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Differential activation of parts of the latissimus dorsi with various isometric shoulder exercises

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ABSTRACT

As no study has examined whether the branches of the latissimus dorsi are activated differently in different exercises, we investigated intramuscular differences of components of the latissimus dorsi during various shoulder isometric exercises. Seventeen male subjects performed four isometric exercises: shoulder extension, adduction, internal rotation, and shoulder depression. Surface electromyography (sEMG) was used to collect data from the medial and lateral components of the latissimus dorsi during the isometric exercises. Two-way repeated analysis of variance with two within-subject factors (exercise condition and muscle branch) was used to determine the significance of differences between the branches, and which branch was activated more with the exercise variation. The root mean squared sEMG values for the muscles were normalized using the modified isolation equation (%Isolation) and maximum voluntary isometric contraction (%MVIC). Neither the %MVIC nor %Isolation data differed significantly between muscle branches, while there was a significant difference with exercise. %MVIC was significantly higher with shoulder extension, compared to the other isometric exercises. There was a significant correlation between exercise condition and muscle branch in the %Isolation data. Shoulder extension and adduction and internal rotation increased %Isolation of the medial latissimus dorsi more than shoulder depression. Shoulder depression had the highest value of %Isolation of the lateral latissimus dorsi compared to the other isometric exercises. Comparing the medial and lateral latissimus dorsi, the medial component was predominantly activated with shoulder extension, adduction, and internal rotation, and the lateral component with shoulder depression. Shoulder extension is effective for activating the latissimus dorsi regardless of the intramuscular branch.

1. Introduction

In the musculoskeletal system, certain broad muscles with many insertions and origins are thought to have different kinematic functions according to the fiber arrangement (Paton and Brown, 1995; Brown et al., 2007). The latissimus dorsi originates from the spinous processes of the last six thoracic vertebrae, thoracolumbar fascia, and iliac crest, and inserts into the intertubercular groove of the humerus (Kendall et al., 2005). Since the latissimus dorsi has many neuromuscular end plates and vascular and nerve branches (Watanabe et al., 2010), it used as a donor sites for reconstructive surgery (de Oliveira et al., 2010; Kwon et al., 2011). Surgical methods for preventing morbidity of the latissimus dorsi, such as splitting the thoracodorsal nerve or sparing an area through vascular anatomy, have been suggested (Kwon et al., 2011). However, the contributions of the intramuscular branches of the latissimus dorsi to shoulder exercises have not been clearly established, although these differences are important for the prognosis after surgery and rehabilitation.

Movement at a joint related to muscular activation can be investigated using surface electromyography (sEMG). When using a sEMG, the anthropometric position of the electrode sites is important for reducing spatial variability and measuring an accurate sEMG signal (Hug, 2011). The surface electrode sites for the latissimus dorsi have differed in previous studies: some used a site lateral to T9 over the muscle belly, while others used sites lateral and inferior to the inferior angle of the scapulae (Signorile et al., 2002; Snyder and Leech, 2009; Vera-Garcia et al., 2010). These sites might be differentiated as the medial and lateral branches of the latissimus dorsi, but a few studies have investigated both medial and lateral electrode sites of the latissimus dorsi simultaneously. To our knowledge, two studies have examined the functional differences of the fibers of this broad muscle with changes in the direction of exercises and shoulder position (Paton and Brown, 1995; Brown et al., 2007). Zhao et al. (2003) suggested that the latissimus dorsi can be divided into medial and lateral branches, and that the lateral branch is activated more with shoulder motion.

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Although the muscle induces many shoulder actions, including internal rotation, adduction, and extension of the humerus, and depression of the shoulder girdle, activation depending on branch differentiation has not been specifically reported.

This preliminary study investigated the functional differences in the intramuscular branches of the latissimus dorsi during various isometric shoulder exercises. Based on a report that the lateral branch was activated more with shoulder motion (Zhao et al., 2003), we expected that shoulder exercises would activate the lateral branch of the latissimus dorsi more than the medial branch.

2. Method

2.1. Study population

Twenty asymptomatic males were recruited from a local university using convenience sampling. They had a mean ± SD age of 23.38 ± 1.02 (range 22–26) years and weight-trained twice per week. Subjects with a history of upper extremity pain or discomfort in the past 6 months were excluded. Tightness of the latissimus dorsi was examined before the experiment. Subject lay on a table in the supine position, and was asked to flex his arm fully while remaining in contact with the table (Sahmann, 2002). Three subjects whose lumbar region rose off the table, indicating a tight latissimus dorsi, were excluded from this study. The final study sample comprised 17 males, with a mean height of 175.38 ± 4.88 cm and weighing 66.28 ± 4.75 kg. All subjects were right-hand dominant, with dominance defined as the hand used for writing. Ethics approval for this study was obtained from the Inje University Faculty of Health Sciences Human Ethics Committee. The participants provided informed consent.

2.2. Instrumentation

Surface electromyography data were collected using a Trigno wireless system (Delsys, Boston, MA, USA); the Trigno electrodes (Delsys) were set at a band pass of 20–450 Hz and a common mode rejection ratio of 80 dB. The 27 × 37 × 15-mm sensor has four fixed 5 × 10-mm contact areas, which are half the area of a Bagnoli sensor (10 × 10 mm), and are made of pure silver (99.9%). The sEMG data were corrected using EMG-Works-Acquisition (Delsys) at 2000 Hz. To exclude any influence of electrical noise, the electrode site was prepared by cleaning the skin with alcohol and shaving it lightly. One surface electrode was placed over the right medial latissimus dorsi (MLD), lateral to T9 over the muscle belly (Vera-Garcia et al., 2010; Frost et al., 2009). A second electrode was placed over the lateral latissimus dorsi (LLD) 4 cm below the inferior tip of the scapula, half the distance between the spine and lateral edge of the torso (Cram et al., 1998). Since the MLD is adjacent to the lower trapezius, the muscle belly was identified with manual muscle testing to prevent the electrode from overlapping both the latissimus dorsi and lower trapezius (Fig. 1) (Kendall et al., 2005). A Power-track II digital hand held dynamometer (JTECH Medical, Salt Lake City, UT, USA) was used to measure the strength of each subject. The device expresses the peak load as a numerical value (pounds) during isometric exercises and simultaneously displays the data and provides auditory feedback when exceeding a threshold.

2.3. Exercise procedure

The maximum voluntary isometric contraction (MVIC) was measured to normalize the sEMG amplitude during the shoulder exercsies. Following a previous study that investigated normalization of the latissimus dorsi, three trials of MVIC were performed while applying manual resistance (1) during shoulder extension with adduction in the prone position and (2) while pulling down against a fixed bar in the sitting position (Park and Yoo, 2013). Among the two MVICs for MLD and LLD, the highest mean value was used for normalizing the procedure. After measuring the MVIC, each subject performed three trials of each isometric exercise in shoulder extension, abduction, internal rotation, and depression.

For each isomeric shoulder exercise, 50% of the maximum load was determined using a hand-held dynamometer. The participants performed two trials of maximum efforts for each of shoulder extension, adduction, internal rotation, and shoulder depression within standing position, and the 50% averaged maximum load was determined. After a 5-min rest and 5-min practice, the participants performed each exercise at 50% of the maximum load. While watching the display on the dynamometer, each participant tried to maintain the 50% maximum load for 5 s. The allowable error range of the load was 2.27 kg (5 lbs), and a trial exceeding this error range was regarded as a failure and repeated. To prevent compensatory movement, the subjects were fixed to a pillar by grasping handle bar from the pillar, and one researcher watched to exclude any compensatory movement (Fig. 1). The dynamometer was positioned at the posterior part of the elbow joint in shoulder extension, at the medial part of the elbow joint in shoulder adduction, at the medial forearm in shoulder internal rotation with elbow flexion, and at the inferior surface of the elbow in shoulder depression.

Each subject conducted the exercise within the 5-s time frame using a 60-Hz metronome, and the middle 3 s were analyzed. The sequence of exercises was determined randomly. Each participant was allowed a 5-min rest between exercise sessions and a 60-s rest between trials.

2.4. Data analysis

Three seconds of sEMG data during the exercises were full-wave rectified and averaged, and the data were expressed as the %MVIC and %Isolation values. The %MVIC was normalized relative to the MVIC procedure. To analyze the intramuscular response of the latissimus dorsi, the mean rectified sEMG value recorded from each branch of the latissimus dorsi was calculated using the isolation equation (Fig. 2). Previous studies used this equation to compare intramuscular branches of the trapezius and latissimus dorsi (Paton and Brown, 1995; Arlotta et al., 2011).

PASW Statistics (ver. 18.0; SPSS, Chicago, IL, USA) was used to identify significant differences in the %Isolation and %MVIC between the MLD and LLD. Two-way repeated measures analysis of variance (ANOVA) was used to determine the effects of the muscle branches (MLD and LLD) and isometric exercises (isometric shoulder extension, adduction, internal rotation, and shoulder depression). When significant interactions were observed between factors, one-way repeated ANOVA was performed to evaluate the difference among the four isometric exercises for each muscle. If necessary, post hoc Bonferroni corrections were performed to identify differences among the four exercises. All significance levels were set at $P < 0.05$.

3. Results

Descriptive statistics pertaining to the %MVIC values of the medial and lateral latissimus dorsi are shown in Table 1. The "isometric exercises" factor was associated with a significant difference in the %MVIC value ($F3.14 = 11.913$, $P < 0.001$, effect size = 0.719) but no significant interaction was evident between factors ($F3.14 = 2.953$, $P > 0.05$, effect size = 0.388). Shoulder