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Role of Different Angles of Scapula: its Kinesiometrics Muscle morphology and clinical significance

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Abstract
Introduction: *Evolution resulting in acquisition of bipedal gait has led the human beings to gain free upper limb movement. The scapula hence provides a strong and stable attachment for muscle activity around the scapular angles. Sometimes due to excessive stress and overuse of a particular muscle their point of attachment on scapula gets modified resulting in change in angulation and morphology of muscle hence kinesiometry gets altered leading to various shoulder pathology.*
Method: *Following study measures different angles of scapula namely superior angle (SA), inferior angle (IA), medial/spinovertebral angle (MA), lateral angle (LA), glenoid inclination angle (GIA), gleno-polar angle(GPA), acromial angle (AA) and coracoid angle (CA) in 68 scapulas (R:L= 50:50) obtained from Department of Anatomy, North Bengal Medical College, Darjeeling.*
Result: *Mean value and SD for Superior angle was 89.57º ± 10.47º, Inferior angle was 44.85º ± 8.14º, Medial angle 156.02º ± 9.11º, Lateral angle 62.38 º± 10.05º, Glenoid inclination angle 12.97º ± 2.80º, Gleno-polar angle 38.65º ± 5.65º, Acromial angle 102.54º ± 14.26º and Coracoid angle 88.41º ±9.12º.*
Conclusion: *Measurement of all angles on the right scapulas was greater than that on the left side except medial angle, gleno-polar angle and coracoid angle. The latter two angles also had a significant correlation between right and left scapula.*
Keywords: *Angles of scapula (superior, inferior, medial, lateral, glenoid inclination, gleno-polar, acromial, coracoid) kinesiometrics, morphology of muscle, clinical significance.*

Introduction

Evolution from quadrupedalism to bipedalism has given the upper limb freedom for extensive movements. The discrepancy in shape of glenoid cavity and the size of humeral head makes it more important to study the relationship between the bony anatomy and its kinematics[1].

As studied by Codman EA et al[2] and Inman VT et al[3], to establish equilibrium at glenohumeral joint (component of scapula humeral rhythm[4]) at any position 3 forces are required namely weight of limb acting at its centre of gravity, abducting musculature and friction of head of humerus on glenoid cavity. Thus the mobility at the expense of stability might require skeletal changes in scapula and morphological changes in muscles mainly in the form of variations in the angles of scapula. Thus the present study helped us to analyse these morphological angular variations of the scapula namely superior (SA), inferior (IA), medial (MA), lateral (LA), glenoid inclination (GIA), gleno-polar (GPA), acromial (AA), coracoids (CA) and correlate them with pathological conditions. Out of these Lehtinen JT et al[5] described MA to be prominent only in pathological cases.

Materials and Methods

The study comprised of 68 adult scapula of unknown age and sex, taken from Department of Anatomy, North Bengal Medical College, Darjeeling, West Bengal India. Out of this 34 belonged to right side and 34 to left. Bones selected were free from abrasion, deformity and were complete in all respects. Measurement of angles were done with the help of goniometer in the following procedure.

1. Superior angle: formed where the superior border meets the medial border. Fixed arm of goniometer along superior border of scapula, movable arm along medial border on supraspinous line, angle enclosed was noted. (Angle A in Fig 1)
2. Inferior angle: formed where medial border meets lateral border. Fixed arm placed along medial border movable arm along lateral border, angle enclosed was measured. (Angle B in Fig 1)
3. Medial/ spinovertebral angle: formed by the angular bend between the medial border of supraspinous and infraspinous fossa[6]. Fixed arm was placed along supraspinous line and movable arm along infraspinous line and angle enclosed was measured. (Angle C in Fig 1)
4. Lateral angle: open angle formed where the superior and lateral borders are wedged by the glenoid cavity[6]. Fixed arm was along lateral border touching infraglenoid tubercle and movable arm along the superior border, angle enclosed was measured. (Angle D in Fig 1)
5. Glenoid inclination angle: angle measured between a line perpendicular to the line connecting most cranial and caudal point on glenoid cavity and a line perpendicular to the tangent along medial border of scapula. (Angle F in Fig 2)
6. Gleno- polar angle: angle between a line connecting most cranial and caudal point on glenoid cavity and most caudal point on scapular body.(Angle E in Fig 3)
7. Acromial angle: formed where the lateral border of crest of spine becomes continuous with lateral border of acromial process. Fixed arm was along lateral border of acromion and moveable arm along lower border of the crest of spine, angle enclosed was measured. (Angle G in Fig 4)
8. Coracoids angle: formed where root of coracoids process bends sharply to project forwards and laterally[6]. Fixed arm was along lateral border of coracoids process and movable arm along root of coracoids process, angle enclosed was measured. (Angle H in Fig 4).

Measurements were taken twice by two authors in order to avoid error. The data was analysed using Statistical Package for the Social Sciences version 20. The angular values of the two sides were analysed using unpaired t-test. Statistical significance was set at $p<0.05$.

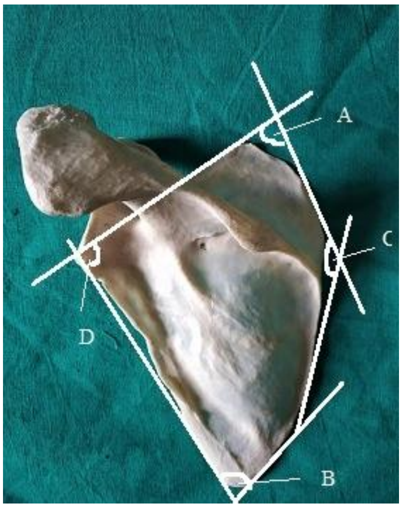

Fig 1: showing SA(A),IA(B), MA(C), LA(D).

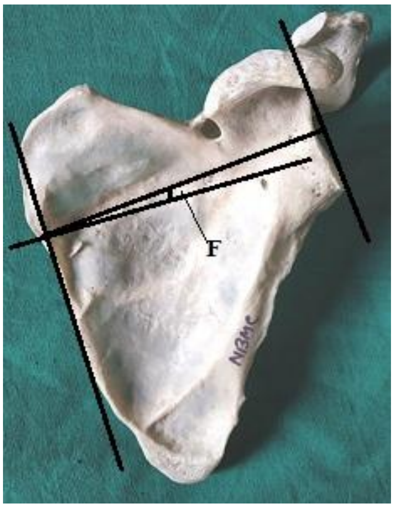

Fig 2: showing GIA(F).

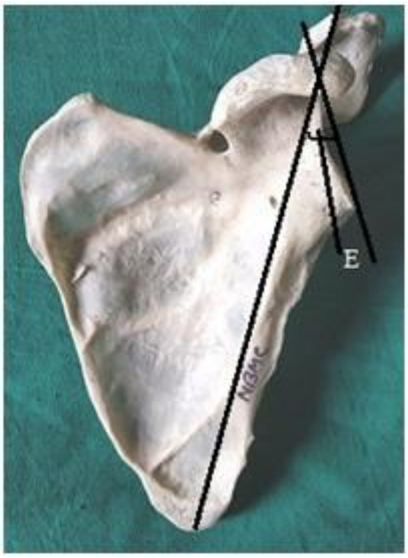

Fig 3: showing GPA (E)

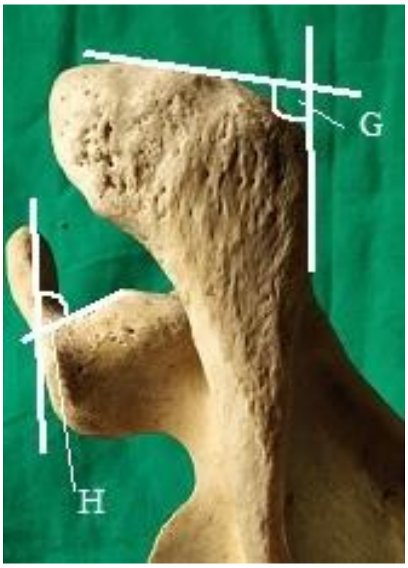

Fig 4: showing AA (G), CA(H).

Results

The observed values of mean and SD of both right and left side along with the p value are documented in the table 1 given below

Table 1: Mean and SD of all the angular measurements of both right and left side scapula along with their p value.

ANGLES	RIGHT SIDE MEAN ± SD (In degrees)	LEFT SIDE MEAN ± SD (In degrees)	TOTAL MEAN ± SD (In degrees)	P VALUE
Superior angle	91.79 ± 10.28	87.35 ± 10.33	89.57 ± 10.47	>0.05
Inferior angle	46.12 ± 8.90	43.59 ± 7.20	44.85 ± 8.14	>0.05
Medial angle	155.62 ± 9.9	156.44 ± 8.38	156.03 ± 9.11	>0.05
Lateral angle	64.97 ± 9.28	59.79 ± 10.27	62.38 ± 10.05	>0.05
Glenoid inclination angle	13.35 ± 2.42	12.59 ± 3.13	12.97 ± 2.80	>0.05
Gleno polar angle	36.29 ± 5.45	41 ± 4.88	38.65 ± 5.66	<0.05 (0.00038)
Acromial angle	105.18 ± 15.13	99.91 ± 13.01	102.54 ± 14.26	>0.05
Coracoids angle	86.03 ± 9.47	90.79 ± 8.31	88.41 ± 9.16	<0.05 (0.031)

Discussion

Bardin[8] observed from his study on development of scapula that the triangular form of scapula emerges even before forces are applied to it, although studies have been done on the kinesiological aspect of scapula but only Inman et al[3] put stress on role of angles of scapula in providing base and leverage to muscles for their effective functioning. Kibler[9] studied that when weakness is present in scapular musculature the normal positioning gets altered which leads to altered biomechanics. These observations thus justify the need for the current study on role of different angles of scapula.

According to Lippert LS et al[4] shoulder complex comprises of shoulder girdle (scapula +clavicle) and shoulder joint (scapula+ humerus). Although movements at shoulder girdle are elevation/ depression, protraction /retraction, upward/ downward rotation and at shoulder joint are flexion/extension, abduction/adduction, medial/ lateral rotation but the movements cannot be strictly delineated as it occurs in a synchronized rhythmic fashion.

1) Superior angle: the mean and SD of superior angle was 89.57 ° ± 10.47 ° (R= 91.79 °± 10.28°, L= 87.35° ± 10.33°). Piyawinijwong et al[10] found mean 84.92° in Thai population which is close to our value where as Solanki[7] in Indian population, Coskun et al[11] in Turkish population and Sharma R et al[12] in Nepalese population found the value to be 99.84°, 124.40° and R=100.32°, L=101.34° respectively. The angle was more on right side with no statistical correlation between the two sides.

   Inman et al[3] suggested that the superior angle provides a base for the upper force couple for elevation and rotation of the scapula. Muscles attached to the superior angle making these movements effective are upper fibers of Serratus anterior acting mainly to stabalize scapula during elevation, Levator scapule and upper fibers of Trapezius which apart from suspensory function assist in upward rotation of scapula. If the upward rotation of scapula is not effective it could result in subacromial impingment[13].

2) Inferior angle: Our mean and SD was found to be 44.85° ± 8.14° (R=46.12° ± 8.9°, L= 43.59° ± 7.2°). Values obtained by Piyawinijwong et al[10] was 39.42° which is again closer to our observation while values obtained by Solanki[7] and Sharma R et al[12] are 68.08° and R=68.1°, L= 59.14° respectively. The angle measured more on right side as in other[10] findings without any statistical significance.

   This angle is the only angle that has undergone drastic changes during evolution. Among the muscles attached to the inferior angle, lower 5digitations of Serratus anterior along with lower fibers of Trapezius form the lower component for force-couple for upward rotation of scapula and helps to keep the vertebral border against the rib cage. Rhomboids attached to inferior angle and lower part of medial border coupled with Levator scapule help in downward rotation of scapula. Parts of Infraspinatus, Teres minor and Subscapularis attached to lower part of scapula also help in depressor action of humerus which is countered by the superior part of capsule and Supraspinatus.

3) Medial angle: In our study mean and SD was found to be 156.03° ± 9.11°(R= 155.62° ± 9.9°, L= 156.44° ± 8.38°) Our observation was comparable with findings of Sharma R et al[12] who got the value as R=151.3°,L= 143.96°. Solanki[7] found it to be 142.2°. Left side values were found to be greater than right sided values without any significant correlation.

   According to Oladipo GS[14] the medial border possesses 2 distinct parts for muscle attachment, one extending from superior angle to the origin of spine- superomedial border giving attachment to Levator scapule and other extending from spine to inferior angle-inferomedial border giving attachment to rhomboid group of muscle. These borders enclose an angle the medial angle, making scapula structurally quadrangular rather than triangular. Levator scapule muscle is inserted downwards diagonally into the superomedial border. Widening of this border will increase this angle and the attachment of levator scapule which will now be more steep, lower fibers of this muscle will thus be slacking and the burden bearing ability of the muscle will be lost. The increase in the medial angle might shift the attachment of fibers of rhomboid muscle across the angle upward giving it an additional elevating function along with its own retracting function. Inmam et al[3] suggested that the angle could develop as a result of uneven skeletal changes in scapula, increase in scapular index and change in relative shape of supraspinous fossa.

4) Lateral angle: Was found to be 62.38 º± 10.05º (R= 64.97º ± 9.28º, L= 59.79º ± 10.27º). Mean value of our study was comparable with those of Sharma et al[12] R=65.9º L=57.54º. Although Solanki[7] did not differentiate between the two sides but his mean total was 76.44º. Here again the right side values were greater but there was no statistical correlation between the two sides.

   To establish equilibrium and stability[3] at glenohumeral joint in which humeral head is larger than the glenoid cavity 3 forces are required namely weight of limb acting at its centre of gravity through coracobrachialis muscle, abducting musculature through deltoid muscle and pressure and friction of head of humerus at glenoid cavity through rotator cuff (Supraspinatus, Infraspinatus, Teres minor and Subscapularis). Any variation of these forces acting at lateral angle can lead to dislocation and sublaxation of shoulder joint.

5) Glenoid inclination angle: In our study mean and SD was found to be 12.97º ± 2.8º (R=13.35º ± 2.42º, L= 12.59º ± 3.13º). According to Lingamdene PE et al [15] mean and SD were found to be 11.58º ± 2.02º. Right sided values were greater than left with no significant correlation between the two sides.

   According to Hughes et al[16] an increase in GI angle is associated with full thickness rotator cuff tears while Dirk et al[17] emphasized the knowledge of GI angle for treatment of glenoid fracture and shoulder arthroplasty[18]. GI angle is also used to define caudal dislocation of glenoid which is thus defined as GI angle greater than 20º.

6) Gleno-polar angle: Mean and SD was found to be 38.65º ± 5.66º (R= 36.29º ± 5.45º, L= 41º ± 4.88º) Lingamdene PE et al[15] found GP angle to be 34.34º ± 4.63º. The left side values were greater than right with p value 0.00038.

   GP angle measures the obliquity of glenoid articular surface in relation to scapula body. Normal value is 30º to 45º. According to Kim et al[19] for deciding the treatment and prognosis of floating shoulder which is ipsilateral fracture of mid shaft of clavicle and neck of glenoid, the knowledge of GP angle is very important.

7) Acromial angle: Found to be 102.54º ± 14.26º (R= 105.18º ± 15.13º, L= 99.91º ± 13.01º) was compareable to findings of Sharma et al [13] R= 107.68º L= 105.26º. Values obtained by Solanki[11] and Coskun et al[12] were 135.30º and 124.40º respectively.

   With evolution, the development of acromion process caused detachment of Deltoid from inferior angle and increased leverage on the acromion process. The two muscles Deltoid and Trapezius attached to the process are responsible the scapula- humeral rhythm. According to Solanki BS[11] formation of acromial angle is compensatory for the developing deficiency in the intermediate part of the muscle lying opposite to the spine of the scapula.

8) Coracoids angle: Mean and SD was found to be 88.41º ± 9.16º (R= 86.03º ± 9.47º, L= 90.74º ± 8.31º), these coincided with values obtained by Sharma et al[13] R=84.24º, L=82.02º, while Solanki[11] and Coskun et al [12] found it to be 94.30º and 124.8º respectively. The left sided values were greater with stasistical significance of 0.031.
The development of acromial process in higher mammals has lead to the transference of insertion of Pectoralis minor as a separate muscle into the coracoids process instead of humerus as in lower animals. the muscle thus helps to depress the shoulder.
The short head of Biceps absent in primitive mammals originates from the coracoids process and is responsible for flexion and abduction of shoulder thus assisting in free movement of upper limb.

Conclusion

All the angles of scapula were greater on right compared to left except for medial angle, Gleno-polar angle and coracoid angle. The latter 2 when compared on both sides had a significant correlation. The values obtained in the present study corresponded more with the findings of Sharma et al[13] with some differences thus showing some racial and regional factors in play. The study thus helped us to analyse the role of different angles with respect to morphology of muscles attached to them and study the possible variation of these angles in different pathological conditions.

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