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DYNAMIC STABILITY OF THE GLENOHUMERAL JOINT

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Stability of the glenohumeral joint during every phase of movement which is known as dynamic stability has not attracted the attention of anatomists (Saha 1967, 1969). They were preoccupied with the stability of the glenohumeral joint in stance, i. e. static stability.

This paper attempts to clarify the factors responsible for dynamic stability. The critical stage of dynamic stability of the glenohumeral joint is easily appreciated if we see an axial skiagram of the joint in 120° of abduction (Figure 1). Except for a small area, most of the articular surface of the head of the humerus is out of the socket and anterior to the glenoid cavity (Saha 1967).

A shallow glenoid, one third of the articular surface of the head of humerus in the normal adds to this precarious condition. How, in this critical stage, which commences at 60° of abduction, is the head of humerus retained in the glenohumeral joint?

Instability peculiar to the glenohumeral joint is mostly anterior, to a less extent inferior and least posterior. Injury is capable of dislocating any joint in any direction depending on the direction and degree of violence. While this is true for the glenohumeral joint as well, many of these are known to dislocate with minimum trauma or without any trauma as putting the hand in the sleeve of a coat while wearing it, bowling, doing the breast stroke while swimming, changing position in sleep, etc. This instability has been seen to be anterior in these cases.

Thus, it is essential that we have a thorough understanding of the dynamic stability in various phases of movement and how this is affected in certain glenohumeral joints. Dynamic stability is dependent on several factors (Editorial, Indian J. Surg., 1967).

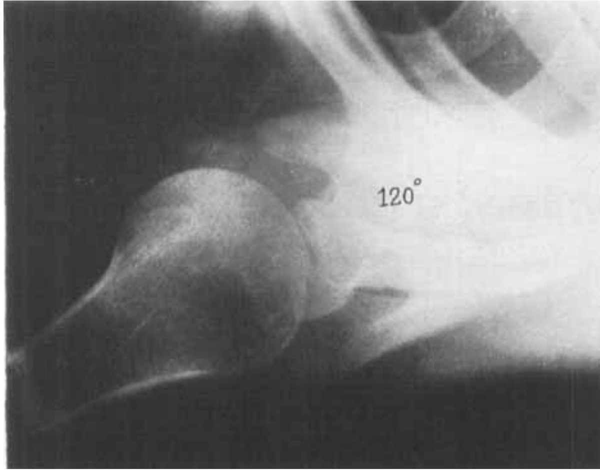


Figure 1. Axial view of the left gleno-humeral joint in 120° of abduction shows most of the articular surface of the head of the humerus except a small area is anterior to the socket of the glenoid cavity.

A. *Development of the Glenoid*

Anthropometrically the state of development of the glenohumeral joint can be expressed as percentage ratios of the maximum transverse and vertical diameters of the articular surface of the glenoid and the head of the humerus (the latter with the help of caliper).

$$\text{Glenohumeral index} = \frac{\text{Maximum diameter of the glenoid}}{\text{Maximum diameter of head of the humerus}} \times 100.$$

In the living this is not feasible. Skiagraphy of the glenohumeral joint is taken in two directions, antero-posterior and axial views at right angles to each other in 120° abduction. Maximum transverse and vertical diameters of the glenoid and the head of the humerus are computed from these skiagrams (Sarker 1969).

The development of the glenoid if falls above a certain level in transverse and vertical measurements, adds to the stability. The vertical and transverse glenohumeral indices were worked out from 50 normal shoulder joints of adults, mostly drawn from the patients and staff of the N. R. S. Medical College Hospitals. Of these, 34 were found to have a close distribution. The remaining 16 were scattered on either side. The mean value for vertical indices was 75.3 and that for transverse 57.6. The standard deviations were ± 3.9 for vertical and ± 5.6 for transverse glenohumeral indices. If we include the extreme cases, 75.3 ± 7.8 should be the vertical and 57.6 ± 11.2 the

transverse glenohumeral indices. The data favourably compare with the anthropological data. The transverse glenohumeral index, which is less than the vertical, plays an important role in the maintenance of horizontal stability, while the vertical glenohumeral index plays a less important role. Incidentally, the transverse glenohumeral index is greater in primates e. g., gibbon. The depth of the glenoid cavity in man is much less compared with that of the other primates. This and increased transverse glenohumeral index have their role in maintenance of dynamic glenohumeral stability in primates specially where brachiation reached its maximum. Gibbon is an example.

B. *Power of the Horizontal Steerers (Rotators)*

The glenohumeral joint is not a static fulcrum. Radiological investigations in the living, lamp black impression studies during simulated movements of dissected joints, and theoretical considerations established that the contact surfaces of the humerus, and to a much less extent that of the glenoid, change with the movement, confirming the joint's multiaxial nature.

The physical process of change-over of the articular surfaces of the humeral head in the glenoid is brought about by rolling. These are movements taking place at the joint level and are distinct from classical movements (of the distal end). Rolling may be vertical and horizontal (Figures 2 & 3) (Saha 1950, 1958, Saha et al. 1956).

The power required for change-over by rolling of the humeral articular surfaces in the glenoid is provided by subscapularis, supraspinatus, infraspinatus and upper half of teres minor in three directions, the fourth being helped by gravity. Their advantageous insertions at the outer end of head-neck axis of the humerus are most suitable to control the rolling of the head. This has been established mathematically, from multilead electromyography in the normal, surgically rehabilitated flail shoulder following poliomyelitis, and in brachial plexus injuries where girdle muscles are used.

In abduction, those muscle fibres of the steerers (short rotators) which fall in the direction of elevation give coplaner rolling from the commencement of elevation. This is confirmed by the simultaneous rise of the action potentials of deltoid and supraspinatus. The remaining muscle fibres help horizontal rolling for that particular movement. This is obvious from the action potentials of infraspinatus and subscapularis; only the rise is earlier in subscapularis and later in infra-

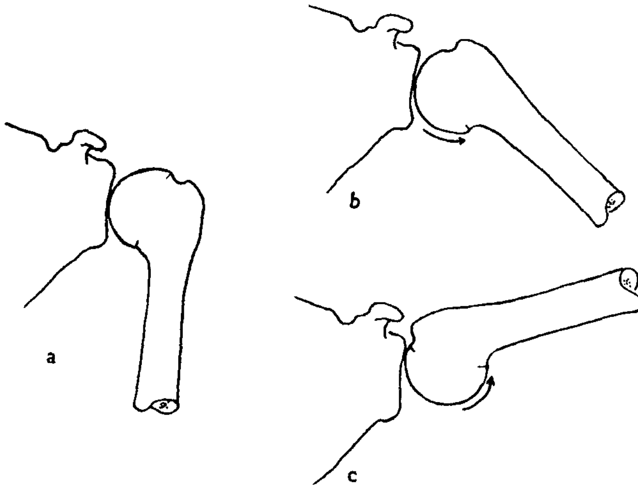


Figure 2.

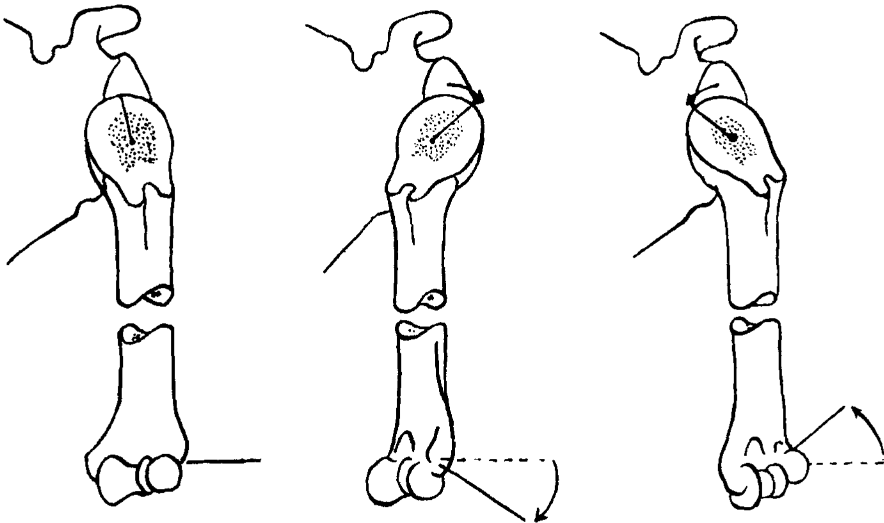


Figure 3.

Figures 2 and 3. Diagramatical change-over of the articular surfaces in vertical and horizontal directions by rolling.

spinatus in abduction. The resultant of these two components—horizontal and vertical in successive phase—give the consecutive positions of the actual path taken by the head of the humerus during elevation (Figure 4).

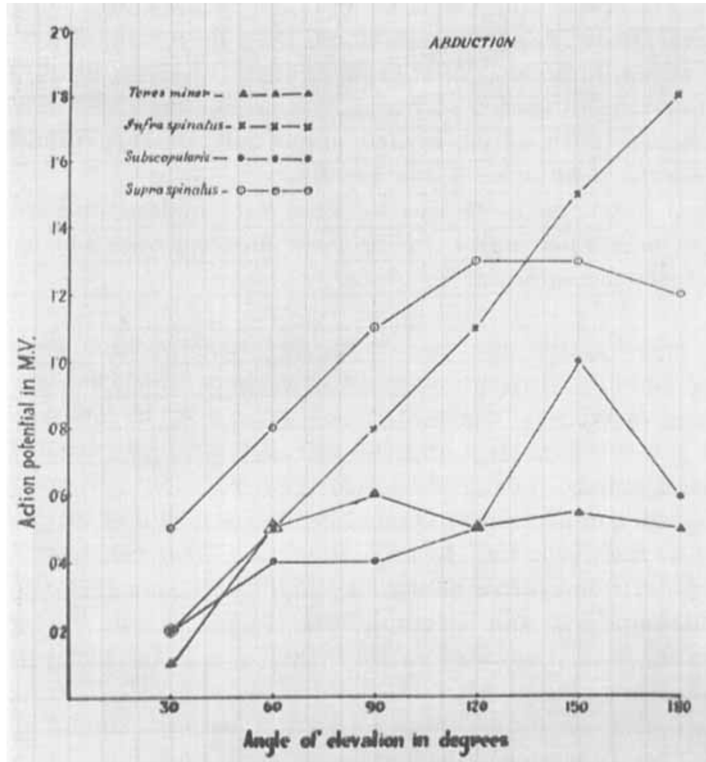


Figure 4. Simultaneous electromyograph of supraspinatus, subscapularis, infraspinatus and teres minor. Ordinate represents the action potential in milli volts and the abscissa the angle of abduction in degrees. There is continuous rise in the action potential of the infraspinatus and subscapularis to 120° when subscapularis shows a sudden increase to 150° followed by a decline from 150° to 180°. The action potential of infraspinatus continues to rise to 180°.

Steering muscles do not act as isolated units; the muscle fibres, which in a particular movement steer the head vertically, may act as a horizontal steerer in another movement and vice versa. Thus the muscles are classified according to their role in different phases of elevation (Saha 1961).

a. Innermost group of three and half steerers *viz.*, subscapularis, supraspinatus, infraspinatus and upper half of teres minor muscles supply the main power in adjusting the head. The supraspinatus is the vertical, subscapularis the anterior and infraspinatus and teres minor the posterior horizontal steerers in abduction.

b. The intermediate group of three and half muscles, *viz.*, sternal head of pectoralis major, latissimus dorsi, teres major and lower half of teres minor; these are mainly rollers of the humeral head but their insertions are in such a way arranged on the shaft of the humerus that their rotating action is more important. Besides rotation, they stabilise the head in each new position.
c. The last outer group of two muscles, *viz.*, deltoid and clavicular head of pectoralis major are primary movers, insertion being far away from the fulcrum.

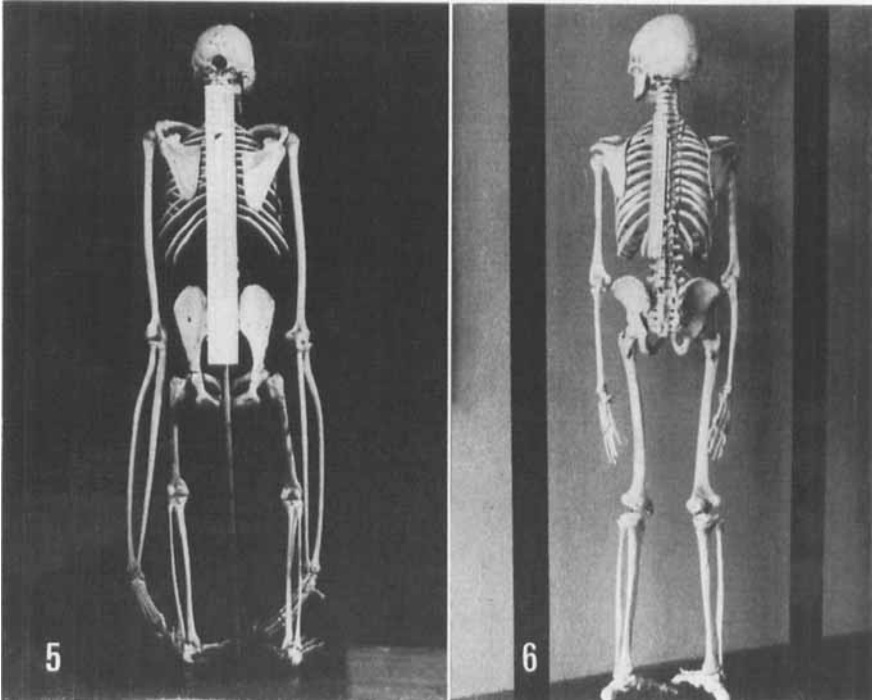
While investigating the power of the steerers that ensure the horizontal stability during movement in various directions, multi-lead electromyography was constantly put into use. In abduction the power of the subscapularis and the infraspinatus progressively rises to stabilise the head during abduction from 60°–150°; thereafter, the power of subscapularis shows a rapid decline and that of infraspinatus continues to rise from 150° to 180° abduction. This confirms the role of subscapularis and infraspinatus as stabilisers (Saha 1963, 1964).

The subscapularis and infraspinatus stabilise from 0°–150° and infraspinatus, almost alone from 150°–180°, i. e. to the terminal phase of the abduction (Figure 4).

In brachiating primates, these horizontal steerers should be more powerful than in man because of increased retrotorsion and consequently their liability to anterior dislocation in the process of raising the limb. Subscapularis and infraspinatus fossae from which respective muscle takes its origin are relatively larger than those of human beings when compared with their height (Figures 5 & 6).

Further evidence is seen in postpolio flail shoulder where all the steerers are paralysed. We treat such cases by giving vertical and horizontal steerers; of the horizontal steerers preferably a posterior one is chosen. In the absence of a posterior steerer we choose an anterior one from upper two digitations of serratus anterior, pectoralis minor or upper part of pectoralis major whichever is available and convenient. The muscles thus transferred to take over the new role of the paralysed steerers show almost similar electromyographs during abduction and flexion (Figure 7). Is the power of the new anterior horizontal steerer sufficient to stem the instability in those cases having a shallow glenoid or enhance retrotorsion?

In these cases we find the replacement of subscapularis by an anterior steerer is not sufficient to hold the head of the humerus



Figures 5 and 6. Back view of skeletons of gibbon and man with the same scale on the spine for comparison. The scapulae in gibbon are relatively much larger than those in man, confirming the necessity for origins of relatively bulkier muscles subscapularis and infraspinatus.

beyond 90° of abduction. The head of the humerus at this stage suddenly slips out, losing its power and range (Saha 1967). These cases require a posterior horizontal steerer if available to stem the forward slipping or reduction of retrotorsion to allow the head to be retained in the glenoid cavity in absence of posterior horizontal steerer.

C. *Retrotorsion of the Head and Neck of the Humerus*

A quadruped has it head and neck of the humerus directed backwards and its axis is at right angle to the axis of the shaft of the humerus in the horizontal plane through the transepicondylar line and it has no torsion. Torsion of the humerus starts from the primates and increases with the scale of evolution. By torsion is meant the head and neck and upper shaft of humerus undergo posteromedial twist on its axis (Figure 8). This accounts for the radial groove. In other words,

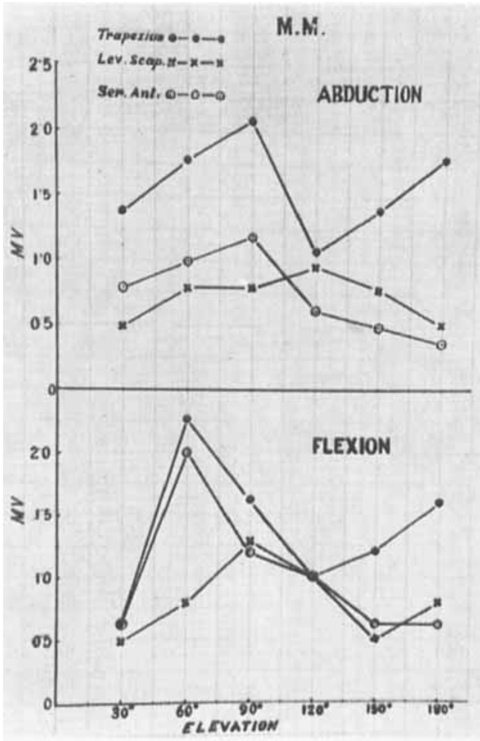


Figure 7. Electromyographs of a rehabilitated post-polio flail shoulder. Ordinate denotes action potential in milli volt and the abscissa elevation in degrees. The upper part of the diagram shows action potential in abduction and the lower in flexion. The prime mover (transferred trapezius) shows almost identical development of power in flexion and abduction. The action potential of the serratus anterior (upper two digitations) shows later rise in abduction and earlier rise in flexion (horizontal steerer). The terminal notching of the curves is due to want of training and reliance upon gravity once the arm is raised above 90°.

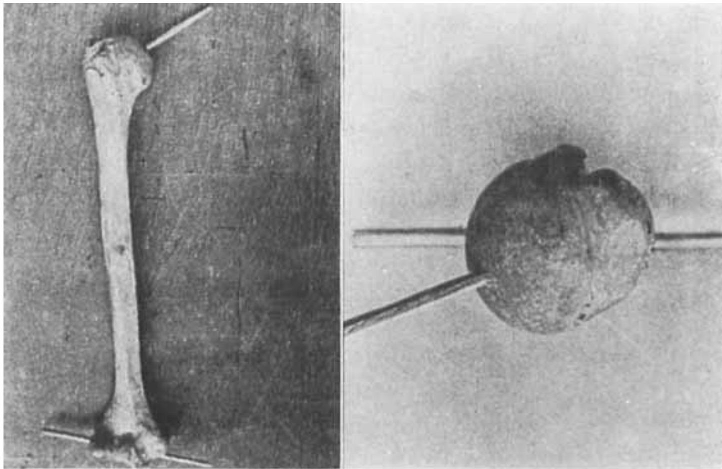


Figure 8. Two stilletes, one introduced in the axis of the head-neck and the other through the epicondyles. The right hand figure shows the retrotorsion of the humerus in "bird's eye" view.

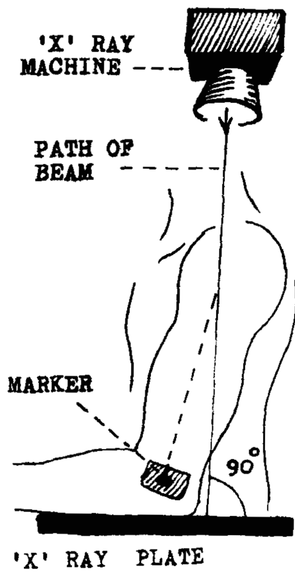


Figure 9. The Mukherjee-Sivaya projection for the determination of retrotorsion of the humerus.

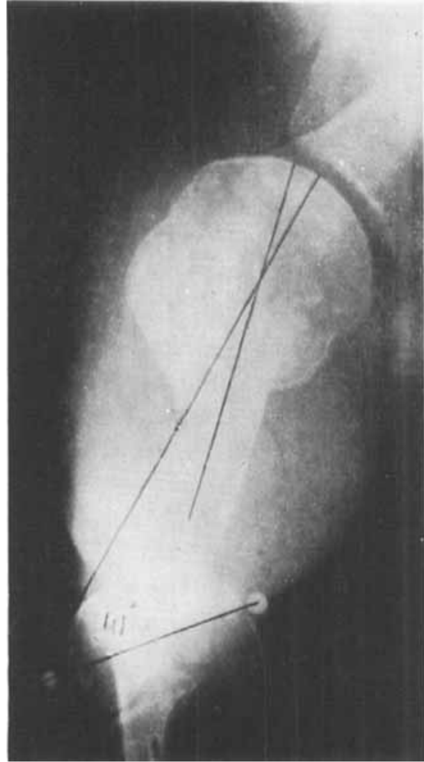


Figure 10. Retrotorsion of the humerus determined by the Mukherjee-Sivaya method.

the dorsal inclination of the head and neck and upper shaft found in man and christened as retrotorsion is the residual dorsal inclination of the quadrupeds. Thus, the primates have more retrotorsion than in men. Retrotorsion may vary with races and may vary in the same individual on the two sides. This is reversed in abduction and accounts for the critical stage. The retrotorsion has no role in maintenance of vertical stability.

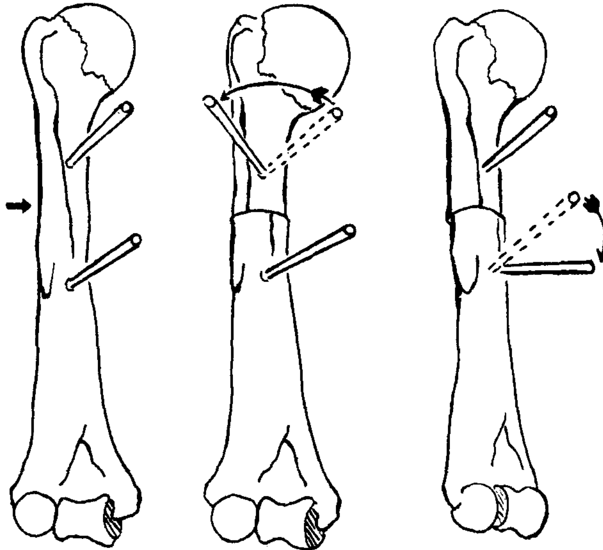


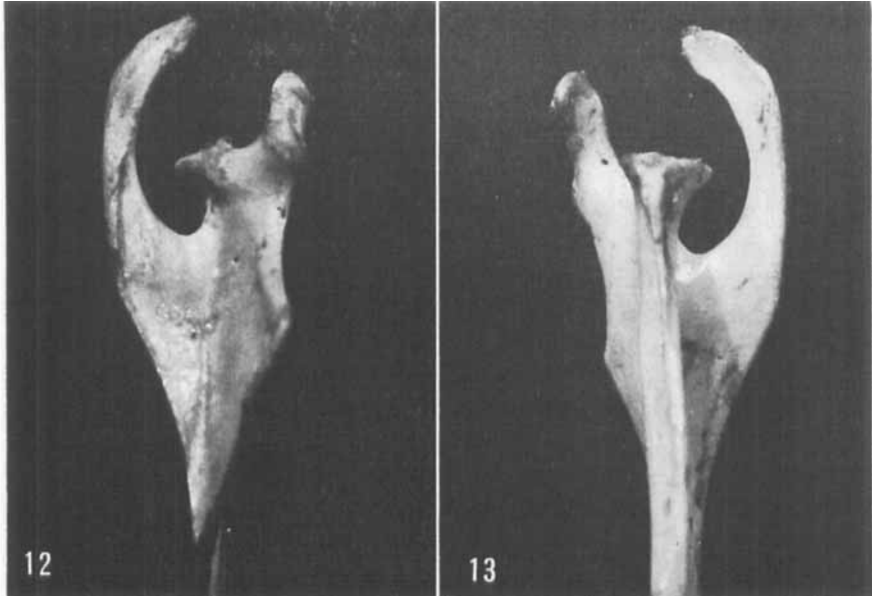
Figure 11. The two ways of reduction of retrotorsion of the humerus by osteotomy of the shaft of the humerus.

Radiologically it can be determined in man by Mukherjee & Sivaya's 10°–15° forward inclination of the arm depending on the bulk to reduce the soft tissue opacity around the humeral shaft in the end-on view (Figure 9). Special care is taken to see that the x-ray beam is at right angle to the cassette which is placed below the elbow with the required inclination. The beam passes through the upper end of humerus, as if this part of the humerus were in end-on view. Forward shift of the epicondyles does not affect the measurement of the retrotorsion angle, provided the shift is made parallel to the original position of transepicondylar line in the end-on view of the humerus. But the junction of the neck and shaft axes, being below the top of the articular surface of the humerus, will be shifted a little forwards in this end-on view. This will introduce a small amount of unavoidable error. Radio-opaque markers are placed on the epicondyles before the skiagram is taken.

The retrotorsion angle determined by this method was on an average of 30° amongst Indians (Figure 10).

The retrotorsion may be altered by rotation osteotomy of the upper shaft of humerus (Figure 11) (Saha et al. 1967).

That arboreal primates have more retrotorsion and are liable to more instability is a paradox. This naturally requires special need of power



Figures 12 and 13. Gibbon's scapula seen from above and below. In both, obvious retrotilt of the glenoid is seen.

Figure 14. A bird's eye view of the human scapula. It shows retrotilt of the glenoid.

from horizontal steerers (vide supra), raising of the anterior lip of glenoid and/or enhanced transverse glenohumeral index to prevent instability. Let us examine whether the glenoid possesses an enhanced anterior lip.

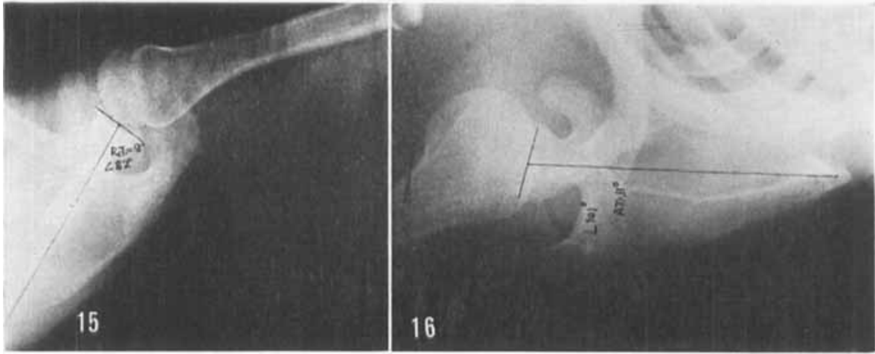
D. *Tilt of the Glenoid*

The plane of the glenoid passing through the glenoid rim is not always perpendicular to the axis of the scapula. The axis of the scapula is defined as the junction of the spine with the blade. The plane may be tilted in two ways—horizontal and vertical.

Horizontal or anteroposterior tilt: The favourable horizontal tilt which maintains the anteroposterior stability may be posterior, neutral and rarely anterior. The posterior tilt or retrotilt, which counteracts the horizontal instability caused by increased retrotorsion, is maximum in primates when compared with that in men (Figures 12, 13, and 14). Anterior tilt is found in the majority of unstable joints (Das et al. 1966).

Horizontal or anteroposterior tilt in the living is determined with the help of axial radiography of the scapula in a bird's eye view position. The limb is placed in 120° abduction and neutral rotation in the scapular plane. A cassette, preferably curved, is placed over the scapula, and the tube is so placed below the axilla so that the rays pass at right angle to the cassette. In true axial view a long-stemmed needle, when passed at right angle to the posterior axillary border parallel to and in contact with the dorsal surface of the infraglenoid portion of the blade of the scapula to make its tip touch the point of attachment of the spine with the body, should show in its end-on view the butt tend. A foreshortened needle signifies that the rays are not parallel to the infra-glenoid portion of the scapula. The axial view of the scapula, when properly taken, shows the axis of the scapula as a line superimposed on edge-on-view of the infraglenoid portion of the blade. The glenoid appears triangular in outline depending on the tilt of the scapula in the vertical plane.

The line joining its most anterior and posterior bony points (base of the triangle) gives the maximum transverse diameter of the glenoid. The axis of the scapula is drawn on the skiagram by joining the midpoint of this line and the junction of the base of the spine with the vertebral border. Difficulties are seldom encountered in determining the axis of the scapula.



Figures 15 and 16. Axial skiagrams show the retrotilt and rare anterior tilt of the glenoid.

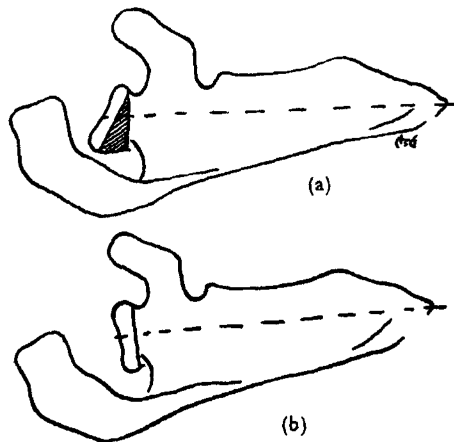


Figure 17. One of the ways of enhancing the retrotilt of the glenoid.

The tilt of the glenoid is determined from the reading on the acromial side of the axis of the scapula. 73.5 per cent had retrotilt with an average of 7.4° and 26.5 per cent had anterior tilt from 2° to 10°. Similar studies were made in 21 cases of recurrent anterior dislocation (all types), anterior tilt was found in 80 per cent (17 cases) (Figures 15 and 16). The horizontal tilt may be altered as shown in the diagram by wedge osteotomy (Figure 17).

Vertical tilt: The vertical stability does not depend so much on vertical tilt of the glenoid articular surface. In the plane of the scapula the scapular axis bears an average angle of 104.9° ± 6.3 with the vertical diameter of the glenoid and is open below. The glenoid artic-

ular surface normally rotates in the anteroposterior axis. This makes the glenoid articular surface relatively horizontal on which the head of the humerus plays. In rare instances the vertical stability may be affected by the medial inclination of the lower end of the glenoid articular surface with the axis of the scapula; in other words the angle is below 90°. In such rare instances, the individual dislocates the glenohumeral joint downwards at will.

Thus the stability of the glenohumeral joint is summarised as follows (Saha 1969):

Factors	Enhancing stability	Predisposing instability
State of development of the glenoid cavity	Glenohumeral indices 75.3 ± 7.8 and 56.6 ± 11.2 or more in vertical or transverse respectively	Glenohumeral index less than the preceding figures (hypoplasia and aplasia)
Tilt of the glenoid	A. Horizontal retrotilt B. Vertical 104.9 ± 6.3	Anterior tilt Very rare for conclusion
Retrotorsion of the humerus	Less retrotorsion	More retrotorsion
Power of the horizontal steerers e.g. subscapularis, infraspinatus and upper part of the teres minor	More power	Less power

SUMMARY

Dynamic stability of the glenohumeral joint is a function of developmental status of the glenoid, horizontal and to a much less extent vertical tilt of the glenoid, retrotorsion of the humerus and the power of the steerers, particularly the horizontal steerers (in abduction). The horizontal steerers include subscapularis, infraspinatus and upper half of the teres minor.

Morphological studies, determination of the tilt of the glenoid and

retrotorsion of the humerus were done anthropometrically and radiologically both in the normal and in cases of recurrent anterior dislocation of the shoulder.

Simultaneous electromyography of the muscles of shoulder during abduction and flexion were extensively used in the normal and in the rehabilitated flail shoulder following poliomyelitis and brachial plexus injury.

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