The belly-press test for the physical examination of the subscapularis muscle: Electromyographic validation and comparison to the lift-off test

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The purpose of this study was to determine the validity of the belly-press test as a clinical test for the subscapularis muscle with the use of electromyography (EMG). In addition, the belly-press and lift-off tests were compared to determine whether the two physical examination techniques are equivalent in their evaluation of the upper and lower portions of the subscapularis muscle. EMG data of 7 muscles (upper subscapularis, lower subscapularis, infraspinatus, latissimus dorsi, teres major, pectoralis major, and supraspinatus) were studied in 16 healthy volunteers. Average EMG amplitudes were contrasted within and between tests. Both the belly-press and lift-off tests activated the upper and lower portions of the subscapularis muscle greater than all other muscles, indicating that both tests are valid and specific for evaluation of the subscapularis muscle ($P < .05$). The belly-press test was found to activate the upper subscapularis muscle significantly more than the lift-off test ($P < .05$), whereas the lift-off test was found to pose a significantly greater challenge to the lower subscapularis muscle than the belly-press test ($P < .05$). These findings may improve the clinical testing and assessment of the subscapularis muscle. (J Shoulder Elbow Surg 2003;12:427-30.)

Efforts to isolate the subscapularis muscle on physical examination testing have been few. Gerber and Krushell[6] described the lift-off test as a highly reliable maneuver to detect subscapularis rupture, and a subsequent electromyographic (EMG) study by Greis et al[8] demonstrated that this maneuver isolated the subscapularis muscle. Gerber et al[7] later described an alternative maneuver for detecting subscapularis muscle rupture called the belly-press test. This test has been shown to be clinically reliable[7,15] and is often used when a patient is unable to perform the lift-off test because of pain or limited range of motion. To our knowledge, no study has validated the belly-press test as a physical examination of the subscapularis muscle.

Several investigators have shown that the subscapularis muscle receives its innervation by at least two separate nerves.[10,11,14] In addition, the EMG activation levels of the upper and lower portions of the subscapularis muscle have been shown to be different during several shoulder internal rotation movements.[10] These independent innervations and functions may suggest independent clinical tests for both the upper and lower portions of the subscapularis muscle.

The purpose of this study was to validate the belly-press maneuver and to compare the lift-off and belly-press tests to determine whether they are interchangeable as physical examination tools in the evaluation of the upper and lower portions of the subscapularis muscle.

MATERIALS AND METHODS

Ten male (28.4 years, 1.9 m, 88.7 kg) and six female subjects (25.0 years, 1.6 m, 58.0 kg) with no history of shoulder injury were informed of the procedures involved in this study and gave written informed consent to act as subjects, in accordance with the Vail Valley Medical Center's Internal Review Board policy regarding the use of human subjects and informed consent.

For each subject, EMG activity of 7 shoulder muscles was monitored with surface and indwelling bipolar electrodes during two clinical tests designed to assess the integrity of the subscapularis muscle. Pre-gelled silver-silver/chloride bipolar surface electrodes (Medicotest A/S, Rugmaken, Denmark) were used to measure the muscle activity of the latissimus dorsi, teres major, pectoralis major (sternal

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portion), and infraspinatus muscles. The electrodes were placed as described by Basmajian and DeLuca[1] in line with the direction of the muscle fibers with a center-to-center interelectrode distance of approximately 25 mm. Indwelling electrodes for the supraspinatus and upper and lower subscapularis muscles were placed within the muscle substance by the Basmajian and DeLuca technique.[1] Standard anatomic references for the placement of the surface and indwelling electrodes have been described in previous studies.[3,9,10,14] Electrode placements were confirmed from a manual muscle test of the primary muscle.

The testing session began with a series of 5 isometric maximum voluntary contractions (MVC) for each muscle. The standardized MVC procedures and protocols have been previously reported.[2,9]

EMG data were collected (1200 Hz) with the TeleMyo telemetric hardware system (Noraxon, USA, Inc, Scottsdale, Ariz) online with the A/D board of a motion-capture system (Motion Analysis, Santa Rosa, Calif). Each EMG signal has a bandwidth of 3 dB at 16 to 500 Hz. The lower cutoff filter is a first-order high-pass design, and the upper cutoff filter is a sixth-order Butterworth low-pass design. The differential amplifier has a fixed gain of 1700, a differential input impedance of 10 mega ohms, and a common-mode rejection ratio of 130 dB. Although the transmitter automatically removes the low-frequency noise component from the signals, a resting trial was collected and used to remove any additional noise. In addition to the EMG data, a manual timing signal was recorded with the software of the motion-capture system to assist in defining the start and end of each trial.

Upon the instruction of both physical examination maneuvers, the subjects practiced until they were able to perform both maneuvers without any compensation (see below). This typically took only one practice trial and was observed to be quite reproducible by each subject. The clinical tests were maximally performed for 3 trials, each lasting 3 seconds, to standardize the procedures. The testing order was randomly selected for the first subject, and this order was reversed for each subsequent subject.

The lift-off test was performed according to the description by Gerber and Krushell[6] This test began with the dorsum of the hand at the position of the midlumbar spine. The subjects were asked to lift the dorsum of the hand off of the back maximally by internally rotating the shoulder. The test would be considered positive for subscapularis dysfunction if the subject could not lift the hand off of the back or if the subject performed the lifting maneuver with elbow or shoulder extension.

The belly-press test was performed according to the description by Gerber et al.[7] This maneuver began with the palm of the hand against the upper abdomen, just below the level of the xyphoid process (Figure 1, *A*). Subjects were then asked to press maximally into the abdomen by internally rotating the shoulder. The test would be considered positive for subscapularis dysfunction if the patient demonstrated flexion at the wrist and shoulder adduction and extension.[7] This unconscious compensation is seen as patients maintain pressure against the abdomen by dropping the elbow behind the trunk and extending, rather than internally rotating, the shoulder (Figure 1, *B*).

All EMG data were processed with custom software with

Figure 1 A, The belly-press test is performed by pressing the palm into the abdomen by internally rotating the shoulder. **B**, A positive sign for the belly-press test is noted if the patient compensates to maintain pressure against the abdomen by dropping the elbow behind the trunk and extending, rather than internally rotating, the shoulder.

Table I Means (SD) expressed as percentage of MVC for average EMG amplitudes during lift-off and belly-press tests

Muscle	Lift-off test	Belly-press test
Upper subcapularis**	57.0 (41.3)	86.3 (60.4)
Lower-supscapularis**	79.9 (34.2)	59.1 (42.4)
Supraspinatus	18.2 (20.5)	21.8 (12.4)
Teres major	22.6 (10.4)	19.3 (9.2)
Infraspinatus	17.5 (5.8)	15.7 (9.2)
Latissimus dorsi	16.4 (14.8)	17.5 (13.9)
Pectoralis major	10.2 (6.5)	13.3 (9.6)

**$P < .05$.

a 50-ms root-mean-square (RMS) smoothing window algorithm.[2] Maximal EMG reference values were calculated for each muscle by using the average of the 5 peak EMG signals and represented 100% MVC. Average EMG amplitudes were calculated during the middle 50% of each trial for both clinical tests[10] and expressed as a percentage of MVC (%MVC).

Group means and SDs were calculated from the three trials of EMG data (%MVC). A 2 × 7 (clinical test by muscle) mixed-factor repeated-measures analysis of variance was used to determine muscle activation differences (%MVC) within and between tests. Significant omnibus F values were scrutinized with the Tukey post hoc method, with an alpha level of $P \leq .05$.

RESULTS

Mean and SDs for average EMG activity (%MVC) for all muscles during each clinical test are displayed in Table I. A significant omnibus F value was found for the clinical test by muscle interaction term, indicating that the clinical tests evoked different muscular responses from the muscles tested ($P < .05$). Post hoc analyses for within-test muscle activation comparisons revealed that upper and lower subscapularis muscle activity was significantly higher than that of all other muscles ($P < .05$) (Figure 2). The next most active muscles for the lift-off and belly-press tests were the teres major and supraspinatus, respectively. However, these muscles, as well as the other internal shoulder rotators including the pectoralis major and latissimus dorsi, were activated less than 25% MVC. Upper and lower subscapularis muscle activity was not different within each test ($P > .05$).

Post hoc analyses for between-test muscle activation comparisons revealed that upper subscapularis EMG activity was greater during the belly-press test and lower subscapularis EMG activity was greater for the lift-off test (both $P < .05$). The EMG activity of the supraspinatus, teres major, infraspinatus, latissimus dorsi, and pectoralis major muscles demonstrated no significant differences between tests (all $P > .05$).

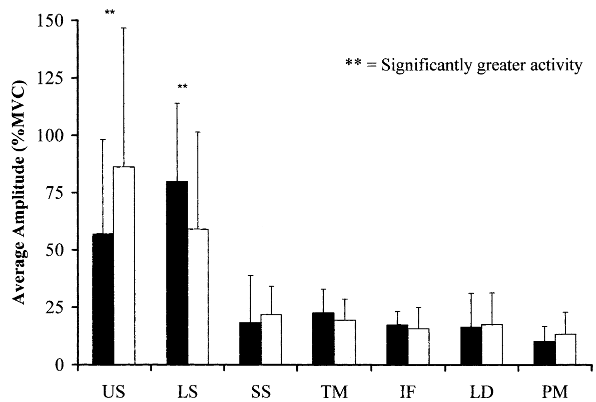

Figure 2 Muscle activity recorded during the lift-off (*black bars*) and belly-press (*white bars*) physical examination tests. Both clinical tests stimulated the upper subscapularis (*US*) and lower subscapularis (*LS*) muscles statistically greater than all other muscles tested ($P < .05$). *SS*, Supraspinatus; *TM*, teres major; *IF*, infraspinatus; *LD*, latissimus dorsi; *PM*, pectoralis major.

DISCUSSION

In this study the belly-press and lift-off tests were both found to be valid methods of testing the upper and lower portions of the subscapularis muscle. Performance of the lift-off and belly-press tests elicited muscle activity greater than 57% MVC for the upper and lower subscapularis muscles, whereas all other muscles tested were below 23% MVC, indicating that the other shoulder internal rotators contribute little to internal rotation during both of these tests. These data are in agreement with those of other researchers who have studied the EMG activity of shoulder muscles during the lift-off test.[8] According to our results, the subscapularis muscle is the primary muscle that is significantly challenged during the lift-off and belly-press tests.

Clinical reports of subscapularis muscle function during physical examination have almost exclusively been limited to the performance of the lift-off test, as this test has been shown to diagnose or exclude reliably a clinically relevant rupture of the subscapularis tendon. Although the lift-off test has become one of the most widely used examinations by which to diagnose subscapularis deficiency, other authors have questioned its validity. Specifically, Stefko et al[17] showed that their subjects could perform the lift-off maneuver despite a regional nerve block of the subscapularis muscle. In addition to this discrepancy, physical examination of the subscapularis muscle is often left incomplete when the patient is unable to perform the lift-off test because of shoulder pain or stiffness.

An alternative maneuver called the belly-press test may offer a solution to these problems. In the few articles that have reported the clinical results of this test, it has been shown to diagnose subscapularis muscle rupture accurately in 100% of the patients tested.[7,15] These results, in combination with those in this study, would indicate that the belly-press test does rely on the performance of internal shoulder rotation primarily performed by the subscapularis muscle. Although the lift-off and belly-press tests are often used interchangeably, this study provides data supporting the use of either test in the evaluation of the subscapularis muscle.

An additional goal of this study was to compare the lift-off and belly-press tests to determine whether they elicit the same response in the upper and lower portions of the subscapularis muscle. Cadaveric studies showing the subscapularis muscle to have at least two separate innervations and functions[10,12-14] prompted this goal. Although both tests stimulated both upper and lower portions, there was a significant difference between the two maneuvers. The lift-off test posed a significantly greater challenge to the lower subscapularis muscle, whereas the belly-press test elicited a significantly greater response in the upper subscapularis. With the growing awareness of subtle superior subscapularis tendon tears,[5,16] the clinical performance of both of these tests may assist in a more complete assessment and diagnosis of subscapularis tendon tears or rupture.

One possible explanation for these muscle activation differences is the position of shoulder abduction during testing. In the lift-off test, the humerus is at approximately 0° of shoulder abduction, whereas performance of the belly-press test requires 45° of shoulder abduction. Kadaba et al[10] found that the abduction angle had a significant effect on which portion of the subscapularis was most active, but their study concluded that the lower subscapularis activity increased with increasing abduction. Conversely, DiGiovine et al[5] found greater EMG activity of the upper subscapularis muscle during pitching when the arm was at approximately 90° of shoulder abduction. Thus, muscle activation differences between tests may result from the initial shoulder position, but further research is warranted to substantiate that the upper subscapularis muscle fires with greater intensity than the lower subscapularis muscle at greater humeral elevation positions.

This study found the belly-press test to be a valid physical examination test for the subscapularis muscle. In addition, the belly-press test was found to be superior to the lift-off test for activating the upper subscapularis muscle and the lift-off test to be superior in activating the lower subscapularis. Our data support the assertion that the upper and lower portions of the subscapularis muscle are functionally independent and that proper physical examinations of these muscles may require evaluations of both.[4]

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