling posture at a joint,[32,58] inhibiting muscle activity,[59] reducing pain,[52] increasing motoneurone excitability,[74] and increasing joint torque.[23] Taping has also been reported to enhance proprioception.[87] Although the taping technique used in this study appears to alter static postural measurements, there is no evidence that it had an effect on posture during movement. There are other potential reasons for the beneficial effect of the taping technique used. Potential benefits include improved muscular effort,[23] enhanced sensory motor control,[8,33,43,87] cutaneous stimulation,[26,74,79] pain modulation via altered sensory input,[63] and facilitation or inhibition of muscle activity.[2,73]

Further research is necessary to determine if these or other mechanisms are involved in the observed changes. Future research is also required to determine the long-term effectiveness of the taping procedure and its relevance in a rehabilitation program. Although the data were entered by an assistant, the investigator was not blinded to the postural measurements as they were being taken. This is a limitation of this investigation and future studies should endeavor to employ procedures that blind the investigator from the linear and angular measurements. It is important to emphasize that, although the majority of subjects responded positively to the procedure, a number did not demonstrate an increase in range of shoulder motion and in some there was a decrease in range and an increase in pain. Future studies could aim at determining the characteristics of subjects who benefit from postural change and those in which the technique has a detrimental effect. The technique used to change posture described in this investigation, and modifications to this technique, may possibly be considered as part of the clinical assessment of a patient, in an attempt to determine the relevance of posture and the potential benefit of changing posture for that individual patient. Furthermore, as the findings from the multiple regression analysis did not suggest that changes in posture individually contributed significantly to increases in shoulder range, and, as some subjects responded negatively to the postural changes used in this investigation, it may be beneficial to assess the individual effect of elevating, protracting, and increasing the anterior sagittal plane position of the scapula on individual subjects to determine the influence of each factor on range of movement and pain. These individual postural variations could also be investigated in future investigations.

The basis for correcting muscle imbalances and posture is based upon models suggesting that the postural fault is associated with acromial impingement of the subacromial tissues.[3,6,28,89] The acromial mechanism of impingement has been challenged with studies suggesting that the acromion may not be involved in the pathogenesis of the condition,[34] the joint and not the acromial side of the supraspinatus tendon is more vulnerable,[69] and the pathology in SIS may involve an intrinsic degenerative tendinosis and not an inflammatory tendinitis caused by acromial irritation.[12,76,78,96] As the exact cause and nature of SIS remains unknown, future research is necessary to establish the mechanism that postural change may have on the pathology.

CONCLUSION

The forward head or ''slouched'' posture has been associated with an increased thoracic kyphosis, forward shoulder posture, and a scapula that is protracted, elevated, anteriorly tilted, and downwardly rotated. This combination of postures has been associated with a reduction in glenohumeral movement and a number of clinical conditions including SIS. There is little evidence that posture does follow the set patterns described in the literature, and the evidence to support the belief that correcting posture and muscle imbalance will produce an improvement in function and reduction in pain is also limited. The results of the current study, combining active correction of posture and taping, suggest that there may be a short-term improvement in the range of shoulder flexion and scapular plane abduction in asymptomatic subjects and those with SIS. There may be a place for the techniques described in this study in the assessment of patients to determine the possible benefit of postural changes and taping on SIS. Future research needs to determine the long-term benefits of treating muscle imbalances and changes in posture in the conditions where it is thought to be involved as an etiological factor.

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