The Biomechanics in the Shoulder Instability

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Ⅰ.Introduction

Biomechanics of the glenohumeral joint is closely related to the anatomic architecture of this joint. The glenohumeral joint possesses the largest range of motion of any diarthrodial joint in the human body, mainly due to its relative lack of bony restraint. In the absence of bony constraints, stability to the joint is provided by the surrounding soft tissue envelope that has a major role in stability. A complex interaction of four joints and 26 muscles allows for such a large range of motion Perhaps, the best means of clearly approaching shoulder biomechanics lies in a systemic examination of the stabilizing mechanisms of the glenohumeral joint. In a broad sense, these multiple factors may be classified into two main categories: static and dynamic.

Dynamic stability is provided by the rotator cuff and deltoid muscles, while static restraint is provided by the congruent articulating cartilage surfaces and by the joint capsule, through its thickenings known as the glenohumeral ligaments. Biomechanical studies of the shoulder involving ligament cutting studies have generated a more precise understanding of individual contributions of the various ligaments and capsular regions to shoulder instability.

Static Factors	*Dynamic Factors*
Articular congruence	Rotator cuff
Articular version	Biceps tendon
Glenoid labrum	Negative pressure
Capsule and ligament	Scapulothoracic motion

Disruption of one or more of these restraint mechanisms can lead to the development of abnormal glenohumeral kinematics with associated debilitation of the patient and/or long-term secondary destrugtive changes at the joint, including such entities as cuff tear arthropathy.

Ⅱ.Static Factors

A.Articular Congruence: In an adducted position, with the arm hanging at the side, the scapular faces 30° anteriorly on the chest wall. It is also tilted 3° upward relative to the transverse plane and 20° forward relative to the sagittal plane. The articular surface of the humeral head is inclined dorsally in retrotorsion relative to its shaft. The neck shaft angle averages 130° to 140°, and tetrotorsion averages 30° relative to the transepicondylar axis of the distal humerus. The glenoid face presents a shallow concavity for the humeral articulation. This face offers a nearly "pear-shaped" surface for the articulation of the humeral head, being narrow superiorly and wider inferiorly, with average anteroposterior and superoinferior dimensions of 25 mm and 35 mm, respectively. By contrast, the respective humeral head dimensions measure 45 mm and 48 mm. Thus, the percentage of humeral head surface area which the glenoid can accomodate is approximately 30%. Only one third of the articular surface of the humerus is covered by glenoid in any position of arm rotation. This anatomic arrangement, described by Saha as the *glenohumeral index* (ratio of the glenoid diameter to the humeral head diameter), describes the anatomic basis for relative instability of the glenohumeral joint. In the saggital plane this ratio is 0.75, and in the transverse it is 0.6. Clinical conditions such as glenoid fractures, glenoid dysplasia, and labral detachment reduce this ratio and make the joint more susceptiblity. In a normal shoulder, the combined retroversion of the humeral head and glenoid is 30° to 40°. Some surgeon suggested that abnomal version of the glenoid or humerus may affect shoulder stability, but this is not universally accepted.

B.Glenoid Labrum: The glenoid labrum functions through several mechanisms to stabilize the humeral head in the glenoid. It anchors the IGHLC and increases the glenoid depth, stabilizing the joint through a concavity-compression mechanism. This anatomic arrangement also acts in a fashion analogous to a chock-block, preventing the humeral head from translating with rotation. The recent work of Howell and Galinat has shown that the presence of the labrum significantly enhances the depth in both vertical and transverse directions.

C.Glenohumeral Ligaments: These capsular thickenings reinforce the capsule and serve as static checkreins to extreme translations and rotations of the humeral head on the glenoid. These ligaments are named on the basis of their glenoid attachment. Material properties of the glenohumeral ligaments have recently been characterized (Bigliai and colleagues). The capsule (and ligaments) is normally a lax structure, with a surface area to times that of the humeral head. This is a necessary arrangement to permit the normal range of motion necessary for the joint. In addition, the capsule is prone to significant plastic deformation before complete failure;*therefore, it is likeiy that all traumatic injuries cause some laxity of the capsule even in the presence of a Bankart lesion.*Because of their different origins and insertions, each ligament has a different role depending on arm position and direction of applied force.

(1)Superior glenohumeral ligament(SGHL)and coracohumeral ligament(CHL):
These structures paraliel each other and are best considered together. The CHL was believed to be the more significant structure, however, investigations have now suggested otherwise. The CHL has the stiffness and load-bearing capacity to resist extreme transistions of the humeral head on the glenoid. Together, these ligaments limit external rotation with the arm in adduction, inferior translation of the adducted humerus, and posterior translation when the shoulder is adducted, flexed, and internally rotated.

(2)Middle glenohumeral ligament(MGHL): It is the most variable of the GHL in terms of size and development, being well defined in approximately 60% of cases. Biomechanically, it limits the following motions: 1)external rotation of the adducted shoulder, 2)inferior translation of the adducted and externally rotated humerus, and 3) anterior translation of the slightly abducted humerus(45°).

(3)Inferior glenohumeral ligament (IGHL):consists of an anterior and a posterior band and intervening axillary pouch. The role of the IGHL in anterior glenohumeral stability is supported by its anatomy, geometry, and biomechanical properties. The complex functions like a hammock or sling with the shoulder abducted. Biomechanically, this structure limits the following motions: 1)anterior translation of the abducted shoulder, 2)posterior translation of the abducted shoulder, and 3)inferior translation of the abducted shoulder.

Ⅲ.**Dynamic Factors:**In the past decade, a growing body experimental and clinical work has demonstrated that the most important stabilizing factor for the glenohumeral joint is the combined effect of the intrinsic muscles that cross it (i.e., the rotator cuff muscles and the long head of the biceps brachii). Stability may be afforded through several mechanisms. If one appreciates that the glenohumeral ligaments function as passive checkreins only at the extremes of rotation and translation, then it is understandable why dynamic stabilization of the joint is essential, especially in the midranges of motion.

A)Joint compression: This enhances stability through a concavity-compression effect.

The magnitude of this effect is greater than that provided by capsular restraint.

B)Barrier effect:A contracting portion of the rotator cuff can function as an actual barrier to translation by becoming rigid with contraction.

C)Secondary dynamization of the capsule can occur through direct attachments of rotator cuff tendons. Contraction of the rotator cuff may create tension in the capsule, thus stabilizing the joint.

D)Steering effect: A coordinated steering effect occurs through synergistic, sequential contractions of portions of the rotator cuff during arm motions.

Normally, glenohumeral joint has a negative intra-articular presure relative to the atmosphere. This is because of the closed space surrounded by an elastic sphere of ligaments and muscles. This negative pressure is proportional to the force tending to displace the humeral head away from the glenoid, because a suction effect developes in this closed joint space surrounded by elastic soft tissue. Although this effect has a role in stabilizing the humeral head in the glenoid, it probably is clinically important only in an adducted shoulder resting at the side without side without any muscle activity.

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