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Contribution of the supraspinatus to the external rotator lag sign: Kinematic and electromyographic pattern in an in vivo model

Davide Blonna, MD[a,*], Silvia Cecchetti, BME[b], Alessandra Tellini, MD[a], Davide Edoardo Bonasia, MD[a], Roberto Rossi, MD[a], Richard Southgate[c], Filippo Castoldi, MD[a]

[a]*University of Turin Medical School, Umberto I, Mauriziano Hospital, Torino, Italy*
[b]*Gait Analysis Laboratory, Regina Margherita Hospital, Torino, Italy*
[c]*Mayo Clinic, Rochester, MN*

Hypothesis: The external rotation lag sign (ERLS) is a test designed to assess the integrity of the supraspinatus (SSP) and infraspinatus tendons. This study intends to determine the electromyographic pattern of shoulder girdle muscles during a series of ERLS tasks conducted at full adduction and 20° of elevation to figure out the better way to perform the test. The second aim is to assess the final contribution of the SSP to the ERLS by measuring the amount of lag after an SSP block induced by botulinum toxin.

Materials and methods: Ten subjects with healthy shoulders were examined by a series of five ERLS trials at full adduction and 20° of elevation in the scapular plane. Surface and intramuscular electromyographic activity of the shoulder girdle muscles was recorded and normalized against either the mean activity of all the muscles or the peak activity. The lag was simultaneously measured by an infrared optoelectronic system before and after the selective block of the SSP muscle.

Results: The SSP contributed 20% of the electrical activities during the ERLS, which was found to be significantly greater than the contributions of the other shoulder girdle muscles, except for the infraspinatus. The selective block of the SSP caused a lag of 4° in all 10 shoulders at 20° but no increase in lag at 0° of elevation.

Conclusions: The ERLS is potentially able to detect an isolated SSP tear if the test is performed correctly (20° of abduction). The deltoid and biceps muscles are almost silent during the test, limiting confounding factors.

Level of evidence: Basic Science Study; Electrodiagnostic Study

Keywords: Lag sign; supraspinatus tear; diagnosis; electromyography; clinical test; botulinum; rotator cuff tear; physical examination

Supraspinatus tears are among the most common pathologies of the shoulder girdle, and therefore the clinical diagnosis of such tears is of great relevance. In an older population, the tear is easily diagnosed, because of a high

*Reprint requests: Davide Blonna, MD, University of Turin Medical School, Mauriziano "Umberto I" Hospital, Largo Turati 62, 10128 Torino, Italy.

E-mail address: davide.blonna@virgilio.it (D. Blonna).

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pretest probability. However, this is not the case for younger patients. Associated painful conditions of the long head of the biceps (LHB) or the acromioclavicular joint may in fact result in a high false-positive rate.[17] In fact, tests that elicit pain, such as the Hawkins and Neer tests, lead to an overdiagnosis of supraspinatus tears.[13] Conversely, tests that evaluate the muscle's strength like the Jobe test can produce false-negative results because of the coactivation of strong agonist muscles such as the deltoid.[14]

The external rotation lag sign (ERLS), described by Hertel et al[8] in 1996, has been widely accepted as a valid test for the diagnosis of tears involving at least the infraspinatus. More recently, the test has been re-evaluated.[2] In a population with a low pretest probability for supraspinatus tears, the test has been confirmed to be both highly specific and moderately sensitive for an isolated supraspinatus tear when the surgeon looks for small degrees of lag.

However, some concerns are still present regarding the use of the ERLS in the diagnosis of an isolated supraspinatus tear. The reasons for this skepticism could be found in the relative absence of laboratory data and clinical study to support the use of the ERLS. This situation is probably because of the difficulties in reproducing the ERLS in vitro. Furthermore, it is our impression that some confusion in the correct way to perform the test has led to a decrease in the sensitivity of the test. In fact, the test that has been conducted in full adduction (arm at the side[17]) instead of at 20° of elevation in the scapular plane (abduction), as described in the original article.[8] The consequences of this variation are unknown.

The aim of this study was to investigate the electromyographic (EMG) basis of the ERLS in healthy young volunteers in 2 arm positions: (1) 20° of elevation in the scapular plane and (2) full adduction. The second aim was to find out whether the electrical contribution of the supraspinatus may justify a significant increase in lag in the case of an isolated supraspinatus tear. We tested this hypothesis by simulating a supraspinatus tear by temporarily blocking the muscle using botulinum toxin type A.

Materials and methods

We recruited 10 volunteers, 9 men and 1 woman (mean age, 31.3 ± 4.4 years). The nondominant shoulder was evaluated in this study. Informed consent was obtained from all subjects. The study was conducted after approval from our institution's internal review board. The inclusion criteria were healthy subjects without any history of shoulder surgery, pain, or major trauma. The subjects were clinically evaluated by an orthopaedic surgeon with a specific interest in the shoulder to exclude any shoulder disease. The subjects were then evaluated by magnetic resonance imaging to exclude an asymptomatic supraspinatus cuff tear.

After we explained the testing procedure and 3 trials to familiarize the subjects with the protocol, each subject was tested using the ERLS performed by the same researcher. The ERLS was performed 5 times in 2 different positions: full adduction (Figure 1, *A*) and 20° of elevation in the scapular plane (abduction) as previously described[2,8] (Figure 1, *B*). Of the 5 ERLS trials, the first and the last were excluded from the analysis, leaving 3 trials in each position for the analysis (3 trials in adduction and 3 in elevation for 10 shoulders, for a total of 30 trials in full adduction and 30 at 20° of elevation). The mean of the variables for each 3 trials was used for analysis. The tester performed the ERLS series with a random interval between each trial. The use of a metronome was avoided so that the subjects would not learn to anticipate the lag and thus alter the results of the experiment.

The second part of the study consisted of a simulation of an isolated supraspinatus tear by inducing a selective block of the muscle by injecting it with botulinum toxin type A (90 U of Dysport [Ipsen, Brisbane, CA] in 2.5 mL of 0.9% sodium chloride). The injection was performed with an injectable needle electrode inserted 1.5 cm above the midpoint of the spine of the scapula. Before the intramuscular injection, the correct position was checked by asking the subject to abduct the arm against resistance. The subjects were followed closely with daily examinations to detect any discomfort, pain, or complications. After 3 to 4 weeks, all subjects were re-evaluated with the same protocol described previously.

Two months after the injection, the subjects underwent a physical examination to check for full recovery of the supraspinatus muscle. This included a neurologic physical examination as well as a fine-wire electrode evaluation of supraspinatus activity.

Measurement of lag

An ex novo biomechanical model was used to measure the amount of lag. The model was designed according to the requirement that it reproduce the real-life clinical setting when performing the ERLS. This means that the experimental model allows for unconstrained natural movement of the arm including compensatory movement of the trunk.

The internal rotation of the arm (ie, lag) during the ERLS is the result of rotational movement of the epicondylar axis of the elbow (Figure 2). The rotation of the epicondylar axis was assessed with a 3-dimensional (3D) system for upper extremity analysis using retroreflective skin markers.

The experimental model was based on the definition of 2 orthogonal Cartesian frames (Y [trunk] and Y' [humerus]) built around the subject. The axes were defined by various bony landmarks: posterior corner of the acromion, anterior-superior iliac spine, xiphoid process, spinous process of the T8 dorsal vertebra, and epicondyles. The markers for the epicondyles were positioned 1 cm proximal to the real epicondyle to avoid interference between the hand of the tester (holding the elbow of the tested subject) and the markers. To limit bias due to soft-tissue movement, the 2 markers at the epicondyles were fixed by use of 2 cm of circumferential adhesive tape.

The bony landmarks were tracked 3-dimensionally by use of reflective skin markers measuring 20 mm in diameter with a system borrowed from the gait analysis. Three-dimensional kinematic data were collected with the BTS SMART-e analog motion capture system (BTS, Milan, Italy) and 6 infrared cameras. This system is accurate to within 0.3 mm. The data were sampled at 100 Hz. BTS TrackLab 2.0 software was used for the 3D kinematic reconstruction to obtain the degree of internal rotation of the epicondylar axis (ie, amount of lag).

The markers applied to the xiphoid process, T8 vertebra, and anterior-superior iliac spine were used to defined an orthogonal Cartesian frame linked with the trunk (Y). The center of rotation of