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Electromyographic assessment of isometric and dynamic activation characteristics of the latissimus dorsi muscle

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ABSTRACT

The aim of the current study was to analyze the activation characteristics and potential compartmentalization of the latissimus dorsi (LD) muscle during common maximal voluntary isometric contractions (MVICs) and functional dynamic tasks. Surface electromyography (sEMG) was used to measure activation magnitudes from four electrode sites (referenced to the T10, T12, L1 & L4 LD vertebral origins) across the fanning muscle belly of the LD. In addition, EMG waveforms were cross-correlated to study temporal activation timing between electrode sites (T10-T12, T12-L1, L1-L4 & T10-L4). The MVICs that were tested included a humeral adduction, humeral adduction with internal rotation, a chest-supported row and a humeral extension. Dynamic movements included sagittal lift/lowers from the floor to knee, knee to hip and hip to shoulder. No magnitude-based ($p = 0.6116$) or temporal-based differences were observed between electrode sites during the MVIC trials. During dynamic movements no temporal-based, but some magnitude-based differences between electrode sites were observed to be present; these differences were small in magnitude and were observed for both the maximum ($p = 0.0002$) and mean ($p = 0.0002$) EMG magnitudes. No clear pattern of compartmentalization was uncovered in the contractions studied here. In addition to these findings, it was determined that the most effective MVIC technique for LD EMG normalization purposes was a chest-supported row MVIC, paired with a T12 electrode site.

1. Introduction

Anatomically, the latissimus dorsi (LD) muscle has a unique design, comprising a long and broad fanning origin across the thoracic and lumbar spine with a common insertion point on the anterior humerus. Functionally, due to its humeral attachment, the LD muscle has primarily been characterized as a shoulder joint muscle that contributes to adduction, extension and medial rotation of the upper limb (Bogduk et al., 1998). It is also clear that the LD can act as an extensor and lateral bender of the spine (Schultz and Andersson, 1981; McGill and Norman, 1986; McGill, 1987; Vera-Garcia et al., 2010). Due to its large surface area, broad attachment across the spine, obliquities in fiber direction within the muscular belly, and variability in neurovascular supply, some researchers have speculated that the muscle may display compartmentalization of primary function (Herring et al., 1993; Brown et al., 2007; Hendy, 2009; Gerling and Brown, 2013). When characterized during ballistic isometric activations researchers have suggested that the LD muscle can be subdivided into at least six separate functional units (Brown et al., 2007). These functional units were described on the basis of differences in electromyographic (EMG) activation intensity (integrated EMG) and onset/offset timing as well as cadaveric based lines of action. From a structural standpoint, architectural analysis by Gerling and Brown (2013) suggests potential functional differences in the thoracic and lumbar regions of LD based on differences in physiological cross-sectional area (PCSA) and fascicle length. Considering these findings, it could be expected that surface EMG (sEMG) based studies of the LD muscle would be heavily influenced by electrode placement, the nature of the targeted dynamic or static activation task, and normalization (e.g. maximum voluntary isometric contraction (MVIC)) techniques.

In the assessment of EMG-based intramuscular compartmentalization two separate parameters have been previously studied throughout the literature. These parameters include both the assessment of muscular activation magnitude (e.g. DeSousa and Furlani, 1974; Furlani and Bankoff, 1987; Mirka et al., 1997) as well as the timing of muscular activation (e.g. Prince et al., 1994; Brown et al., 2007; Moreside et al., 2008). Each of these parameters can be estimated using sEMG electrode arrays arranged across a single muscle of interest. Analytical methods that have been employed previously include comparing variations of mean and peak

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normalized EMG magnitudes (e.g. Mirka et al., 1997; Holtermann et al., 2009) as well as cross-correlated activation timing differences (e.g. Prince et al., 1994; Moreside et al., 2008). Previous works have suggested the capacity for selective activation (compartmentalization) based of off activation magnitude comparisons within the external oblique muscle (Furlani and Bankoff, 1987; Mirka et al., 1997), as well as temporal comparisons within the rectus abdominus (Moreside et al., 2008) and erector spinae muscles (Prince et al., 1994). Based on these results, it is possible that a muscle with anatomical architectural diversity such as the LD (Gerling and Brown, 2013) may show these compartmentalization characteristics as well. This functional evidence of muscle compartmentalization would be especially relevant during tasks commonly assessed within a research setting including muscle MVICs and dynamic activation tasks.

Having actions at both the shoulder and spine, activation patterns of the LD can be characterized using sEMG for a variety of muscular contraction activities. To account for variability in surface electrode placement (Mesin et al., 2009), changes in tissue impedance (Hewson et al., 2003), subject testing day (Frost et al., 2012) and subject muscle size (Häkkinen et al., 1998) previous investigations using sEMG have often normalized the experimental signals to a percentage of a participant's MVIC. Normalized EMG signals specifically allow for physiological comparisons to be made amongst different muscles, different individuals and across testing days. Throughout the scientific literature there has been an inconsistency regarding the MVIC technique used to normalize the LD muscle, with some studies reporting activations >100% during sub-maximal dynamic tasks when normalized to an MVIC value (e.g. Youdas et al., 2010). Supra-maximal EMG values such as these may suggest differences in LD recruitment and activation between the MVIC and dynamic movement tasks (Kallio et al., 2013), further accentuated if functional compartmentalization is present within the muscle. Throughout the scientific literature several studies have sought to identify optimal normalization procedures for muscles of the upper limb (Boettcher et al., 2008) and trunk (Vera-Garcia et al., 2010). These studies, however, did not test the same MVIC techniques and thus could not arrive at the same result. To account for these MVIC inconsistencies a recent investigation by Park and Yoo (2013) compared a variety of commonly administered LD MVIC techniques and determined that an isometric humeral extension technique elicits maximal MVIC voltage; however only a single electrode placement location was tested, thus not accounting for any potential functional compartmentalization within the muscle.

To build from these previous works, the purpose of the current study was to identify potential regional differences (compartmentalization) in activation magnitude and timing during MVIC techniques and functionally relevant dynamic movement tasks. A secondary purpose of the current study was to further assess if an optimal (maximal voltage) MVIC normalization technique exists throughout the entire LD muscular belly. It was hypothesized that activation magnitude and timing compartmentalization would be present during the manoeuvres analyzed, based on previous work (Brown et al., 2007). Further, it was hypothesized that thoracic LD activation would be maximized in a humeral extension contraction (as per Park and Yoo, 2013), while lumbar LD activation would be maximized during a humeral adduction contraction (based on anatomical considerations by Gerling and Brown, 2013).

2. Methodology

2.1. Participants

Sixteen healthy, recreationally active, right handed individuals participated in this study. Eight of the participants were male (mean age 23 ± 1.8 years; height 1.8 ± 0.04 m; and mass 76.9 ± 10.6 kg) and eight of the participants were female (mean age 22 ± 1.2 years; height 1.7 ± 0.09 m; and mass 61.6 ± 8.6 kg). Exclusion criteria included persistent pain within the past year (causing absence from school, work or regular activity), or treatment for pain or injury in the shoulder or lumbar spine. All participants had not completed any intense physical exercise involving the LD within 24 h prior to testing. All participants completed a health screening questionnaire and signed informed consent prior to data collection. The protocol was approved by the local Research Ethics Board.

2.2. Equipment

Participants were asked to complete all testing sessions while wearing comfortable athletic clothing. All MVIC techniques (Fig. 1) were completed while the subject was standing, or while lying prone on a chiropractic-style bench. Dynamic sagittal lifting/lowering scenarios were completed using adjustable shelving positioned individually to the standing height of each participant's patella, anterior superior iliac spine and acromion (Section 2.3). All dynamic lifting scenarios required participants to lift a 42 cm × 31 cm × 27 cm box (mass 8 kg females; 12 kg males) using handles, for a total of 2 repetitions (consisting of consecutive lift-lower cycles) at a self-selected rate (Fig. 2). A mechanical push-button switch was installed into the base of the loading box to distinguish between the lifts and lowers of each dynamic movement. sEMG was collected unilaterally from the right latissimus dorsi (LD) muscle. After shaving and prepping with rubbing alcohol, 22 × 28 mm Ag/AgCl surface electrodes (Blue Sensor, Medicotest Inc., Ølstykke, Denmark) were placed at 4 sites in an array across the LD muscle with a 30 mm inter-electrode distance (Fig. 3). Electrode sites were determined with reference to the location of particular spinous processes, and each bi-polar pair followed the approximate lines of muscle fibers spanning from these spinous processes. Two electrode sites were tested in the thoracic region (T10 & T12) and two electrode sites were tested in the lumbar region (L1 & L4). Raw EMG signals were band-pass filtered from 10 to 1000 Hz, amplified (AMT-8, Bortec Calgary, AB, Canada; input impedance: 10 GΩ, CMRR: 115 dB (@60 Hz)) and captured digitally at 2048 Hz.

2.3. Procedure

Following electrode placement participants were asked to complete a series of isometric (MVIC) and dynamic (sagittal lift/lower) LD activation manoeuvres. Each participant completed two repeated sets of four different MVICs targeting the LD. These MVIC techniques included a humeral adduction (ADD), a humeral adduction with internal rotation (ADD + INT), a chest-supported row (ROW), and a humeral extension while internally rotated (EXT); all were performed against manual resistance applied by the experimenters (Fig. 1). Each MVIC was performed by the participant ramping up activation to maximum over an approximate two second period, a two second hold at maximum and a two second ramp down to rest. To elicit the ADD and ADD + INT MVICs the participant was asked to stand comfortably with his/her feet shoulder width apart and contract against experimenter-provided resistance applied at the elbow (e.g. Lehman et al., 2004; Vera-Garcia et al., 2010). To elicit the ROW MVIC the participant was asked to flex at the hips with feet on the floor, and place his/her torso prone atop a chiropractic-style bench where the experimenter applied manual resistance at the elbow, resisting extension of the humerus. To elicit the EXT MVIC the participant was asked to lie prone on the chiropractic-style bench while the experimenter applied manual resistance at the wrist, resisting extension of the arm (e.g. Kendall et al., 2005; Boettcher et al., 2008; Youdas