An Electromyographic Analysis of Normal Shoulder Muscular Co-ordination During Activities of Daily Living

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INTRODUCTION
The minimal bony constraint of the glenohumeral joint (GHJ) enables it to achieve a remarkable range of motion. Consequently, the stability of the joint must be maintained by the surrounding soft tissue structures; in particular the rotator cuff. The data available on normal shoulder function is sparse due to complex kinematics of the GHJ and technical difficulties in acquiring the data. Previous studies have been limited to planar shoulder movements which presents significant limitations when considering the function of the shoulder during activities of daily living. This study aims to define the activation patterns and coordination of muscles and muscle groups around the shoulder during activities similar to those of daily living. This will provide a better understanding of the normal shoulder function and hence, a basis for understanding the potential impact of shoulder pathology.

METHODS
Twelve healthy male volunteers with no history of upper extremity complaints or other musculoskeletal problems were included in the study. Informed consent was obtained from all participants and the study had Local Research Ethics Committee approval.

The EMG signal was recorded from 13 shoulder muscles using a TeleMyo 2400 G2 Telemetry System in conjunction with MyoResearch XP software (Noraxon Inc., Arizona, USA). The EMG signal was differentially amplified, digitalised and band-pass filtered in accordance with international guidance. Surface electrodes were utilised to record the activity of 10 muscles: anterior, middle and posterior deltoid; pectoralis major, upper trapezius, serratus anterior, latissimus dorsi, teres major, brachii, and brachioradialis. Bipolar hooked fine wire electrodes were used for the intra-muscular recording of the supraspinatus, infraspinatus and subscapularis muscles.

EMG data was recorded as participants performed a modified version of Task 1 of the Functional Impairment Test-Hand/Neck/Shoulder and Arm (FIT-HaNSA). This is a reliable and valid test for the assessment of upper limb functional status which is based on activities of daily living. Modifications were made to ensure coherent EMG data was recorded: a 1kg mass was lifted from a shelf position at the level of the participant’s anterior superior iliac spine to a second shelf 25cm above (phase 1) and back to the lower shelf (phase 2). Participants performed 20 continuous cycles. The root-mean square (RMS) amplitude was calculated and normalised to the mean. Time normalisation was performed allowing averaging of the EMG data across the normalised cycle for each data point to produce an average activation profile. The paired samples t-test was used to compare muscle activity during phase 1 and 2. In order to investigate muscular coordination, the correlation between the activation pattern of pairs of muscle groups was sought using the Pearson Correlation Coefficient (PCC).

RESULTS
The EMG measurements were repeated on 4 subjects in order to establish the reproducibility of the methods; no significant inter-session effects were identified with regards to the muscle activation patterns.

The results of 12 healthy male volunteers are reported. The normalised signal amplitude was found to be significantly higher during phase 1 than phase 2 for the anterior deltoid, middle deltoid, pectoralis major, upper trapezius, serratus anterior, latissimus dorsi, teres major, biceps brachii, supraspinatus, infraspinatus and subscapularis. Table 1 presents the PCC comparing the activation patterns of the studies muscle groups. There are significant and high correlations between the deltoid and RC, the deltoid and ‘adductor’ muscles; and the RC and ‘adductor’ muscles. The similarity in activation pattern for the rotator cuff muscles is illustrated by Figure 1.

Table 1: The PCC comparing the relationships between the muscle groups - p value < 0.05 indicates the correlation is significant. Muscle groups comprised as follows: deltoid – anterior, middle and posterior deltoid; adductors – latissimus dorsi and teres major; elbow flexors – biceps brachii and brachioradialis; rotator cuff – supraspinatus, infraspinatus and subscapularis.

<table>
<thead>
<tr>
<th>Muscle Groups</th>
<th>Deltoid</th>
<th>‘Adductors’</th>
<th>Elbow Flexors</th>
<th>Rotator Cuff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltoid</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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<td>‘Adductors’</td>
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<td>-</td>
<td>-</td>
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<td>Elbow Flexors</td>
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<td>Rotator Cuff</td>
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</tbody>
</table>

DISCUSSION
This study established a reliable method for studying muscle activation patterns and inter-muscular coordination during activities of daily living. The similarity in activation pattern of the rotator cuff muscles (Figure 1), illustrates that they are operating as a functional unit. Further, the activity of the latissimus dorsi and teres major was higher during phase 1, where the arm was elevated, than during phase 2. During phase 1 the muscles were contracting eccentrically, generating a force opposed to the deltoid and pectoralis major, stabilising the humeral head relative to the glenoid fossa. Therefore, the muscular component of GHJ stability is wider than the traditionally accepted notion of a balance between the rotator cuff and deltoid, as indicated by the concept of the coronal and transverse force couples. Consequently, during movements of the arm there is a coordinated and synchronous relationship between the activity of the muscle groups which insert on the humeral head. However, the conclusions of this study are limited to activities incorporating movements similar to those employed by the test in protocol. Further understanding would be gained by devising additional tasks which operate within a different range of motion.

It is thus apparent that the deltoid, adductor and rotator cuff muscles all contribute to the muscular component of GHJ stability. Given that muscles’ have the capacity to vary the level of contraction, muscular stability can be adapted as required to meet task specific demands.

REFERENCES