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Role of Proprioception in Pathoetiology of Shoulder Instability

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Proprioception is a specialized sensory modality that gives information about extremity position and direction of movement. This kind of afferent sensory feedback is probably important in mediating muscular control of the shoulder joint. As this articulation is minimally constrained, such a coordinated dynamic control of muscles about the joint is necessary for stability during arm motion. The authors evaluated proprioception in individuals with normal shoulders, unstable shoulders, and after surgical stabilization, by assessing threshold to detection of passive motion and the ability to passively reposition the arm in space. In normal shoulders there is no difference between the dominant and nondominant shoulder, though in unstable shoulders there is a significantly decreased proprioceptive ability. Surgical stabilization normalizes proprioception of the shoulder.

Because the human glenohumeral joint is minimally constrained by articular surface conformity, static and dynamic stability is provided by the combined effect of both capsuloligamentous structures and rotator cuff and biceps.[21,37,40–42] The ligamentous structures, however, function only at extreme positions of rotation to prevent excessive translation or rotation of the humeral head on the glenoid. In the midranges of rotation, the capsuloligamentous structures remain relatively lax.[11,19,20,29,36,38,41] In the midranges of motion most joint stability is through dynamic action of the rotator cuff and biceps tendons. Contraction of these muscle tendon units creates joint compression and increases the concavity compression fit of the humeral head into the glenoid socket.[7,28] Furthermore, a coordinated, synergistic contraction of the rotator cuff and biceps may protect the ligamentous structures from injury by increasing torque resistance against excessive rotation and preventing excessive translations of the humeral head.[6,8,9,13,14,22,32] Because the glenohumeral ligaments are relatively weak[4,31] compared with the knee ligaments, such a dynamic protective mechanism is important to prevent injury to these structures.

HYPOTHESIS: THE ROLE OF PROPRIOCEPTION

Placement of the hand for upper limb function is partially dependent on the perception of joint position and joint motion of the shoulder. This sensory modality is termed proprioception and is mediated by peripheral receptors in articular, muscular, and cutaneous

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structures. Specialized nerve endings, proprioceptive mechanoreceptors (Pacinian corpuscles, Ruffini endings, Golgi tendon organlike endings), have been shown in the capsule and ligaments of all joints.[1–3,10,12,15–18,24,33,35,39] These mechanoreceptors are specialized neurons that transduce mechanical deformation into electrical signals that transmit information about joint position and motion.[16,17] Stimulation of these receptors results in reflex muscle contraction about the joint as an adaptive control to sudden movements of acceleration or deceleration.[3,35] It has been suggested that receptors in the joint capsule respond primarily to extreme ranges of motion,[16,17] or deep pressure that may occur with translation of the humeral head on the glenoid.[10,15–17]

Proprioceptive sensibility encompasses the sensation of joint motion (kinesthesia) and joint position (joint position sense). Normal proprioceptive sensation and the effect of injury have been shown in the ankle[12,24] and knee[1,2,23,26,30] Furthermore, shoulder instability is associated with proprioceptive deficits.[34] The hypothesis of the authors' studies is that the capsuloligamentous structures may contribute to stability by providing an afferent feedback for reflexive muscular contraction of the rotator cuff and biceps. This dynamic reflexive muscle action may protect against excessive translations and rotations of the glenohumeral joint. Blasier and coworkers[5] have proposed a similar mechanism. Moreover, the authors have hypothesized that injury to these ligaments will result in measurable deficits in proprioception.

RECENT STUDIES

For the past 5 years the authors have studied proprioception in normal, anteriorly unstable, and surgically reconstructed shoulders.[25,27]

Testing Methods

Using a specialized testing apparatus (Fig 1) threshold to detection of passive motion and reproduction of passive positioning was tested. The shoulder was positioned at 90°

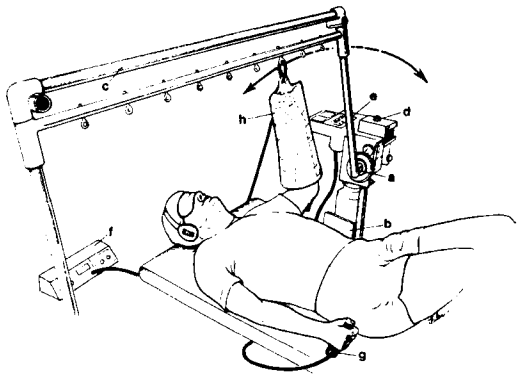

Fig 1. Proprioception testing device. (a) Rotational transducer (1:3 mechanical speed reduction gear train); (b) motor; (c) moving arm; (d) control panel; (e) digital microprocessor; (f) pneumatic compression device; (g) handheld disengage switch; h = pneumatic compression sleeve. Threshold to detection of passive motion is assessed by measuring angular displacement until the subject senses shoulder motion and presses the disengage switch (g). (Reprinted with permission from Lephart SM, Warner JJP, Borsa PA, Fu FH: Proprioception of the shoulder joint in healthy, unstable, and surgically repaired shoulders. J Shoulder Elbow Surg 3:371–380, 1994).

abduction in the plane of the body with the elbow at 90°, and all external stimuli were eliminated by use of a pneumatic cuff applied to the arm, a blindfold, and white noise introduced through headphones. The shoulder was moved at a constant angular velocity of 0.5° per second, with random movement into either internal or external rotation. The test subject indicated when motion was felt by turning off the machine with a button he or she held in the other hand. This tested TTDPM. The RPP was measured by asking the patient to reproduce the initial position in which the shoulder had been placed after it was moved from that reference point. Accuracy was measured as the error in degrees from the starting position.

Results

A total of 90 subjects were tested: 40 healthy college age individuals with normal shoulders; 30 patients with documented posttraumatic,

anterior instability; and 20 patients who had either arthroscopic or open Bankart repairs. All subjects were comparable in gender and age. It was determined that the TTDPM in subjects with normal shoulders averaged 1.5 to 2.2° for all testing conditions and there was no significance of hand dominance (Fig 2A). The subjects with unstable shoulders had a TTDPM value of approximately 2.8° and this was significantly ($p < 0.005$) increased compared with

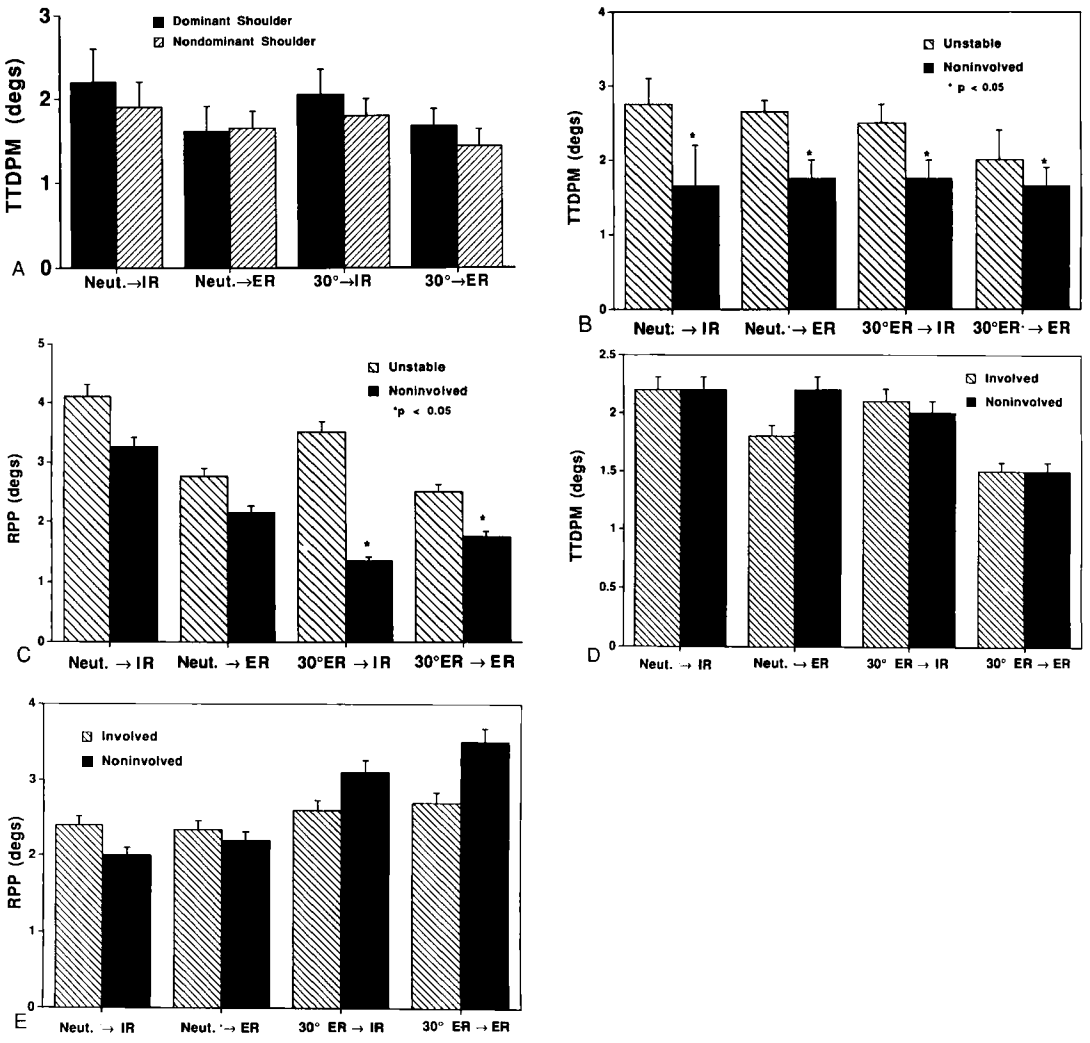

Fig 2A–E. (A) Results are means and standard error of the mean for TTDPM (degrees) of the dominant and nondominant shoulder from starting positions of neutral rotation and 30° external rotation moving into both internal and external rotation. (B) Results are means and standard error of the mean for TTDPM (degrees) of unstable and uninvolved shoulder from starting positions of neutral rotation and 30° external rotation moving into both internal and external rotation. (C) Results are means and standard error of the mean for RPP (degrees) for unstable and uninvolved shoulders from starting positions of neutral and 30° external rotation moving into both internal and external rotation. (D) Results are means and standard error of th mean for TTDPM (degrees) in reconstructed and uninvolved shoulders from starting positions of neutral rotation and 30° external rotation moving into both internal and external rotation. (E) Results are means and standard error of the mean for RPP (degrees) in reconstructed and uninvolved shoulders from staring positions of neutral rotation and 30° external rotation moving into internal and external rotation. (Reprinted with permission.[27])

the shoulders in the subjects with normal shoulders (Fig 2B). RPP was also significantly ($p < 0.01$) less accurate by approximately 1° in the unstable shoulders compared with the normal shoulders (Fig 2C). In patients whose shoulder instability had been repaired, the TTDPM and RPP were no different from that in patients with normal shoulders (Fig 2D).

CONCLUSIONS

It is concluded that there is an association of proprioceptive sensibility with shoulder instability, and surgery restores normal sensibility; however, the testing speed used in the present study was much slower than the speeds that occur with throwing or swimming. Therefore, it is difficult to extrapolate directly to the clinical situation. It is proposed that 1 mechanism for gradual development of shoulder instability may be cumulative injury to the capsuloligamentous structures with loss of this proprioceptive feedback mechanism and, thus, reflexive muscular protection against excessive humeral head translations and rotations.

Blasier and colleagues[5,6] have suggested that individuals with generalized ligamentous laxity have poorer proprioceptive abilities in their shoulders, though their numbers were small and their testing methods were somewhat different than those used here. Future studies will examine the effectiveness of proprioceptive training in nonoperative treatment of instability, and the affect of constitutional hyperlaxity on proprioceptive sensibility.

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