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Original article

Electromyographic study of rotator cuff muscle activity during full and empty can tests

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Abstract

The empty can (EC) and full can (FC) tests are used as diagnostic tools for patients with rotator cuff disease. However, recently concerns have been raised that these tests do not selectively activate the muscle. Therefore, the purpose of this study was to evaluate the rotator cuff muscle activation levels during the EC and FC tests in various positions using electromyography. Twelve healthy, right-handed men without shoulder complaints (mean age: 26.1 years, range: 23−35 years) were included. The tests were performed isometrically with the shoulder elevated at 45° and 90° in the sagittal, scapular, and coronal planes, either in the thumb-up (FC test) or thumb-down (EC test) positions. During these positions, the electromyographic signal was recorded simultaneously from the four shoulder muscles using a combination of surface and intramuscular fine-wire electrodes. The average activation of the supraspinatus and subscapularis was greater during the EC test than during the FC test and in the scapular and coronal planes than in the sagittal plane at 90°. For the infraspinatus, there were no significant differences in any positions between the two tests. Thus, the rotator cuff muscles are influenced by arm position and the elevation plane during the EC and FC tests.

Keywords: diagnostic tests; electromyography; muscles; musculoskeletal system; rotator cuff

Introduction

The rotator cuff muscles play an important role in stabilising the humeral head to the glenoid fossa.[1] Patients with rotator cuff tears complain of decreased shoulder strength, limited range of motion and severe pain. In >90% of these patients, the supraspinatus muscle is involved.[2−4] Therefore, most studies focus on the function of the supraspinatus muscle and its role in the pathophysiology of shoulder complaints.[5−7]

The empty can (EC) and full can (FC) test positions are used as diagnostic tools for assessing supraspinatus insufficiency in patients with rotator cuff disease. Jobe and Moynes[5] reported that the supraspinatus function can be isolated and assessed to some degree with the shoulder near 90° of elevation in the scapula plane, at 20° horizontal abduction, and in full internal rotation (EC test).[8,9] Assessing isometric strength in this position is commonly referred to as the supraspinatus test.[1] Kelly et al compared the EC test to a modified version using 45° of external rotation (FC test) using electromyography (EMG).[7] They reported that the supraspinatus activity in the EC and FC tests was similar.[7]

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In contrast, EMG studies have indicated that the EC and FC tests do not selectively activate the supraspinatus.[10] Boettcher et al reported that the EC and FC tests activated the supraspinatus as well as other muscles, including the infraspinatus, subscapularis, deltoid, trapezius, and serratus anterior.[10] Additionally, they mentioned that the activities of the supraspinatus and the surrounding muscles did not differ between the EC and FC tests.[10] However, these studies exclusively examined the activity of the muscles in the scapular plane at 90° of elevation, and not in the sagittal or coronal planes. Yasojima et al reported that the EMG activity of the supraspinatus was significantly higher than that of the other rotator cuff muscles at 45–60° of elevation in the scapular plane according to the FC test.[11] They also suggested that this position (45–60°) was better in both tests for decreasing impingement and compensatory motions.[11]

Therefore, we examined the rotator cuff muscle activity during the EC and FC tests in six elevation positions (i.e., the sagittal, scapular, and coronal plane at 45° and 90°) using EMG. The primary aim of this study was to compare the activation levels of the rotator cuff muscles between the EC and FC tests in the six different elevation positions, and the secondary aim was to compare the muscle activation levels among the three planes.

Materials and methods

Participants

We examined the dominant shoulders of 12 sedentary right-handed male participants. No participant had any history of shoulder pain or injuries before the study. The mean age was 26.1 years (range: 22–31 years), mean height was 171.4 cm (range: 158–182 cm), and mean weight was 63.9 kg (range: 54–76 kg). The Institutional Review Board approved the study protocol (No. 09078), and all the participants provided written informed consent.

EMG recording

EMG signals were recorded simultaneously from four shoulder muscles using a combination of surface and intramuscular fine-wire electrodes. The electromyograms were collected using a sampling of 1000 Hz from the MultiTelemeter System WEB-5000 (Nihon Kohden, Tokyo, Japan). This unit provides a signal amplification of 1000 times, common mode rejection ratio > 54 dB, input impedance > 10 MΩ, and gain of 100 dB. Output from the unit was linked to a 16-bit analog-to-digital converter on a personal computer, and the raw data were monitored and collected in MotionMonitor version 8.43 (Innovative Sports Training, Chicago, IL, USA) for off-line analysis.

The surface electrodes were used to record activity from the infraspinatus muscles. The inter-electrode distance was 10 mm. Beforehand, the skin was cleaned with alcohol pads, and the electrodes were applied parallel to the muscle fibres. Placement of the surface electrodes was selected according to published studies involving EMG data collection from the muscles of interest.[12] Bipolar intramuscular electrodes (50 μm urethane-coated stainless steel wire; Unique Medical Co., Ltd., Tokyo, Japan) were used for the supraspinatus and upper and lower subscapularis muscles. The intramuscular electrodes were prepared in accordance with the technique described by Basmajian and DeLuca,[13] and they were inserted according to the recommendations of Kelly et al[14] for the supraspinatus and Kadaba et al for the subscapularis.[15] The electrode wires were inserted into a 23-gauge single-use hypodermic needle. The signal quality was checked to ensure adequate signal-to-noise ratios – signals were excluded if they were of poor quality. The ground electrode was affixed to the skin over the flat surface of the acromion. Correct electrode placement was confirmed by observing all the EMG signals on an oscilloscope during resisted contractions of each muscle.

The EMG activity was recorded for the four muscles while the participants performed maximal voluntary contraction (MVCs) against manual resistance, as previously described for shoulder normalization tests: abduction 90° with internal rotation ("empty can"), internal rotation in 90° abduction ("internal rotation 90°"), flexion at 125° with scapula resistance ("flexion 125°"), and horizontal adduction at 90° flexion ("palm press").[16] Strong verbal encouragement was provided during every contraction to promote maximal effort. The EMG data from the MVCs were used to normalise the EMG amplitude (% MVC) during the testing protocol.

Experimental procedures

Each participant was seated upright in a chair. A posture hold bar and cephalic strap were used to minimise trunk compensatory movements during the experiment. The test was performed with the shoulder at 45° and 90° of elevation in the sagittal, scapular, and coronal planes with the thumb-up (FC test) and the thumb-down (EC test) (Fig. 1). The coronal plane was defined as being parallel to the trunk. The sagittal plane was defined as being 90° anterior to the coronal plane. The scapular plane was defined as being 40° anterior to the coronal plane. Shoulder muscular activity was measured while the participants held a dumbbell weighing 3 kg for 5 seconds in the described positions. According to the preliminary research,[17] 3 kg is equivalent to 10–20% of the maximal muscle strength at 90° of arm elevation. Trials in each position were repeated twice and were randomly assigned to the subjects. Each participant was given 30-second rests between each of the trials to eliminate possible muscle fatigue.

Data reduction

The original raw EMG signal was band-pass filtered at 20–450 Hz. The root-mean-square amplitude of the EMG signal was computed using a 600-millisecond window. The first and last second of EMG data were omitted from the analysis. The EMG value of each muscle was then expressed as a percentage of the EMG value during the MVC. The two trials were averaged, and the EMG data for each test position were analysed. The mean EMG values for 3 seconds at each test position were used in the analysis.