Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms

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Objective: To determine if the muscle force and electromyographic activity in the scapular rotators of overhead athletes with impingement symptoms showed differences between the injured and non-injured sides.

Methods: Isokinetic peak force was evaluated during protraction and retraction of the shoulder girdle, with simultaneous recording of electromyographic activity of the three trapezius muscles and the serratus anterior muscle, in 19 overhead athletes with impingement symptoms.

Results: Paired t-tests showed significantly lower peak force during isokinetic protraction at high velocity (p<0.05), a significantly lower protraction/retraction ratio (p<0.01), and significantly lower electromyographic activity in the lower trapezius muscle during isokinetic retraction on the injured side than on the non-injured side (p<0.05).

Conclusion: These results confirm that patients with impingement symptoms show abnormal muscle performance at the scapulothoracic joint.

The shoulder plays a vital role in many athletic activities. Overhead movements such as throwing, swimming, and serving in tennis repetitively place the shoulder in vulnerable positions possibly leading to impingement syndrome. This syndrome has been classified as primary or secondary. Primary impingement refers to mechanical encroachment into the subacromial space by the humeral head, often seen in middle aged patients. The symptoms of secondary impingement syndrome are thought to be a result of shoulder instability, posterior capsule tightness, and scapulothoracic weakness, which may contribute to functional shoulder instability. Functional shoulder instability has been defined as the clinical situation in which the pathology does not allow the humeral head to move excessively relative to the confines of the glenoid fossa or to pass over the rim as in a subluxation of dislocation (anatomical glenohumeral instability). However, generally lax or overstretched glenohumeral ligaments intermittently jeopardise normal shoulder function. The patient feels that he/she cannot trust or control the stability of the shoulder, hence the designation “functional shoulder instability”.

in this report. The mean age was 21.9 years (range 18–25). Thirteen patients were volleyball players, three were tennis players, and three were athletes from other overhead sports. All subjects completed questionnaires on their shoulder pain, training, and athletic performance.

Shoulder impingement was determined by history taking and confirmed by physical examination (Neer, Hawkins', supraspinatus, apprehension, and relocation tests). Patients were included in the impingement group if they fulfilled at least two of the following five criteria.34 Subjects performed three five second maximum voluntary contractions for each muscle by having the subject perform isometric exercises against the wall, and stretching exercises for the rotator cuff and scapular muscles. The non-injured shoulder was tested first, followed by the injured shoulder.

For inclusion, at least one impingement sign needed to be positive, with in addition a second positive impingement test or a painful apprehension/positive relocation test.22 It is thought that patients with minor instability and secondary impingement will experience pain, but not apprehension with these tests.26 32 Although not agreed on in literature, these tests are currently considered to be valuable in the clinical evaluation of symptoms associated with impingement.10 32

Subjects were excluded if they had a history of dislocation of the shoulder, shoulder surgery, current symptoms related to the cervical spine, or documented structural injuries to the shoulder complex. All subjects gave their written informed consent to participate in the study. The study was approved by the ethics committee of Ghent University.

Testing procedure

EMG recording

Before electrode application, the skin was cleaned with alcohol to reduce impedance (typically <10 kOhm). Bipolar surface electrodes (Blue Sensor; Medicotest, Ballerup, Denmark) were placed with a 1 cm interelectrode distance over the upper, middle, and lower portions of the trapezius muscle and the lower portion of the serratus anterior, according to the instructions of Basmajian and DeLuca.33 A reference electrode was placed over the clavicle. Each set of bipolar recording electrodes from each of four muscles was connected to a Noraxon Myosystem 2000 EMG receiver (Noraxon USA, Inc, Scottsdale, Arizona, USA). The sampling rate was 1000 Hz. All raw myoelectric signals were pre-amplified (overall gain = 1000, common rate rejection ratio 115 dB, signal to noise ratio <1 μV RMS baseline noise, filtered to produce a bandwidth of 10–1000 Hz). Measurements from the Biodex dynamometer and EMG recordings were fully synchronised through the analogue input of the EMG receiver. Both EMG signals and movement direction/isokinetic force production were stored using the Myoresearch software program.

Before isokinetic testing, EMG signal quality was verified for each muscle by having the subject perform isometric contractions in manual test positions specific to each muscle of interest.44 Subjects performed three five second maximum voluntary isometric muscle contractions against manual resistance from the principal investigator, with a five second pause between contractions.28 29 As a normalisation reference, EMG data were collected during maximal voluntary contraction for each muscle. After signal filtering with a low pass filter (single pass, Butterworth, 6 Hz low pass filter of the 6th order) and visual inspection for artefacts, the peak average EMG value over a window of one second was calculated for each trial. Further calculations were performed with the mean of the repeated trials as a normalisation value (100%).22 35 36

Isokinetic evaluation

All tests were performed using a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, New York, USA). The testing session started with a warm up procedure, consisting of shoulder movements in all directions, push up exercises against the wall, and stretching exercises for the rotator cuff and scapular muscles. The non-injured shoulder was tested first, followed by the injured shoulder.

For the testing procedure, the closed chain attachment was fixed to the isokinetic dynamometer in a horizontal position. The hand grip was inserted into the attachment receiving tube with the neutral handle facing up, in order to keep the glenohumeral joint in a neutral rotational position. The chair was rotated to 15˚ and the dynamometer to 45˚ (fig 1). Subjects were assessed in the seated position with arm horizontal in the scapular plane, which is 30˚ anterior to the frontal plane. Subjects were instructed to keep the elbow extended. The trunk was stabilised by a strap positioned diagonally from the contralateral shoulder across the chest. Subjects were first tested at 12.2 cm/s (angular velocity 60˚/s) and then at 36.6 cm/s (angular velocity 180˚/s). Range of motion was assessed by asking the subject to perform a maximal protraction and a maximal retraction movement. No correction was made for gravity because the movement was in a horizontal plane. The test started in a maximally retracted position; the subjects were then instructed to perform maximal protraction and retraction movements over the total range of motion. Five repetitions were performed at a linear velocity of 12.2 cm/s and, after a rest period of 10 seconds, 10 repetitions at a linear velocity of 36.6 cm/s. All subjects performed five familiarisation trials before data were collected, and they all received verbal encouragement. Visual feedback from the computer screen was not allowed. After the tests, the results were printed on a report consisting of peak force and total work values. In a previous study, the test-retest reproducibility of this procedure was found to be...
good to excellent for the peak force values (intraclass correlation coefficient 0.88–0.96) and very good for total work values (intraclass correlation coefficient 0.82–0.89).

EMG signal processing
All raw EMG signals were analogue/digital converted (12 bit resolution) at 1000 Hz. They were then digitally full wave rectified and low pass filtered (single pass, Butterworth, 6 Hz low pass filter of 6th order). Results were normalised to the maximum activity observed during the maximal voluntary contraction trials. After rectification, filtering, and normalisation, further analysis was performed on five periods for each movement direction at low velocity and 10 periods for each movement direction at high velocity. Periods were defined by markers, automatically placed on the EMG signal, defining a protraction or a retraction movement. The mean amplitude EMG signal, expressed as a percentage of maximal voluntary contraction, was used to assess the activity of the three parts of the trapezius muscle and the serratus anterior muscle in each movement direction, at both linear velocities.

Statistical analysis
Mean (SD) was calculated for all dependent variables— isokinetic peak force for protraction and retraction, and EMG activity of upper trapezius, middle trapezius, lower trapezius, and serratus anterior—expressed as percentage of maximal voluntary contraction during isokinetic protraction and retraction, at both low and high velocity. In addition, the agonist/antagonist muscle ratio was calculated for both sides, with the protraction force as the agonist value and the retraction force as the antagonist value.

As all data were normally distributed with equal variances, parametric tests were used for statistical analysis. Differences in isokinetic peak force and scapular rotator EMG activity between the injured and non-injured side were analysed with paired t tests. The α level was set at 0.05. All statistical analysis was performed with the Statistical Package for Social Sciences (SPSS), version 10.0.

RESULTS
The results of the descriptive statistical analyses are summarised in Table 1 for the isokinetic peak force values and agonist/antagonist ratios at both speeds for both sides, in Table 2 for the EMG activity of the three trapezius muscles and serratus anterior muscle during isokinetic protraction at both speeds for both sides, and in Table 3 for the EMG activity of the same muscles during isokinetic retraction.

The statistical analysis with paired t tests revealed significantly lower isokinetic protraction peak force on the injured side at high velocity (p<0.05) compared with the non-injured side, a significantly lower protraction/retraction ratio at low velocity for the injured shoulder (p<0.01), and significantly less EMG activity in the lower trapezius during isokinetic retraction at high velocity on the injured side (p<0.05).

DISCUSSION
The purpose of this retrospective study was to investigate two aspects of motor control about the shoulder girdle, namely isokinetic protraction and retraction force production and associated muscle activity in the scapular muscles, and to identify any deficits in these parameters in overhead athletes with shoulder impingement symptoms, compared with their contralateral non-injured side. In our investigation, peak force values for isokinetic protraction ranged from 237.9 to 369.2 N, depending on the movement velocity and the side tested. These values are slightly higher than those obtained in a previous study on normal subjects. However, in the previous study, normal, non-athletic subjects were evaluated in order to establish day to day repeatability of the procedure. The higher values obtained in this study probably reflect overall enhanced muscle performance in overhead athletes compared with non-athletic subjects. However, it is striking that, in contrast with the study on healthy subjects, in whom no significant differences were found between the dominant and non-dominant sides, the injured shoulders in this study showed significantly lower protraction peak force at high velocity. As, to our knowledge, isokinetic performance of the shoulder girdle muscle has not been investigated in patients with shoulder problems, we have no experimental data with which to compare our results. However, several authors have emphasised the importance of scapula protraction during throwing movements. During the acceleration phase in
Evaluation of scapular rotators in overhead athletes

In overhead athletes, the scapular rotators play a crucial role in shoulder function and stability. Abnormalities in the function of these muscles can lead to shoulder impingement syndrome and other shoulder-related injuries. This study aimed to evaluate the isokinetic force in the scapular rotators in professional baseball players and to compare the results with healthy, non-athletic subjects.

**Methodology**

The study involved 19 professional baseball players and 19 healthy, non-athletic subjects. The isokinetic force in the scapular muscles was evaluated using a 12-inch lever arm dynamometer. The participants performed concentric protraction and retraction movements at different velocities (120–300°/s) and isometric muscle strength, whereas isometric muscle strength was measured at 30°/s. The results were compared between the injured and non-injured sides, and between different muscle groups.

**Results**

The study found significant side differences in the force output. A decreased protraction force may compromise this functional shoulder stability and lead to tensile overload in the glenohumeral joint. In addition, it has been suggested that the scapulothoracic muscles may be inhibited by painful conditions around the shoulder. The serratus anterior muscle force, suggesting weakness in the serratus anterior muscle and decreased EMG activity in the lower trapezius muscle were significant side differences with respect to protraction. Eccentric force output and EMG activity are relevant muscle performance variables, especially in the overhead throwing motion. The lower trapezius muscle is particular important for its eccentric role in shoulder protraction. Future research directions should emphasise these functional muscle performance parameters.

**Conclusions**

This study highlighted isokinetic force and muscle activity associated with protraction and retraction movements in the scapular plane in patients suffering from shoulder impingement. Future research is necessary to evaluate these parameters in overhead athletes without impingement symptoms to create a reference base for clinical evaluation and rehabilitation of scapular function in patients with shoulder pain.

**Take home message**

Overhead athletes with impingement symptoms show a decrease in force in the serratus anterior muscle and an imbalance in the lower trapezius muscle. This may indicate conservative treatment of shoulder impingement.

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### Table 3

Electromyographic activity of upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA), expressed as percentage of maximal voluntary contraction (MVC), during isokinetic retraction movements at low (12.2 cm/s; five repetitions) and high (36.6 cm/s; 10 repetitions) velocity

<table>
<thead>
<tr>
<th>Velocity (cm/s)</th>
<th>UT (% MVC)</th>
<th>MT (% MVC)</th>
<th>LT (% MVC)</th>
<th>SA (% MVC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-injured</td>
<td>Injured</td>
<td>p Value</td>
<td>Non-injured</td>
</tr>
<tr>
<td>12.2</td>
<td>37.3 (17.8)</td>
<td>36.3 (13.3)</td>
<td>0.83</td>
<td>23.7 (16.1)</td>
</tr>
<tr>
<td>36.6</td>
<td>45.0 (16.1)</td>
<td>43.2 (9.8)</td>
<td>0.62</td>
<td>25.2 (16.7)</td>
</tr>
</tbody>
</table>

Values are mean (SD) (n = 19).

*Significant difference, p < 0.05.
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