Clinical Measurement of Scapular Upward Rotation in Response to Acute Subacromial Pain

Shoulder pain is among the most common musculoskeletal symptoms seen in primary care, with a lifetime prevalence of up to 67%. Greater than 60% of patients seeking treatment for shoulder pain have been reported to have conditions involving subacromial structures (rotator cuff and/or bursa). The relationship between pain, functional deficits, and tissue damage is unclear. Given the high prevalence of pathological findings in shoulder tissues using diagnostic testing of asymptomatic individuals, pain may be accountable for functional alterations seen in patients with shoulder pathology. The etiology of rotator cuff injury is multifactorial. Its proposed contributors include decreased anatomical space beneath the coracoacromial arch, intrinsic tendon degeneration, and/or movement alteration of the scapula or humerus, which is suggested to contribute toward mechanical impingement of the rotator cuff. Movement alteration has the potential to limit space inferior to the coracoacromial arch through positioning of either the humeral head or scapula. Several investigations have aimed to determine if adaptations in scapular movement occur in individuals with impingement or rotator cuff disease. A narrative review of studies assessing scapular kinematics by Ludewig and Reynolds noted some consensus among adaptations found in individuals with impingement or rotator cuff disease. Specifically noted were decreased scapular movement toward upward rotation, posterior tilt, and external rotation during humeral elevation. Such adaptive motions may contribute to shoulder disorders by decreasing the available subacromial space. Patients with shoulder pathology often report an inability to perform lifting tasks or overhead reaching, likely due to pain. Upper extremity athletes have also commonly reported shoulder symptoms that limit athletic participation. Thus, many physical therapy interventions are designed to restore or normalize muscle

**STUDY DESIGN:** Block-counterbalanced, repeated-measures crossover study.

**OBJECTIVES:** To assess scapular upward rotation positional adaptations to experimentally induced subacromial pain.

**BACKGROUND:** Existing subacromial pathology is often related to altered scapular kinematics during humeral elevation, such as decreased upward rotation and posterior tilting. These changes have the potential to limit subacromial space and mechanically impinge subacromial structures. Yet, it is unknown whether these changes are the cause or result of injury and what the acute effects of subacromial pain on scapular upward rotation may be.

**METHODS:** Subacromial pain was induced via hypertonic saline injection in 20 participants, aged 18 to 31 years. Scapular upward rotation was measured with a digital inclinometer at rest and at 30°, 60°, 90°, and 120° of humeral elevation during a painful condition and a pain-free condition. Repeated-measures analyses of variance were conducted for scapular upward rotation position, based on condition (pain or control) and humeral position. Post hoc testing was conducted with paired t tests as appropriate.

**RESULTS:** Scapular upward rotation during the pain condition was significantly increased (range of average increase, 3.5°-7.7°) compared to the control condition at all angles of humeral elevation tested.

**CONCLUSION:** Acute subacromial pain elicited an increase in scapular upward rotation at all angles of humeral elevation tested. This adaptation to acute experimental pain may provide protective compensation to subacromial structures during humeral elevation. J Orthop Sports Phys Ther 2013;43(4):199-203. Epub 14 January 2013. doi:10.2519/jospt.2013.4276

**KEY WORDS:** experimental shoulder pain, impingement syndrome, rotator cuff
function to the scapular muscles, in an attempt to facilitate optimal scapular positioning and return to function or sport.\(^5,6,13\) One limitation of the existing literature regarding scapular adaptation to shoulder injuries is the lack of prospective studies assessing movement prior to and following shoulder injury.

Experimental pain models allow assessment of the influence of pain in individuals without tissue injury. Hypertonic saline injection into muscle or periarticular structures creates transient local or referred pain and has been shown to be an appropriate model for simulating musculoskeletal pain.\(^3,21\) Pain models can thus provide valuable information on the role of pain, while minimizing undue harm associated with injury. The aim of this study was, therefore, to evaluate the role of experimentally induced subacromial pain in scapular upward rotation position in an attempt to prospectively assess scapular adaptation. The information gleaned from this study may provide clinicians with a better understanding of the role of acute pain in scapular position. The authors hypothesized that participants would exhibit an adaptation of decreased scapular upward rotation similar to individuals with subacromial pathology.\(^7,19\)

**METHODS**

**Participants**

A sample of convenience of 20 participants (10 men, 10 women; age range, 18-31 years) was recruited to participate in the study. The age group was specifically chosen to decrease the likelihood of age-related degeneration of the rotator cuff. Participants were considered healthy if they reported no history of seeking medical care for shoulder or neck injuries and no current shoulder or neck pain. All testing was completed in a university research laboratory using procedures approved by the University of Otago Human Ethics Committee. All participants provided informed consent, as per University guidelines. The rights of all participants were protected.

**Instrumentation**

Clinical measures of scapular upward rotation were recorded using a digital inclinometer (The Saunders Group, Chaska, MN). The inclinometer is capable of measuring angles from a horizontal or vertical reference and specified by the manufacturer to be accurate within 1.0°. The inclinometer was modified by attaching 2 wooden palpation dowels to the bottom of the instrument.\(^8,11,28,35\) Upward/downward rotation of the scapula was measured relative to horizontal by aligning the indented Y of each palpation dowel along the medial and lateral aspect of the scapular spine (FIGURE1).\(^8,11,15\) Prior research has indicated that measurement of scapular upward/downward rotation with a modified digital inclinometer is a reliable procedure.\(^6,11\) A priori reliability testing of 15 healthy participants, tested twice over a 48-hour period, was performed by the principal investigator. The reliability of the measurement of scapular upward/downward rotation was calculated using an intraclass correlation coefficient (ICC\(_{2,1}\)) and standard error of measurement (SEM) for the following angles: arms at rest (ICC = 0.87; SEM, 0.87°), 30° (ICC = 0.94; SEM, 0.92°), 60° (ICC = 0.97; SEM, 0.89°), 90° (ICC = 0.97; SEM, 0.84°), and 120° (ICC = 0.96; SEM, 0.86°).

The SEM was calculated as group SD \(\times \sqrt{1-ICC}\). To be consistent with previous research, scapular upward rotation was measured at 5 angles of humeral elevation in the scapular plane: rest position (arms at side), 30°, 60°, 90°, and 120°.\(^8,11\) The measurement of humeral elevation was performed with the digital inclinometer immediately prior to scapular measurement. Scapular measurements, which were relative to horizontal and not to the thorax, were recorded during the pain and no-pain conditions.

**Experimental Pain Protocol**

A sports medicine physician induced the experimental subacromial pain by injecting 2.0 mL of 5.0% hypertonic saline into the subacromial bursa, using a posterior approach. This method of pain induction has been shown to provide a moderate, short-lasting pain sensation in the targeted tissues.\(^2\) Pain level was monitored using a visual analog scale (VAS), which consisted of a 10-cm horizontal line. Pain intensity was measured and recorded as the distance in centimeters (range, 0-10 cm) starting from the left side of the line (no pain) and ending on the right (worst pain imaginable). Pain level was reported immediately following the scapular measurements and prior to the control condition. The VAS has been reported to have the highest accuracy scores in clinical research,\(^33\) with scores of 1.0 or greater indicating a painful condition.\(^33\)

As gender differences in pain studies have been noted previously,\(^8,11\) the present study employed block counterbalancing by gender, such that 5 men and 5 women had scapular variables measured with pain first, the control condition of no pain second, and vice versa. When the pain condition was completed first, a period of at least 20 minutes was allotted following completion of data collection to allow pain-free testing in the no-pain condition. All testing was completed on the dominant shoulder, as determined by participant response to the question, “Which arm would you use to throw a ball for maximum accuracy?”

**Data Analysis**

SPSS Version 20 software (SPSS Inc, Chicago, IL) was used to analyze the data. Repeated-measures analyses of variance were conducted for scapular upward rotation to test for the condition-by-pain...
(pain and control by humeral elevation angle) interaction. If the Mauchly sphericity test was statistically significant, degrees of freedom were corrected using the Greenhouse-Geisser method. Post hoc testing was conducted with paired t tests using a Bonferroni correction, and significance was based on an a priori level of P = .05 for all analyses.

RESULTS

The participants’ demographic information was mean (range) age, 22.3 (18-31) years; body mass, 71.6 (52-107) kg; and height, 1.72 (1.56-1.87) m. Nineteen participants were right-hand dominant. The experimental pain condition was successful in creating a pain response among participants, with mean ± SD VAS scores of 5.3 ± 2.4 cm. All participants reported pain at 0/10 prior to the control condition.

For scapular upward rotation, a significant interaction effect (condition by position) was found (F = 3.88; df = 19, 48.85; P = .018). The Mauchly test was significant; thus, the Greenhouse-Geisser method was employed. Scapular upward rotation for the pain condition was significantly increased at all angles of humeral elevation tested (Figure 2). Specifically, upward rotation was increased by an average of 3.5° in the resting position (95% confidence interval [CI]: 1.5°, 5.5°; P = .002), 6.6° at 30° of humeral elevation (95% CI: 4.7°, 8.5°; P = .001), 7.7° at 60° of humeral elevation (95% CI: 5.5°, 10.0°; P = .001), 7.3° at 90° of humeral elevation (95% CI: 5.5°, 9.0°; P = .001), and 7.5° at 120° of humeral elevation (95% CI: 4.9°, 10.1°; P = .001).

DISCUSSION

Patients with signs and symptoms associated with subacromial impingement and/or rotator cuff disease have demonstrated alterations in scapular kinematics in several prior investigations.14,17-19,29 Common adaptations include a decrease in scapular upward rotation as well as posterior tilt. It has been suggested that these kinematic changes decrease the available subacromial space, which may injure subacromial tissues if occurring before the injury and/or limit the ability to recover from impingement if occurring after the injury.14 The current study demonstrated that scapular alterations occurred in response to the introduction of a pain stimulus into the subacromial space. Contrary to our hypothesis, scapular upward rotation was significantly increased in individuals experiencing acute, moderate, subacromial pain. The increased upward rotation found is divergent from the adaptations found in individuals with subacromial pathology and is suspected to increase the available subacromial space and potentially limit injury or repeated damage to the subacromial tissues.5,23

One limitation of prior investigations is the lack of data to suggest whether these kinematic changes cause or result from the injury. The current study was able to replicate subacromial pain in an attempt to determine scapular adaptation to acute pain. This was a crossover study using experimental pain induction and, therefore, not a true prospective study. However, the acute effects of pain created compensatory increases in scapular upward rotation that may be protective of subacromial structures. Patients with shoulder injuries, on the other hand, often demonstrate decreased upward rotation.13,15-19 The divergence of these findings may indicate that decreased upward rotation precedes and contributes to the shoulder pathology displayed in clinical populations. This mechanism of injury has been hypothesized, given the suggested contribution of decreased upward rotation to reduced subacromial space and subsequent mechanical insult to subacromial tissues.15,23 Another possible explanation for patients exhibiting decreased upward rotation is an abnormal and deleterious response to subacromial pain or an adaptation to acute pain that varies over time following the initial response.

The findings of the current study are consistent with findings in individu-
als following experimentally induced suprascapular nerve block.\textsuperscript{20} With supraspinatus and infraspinatus muscle activity diminished subsequent to the nerve block, increased scapular upward rotation was noted, even though these muscles do not directly control scapular motion. These 2 studies both attempted to simulate injury to identify adaptation induced by either experimental condition (nerve block\textsuperscript{20} or shoulder pain as in the current study). The acute adaptation of increased upward rotation is consistent between these studies. Although the observed adaptation appears to be a positive compensation, it should be recognized that these positions deviate from the control condition in individuals without shoulder pathology and are thus compensatory and abnormal. Interestingly, another study\textsuperscript{22} demonstrated that individuals 2 years post–surgical rotator cuff repair displayed normalization of the increased scapular upward rotation found presurgically. This further supports the idea that the adaptation is a deviation from normal kinematics, even though it is hypothesized to be beneficial.

Patients with shoulder pathology often report an inability to perform lifting tasks or overhead reaching. The current study suggests that the adaptations to acute subacromial pain manifest differently from those to subacromial shoulder injury. One of the important differences between this experimental group and prior shoulder-injured groups is the presence of tissue damage. The contributions of scapulothoracic and glenohumeral movement to overhead reaching probably differ between these 2 groups. In individuals with shoulder injury, it may be that overhead reaching is achieved through a greater contribution of glenohumeral movement compared to scapulothoracic movement.\textsuperscript{23-24} In the current healthy participants with acute pain, greater scapulothoracic movement and less glenohumeral movement appear to have contributed to the overhead-reaching task. The greater role of glenohumeral movement in overhead reaching in patients with subacromial shoulder injury may predispose subacromial tissues to impingement and inflammation, which results in tissue damage. The differing movement patterns in this group of healthy participants indicate that pain may not be the factor that creates abnormal scapular positioning (decreased upward rotation) in symptomatic patients. In addition to subacromial tissue damage, there may be several other causes for decreased upward rotation in patients with shoulder injury, such as altered neuromuscular control, selective tissue tightness, muscle fatigue/weakness, or other unknown factors.\textsuperscript{25}

**Limitations**

Hypertonic saline was used to elicit acute subacromial pain in healthy individuals. It is unknown how well experimental pain mimics true shoulder pathology, and the responses to organic pain may differ from the experimental pain condition. Additionally, pain scores varied among participants and were not uniform. Hypertonic saline, however, is commonly used to study musculoskeletal pain responses.\textsuperscript{2} Moreover, no osmotically neutral saline injection was given in the control condition. Therefore, the increased fluid volume in the subacromial space may have incited the adaptations found. The authors feel that this is unlikely given the small volume (2 mL) of saline injected into the subacromial space and the crossover design used. Scapular upward rotation was recorded during static humeral positions relative to the horizontal and not to the thorax. It is possible that, in addition to the uniplanar motion measured by the inclinometer, other scapular or clavicular motions contributed to the measures reported, yet this was not noted visually during data collection. Scapular measurement using a validated motion analysis system would provide greater information on the role of experimental subacromial pain. Furthermore, though the static measures used in the current study have been favorably compared to dynamic measures using an electromagnetic tracking device, the adaptations found may differ during dynamic functional tasks.\textsuperscript{2} Finally, not blinding the investigators to the pain or control condition, which in this study would have been difficult given the participants’ responses to elevation of the humerus during the scapular measurement, might have influenced the results. It should be noted, however, that the findings were contrary to our hypothesis.

**CONCLUSION**

Experimental subacromial pain, elicited by subacromial hypertonic saline injection, induced positional changes of increased scapular upward rotation at several angles of humeral elevation compared to a control condition of no pain in young individuals without reported shoulder pathology. These data indicate that scapular adaptation of increased upward rotation, which may improve or maintain available subacromial space, occurs in response to shoulder pain without tissue damage. The adaptations noted differ from previously reported kinematic changes associated with subacromial pathology, implying that decreased upward rotation may precede shoulder injury. The positional changes found in this study did differ from the control condition and, therefore, should be considered atypical and compensatory. Future studies should investigate the role of analgesic injection in patients with symptomatic subacromial pathology to further determine the role of pain in scapular upward rotation.

**KEY POINTS**

**FINDINGS:** Experimental subacromial pain induced increased scapular upward rotation with arm elevation in individuals without reported shoulder pathology.

**IMPLICATIONS:** Scapular positional adaptation to acute experimental pain differs from reported adaptations to subacromial pathology and may provide tendon protective compensation during humeral elevation.

**CAUTION:** Acute organic pain may differ...
from the adaptations found using experimentally induced pain. It is unknown how long the adaptive response lasts, and it may change over time.

REFERENCES