

MUSCLE CONTRIBUTIONS TO JOINT STABILITY IN THE ANATOMICAL SHOULDER

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INTRODUCTION

During the course of normal shoulder movement, muscles and tendons translate and rotate with their bone-embedded origins and insertions. Because the spatial relationship between the origins and insertions of these structures varies according to joint motion, muscle lines-of-action (LOA) and moment arms must also change through the range of movement. As a result, articulating forces, bone-stress distributions, and joint stability may vary significantly. The present study investigated the contribution of shoulder musculature LOA to the superior stability of the glenohumeral joint. At present, no study has measured the LOA of all the major muscles spanning the shoulder in flexion and abduction, nor quantified the contribution of these muscles to joint stability.

METHODS

Eight fresh-frozen, entire upper extremities were mounted on a custom designed dynamic shoulder cadaver testing apparatus. Tendons of the following muscles and muscle sub-regions were identified and separated: deltoid (anterior, middle, inferior), subscapularis (inferior, middle, superior), supraspinatus (anterior, posterior), teres minor, latissimus dorsi (superior, middle, inferior), and pectoralis major (superior, middle, inferior).

To remove muscle-slack, nylon-lines were sutured to all tendons and passed through a pulley system to hanging weights of 10 N; the pulleys were positioned to reproduce each muscle's line-of-pull, as determined by visual inspection and using a computational model (Garner and Pandy,

2001). Retro-reflective marker triads were inserted into the humerus and scapula, and joint angles computed from the marker trajectories using a 6-camera Vicon motion capture system. Scapula and humeral coordinate systems were defined by digitizing bony prominences, as described in Garner and Pandy (2001). The humerus was passively held at 30°, 60°, 90° and 120° of elevation in scapula-plane abduction (scaption) and flexion. At each joint angle, LOA were calculated by digitising bony and soft tissue landmarks using a marker wand. Muscle LOA for each scapulohumeral muscle bundle were defined by the force-vector projection from the last tendon wrapping via-point (the point where the muscle-tendon loses contact with the head of the humerus), to the centroid of origin of the muscle sub-region, and expressed in the scapula reference-frame.

Stability ratios were computed to assess muscle potential contributions to glenohumeral joint stability; superior stability ratios (SSR) were computed by dividing superior shear components of the muscle's LOA by the compressive component.

RESULTS

The inferior latissimus dorsi was a potential inferior destabiliser, but may stabilise the glenohumeral joint with the combined superior shear of the superior pectoralis major and the anterior deltoid, particularly in flexion (Figure 1). The superior subscapularis and anterior supraspinatus had the greatest stabilising capacity of the rotator cuff muscles during scaption and flexion, while the inferior subscapularis and teres minor had the greatest destabilising potential.

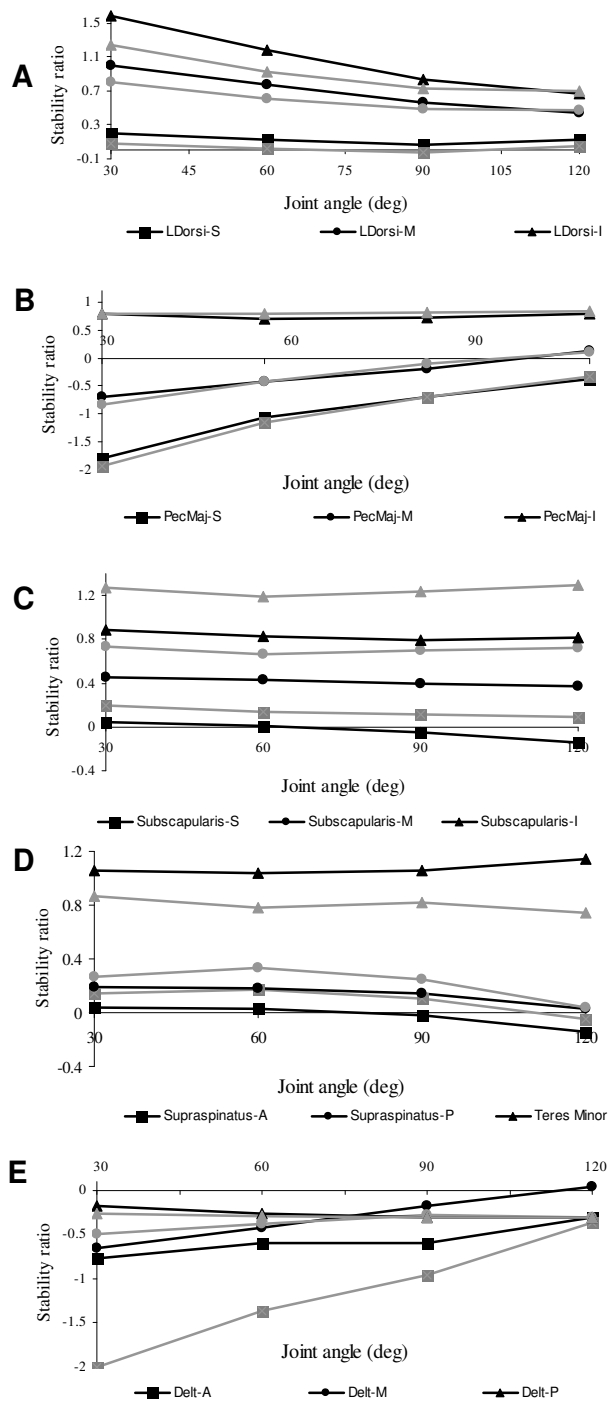


Figure 1. Superior stability ratios for (A) latissimus dorsi, (B) pectoralis major, (C) subscapularis, (D) supraspinatus and teres minor, and (E) deltoid Black lines show scaption data and grey lines flexion data

DISCUSSION

The results of this study provided anatomical evidence of the superior stabilising potential of specific rotator cuff muscles, and how the potentially destabilising prime movers of the shoulder may interact to produce stable leverage during elevation. At present, contributions of latissimus dorsi and pectoralis major to joint stability have received very little attention in the literature and are not well understood; for the first time in a study of glenohumeral joint stability, multi-pennate muscles of broad origin were divided into functionally distinct sub-regions and investigated individually.

Quantifying the LOA and stabilising potential of the shoulder musculature helps to establish a better understanding of the normal function of the glenohumeral joint, and may assist surgeons in planning shoulder joint surgery including arthroplasty or reconstructive procedures such as tendon-transfer.

SUMMARY

Measuring the lines-of-action and stability ratios of sub-regions of the shoulder muscles during scaption and flexion demonstrated the potential contribution of the shoulder musculature to glenohumeral joint stability during arm elevation. The results presented provided evidence for specific muscle sub-region function, which may assist in the planning of surgery for the diseased or injured shoulder. The data presented may also assist in development and validation of computational models of the shoulder complex.

REFERENCES

Garner and Panday (2001) *Comp Meth Biomech Biomed Engin* 4, 93-126