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# The upper and lower segments of subscapularis muscle have different roles in glenohumeral joint functioning

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ABSTRACT

Subscapularis muscle is divided into two independent segments, upper and lower (USUB and LSUB), but the role of each segment in glenohumeral functioning is unclear. We compared the electromyographic (EMG) activity of USUB and LSUB during a variety of shoulder movements, with and without an external translation force. Intramuscular electrodes were inserted in USUB and LSUB segments of 20 adults without pathology and EMG activity was measured in stabilization trials (with and without an anterior or posterior directed force at the humerus and isometric rotations) and two shoulder positions (shoulder neutral, abduction). Maximal voluntary isometric contraction (MVIC) trials were performed in abduction, internal and external rotation of the shoulder. In MVIC trials, USUB showed higher activity during internal rotation ($p = 0.03$), whereas LSUB showed higher activity during external rotation ($p < 0.01$). In stabilization trials, the interaction effects were significant for muscle segment × condition ($p < 0.01$), and approached significance for muscle segment × position ($p = 0.06$). In the neutral position, the pattern of activity for LSUB was similar to USUB. In the abducted position the LSUB, unlike USUB, was more active during external rotation ($p = 0.06$) and also showed increased activity in response to the posterior directed force at the humerus ($p = 0.04$). Our results suggest that USUB primarily acts as an agonist for internal rotation. In contrast LSUB was particularly active in external rotation in the abducted position and demonstrated increased EMG activity in response to the posteriorly directed force at the humerus in that position, suggesting more of a role in glenohumeral stabilization.

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## 1. Introduction

The subscapularis muscle is divided into upper and lower segments (USUB and LSUB) that are innervated separately and have different lines of action (Kadaba et al., 1992; Kasper et al., 2008; Liu et al., 1997). This may contribute to the USUB and LSUB muscle segments acting as independent muscle units (Kadaba et al., 1992; Kasper et al., 2008; O'Connell et al., 2006), therefore accounting for the variation in roles described in previous studies (Inman et al., 1994; Ovesen and Nielsen, 1985). Among these roles subscapularis has been reported to act as the primary internal rotator of the humerus (Morag et al., 2011) and a stabilizer of the glenohumeral joint (Ovesen and Nielsen, 1985), especially in abducted and externally rotated position of the arm (Halder et al., 2000). It has been proposed to counterbalance the infraspinatus by resisting anterior displacement in the axial plane and inhibit the shearing forces of the deltoid in the coronal plane (DePalma et al., 1967; Aluisio et al., 2003).

Although once thought to be uncommon, subscapularis tears are now recognized to have a prevalence of nearly 30% in all arthroscopic shoulder surgeries and up to 59% in arthroscopic rotator cuff procedures (Arai et al., 2008). Injury, weakness or reduced activation of either segment of the muscle may lead to shoulder pain, dysfunction, impingement and/or instability (Decker et al., 2003; Gerber et al., 1996).

Previous electromyographic (EMG) studies have demonstrated conflicting findings regarding subscapularis muscle function during common shoulder movements (Kadaba et al., 1992; Nemeth et al., 1990; O'Connell et al., 2006; Wickham et al., 2014), leading to recommendations for further research (Wickham et al., 2014). One reason for these conflicting findings could be that some studies evaluated the subscapularis muscle as a single muscle unit (Ganderton and Pizzari, 2013; Malanga et al., 1996). Decker et al.

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(2003) investigated the differences in the USUB and LSUB EMG activity and found greater activity in the USUB compared to the LSUB during internal rotation at 90° of abduction, while others reported USUB muscle activity decreasing significantly throughout the abduction movement from 0 to 90° (Kadaba et al., 1992; McCann et al., 1994). In a recent study, Wickham et al. (2014) reported no differences in the two parts of the muscle during internal rotation movement and greater activity in the LSUB as compared to the USUB during shoulder abduction and flexion, consistent with lower segment of subscapularis having a stabilizing role at the glenohumeral joint (Rathi et al., 2016b; Wickham et al., 2014). However, these studies have not explored the potentially different roles of the two segments of subscapularis muscle in providing glenohumeral joint stability by opposing the anterior and posterior directed force at the humerus.

The discrepant findings on the roles of upper and lower segments of subscapularis muscle, the paucity of research on its stabilizing role and the frequency of subscapularis injuries indicate that further investigations are warranted. Since most lesions of the subscapularis muscle affect the upper segment of the subscapularis tendon (Pennock et al., 2011), a clear distinction of the role of the two segments in glenohumeral stability may help clinicians in designing more specific treatment protocols and rehabilitation programs.

Therefore, we aimed to compare the EMG activity of the USUB and LSUB during resisted isometric contractions, with and without an anterior and posterior directed force at the humerus in neutral and abducted positions and also during maximal voluntary isometric contractions in different positions. Based on the existing literature, two hypotheses were examined: (1) Consistent with its role as an agonist for internal rotation, it was hypothesized that USUB would show higher activity than LSUB during isometric internal rotation. (2) Given its purported stabilizing role, it was hypothesized that (a) LSUB would show higher activity than USUB during isometric external rotation in the abducted position, (b) LSUB would show increased activity in response to anterior and posterior directed forces at humerus, while USUB would not demonstrate any changes in activity in response to anterior and posterior directed forces.

## 2. Materials and method

### 2.1. Design

This study involved repeated measurements of intramuscular EMG activity of USUB and LSUB muscle segments in positions and conditions involving isometric internal and external rotation contractions and anterior and posterior directed forces at the humerus. This is a secondary analysis of an experiment confirming the role of rotator cuff muscle contraction in limiting glenohumeral joint translation against anterior and posterior directed forces at humerus and these results are reported elsewhere (Rathi et al., 2016b).

### 2.2. Participants

Based on the sample size calculation described previously (Rathi et al., 2016b), twenty healthy participants (10 men, 10 women) aged between 18 and 37 years (mean = 23.6 ± 5.3 years) volunteered to participate in this study. The participants had no history of pain, injury or surgery in their dominant shoulders and were recruited from a university population. The University Ethics Committee approved all research procedures (14-079) and all participants gave written informed consent prior to participation.

### 2.3. Material and apparatus

Two bipolar fine-wire intramuscular electrodes were prepared using Teflon-coated stainless steel wire (A-M systems Inc, Carlsborg, WA) and 22-gauge, 7 cm biopsy needle according to methods first described by Basmajian and Stecko (1962). Using sterile procedures, electrodes were inserted under real time ultrasound (Sequoia 1200, Samsung, USA) guidance using published guidelines into the upper and lower segments of subscapularis (Wickham et al., 2014) of the dominant (used for throwing) arm of each participant. With the participant positioned halfway between supine and side-lying and with the arm abducted and the hand placed behind the head, the lateral border of the scapula was palpated with markings for needle insertion placed 20 mm anterior to the lateral border at distances of 45–60 mm and 95–110 mm above the inferior angle of the scapula (Wickham et al., 2014). A Delsys Trigno wireless EMG system and its associated software analysis package (2000 Hz, EMGWorks version 4.2, Delsys Inc., Boston, USA) were used to collect and analyze raw EMG data. An anterior and posterior directed force at the humerus of 60 N similar to the force used in previous studies (Rathi et al., 2016a,b; Yeap et al., 2003) was applied by an assistant with force monitored through a hand held dynamometer (Lafayette, USA). The force was ramped up for 1–2 s and then maintained for up to 8 s. Any trial where the force was outside the range of 50–70 N was discarded and repeated.

### 2.4. Procedure

Participants were seated upright in a chair with backrest with feet resting on the floor to ensure maximum stability during testing. The upper limb was fixed in one of two positions (Fig. 1A and B) without the need for any muscular activity using Velcro straps, and a customized elbow, hand and wrist orthosis. A vertical board was strapped across the chest to stabilize the trunk to the chair, so that anterior or posterior directed forces at humerus were isolated, as much as possible, to the humeral head rather than the torso. The hand held dynamometer was placed at the anterior part of the humeral head to apply the posterior directed force at the humerus and at the posterior part of the humeral head for the anterior directed force at the humerus. The methods used in this study have shown excellent intra-rater reliability (ICC absolute agreement 0.98) with low levels of measurement error (SDdiff $\leq$ 0.2 mm) (Rathi et al., 2016a) with magnitude of glenohumeral joint translation ranging from 1.4 to 3.0 mm (Rathi et al., 2016b). Using ultrasound to measure glenohumeral joint translation has been found comparable to stress radiography in measuring glenohumeral joint translation, demonstrating moderate to high levels of criterion validity ($r = 0.79$, $r^2 = 0.62$) (Borsa et al., 2005).

In the original study, for the stabilization trials (designed to assess glenohumeral translations), participants were tested in two shoulder positions (Rathi et al., 2016b): (1) shoulder at neutral: shoulder adducted and 0° internally rotated, 90° elbow flexion, forearm neutral pronation- supination, hand and wrist in neutral fixed to desktop with customized orthosis and straps (Fig. 1A); (2) shoulder abducted and externally rotated to 90°, 90° elbow flexion, forearm neutral pronation- supination, hand and wrist in neutral fixed to raised platform with customized orthosis and straps (Fig. 1B). In each position, participants were tested under six testing conditions: isometric internal rotation (IR), isometric external rotation (ER), IR and anterior directed force at the humerus (AT) (IR + AT), ER and anterior directed force at the humerus (ER + AT), IR and posterior directed force at the humerus (PT) (IR + PT) and ER and posterior directed force at the humerus (ER + PT). The sequence of testing was randomly allocated for each participant. Participants were instructed on how to produce the

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