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THE ROLE OF PROPRIOCEPTION IN SHOULDER INSTABILITY

SCOTT M. LEPHART, PhD, ATC, and RAJESH JARI, MD, MSc

Stability of the shoulder joint is derived from a number of different mechanisms involving the articular geometry, dynamic (muscular) stabilizers, static capsuloligamentous tissues, and intra-articular forces (negative intraarticular pressure, surface forces of adhesion and cohesion). Capsuloligamentous structures might contribute to the joint stability by providing an afferent feedback for reflexive muscular contraction of rotator cuff and the biceps brachii. The role of proprioception in allowing a feedback mechanism to work, which in turn allows a synergistic contraction of muscle groups, may be vital both for normal functioning of the muscle groups of the shoulder joint and in protecting the shoulder against potential instability. Significant proprioceptive deficits have been reported in patients who had chronic, traumatic anterior shoulder instability and surgical stabilization of such shoulders restored proprioceptive deficits. Whereas the many studies done on proprioceptors and their distribution patterns are relatively free of controversy, the relationship between proprioception deficit and instability is still not crystal clear. However, most studies have shown that proprioception may play an important role in contributing to joint stability. Future work needs to look at the exact mechanisms of proprioception, whether proprioceptive sensibilities are congenital or acquired factors, and whether there is any role for proprioceptive prophylaxis in modern day injury prevention.

KEY WORDS: proprioception, shoulder joint, joint stability, muscle groups, rehabilitation
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Sherrington (1906) defined the proprioceptive system as "afferent information from proprioceptors located in the proprioceptive field that contribute to conscious sensations (muscle sense), total posture (postural equilibrium) and segmental posture (joint stability)." Contemporary descriptions of proprioception further include perception of afferent sensation, which aids the control of limb position and movement sense, ie, kinesthesia (Greek, defined as sensation of motion).^{1,2}

Proprioception is mediated by peripheral receptors that include specialized nerve endings, proprioceptive mechanoreceptors, Pacinian corpuscles, Ruffini endings, and Golgi tendon organs which have been shown in the capsule and ligaments of all joints in articular, muscular, and cutaneous structures. Hence, it has been proposed that proprioception is a "specialized sensory modality that gives information about extremity position and direction of movement, which is important in mediating muscular control of the shoulder joint."²

The existence of mechanoreceptors and free nerve endings in the glenohumeral ligaments has been reported widely.^{3,4} These authors detected Pacinian corpuscles in the ligaments and suggested that these mechanoreceptors may control the stabilizing musculature. Vangsness et al found that the most abundant mechanoreceptors in the

glenohumeral joint were classical Ruffini end organs, but they also located Pacinian corpuscles in the capsular ligaments. The glenoid labrum itself had no mechanoreceptors, but occasional free nerve endings were seen in the surrounding connective tissue.^{5,6}

PROPRIOCEPTORS

Specialized nerve endings, proprioceptive mechanoreceptors, Pacinian corpuscles, Ruffini endings, and Golgi tendon organs have been shown in the capsule and ligaments of all joints. Vangsness et al further studied proprioceptors in the shoulder joint and, using a modified gold chloride staining technique, found that two morphological types of mechanoreceptors and free nerve endings existed in ligaments. Slow-adapting Ruffini end organs and rapidly adapting Pacinian corpuscles were identified in the superior, middle, inferior, and posterior glenohumeral ligaments.^{5,6} They thus hypothesized that any disruption of the labrum, ligaments, or capsule by trauma or surgery would deprive the shoulder of mechanical stability and may cause a decrease in proprioception owing to the loss of these afferent neural receptors.⁵ Gohlke et al studied the distribution and morphology of mechanoreceptors in the human glenohumeral joint capsule and rotator cuff in comparison with the coracoacromial ligaments using immunofluorescence. They found that Ruffini corpuscles were more highly concentrated in the coracoacromial ligament, whereas Pacinian endings were higher in the joint capsule. They postulated that these high concentrations of proprioceptors suggested that they were both involved in neurosensory control of glenohumeral stability, although they were not predominantly responsible for maintaining joint stability.⁷

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SHOULDER STABILITY

Stability of the shoulder joint is derived from a number of different mechanisms involving the articular geometry, dynamic (muscular) stabilizers, static capsuloligamentous tissues, and intra-articular forces (negative intraarticular pressure, surface forces of adhesion, and cohesion). At mid ranges of motion, the capsular ligaments are relatively lax, and stability is maintained largely by the muscle forces of the rotator cuff, which compress the humeral head into the relatively concave glenoid.⁸ As the end ranges are reached, the capsular stabilizers assume more importance in providing stability for the joint. Current research has focused on how these capsulolabral tissues may interact with the dynamic stabilizers and specifically what role is played by proprioceptive feedback from the ligaments to muscles in contributing to glenohumeral stability.^{2,5,9,10}

Glenohumeral instability has been defined as the "inability to maintain the humeral head in the glenoid fossa." The spherical head of the humerus, which is a large globular bony structure whose articular surfaces forms approximately one-third of an irregular sphere, articulates *against* and not within a small shallow glenoid fossa.¹¹⁻¹³ The glenoid cavity has a slight concave articular surface covered by hyaline cartilage. In the center there is an area that DePalma noted to be thinner and having greater contact with the head of the humerus. This has led to the belief that there is a factor of inherent instability even in the normal shoulder joint.¹⁴ In the shoulder joint, stability has been sacrificed at the expense of mobility and an increased range of motion. This predisposes the shoulder to both traumatic and atraumatic instability.¹⁰

Joint laxity and instability may result in damage to the capsuloligamentous structures when additional repetitive movements in a joint cause micro-trauma.⁹ It has also been postulated by many authors that a coordinated synergistic contraction of the rotator cuff and biceps may protect the ligamentous structures from injury by increasing the torque resistance against excessive rotation and preventing excessive translation of the humeral head against the glenoid fossa.¹⁵⁻¹⁷ Warner et al proposed that capsuloligamentous structures might contribute to the joint stability by providing an afferent feedback for reflexive muscular contraction of rotator cuff and the biceps brachii. They also proposed that this dynamic muscular action might protect against excessive translations and rotations of the glenohumeral joint.² Guanche showed the existence of several ligamentomuscular reflex arcs in the glenohumeral joint and concluded that the existence of such arcs suggested that the ligaments and muscles function synergistically in stabilizing the shoulder.¹⁸

The role of proprioception in allowing a feedback mechanism to work, which in turn allows a synergistic contraction of muscle groups, may be vital both for normal functioning of the muscle groups of the shoulder joint and in protecting the shoulder against potential instability. Multiple studies have demonstrated that after injury to the shoulder capsule and ligaments, glenoid labrum or pericapsular muscles, there is a related deficit in joint proprioception.^{9,19} Lephart and Henry proposed a paradigm (Fig 1) illustrating the relationship between shoulder instability and proprioception.

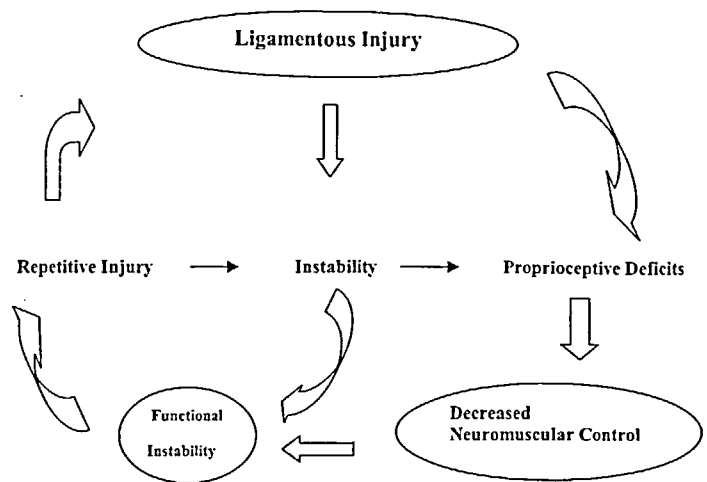


Fig 1. Paradigm illustrates relationship between glenohumeral joint instability and mechanoreceptor damage. (Reprinted, by permission, from Lephart SM and Henry TJ: Restoration of proprioception and neuromuscular control of the unstable shoulder, in Lephart SM, Fu FH (eds): Proprioception and Neuromuscular Control in Joint Stability. Champaign, IL, Human Kinetics, 2000, p 407.)

This model stresses the importance of restoring proprioceptive deficits and reestablishing neuromuscular control. Functional stability of the shoulder is dependent on co-activation of the musculature as well as reactive neuromuscular characteristics. Three levels of motor control need to be addressed, ie, spinal reflex, cognitive programming, and the brain stem.^{19,20}

Functional instability that occurs after injury to the capsuloligamentous structures is in part the result of partial deafferentation. The excessive joint laxity associated with the resulting microtrauma damage to the neural receptors also contributes. Deafferentation may result in disruption of afferent signal altering transmission to the central nervous system. Injury to any of these structures was thus postulated to cause a disruption of this neuromuscular mechanism. These neuromuscular deficits result in diminished joint position sense, kinesthetic awareness, and abnormal humeral and scapular muscular firing patterns.^{19,21} Lephart et al further hypothesized that proper dynamic control was mediated by a proprioceptive feedback loop provided by tension that develops in the joint capsule and ligaments. Smith and Brunoli were among the first to investigate the effect of capsuloligamentous injury on proprioception in the shoulder; they reported that patients with unilateral, recurrent, traumatic anterior shoulder instability demonstrated proprioceptive deficits.²² Lephart et al reported significant proprioceptive deficits in patients who had chronic, traumatic anterior shoulder instability and also showed that surgical stabilization of such shoulders restored proprioceptive deficits.⁹ In a recent preliminary studies investigating multidirectional instability, there were significant proprioceptive deficits found in the unstable shoulder that thermal capsulorrhaphy and rehabilitation seemed to restore to a significant level,²³ whereas no deleterious effects with proprioceptive ability were reported after treatment of shoulder instability with thermal capsulorrhaphy.²⁴

Jerosch and Thorwesten showed that a proprioceptive deficit was measurable in patients with posttraumatic glenohumeral instability, and that was postulated by them to be a cause for a more permanent instability.²⁵

These series of studies showed that proprioceptive deficits that may be caused by partial deafferentation result when capsuloligamentous structures are damaged and reconstructive surgery and rehabilitation seemed to restore some of the proprioception deficits.

CONCLUSION

Whereas the many studies done on proprioceptors and their distribution patterns are relatively free of controversy, the relationship between proprioception deficit and instability is still not crystal clear. Whether proprioception deficits are the cause of, or part of the cause of, instability is also in dispute. However, most studies have shown that proprioception may play an important role in contributing to joint stability. How much exactly is not precisely defined.^{1,26} After injury to the shoulder capsule and ligaments, glenoid labrum or pericapsular muscles, there is a related deficit in joint proprioception. Treatment of such an injury needs to consider proprioceptive training and rehabilitation in addition to any surgical intervention. Several workers have confirmed that the shoulder joint is better or closely restored to normal when proprioception is normalized.^{9,27,28}

Whether mechanoreceptors are mechanically deformed or just "switch off" after injury to the capsule and/or labrum, they may not be sufficiently stimulated in a lax or injured capsule. After surgery or rehabilitation, it is controversial whether this mechanical deformity is reversed or proper tension in the capsule and ligaments induce a "switch on phenomenon" of the mechanoreceptors. Goertzen et al showed that in the knee at least, a repopulation of receptors occurs in the anterior cruciate ligament graft tissue.²⁹ Lephart et al showed that after surgery, there is restoration of proprioception in the shoulder, and this may be related to repopulation of receptors in the capsule and the ligaments.⁹

Surgical or conservative rehabilitation and exercises to enhance proprioception and restore neuromuscular control need to be looked at closely in combination to improve the functional outcomes in patients who have instability. In looking for new surgical techniques, therefore, anatomic and neurophysiologic feedback mechanisms need to be restored as closely as possible to the normal state. Future work needs to look at the exact mechanisms of proprioception, whether proprioceptive sensibilities are congenital or acquired factors, and whether there is any role of proprioceptive prophylaxis in modern day injury prevention.

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