ARTICLE IN PRESS

J Shoulder Elbow Surg (2016) ■■, ■■–■■

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

# The influence of induced shoulder muscle pain on rotator cuff and scapulothoracic muscle activity during elevation of the arm

**Birgit Castelein, MSc, PT[a,*], Ann Cools, PhD, PT[a], Thierry Parlevliet, MD[b], Barbara Cagnie, PhD, PT[a]**

[a]*Department of Rehabilitation Sciences and Physiotherapy, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium*
[b]*Department of Physical Medicine and Orthopedic Surgery, University Hospital, Ghent, Belgium*

**Background:** Altered recruitment of rotator cuff and scapulothoracic muscles has been identified in patients with subacromial impingement syndrome. To date, however, the cause–consequence relationship between pain and altered muscle recruitment has not been fully unraveled.
**Methods:** The effect of experimental shoulder pain induced by injection of hypertonic saline in the supraspinatus on the activity of the supraspinatus, infraspinatus, subscapularis, trapezius, and serratus anterior activity was investigated during the performance of an elevation task by use of muscle functional magnetic resonance imaging in 25 healthy individuals. Measurements were taken at 4 levels (C6-C7, T2-T3, T3-T4, and T6-T7) at rest and after the elevation task performed without and with experimental shoulder pain.
**Results:** During arm elevation, experimentally induced pain caused a significant activity reduction, expressed as reduction in T2 shift of the IS ($P = .029$). No significant changes in T2 shift values were found for the other rotator cuff muscles or the scapulothoracic muscles.
**Conclusions:** This study demonstrates that acute experimental shoulder pain has an inhibitory effect on the activity of the IS during arm elevation. Acute experimental shoulder pain did not seem to influence the scapulothoracic muscle activity significantly. The findings suggest that rotator cuff muscle function (infraspinatus) should be a consideration in the early management of patients with shoulder pain.
**Level of evidence:** Basic Science Study; Kinesiology


**Keywords:** Experimental pain; rotator cuff; scapula; muscle functional magnetic resonance imaging; exercise; muscles; shoulder pain

The Ghent University Hospital Ethical Committee (Registration Number: B670201215743 - Study Number 2012/868) approved the protocol for this study.

*Reprint requests: Birgit Castelein, MSc, PT, Department of Rehabilitation Sciences and Physiotherapy, University Hospital Ghent, De Pintelaan 185, 3B3, B-9000 Ghent, Belgium.

E-mail address: Birgit.Castelein@ugent.be (B. Castelein).

Shoulder pain is a common complaint, and the lifetime prevalence reaches 66.7%, with women reporting shoulder pain more often than men.[32] Shoulder impingement symptoms (SISs) are present in 40% of those patients.[28,32,47] Altered muscle activation patterns of the rotator cuff and the

1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
http://dx.doi.org/10.1016/j.jse.2016.09.005

scapulothoracic muscles have been found in patients with painful SIS,.[2,9,11,17,29-31,35,37,38] However, to date, it is not clear whether pain is the source of altered muscle activation patterns or whether pain arises secondary to alterations in the muscle activity patterns.

The use of experimental pain may be valuable to study the effect of acute pain on muscle recruitment and allows evaluation of the causative relationship between pain and dysfunction.[25,44] Experimental pain has some advantages over clinical pain because it creates a pain model with relatively consistent location, duration, and intensity of pain in contrast to the high between-subject variation and the heterogeneity of shoulder pain in clinical studies. The few studies of experimental pain in the shoulder region used electromyography (EMG) to investigate the influence of pain on muscle recruitment and activation.[1,18,42,43] The use of EMG as the primary method for evaluating the activity of the rotator cuff and scapulothoracic muscles in patients with shoulder pain has some limitations, including cross talk, variable signaling through subcutaneous tissue, difficulty with accurate electrode placement, and the physical movement of the muscle. Moreover, muscles that lie deeply, such as the rotator cuff muscles, can only be measured with fine-wire EMG; however, this fine-wire method is invasive and is limited to the activity of 1 motor unit.

An alternative technique that is able to evaluate muscle recruitment patterns is muscle functional MRI (mfMRI). mfMRI is a noninvasive technique based on the differences in water relaxation values (T2-relaxation) of the muscles,[5] is comparable with EMG for quantifying muscle activity in response to exercise, and overcomes the limitations of surface EMG.[16] The technique relies on an acute activity-induced increase in T2 relaxation times of muscle water, resulting from underlying metabolic reactions.[5] The shifts in T2 values upon exercise (T2 shift) relate to the amount of work performed by the muscle.[16] The advantages of mfMRI are that it can map the intermuscular recruitment patterns with a very high spatial accuracy, is noninvasive, and has a high sensitivity and specificity.[5,26,34] Unlike EMG, however, it cannot provide real-time information about the amount and timing of the underlying muscle activity. Because of its excellent spatio-temporal resolution, mfMRI can be used as a noninvasive evaluation of the function of muscles around the scapula, such as the rotator cuff and the serratus anterior (SA), that are challenging to evaluate with EMG. mfMRI has also been used to investigate the influence of experimental pain on spinal muscles.[3,6,15]

Only a few studies to date have used the mfMRI technique to evaluate the muscles around the shoulder region.[7,24,41,45] Cahoy et al[7] and Horrigan et al[24] evaluated the rotator cuff muscles before and after different exercises. Takeda et al[45] determined with mfMRI the best exercise (empty can, full can, and horizontal abduction) for strengthening the supraspinatus (SS) muscle, whereas Sheard et al[41] used mfMRI to investigate the SA muscle function during isometric upper limb exercise in individuals with neck pain and scapular dysfunction compared with healthy controls.

These 4 studies used mfMRI to investigate muscle function around the shoulder, but studies investigating differences between individuals with and without shoulder pain (experimental or clinical pain) are currently lacking. Therefore, the aim of this study was use mfMRI to examine the effect of experimentally induced pain on muscle activity of the rotator cuff and scapulothoracic muscles in healthy individuals when performing elevation in the scapular plane.

## Materials and methods

### Participants

The study recruited 25 healthy individuals (9 men 16 women). Candidates were excluded if they reported past or current neck or shoulder pain, if MRI was contraindicated, or if they performed upper limb training or overhead sports more than 6 hours weekly. The study participants were a mean age of 30.5 ± 12.5 years, a mean weight of 69 ± 12.9 kg, and a mean height of 173.5 ± 9.3 cm. Before taking part in the study, participants had to read and sign the informed consent.

### Test procedure

All subjects were asked to avoid heavy overhead activities 48 hours before the testing took place. Participants were tested under 2 conditions: first without pain and then with experimental shoulder pain. MRIs were obtained at 3 different times: at rest, immediately after the performance of the exercise without pain, and immediately after the performance of the exercise while having shoulder pain. First, the subjects lay supine for 15 minutes, after which a resting MRI was obtained ("rest"). Then, subjects performed an exercise protocol consisting of an elevation exercise in the scapular plane outside the scanner room. Immediately after this exercise, the second MRI was taken ("post").

After a minimum of 45 minutes of rest, which is required to allow recovering of approximately 98% of the T2 shifts,[10] muscle pain was elicited by the injection of hypertonic saline into the SS muscle of the dominant arm. While having muscle pain, the subjects performed the same scapular elevation task, which was immediately followed by the third MRI ("postpain"). The difference in T2 before and after the elevation exercise, which is referred as the T2 shift, was measured for the infraspinatus (IS), subscapularis (SUB), trapezius, and SA muscles, as it indicates the magnitude of underlying metabolic muscle activity resulting from exercise.

### Exercise protocol: arm elevation in the scapular plane

The subjects performed humeral elevation in the scapular plane (30° to the frontal plane) with the dominant arm. This exercise was chosen because this demands high activity of the rotator cuff and the scapulothoracic muscles. Participants were instructed to perform 3 sets of 10 repetitions, with 15 seconds of rest between the sets. The participant was standing and was asked to raise and lower the arm. The up and down movements both lasted 3 seconds without break