In Vivo Intratendinous Strain Analysis of the Intact Supraspinatus by Speckles with Ultrasound
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**INTRODUCTION:**
Rotator cuff tear tendon is one of the most common causes of shoulder pain and disability. The pattern of rotator cuff tendon tear is various, including full-thickness tear, articular or bursal side partial-thickness tear and intratendinous delaminated tear. There are, however, limited reports about the mechanical factors influencing on in vivo strain pattern of rotator cuff tendon and understanding about the intratendinous strain characteristics during active motion is very poor. To our best knowledge the current investigation is the first effort to observe in vivo strains and movements which occur in the critical zone of the supraspinatus tendon in the live shoulder. The purpose of this study was to analyze the intratendinous strain of supraspinatus tendon in vivo by landmarks with high resolution ultrasound images. Our hypotheses were: (1) there would be a regional strain differences and shearing between the superficial region and deep region within the supraspinatus during shoulder motion and (2) there would be a different strain pattern between isometric and isotonic shoulder motions.

**METHODS:**
Eight healthy volunteers who have no history of shoulder disability were enrolled in this study. All volunteers are male and the average age was 26.8 years, range 25 to 29 years. All volunteer underwent unilateral 2-dimensional speckle tracking echocardiography (2D STE) in long-axis direction on the supraspinatus tendon of the shoulder. The peak strain and transverse displacement within the tendon were recorded and analyzed by motion tracing program in 2D STE. And to simulate daily activity, the shoulder motion was evaluated in two ways of isometric and isometric shoulder movement. For isometric movement each volunteer was instructed to elevate actively his arm till 90° and for isometric movement each volunteer contract shoulder muscle without any movement at 0° of abduction with neutral position.

We have employed commercially available echocardiogram system (Vivid 7, GE Vingmed ultrasound AS, Horten, Norway) with 2D STE. The images were obtained using 3.5-MHZ trasducer and displayed with B-mode images (Fig. 1. left). The ROI consisted of three kernels equally distributed from the superficial layer to the deep layer of the supraspinatus tendon. The 2D STE tracked down transverse displacement of each kernel and calculated strain from the change of length between them, which were displayed in the monitor with M-Mode images (Fig. 1. right).

The statistical analyses were performed with One-way ANOVA LSD(Least Significant Difference) and Mann-Whitney U-test using software(SPSS 13.0, SPSS Inc, Chicago, Ill) and a P value less than .05 was considered statistically significant.

**RESULTS:**
The average transverse displacement of each kernel within the supraspinatus tendon was 1.05±0.39 mm and the average peak strain of each kernel was 11.17±8.14% in isometric shoulder movement. In isometric movement, the average transverse displacement of each kernel within the supraspinatus tendon was 1.16±0.39 mm and the average peak strain of each kernel was 10.49±6.47%. In isometric movement, the mean transverse displacement of superficial region (1.42±0.23 mm) is significantly larger than that of deep region (0.66±0.12mm) (Fig 3A) and the mean peak strain of superficial region (19.31±2.85%) is also significantly higher than that of deep region (3.59±0.75%)(Fig 3C). However, in isometric movement, the transverse displacement of superficial region (0.77±0.15mm) is significantly smaller than that of deep region (1.50±0.23mm) (Fig 3B) and the peak strain of superficial region (4.93±1.24%) is significantly lower than that of deep region (16.96±3.78%) (Fig 3D).

**DISCUSSION:**
This in vivo strain analysis study has demonstrated two distinct observations. First, consistent with the first hypothesis, there is a difference of strain across the thickness of tendon, resulting in shearing between the superficial and deep part within the supraspinatus tendon during both isometric and isotonic contraction. Second, the strain and displacement patterns are totally different between the isometric and isotonic movement of the shoulder, which is consistent with our second hypothesis. We suggest a possible theory that the supraspinatus tendon has a characteristic of a shear strain within the tendon and the different pattern of strains between isometric and isotonic tendon contraction alternatively aggravate the shearing in daily activity, causing small intratendinous defects to propagate into the delaminated tear of the supraspinatus tendon. We believe this study can elucidate the biomechanical behavior of intact supraspinatus tendon in vivo and these data provide the insight into the pathogenesis of the delaminated rotator cuff tears.