Title Page

Differences in scapular orientation between standing and sitting postures at rest and in 120°scaption: A cross sectional study.

Abstract

Background: Scapular orientation may be influenced by static body posture (sitting and standing) and contribute to the development of shoulder pain. Therefore a consistent body posture should be considered when assessing scapular orientation as well as enhancing optimal scapular positioning.

Objective: To determine if there are differences in scapular orientation between standing, neutral sitting and habitual sitting, while adjusting for spinal posture.

Design: A single group randomised repeated measures study.

Setting; University Laboratory

Participants; Twenty-eight participants with shoulder pain were recruited from the community.

Methods; Scapular orientation between standing and seated positions was compared, with the arm by the side and at 120° of glenohumeral scaption. Thoracic kyphosis and lumbar lordosis angles were used as covariates.

Main Outcome Measurements; Scapular elevation, lateral translation, upward rotation, and posterior tilt.

Results: Scapular orientation was marginally but significantly different between sitting postures for lateral translation (mean 0.5cm (95%CI 0.2 to 0.7 cm), p<.001), upward rotation (mean 3° (95%CI 1.1 to 5.0°) p<.001), and posterior tilt (mean 2.3° (95%CI 0.2 to 4.3°) p=.009) in the arm by side position. A small but significant difference between standing and neutral sitting was found for upward rotation (mean 1.8° (95%CI 0 to

3.7°) p=.02), and between standing and habitual sitting for lateral translation (mean 0.6cm (95%CI 0 to 1.1cm) p=.02) in the arm by side position.

Conclusions: The results of this study suggest that scapular orientation can be slightly affected by body posture, although the clinical relevance is uncertain. To enhance scapular upward rotation or posterior tilt, it may be preferable to place the patient in neutral sitting.

Keywords: Posture, Shoulder Impingement Syndrome, Shoulder Pain, Spinal Curvatures, 2D Kinematics

Introduction

Scapular orientation is considered a primary influence in the development and maintenance of shoulder pain.[1,2] While it is acknowledged that shoulder pain may be multifactorial, a majority of cross-sectional studies demonstrate a significant difference between symptomatic and asymptomatic groups[3-17] for scapular orientation in diverse conditions such as spinal cord injury[18], post breast cancer treatment[16], chronic obstructive pulmonary disease[19], rotator cuff tendinopathies[13,15], glenohumeral or acromioclavicular osteoarthritis[13,20], adhesive capsulitis[13], internal impingement[14] and multidirectional instability.[12] In addition, a number of longitudinal studies have demonstrated that scapular orientation or dyskinesis assessed under load can be predictive of shoulder pain.[21-23]

While the association between scapular orientation and shoulder pain is clear, maladaptive scapular orientation may be multidirectional, with a recent systematic review reporting opposing scapular orientations are linked to shoulder pain in shoulder impingement syndrome.[1] Both increased and decreased scapular upward rotation[4,11,12,14,20,22,24,25], posterior tilt[4,5,8,9,11-14,16], medial rotation[4,6,7,12,13,16] and lateral translation[9,20,22] have been associated with shoulder pain. Elevation appears to be the only scapular orientation that has a unidirectional (increased) association with shoulder pain.[8,9,11,14,15] It would seem that all scapular orientations are important to consider carefully in shoulder pain and an exploration of what influences scapular orientation is necessary.

Multiple theoretical influences on scapular orientation have been proposed[1,2,26] and may include a variety of biopsychosocial factors. Many anatomical structures connect the scapula to the axial spine and thus it is plausible that spinal position may influence scapular orientation. In healthy individuals, an increase in thoracic kyphosis is associated with increased scapular elevation, lateral translation[27], medial rotation[28] and decreased posterior tilt.[27,28] Ipsilateral thoracic rotation is also associated with decreased scapular medial rotation[29] and increased upward rotation.[30,31] Individuals with scoliosis have significantly decreased scapular posterior tilt and increased upward rotation in comparison to controls.[32] Although spinal position can influence scapular orientation in asymptomatic individuals, this has not been confirmed in individuals with shoulder pain.

Body postures such as standing and sitting appear to influence spinal position, but to date have not been considered with respect to shoulder pain. Standing is known to induce a greater lumbar lordosis in comparison to sitting in healthy populations.[33-35] Sitting can slightly increase thoracic kyphosis in comparison to standing.[36] Given that the relationships between scapular orientation and body posture are likely to be mediated by spinal position, studies investigating scapular orientation should also consider spinal position.

The relationship between body posture (sitting) and scapular orientation has been investigated in a small group of asymptomatic adults.[37] Maximally slouched sitting was compared to upright sitting, to determine if maximal slouching had a detrimental impact on scapular orientation. However the effect of more typically adopted postures (such as habitual sitting or standing) on scapular orientation, to the authors' knowledge, has not been studied to date. Thus, there is no indication from research whether one habitually adopted posture is influential on scapular orientation, and subsequently may be better than another for completing home shoulder exercise programs, or whether it would be better to instruct patients to complete exercise programs in a more controlled body posture (such as neutral).

If scapular orientation is shown to change with body posture, either in standing or sitting, then it could be an influential factor to consider, monitor and record during the assessment and intervention of individuals with shoulder pain. Additionally it may be advantageous to provide rehabilitation exercise and advice on the body posture that most enhances the desired scapular orientation. It is important to examine typically adopted functional body postures, as these are the most common positions individuals use in occupational, social and leisure aspects of everyday life.

The aim of this study is to determine if scapular orientation changes between sitting and standing postures in participants that have shoulder pain, when the arm is by the side and when the glenohumeral joint is in 120° of scaption. Scaption for this study is defined as glenohumeral elevation 30 degrees anterior to the coronal plane. Thoracic kyphosis and lumbar lordosis were measured in sitting and standing, to determine their influence on body postures and scapular orientation changes.

Material and Methods

Participants

A sample of 30 participants aged 18-50 years of age were recruited through radio advertisements, local sporting clubs, and flyers on community noticeboards, between July and November 2014. Screening for eligibility took place via email and telephone. Inclusion criteria for the study were current shoulder pain and an ability to elevate the arm above the head “to reach into a cupboard”. Participants were excluded from the study if they described paresthesia or anesthesia in the upper limb, pain in cervical or thoracic regions, and pain upon cervical or thoracic movements or glenohumeral joint instability. Participants gave signed informed consent prior to testing. Curtin University Human Research Ethics Committee approved this study and all rights of the individual were protected. Participants filled out the Disabilities of the Arm and Shoulder (DASH) and a pain characteristics questionnaire. The DASH and pain characteristics questionnaire were used to define the participant demographics and characteristics and not used as outcome measures.

Design and Instrumentation

A repeated measures single session study captured two-dimensional (2D) scapular orientation of the participant's symptomatic side via two digital cameras (Exilim, CASIO EX-ZR800). Biomechanical data was collected with the arm by their side and with the arm at 120° of glenohumeral scaption in a university laboratory. Data was collected with the participant in habitual standing, neutral sitting and habitual sitting on a stool. Lumbar lordosis, thoracic kyphosis and scapular posterior tilt angles were determined from a laterally placed camera ipsilateral to the symptomatic tested arm. Scapular elevation, lateral translation and upward rotation were determined from a posteriorly placed camera. Cameras were positioned horizontally using spirit levels on the tripod and orientation was checked using a plumb line against vertical gridlines in the camera field of view. A scale was placed in the field of view for calibration of calculated distances in later biomechanical analyses.

Poles were positioned at 30° antero-laterally to the participant's test arm to standardize the scaption angle of movement used by the participant from the arm by side position to 120° of motion. The poles, participants and the stool were positioned using floor markings to ensure that participants maintained a consistent glenohumeral plane of motion for all body postures. The order in which participants were placed in each body posture was randomized. Participants marched on the spot between each measurement to ensure consistency in positioning and ensure participant comfort.

Spherical markers were placed on bony landmarks required for digital analysis. Firstly, the location of C7 was determined by extending the cervical spine and locating the most prominent spinous process, while T2, T4, and T8 were located by palpating caudally from C7. The L5 spinous process was identified via palpation of the sacrum and the L5/S1 interspace. The interspaces were then used to count up to, and identify the L3 and T12 spinous processes. Thus, markers were placed on the spinous processes of C7, T2, T4, T8, T12, L3 and L5. Spherical markers were placed onto the most postero-lateral edge of the spine of scapula (defined as the posterior acromion), the root of the spine of scapula and the inferior angle of the scapula. These palpatory techniques for identifying these anatomical landmarks are considered reliable and valid methods.[38-43] Calculation of distances and angles were done using digital analysis software (Silicon-COACH LIVE, Dunedin, NZ) using the spherical markers described. The Silicon Coach LIVE 2D analysis program was chosen as it offered excellent reliability[44-46] and agreement with 3D infrared systems, with Intra Class Correlations between 0.93 and 0.99[44] and co-efficient of determinations (r^2) between 0.90 and 0.92.[46]

Outcome Measures

Independent variables included standing, neutral sitting and habitual sitting, in arm by side and at 120° of glenohumeral scaption. For normal standing posture, participants were placed on a floor mark with feet hip width apart and eyes looking forward towards the wall. For neutral sitting, participants were seated on a stool (centered over the floor mark) with no backrest and hip and knee angle at 90°. Joint angles were determined by an examiner using a goniometer. The examiner then guided the participant through anterior and posterior pelvic tilt three times and positioned the lumbar spine in mid-range.[47,48] For habitual sitting the same stool and hip and knee angles were used. The participant was asked to sit with no further instruction or positioning by the examiner. The postures are shown in Figure1.

Dependent variables included scapula elevation, lateral translation, upward rotation, and posterior tilt. Scapular elevation was determined as the vertical distance between C7 and the root of the spine of the scapula (see Figure 2). Scapular lateral translation was determined as the horizontal distance between a line bisecting T2 and T8 and a vertical line extending down from the root of the spine of the scapula (see Figure 2). Scapular upward rotation was determined as the angle made between a line bisecting T2 and T8, with a line bisecting the most lateral aspect of the spine of the scapula and the root of the spine of scapula (see Figure 2). Posterior tilt was determined as the angle made between the horizontal and a line bisecting the root of the spine of scapula and inferior angle (see Figure 3).

Covariates included lumbar lordosis and thoracic kyphosis. Lumbar lordosis was determined as the angle made between the line bisecting L5 and L3 and a line bisecting L3 and T12 (see Figure 3). Thoracic kyphosis was determined as the angle made between the line bisecting T2 and T4 and a line bisecting T4 and T8 (see Figure 3).

Movement Protocol

Participants were asked to begin with their hands by their side with thumbs positioned anteriorly. The participants were then instructed to move both hands bilaterally into scaption with the symptomatic side following the guide pole, until 120°of scaption was reached and confirmed with a goniometer. The guide pole was then marked at that point for that individual. Greater ranges of motion were not measured as previous studies have shown that substantial error in scapular orientation measurement occurs above 120° of glenohumeral elevation. [49]The examiner then readjusted the inferior angle spherical marker at 120° scaption to ensure accuracy. This process was repeated and captured by digital cameras twice, resulting in three measures for each variable, which were averaged at a later date. One examiner took all measures on all participants.

Statistical analysis

Statistical analysis was conducted using IBM SPSS Version 22.0 for Windows (IBM Corp, Armonk, New York) with significance set at an alpha of 0.05. Mean and standard deviation values were calculated for scapular position in each posture for each plane of movement measured. A repeated measures analysis of variance (RANOVA) was conducted to determine the overall effect of body posture, for each separate scapular position. Mauchly's test for sphericity was examined to determine whether a correction for sphericity was required. Where significant overall differences were found, post hoc contrast analysis was conducted, to determine which individual posture was significantly different to another. Estimated marginal means with 95% confidence intervals (95% CI) were calculated. Where confidence intervals indicated likely differences between individual postures, then individual posthoc contrast differences were calculated. RANOVAs using kyphosis or lordosis as covariates were conducted to adjust for the effect of spinal position. Correction for multiple testing was not performed, as the study was restricted to less than 20 planned comparisons[50-52] Pearson's correlation coefficient (with significance) was calculated to determine the relationship between spinal position (thoracic kyphosis and lumbar lordosis) and scapular orientation. Using G*Power 2.1.9, a minimum of 28 participants was required to determine an effect size of 0.25 between postures, at 80% power with an alpha of 0.05, (assuming sphericity is maintained), using a within subjects factor RANOVA, with 3 repeated measures.[53]

Results

A total of 30 participants were recruited into the study, however one participant was excluded due to an inability to abduct to 120° on the day of testing, and another was excluded to due to data quality issues. The group demographic and pain characteristics of the 28 participants included for analysis can be viewed in Table 1.

For the arm by side position, scapular orientation was marginally but significantly different between the two sitting postures for the lateral translation (mean 0.5cm (95%CI 0.2 to 0.7cm), p<.001), upward rotation (mean 3° (95%CI 1.1 to 5.0°) p<.001), and posterior tilt (mean 2.3° (95%CI 0.2 to 4.3°) p=.009). A small but significant difference between standing and neutral sitting was found for upward rotation (mean 1.8° (95%CI 0 to 3.7°) p=.02) and between standing and habitual sitting for lateral translation (mean 0.6cm (95%CI 0 to 1.1cm) p=.02) in the arm by side position (see Tables 2 and 3). When lumbar lordosis or thoracic kyphosis were incorporated as covariates in the RANOVA, the small differences in scapular orientation due to body posture were no longer evident (p=.05). Thoracic kyphosis or lumbar lordosis was not significantly correlated to scapular position, either at arm by side position or in 120° of scaption. Body posture did not significantly affect scapular orientation at 120° of glenohumeral scaption, either adjusted for spinal posture or not (see Table 2).

Discussion

This study considered scapular orientation in people with shoulder pain in both seated and standing postures, both with the arm at rest by the side and when raised to 120° of glenohumeral scaption. Scapular orientation, considered to be a primary influence in shoulder pain [1,2], has been shown to change with altered body postures[37] and spinal positions[27,28,30,31] in asymptomatic populations, however little is known about the effect of body posture on scapular orientation in people who have shoulder pain. Increased understanding of the role of body posture on scapular orientation in this population could influence clinical assessment and rehabilitative methods.

Statistically significant but small changes in scapular orientations (lateral translation, upward rotation, and posterior tilt) between sitting and standing postures occurred when the arm was by the side, but not when the glenohumeral joint was in 120° of scaption. Although changes in scapular orientation occurred between the different body postures, and hence supporting the underlying premise of this paper, interestingly these differences were not evident when spinal position was taken into account. This may indicate that spinal position (thoracic kyphosis and lumbar lordosis) was responsible for the scapular orientation changes; and with this, a correlation between scapular orientation and spinal position would be expected, however, the correlation was not statistically significant. This lack of correlation may be due to a lack of statistical power for that particular statistical analysis, as the statistical power calculations for this study were based on the primary purpose of determining if there were differences between body posture for scapular orientation and not for correlation analysis. Elevation was the only scapular orientation that was not affected by body posture.

For lateral translation and posterior tilt, the current and previous research show similar results; that habitual sitting, maximally slouched posture or increased thoracic kyphosis induces significantly more lateral translation or decreased posterior tilt of the scapula than does neutral sitting.[27,28,37] However, previous research regarding elevation[27] and upward rotation do not consistently agree with each other or the current findings and may be due to differences in the participants, postures and instrumentation used.

Participant type between previous studies varied from young, healthy[27], predominantly female participants[37] to symptom free women over 50 years of age[28], but a strength of the current study was the use of symptomatic mix-gendered participants. Pre-existing symptoms may have induced different scapular behaviour in comparison to asymptomatic participants. The postures used in the current study were more typically representative of those used in activities of daily living or when performing home exercise programs, compared to the maximally slouched sitting position utilised by prior studies.[27,37] Maximal slouched sitting can induce scapular elevation[27] compared to neutral sitting, but the present study indicates that habitual sitting does not. Given the less dramatic alterations in body posture in the present study, it is not surprising that scapular elevation was not affected. Instrumentation between previous studies varied from 3D kinematic analysis[37], to a mechanical skeletal analysis system[27], and to where little description of instrumentation was provided.[28,54] The current study utilised 2D analyses, different again to previous studies and is discussed further below within the study limitations.

If clinicians wish to influence scapular orientation (except elevation), body posture may be one of a group of mechanisms to utilise. If thoracic or lumbar position is addressed initially, then body posture is not relevant. However, as the monitoring of specific thoracic or lumbar position may be difficult for patients during functional tasks, home exercise or postural programs, then the simple use of body posture may be more achievable for some patients. Given that shoulder pain is associated with either scapular upward or downward rotation[4,11,12,14,20,22,24,25], anterior or posterior tilt[4,5,8,9,11-14,16], and medial or lateral translation[9,20,22], then individual patient presentations will guide the selection of body posture. Slouched sitting posture can also decrease glenohumeral range of motion in comparison to neutral sitting in participants with shoulder pain.[27,55] Body posture is therefore useful to enhance more than one physiological outcome. Body posture had no effect on scapular orientation at 120°, indicating that body posture may be more important at rest, i.e. with computer based work. Thus body posture may be an influential factor in the assessment, and monitoring of patients who report resting shoulder pain, and the use of varied sitting postures or sit-stand workstations to enable standing during computer tasks may also be influential in the management of shoulder pain.

Study limitations

The present study used 2D analysis, which may be criticised for measurement error and an inability to account for movement that is out of plane; in this case, internal rotation of the scapula. However, scapular orientation measurement error due to skin motion artefact, anatomical landmark palpation and digitisation errors[7,56-58] are possible with any measurement tool, with some authors attempting to deal with these issues by using bony pins.[25] Unfortunately bony pins are likely to directly influence the behaviour of the participant and also were not considered ethical for the purposes of this study. To minimise error, 3 sets of measurements were taken by one examiner, data was not collected above 120° and motion data were avoided, as these last two factors increase measurement error.[49,58] Measurement error can cause a Type 2 error, i.e. that a significant relationship is obscured by the "noise" of measurement error,[59,60] but is less likely to cause a Type 1 error where "noise" causes a non-significant relationship to be significant. The potential for the out of plane error associated with 2D analysis was minimised in the current study with consistent and controlled positioning of the cameras, participants and glenohumeral movement.

The findings from this study are drawn from a general population of participants with shoulder pain and may not necessarily be generalized to other specific populations that develop shoulder pain such as athletes, workers, the elderly, and patients with scoliosis or post-surgery. As a result, clinicians who assess variable or specialised populations may see greater or lesser differences in scapular orientation when comparing standing, neutral sitting and habitual sitting. Although this study collected data on the disability experienced by symptomatic participants, it was not powered to correlate this to spinal posture.

Conclusion

This study demonstrated that scapular orientation changed slightly between sitting and standing postures in participants that have shoulder pain, when the arm is by the side, but not when the glenohumeral joint is in 120° of scaption. Thoracic kyphosis and lumbar lordosis mitigated these scapular orientation changes. Clinicians may wish to use body posture to influence scapular position, but must be aware that the changes are only small and other factors may provide a greater influence on scapular orientation. Although a statistical difference was found in this study, this may not translate to a clinical difference in scapular orientation. However, clinically there is no time, effort or monetary cost associated with changing posture to achieve small scapular orientation changes. Therefore, clinical assessment of the shoulder should be standardized for body posture (i.e. consistently in sit, or in stand).

Future research to determine what other factors can more substantially influence scapular orientation and further explore the inter-relationship between shoulder disability, spinal posture and 3D scapular orientation would help to determine just how important spinal posture is to the development and maintenance of shoulder pain and in the possible subtypes of shoulder pain.

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Tables

Table 1 Demographics

Characteristic	**Mean (sd)**	**Minimum - Maximum**
Age (years)	44 (18)	23-74
Gender (Male/Female)	22/6*	NA
Height (meters)	1.76 (.08)	1.58-1.93
Weight (kilograms)	82.7 (14.2)	59.6-116.8
BMI(kilogram/meters^2)	26.7 (3.7)	21.5-39.5
Chronicity of symptoms (months)	47.7 (118.4)	0.5-600.0
Dominant Side (Yes/No)	26/2*	NA
DASH Questionnaire score	15.7 (10.4)	0.8-39.2

sd= standard deviation, *=Frequency provided; NA= Not Applicable; BMI = Body Mass Index; DASH = Disabilities Arm, Shoulder and Hand

Table 2 Unadjusted mean and standard deviation values for scapular orientation and spinal position in standing (Stand), neutral sitting (Sit neutral), and habitual sitting (Sit habitual).

Arm position	Scapular position	Stand Mean (sd)	Sit neutral Mean (sd)	Sit habitual Mean (sd)	RANOVA	Post hoc contrasts for RANOVA
Arm by side	E (cm)	6.9 (1.5)	6.8 (1.7)	6.9 (1.7)	.75	NA
	LT (cm)	12.7 (2.1)	12.8 (2.4)	13.3 (2.5)	.03	Stand vs sit neutral = .69 Stand vs sit habitual = .02 Sit neutral vs sit habitual <.001
	UR (°)	90.3 (7.6)	92.2 (8.1)	89.1 (8.6)	.002	Stand vs sit neutral = .02 Stand vs sit habitual = .21 Sit neutral vs sit habitual <.001
	PT (°)	85.8 (19.5)	86.6 (22.3)	84.3 (22.1)	.41	#Stand vs sit neutral = .71 Stand vs sit habitual = .53 Sit neutral vs sit habitual = .009
	Thoracic Kyphosis (°)	167.1 (15.0)	167.7 (14.8)	167.0 (17.6)	.79	NA
	Lumbar lordosis (°)	164.7 (10.4)	170.8 (9.7)	180.2 (12.7)	<.001	Stand vs sit neutral = .02 Stand vs sit habitual <.001 Sit neutral vs sit habitual = .005
120°	E (cm)	6.3 (1.5)	6.2 (1.8)	6.2 (1.8)	.85	NA
	LT (cm)	11.5 (2.2)	11.6 (2.3)	11.9 (2.3)	.17	NA
	UR (°)	123.9 (9.3)	124.0 (10.8)	124.0 (10.2)	.99	NA
	PT(°)	107.8 (18.4)	109.0 (19.2)	109.4 (21.9)	.69	NA
	Thoracic Kyphosis (°)	170.2 (13.6)	170.1 (13.6)	171.8 (13.4)	.22	NA
	Lumbar lordosis(°)	164.4 (11.5)	168.2 (11.1)	179.6 (13.6)	<.001	Stand vs sit neutral = .12 Stand vs sit habitual <.001 Sit neutral vs sit habitual = .002

sd= standard deviation; E. = elevation. LT= Lateral translation, UR =Upward rotation, PT = Posterior Tilt, NA = not applicable to run the analysis, ;#= Estimated marginal mean confidence intervals indicated that posthoc contrasts were appropriate to conduct.

Table 3 Unadjusted estimated mean differences between postures for scapular position at arm by side and at 120° of glenohumeral scaption.

Arm Position	Scapular orientation	Stand – sit neutral EMM (95% CI)	Stand – sit habitual EMM (95% CI)	Sit neutral – sit habitual EMM (95% CI)
Arm by side	E (cm)	0.1 (-0.3 to 0.5)	0.0 (-0.4 to 0.4)	-0.1 (-0.4 to 0.2)
	LT (cm)	-0.1 (-0.7 to 0.5)	-0.6 (-1.1 to 0.0)	-0.5 (-0.7 to -0.2)
	UR (°)	-1.8 (-3.7 to 0.0)	1.2 (-1.2 to 3.6)	3.0 (1.1 to 5.0)
	PT (°)	-0.8 (-6.3 to 4.7)	1.5 (-4.4 to 7.3)	-2.3 (-4.3 to -0.2)
120°	E (cm)	0.1 (-0.4 to 0.5)	0.1 (-0.4 to 0.5)	0.0 (-0.2 to 0.3)
	LT (cm)	-0.1 (-0.6 to 0.5)	-0.3 (-0.9 to 0.2)	-0.3 (-0.6 to 0.0)
	UR (°)	-0.1 (-2.4 to 2.2)	0.1 (-2.1 to1.8)	0.0 (-1.8 to 1.8)
	PT (°)	-1.2 (-7.5 to 5.1)	-1.6 (7.9 to4.7)	-0.4 (-4.0 to 3.2)

E. = elevation. LT= Lateral translation, UR =Upward rotation, PT = Posterior Tilt, EMM= Estimated marginal means. CI = Confidence Intervals.

Figure legends

FIGURE 1 BODY POSTURES

Standing, sit neutral and sit habitual.

FIGURE 2 POSTERIOR VIEW.

C7 = spinous process of 7th cervical vertebrae,T2 = spinous process of 2nd thoracic vertebrae, T8 = spinous process of 8th thoracic vertebrae. PA = post acromion, ROSS = root of the spine of the scapula. Double lined arrows indicate measured distances. Double lined arcs indicate angles measured. See text for further detail.

FIGURE 3 LATERAL VIEW.

T2 = spinous process of 2nd thoracic vertebrae, T4 = spinous process of 4th thoracic vertebrae,T8 = spinous process of 8th thoracic vertebrae. T12 = spinous process of 12th thoracic vertebrae, L3 = spinous process of 3rd lumbar vertebrae, L5 = spinous process of 5th lumbar vertebrae, IFA = inferior angle of the scapula, ROSS = root of the spine of the scapula. Double lined arcs indicate angles measured. See text for further detail.