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Shoulder impingement: Biomechanical considerations in rehabilitation

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ABSTRACT

Shoulder impingement is a common condition presumed to contribute to rotator cuff disease. Impingement can occur externally with the coracoacromial arch or internally with the glenoid rim. Normal scapulothoracic motions that occur during arm elevation include upward rotation, posterior tilting, and either internal or external rotation. These scapulothoracic motions and positions are the result of coupled interactions between sternoclavicular and acromioclavicular joints. The sternoclavicular and acromioclavicular joints both contribute to scapulothoracic upward rotation. Posterior tilting is primarily an acromioclavicular joint motion. The sternoclavicular and acromioclavicular joint motions offset one another regarding final scapulothoracic internal/external rotation position. This manuscript discusses these coupled interactions in relation to shoulder muscle function. Two case examples are presented to demonstrate application of understanding these interactions and potential mechanisms of movement abnormalities in targeting treatment interventions for movement based subgroups of impingement patients.

Shoulder impingement is a common condition believed to contribute to the development or progression of rotator cuff disease (van der Windt et al., 1995; Michener et al., 2003). A number of impingement categories have been identified including subacromial impingement or "external impingement"; internal impingement, which can be further divided into anterior or posterior (Edelson and Teitz, 2000); and coracoid impingement. Charles Neer described subacromial impingement as the compression and abrasion of the bursal side of the rotator cuff beneath the anterior acromion, and developed the anterior acromioplasty as a treatment (Neer, 1983). External impingement is now understood as a much broader category than that described by Neer, and could include compression or abrasion of the cuff tendons or tendon of the long head of the biceps brachii beneath any aspect of the coracoacromial arch (Neer, 1983). The coracoacromial arch includes not just the acromial undersurface, but also the coracoacromial ligament, and the undersurface of the acromioclavicular (AC) joint.

Internal impingement was first described as a condition noted in overhead athletes, identified in part due to poor outcomes of acromioplasty in this population (Paley et al., 2000). Posterior internal impingement has been postulated to be contact or entrapment of the articular side of the supra or infraspinatus tendons with the posterior/superior glenoid labral complex in a position of glenohumeral abduction and external rotation (Paley et al., 2000; Heyworth and Williams, 2009). Articular surface contact of the cuff with the glenoid labral complex can occur anterior/superiorly as well (Edelson and Teitz, 2000). Articular surface tears are also common in patients without substantive overhead sports exposure (Budoff et al., 2003; Heyworth and Williams, 2009). Impingement of the subscapularis tendon between the coracoid process and lesser tuberosity of the humerus has also been identified as an impingement category, although less commonly discussed in the literature (Okroro et al., 2009).

All categories of impingement are potential mechanisms for the development or progression of rotator cuff disease, or long head biceps tendinopathy (Soslowsky et al., 2002). Physical exam findings consistent with impingement can also be associated with labral tears in internal impingement (Budoff et al., 2003) or develop secondary to instability or as a delayed consequence of adhesive capsulitis. There are multiple mechanisms by which impingement may occur, including excess or reduced motion and abnormal patterns of motion at particular portions of the range of motion (Michener et al., 2003). In addition, anatomic abnormalities of the humerus or acromion have been implicated in impingement (Zuckerman et al., 1992). It should be noted that rotator cuff disease can develop without impingement, through tensile overload or intrinsic tissue degeneration (Soslowsky et al., 2002). Regardless

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of the initial precipitating factor, however, impingement, abnormal shoulder motions, and associated rotator cuff disease often are found in the presence of partial or full thickness rotator cuff tears. In other words, even if rotator cuff disease or tearing did not initiate from impingement or abnormal motion, impingement and abnormal motion are likely to contribute to disease progression.

The purpose of this manuscript is to identify recent advances in understanding of normal and abnormal biomechanics of the shoulder as related to rehabilitation of shoulder impingement. In particular, contributions of sternoclavicular (SC) and AC joint motions to overall scapulothoracic (ST) motion during arm elevation will be discussed. How this biomechanical knowledge can assist in planning targeted interventions for motion based subgroups of shoulder pain patients will be illustrated with two brief case examples.

1. Normal shoulder motion

During normal motion, the scapula will upwardly rotate and posteriorly tilt on the thorax during elevation of the arm in flexion, abduction, scapular plane abduction, or unrestricted overhead reaching (McClure et al., 2001; Braman et al., 2009; Ludewig et al., 2009). Throughout this manuscript, elevation will be used to refer to raising the arm overhead in any of these planes. Scapulothoracic internal or external rotation is less consistent during arm elevation, differing in pattern depending on what plane the arm is elevated in, and depending on what portion of the elevation range of motion is considered (Ludewig et al., 2009). The scapula must adjust in the transverse plane for the intended plane of elevation. For flexion, the scapula will internally rotate somewhat early in the motion, whereas for coronal plane abduction, it will externally rotate at the initiation of the motion. Based on the limited end range data available (McClure et al., 2001; Braman et al., 2009; Ludewig et al., 2009), it appears some external rotation of the scapula will occur near end range for each of these planes of elevation.

Recent investigations have added new knowledge on how SC and AC joint motions contribute to overall ST motion (Ludewig et al., 2004, 2009; Sahara et al., 2006, 2007; Teece et al., 2008). The primary clavicular motion occurring at the SC joint during active arm elevation in any plane except extension is 30° of posterior long axis rotation (Sahara et al., 2007; Ludewig et al., 2009; Fig. 1). Secondarily, the clavicle will retract ~15° at the SC joint during elevation, even with flexion (Ludewig et al., 2009). However, the clavicle also "adjusts" in the transverse plane (less retraction with flexion, more with abduction) similarly to the changes in scapular internal rotation with flexion versus abduction (Ludewig et al., 2009). Finally a small amount of clavicular elevation (typically below 10° in healthy subjects) will occur at the SC joint with humeral elevation in any plane (Sahara et al., 2007; Ludewig et al., 2009). Concurrent with clavicular motion relative to the thorax, measurable motion of the scapula relative to the clavicle is also occurring at the AC joint as the humerus is elevated in any plane (Sahara et al., 2007; Ludewig et al., 2009; Fig. 2). Primary AC joint motions include upward rotation and posterior tilt of the scapula relative to the clavicle. Secondarily the scapula will internally rotate relative to the clavicle at the AC joint, even while abducting the arm (Sahara et al., 2007; Ludewig et al., 2009).

Overall ST motion occurs either through motion of the clavicle relative to the thorax, motion of the scapula relative to the clavicle, or some combination of both. During normal arm elevation in any plane, both clavicular (SC) and scapular (AC) motions described above are contributing to the final position of the scapula on the thorax. However, the non-parallel alignment of the axes of rotation of the SC and AC joints makes their contributions to ST motion challenging to visualize (Teece et al., 2008; Fig. 3). The AC joint axes are aligned consistently with how the axes are described for the scapula on the thorax, such that if the scapula upwardly rotates, posteriorly tilts or internally rotates relative to the clavicle, there is a 1:1 "coupling" with ST motion. In other words 5° of scapular upward rotation relative to the clavicle would contribute to 5° of ST upward rotation. In order to understand the coupling of clavicular motion to ST motion, it is helpful to visualize an axis of rotation embedded along the long axis of the clavicle, and another embedded in the scapula from the root of the scapular spine to the AC joint (Fig. 3). In a superior transverse plane view, first imagine a hypothetical situation where the clavicle and scapular axes are parallel (Fig. 3B). In such a hypothetical alignment, if the clavicle were elevated about its anteriorly directed axis 9° relative to the thorax, the scapula would upwardly rotate 9° on the thorax, assuming no motion of the scapula relative to the clavicle at the AC joint. If the clavicle rotated posteriorly about its long axis 30° relative to the thorax, the scapula would posteriorly tilt 30° relative to the thorax, and if the clavicle retracted 9° relative to the thorax, the scapula would externally rotate 9° relative to the thorax (Teece et al., 2008). Now consider an alternative hypothetical situation where the scapula is internally rotated 90° relative to the clavicle, such that the described axes in the transverse plane are at a 90° angle (Fig. 3C). In such a hypothetical alignment, if the clavicle were elevated about its anteriorly directed axis 9° relative to the thorax, the scapula would anteriorly tilt 9° on the thorax. If the clavicle rotated posteriorly about its long axis 30° relative to the thorax, the scapula would upwardly rotate 30° on the thorax, and if the clavicle retracted 9° relative to the thorax, the scapula would externally rotate 9° on the thorax (Teece et al., 2008). The two scenarios completely change with regard to SC joint contributions to ST upward rotation and tilting, but remain the same for contributions to ST external rotation.

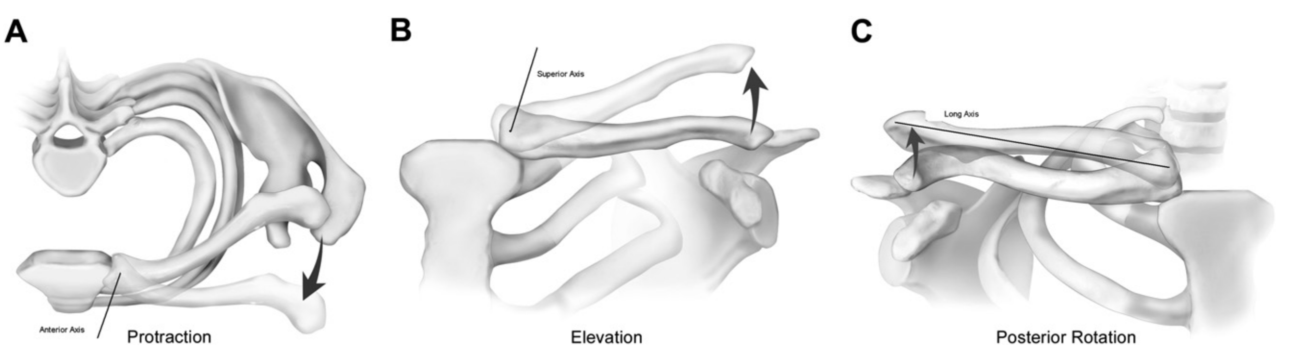

Fig. 1. Clavicular rotations relative to the thorax include protraction/retraction about a superiorly directed axis (A), elevation/depression about an anteriorly directed axis (B), and anterior/posterior rotation about a long axis (C). Adapted from Ludewig et al. (2009).