



Do surface electrode recordings validly represent latissimus dorsi activation patterns during shoulder tasks?



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ABSTRACT

Because of its superficial location surface electrodes are commonly used to record latissimus dorsi (LD) activity. Despite the fact that the recommended electrode placement is over the belly where LD is quite thin no studies have investigated the possibility of signal contamination from muscles lying deep to LD. Therefore, the aim of this study was to determine the validity of using surface electrodes to record activity from LD. Eight asymptomatic subjects performed ramped isometric (0–100% maximum load) and dynamic (70% maximum load) shoulder tasks. Intramuscular electrodes were inserted into LD and the adjacent erector spinae. Surface electrodes were placed over LD around the intramuscular electrodes. Results indicated that while there was no difference in activity level or activation pattern (ICC > 0.94) recorded by the two electrode types during shoulder tasks in which LD would be expected to be active (extension and adduction), significantly lower ($p < 0.05$) LD activity was recorded via intramuscular electrodes during the shoulder flexion and abduction tasks. Therefore, recordings of LD activity by surface electrodes overestimate LD activity during shoulder tasks when this muscle would be expected to be activated at minimum levels. Erector spinae immediately deep to LD was confirmed as a source of crosstalk contamination.

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1. Introduction

Latissimus dorsi (LD) is a large, flat, triangular muscle extending from a broad attachment on the pelvis and thoracolumbar vertebrae to a tendinous attachment into the bicipital groove on the humerus. It is a major extensor, adductor and internal rotator of the shoulder joint. Because of its superficial placement on the back surface electrodes are commonly used to record LD activity. A simple, electronic search of the literature between 2011 and 2013 found over 20 papers reporting LD activity recorded with the use of surface electrodes. The scope of these studies ranged from investigating LD activity during: normal shoulder function (Hawkes et al., 2012b; Rota et al., 2013); various sporting activities including rowing (Bazzucchi et al., 2013), tennis (Rota et al., 2012), pole vaulting (Frere et al., 2012), skiing (Nilsson et al., 2013), baseball (Reyes et al., 2011), golf (Lim et al., 2012) and swimming (Ikuta et al., 2012); exercises (Marchetti and Uchida, 2011); shoulder and trunk dysfunction (Hawkes et al., 2012a; Ntousis et al., 2013;

Wood et al., 2011); classical singing (Watson et al., 2012); and muscle fatigue (Balasubramanian et al., 2014).

Muscle activity can be recorded by surface electrodes that attach to the skin over the muscle of interest or by indwelling (intramuscular) electrodes that are inserted into the muscle. Surface electrodes have the advantage of being non-invasive and sample from a larger cross-section of the muscle of interest than indwelling electrodes. However, their larger pick-up volume means that surface electrodes may detect signals from neighboring muscles lying adjacent or deep to the muscle of interest. This phenomenon, known as crosstalk, is the most significant limiting factor in using surface electrodes to record muscle activity.

In order to reduce the risk of crosstalk from adjacent muscles surface electrodes are commonly placed at the widest section of the muscle of interest. In the case of LD this is on the back over the center of the muscle belly 4 cm below the inferior angle of the scapula (Cram et al., 1998; Nilsson et al., 2013; Ntousis et al., 2013; Park and Yoo, 2013). However, at this position LD is much thinner than near its narrow superior section where it forms part of the posterior axillary wall (Williams et al., 1989). This common electrode placement position therefore, makes surface electrode recordings from LD potentially susceptible to crosstalk from muscles lying deep to LD e.g. erector spinae (ES). Despite this

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obvious, potential source of signal contamination no studies have assessed the validity of using surface electrodes placed over the muscle belly 4 cm below the inferior angle to record activity from LD. As our quick search of the literature indicates there is significant interest in examining activity patterns in LD in a variety of fields. There is thus an urgent need to confirm that surface electrode recordings from latissimus dorsi are not contaminated by crosstalk and truly represent activity from this muscle.

Therefore, the aim of this study was to determine the validity of using surface electrodes to record activity from LD during isometric and dynamic tasks in which LD would be expected to be highly activate (shoulder extension and adduction) and those in which it would be expected to be activated at low levels (shoulder flexion and abduction). If evidence of crosstalk contamination was found in the surface electrode recording from LD, a secondary aim was to determine if ES was the source of this contamination.

2. Methods

2.1. Participants

Eight asymptomatic participants (five male, three female, aged 19–49 years) who had had no pain in their dominant shoulder over the previous two years nor had ever been treated for shoulder pain volunteered to participate in this investigation. A power calculation using G*Power (Faul et al., 2007) showed that eight subjects at an $\alpha = 0.05$, $\beta = 0.80$ would allow the detection of an effect size of 1.16 or, in other words, a difference in the mean EMG signals between the electrode types of approximately 1 standard deviation. Similar studies of comparison between surface and indwelling electrodes have used seven (Hackett et al., 2014) to nine (Johnson et al., 2011) subjects. Ethics approval was granted by the Human Research Ethics Committee of The University of Sydney (approval number 04-2011/13610). All participants provided their written informed consent prior to testing.

2.2. Instrumentation

Electromyographic (EMG) data were collected simultaneously from LD using both surface and intramuscular bipolar electrodes and from ES using intramuscular bipolar electrodes. Intramuscular fine-wire electrodes were manufactured in the Shoulder Laboratory, Sydney Medical School, using the technique described by Basmajian and De Luca (1985) and then sterilized. The bipolar fine-wire electrodes consisted of two Teflon insulated stainless steel wires 0.14 mm in diameter with the insulation stripped from their ends. Using a sterile technique and with ultrasound guidance (Mindray, DP-9900), the electrodes were inserted via a hypodermic needle acting as a cannula into the center of the muscle belly of LD 4 cm below the inferior angle of the scapula and into the adjacent ES. A pair of 3.2 mm diameter silver/silver chloride surface electrodes (Red Dot, 2258, 3M, Sydney, Australia) was placed over the center of the belly of LD in line with the muscle fibers. To accommodate placement of the intramuscular electrodes between the surface electrodes (Giroux and Lamontagne, 1989; Hackett et al., 2014; Johnson et al., 2011), the surface electrodes were placed approximately 25 mm apart. A large ground electrode (Universal Electrosurgical Pad: Split, 9160F, 3 M, Sydney, Australia) was placed on the spine and acromion of the contralateral scapula. See Fig. 1 for electrode placement. Resistances between surface electrodes were $<5 \text{ k}\Omega$. Signals were amplified (Iso-DAM8-8 amplifiers, World Precision Instruments, Sarasota, FL; gain = 100–1000; common mode rejection ratio: 100 dB at 50 Hz; band pass filter 10 Hz to 1 kHz) and recorded with SPIKE 2 software (Version 4.0 Cambridge Electronics Design, Cambridge, UK) using a 16 channel ana-

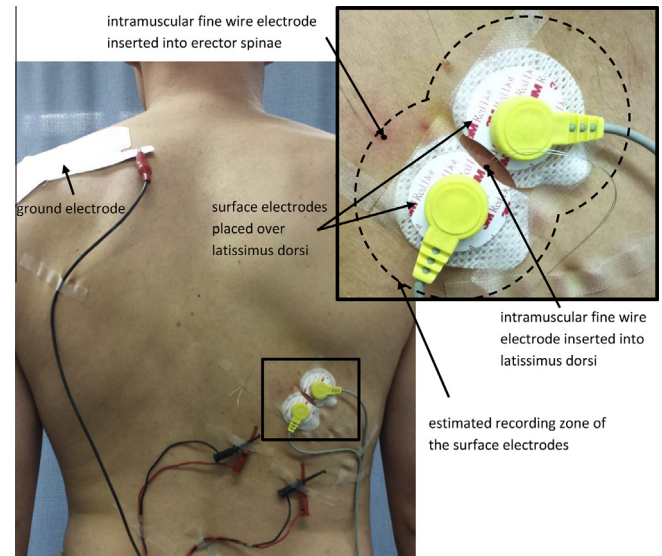


Fig. 1. A photograph of the electrode placement. The dashed lines are the estimated recording zone of the surface electrodes estimated to be ~10–12 mm from the electrodes (Fuglevand et al., 1992). The insertion points have been enhanced with a black dot.

log to digital converter (CED2701, CED Ltd., Cambridge, UK) at a sample rate of 2778 Hz.

Six maximum voluntary contractions (MVCs) were then performed in random order: five standardized shoulder normalization tests (Boettcher et al., 2008; Ginn et al., 2011) known to have a high likelihood of producing maximum activity in LD as well as trunk extension in prone for ES. The shoulder normalization tests consisted of manually resisted shoulder flexion with the shoulder at 125° flexion, abduction with the shoulder abducted 90° and internally rotated, internal rotation at 90° shoulder abduction, shoulder extension at 30° abduction and self-resisted horizontal adduction at 90° shoulder flexion (palm press).

2.3. Test positions

Isometric and dynamic tests of shoulder adduction, extension, abduction and flexion were performed. These tests were selected as they include tasks expected to elicit high LD activity (adduction and extension), as well as ones in which it would be expected to be relatively inactive (abduction and flexion) (Palastanga et al., 2006). The order of the isometric and dynamic tests was block randomized. Prior to testing and electrode placement, the maximum isometric load (100% load) for shoulder adduction, extension, abduction and flexion, was measured (XTRAN load cell S1W, Applied Measurement Australia PTY LTD, Melbourne, Australia) for each participant. The maximum load was used as the target load for the ramped isometric tests and to calculate the 70% maximum load used during dynamic tests.

Dynamic tests were performed using a cable apparatus attached to a pulley. Abduction and adduction were performed in the scapular plane in the range 0–140° abduction. Flexion and extension were performed in the sagittal plane in the range 150° flexion to 30° extension. The order of the tests was randomized with at least 2 min rest between each test to avoid the effects of fatigue. Timing was monitored and standardized at 3 s during the concentric phase, a 1 s pause and 3 s during the eccentric phase of the exercises. A draw-wire was used (micro-epsilon, 94496, Ortenburg, Germany) to synchronize shoulder movement with the EMG signals. Two repetitions of each dynamic test were performed, with at least 30 s rest interval between repetitions.

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