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# Selective activation of the latissimus dorsi and the inferior fibers of trapezius at various shoulder angles during isometric pull-down exertion

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ABSTRACT

The aim of this study was to determine the effect of isometric pull down exercise on muscle activity with shoulder elevation angles of 60°, 90°, and 120° and sagittal, scapular, and frontal movement planes, by electromyography (EMG) of the latissimus dorsi, inferior fibers of trapezius, and latissimus dorsi/inferior fibers of trapezius activity ratio. Fourteen men performed nine conditions of isometric pull down exercise (three conditions of shoulder elevation × three conditions of movement planes). Surface EMG was used to collect data from the latissimus dorsi and inferior fibers of trapezius during exercise. Two-way repeated analysis of variance with two within-subject factors (shoulder elevation angles and planes of movement) was used to determine the significance of the latissimus dorsi and inferior fibers of trapezius activity and latissimus dorsi/inferior fibers of trapezius activity ratio. The latissimus dorsi activity and ratio between the latissimus dorsi and the inferior fibers of trapezius were significantly decreased as shoulder elevation angle increased from 60° to 120°. The inferior fibers of trapezius activity was significantly increased with shoulder elevation angle. The EMG activity and the ratios were not affected by changes in movement planes. This study suggests that selective activation of the latissimus dorsi is accomplished with a low shoulder elevation angle, while the inferior fibers of the trapezius are activated with high shoulder elevation angles.



## 1. Introduction

Selecting a proper strengthening exercise is essential for patients with shoulder injury and dysfunction to regain their muscle performance and functional movement (Holmgren et al., 2012; Marinko et al., 2011). Clinical literature have emphasized the exercise for activating rotator cuff or scapulothoracic musculature, whose muscle components contribute to functional arm elevation (Holmgren et al., 2012; Neumann, 2002). However, some surgery is needed to rehabilitate other muscles such as the latissimus dorsi. The latissimus dorsi is a broad muscle with many vascular branches and innervations; therefore, it has been used as a donor site for reconstructive surgery (Spear and Hess, 2005). According to previous studies, loss of the latissimus dorsi could result in functional impairment after this kind of surgery (Forthomme et al., 2010; Koh and Morrison, 2009; Fraulin et al., 1995). Forthomme et al. (2010) have reported muscle weakness after latissimus dorsi transfer; mainly in the shoulder adductor and internal rotator muscles. In addition, Fraulin et al. (1995) have investigated muscle power after reconstructive surgery, and have concluded that power deficit in the shoulder extension and adduction remains.

In the rehabilitation setting, some recent findings implied the increasing importance of surgery, such as the capsular shift for patients with shoulder instability, to restore normative kinematics. However, the findings also demonstrated that proper postoperative rehabilitation treatment is necessary to regain control of the scapulothoracic and glenohumeral musculature (Kiss et al., 2010; Illyés and Kiss, 2007). Compared with controls, patients with shoulder instability showed greater displacement between the rotation center of the scapula and humerus as well as increased glenohumeral motion and decreased scapulothoracic motion during arm elevation (Illyés and Kiss, 2006). For patients with shoulder instability, strengthening the inferior fibers of the trapezius might be more adequate than strengthening the inferior fibers of the latissimus dorsi. This is because activation of the inferior fibers of the trapezius is directly associated with the scapulothoracic joint, especially the upward rotation of the scapula during arm elevation.

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Representative exercises for strengthening the latissimus dorsi and inferior fibers of trapezius are pull down, pull ups, and rowing exercises. Among these, pull down exertion has been mostly investigated in kinematic and electromyography studies. Several studies have demonstrated that muscle activation depends on grip width, expert instruction, and forearm orientation (Lusk et al., 2010; Snyder and Leech, 2009; Signorile et al., 2002). Signorile et al. (2002) have reported that wide grip hand position produces greater muscle activation than other hand positions. Lusk et al. (2010) have recommended anterior pull down with pronated grip for maximally activating the latissimus dorsi. In a recent study, pull down was suggested as an exercise for independently activating the inferior fibers of trapezius (Arlotta et al., 2011). The inferior fibers of trapezius and latissimus dorsi have similar obliquity of muscle's pull, but the inferior fibers of trapezius could be activated with the high arm elevation angle because the most pronounced scapular motion occurs between 80 and 120 of arm elevation (Ebaugh et al., 2005; Bagg and Forrest, 1988). In addition, the inferior fibers of the trapezius are arranged within the frontal plane, while the arrangement of the latissimus dorsi has components of both the sagittal and frontal planes. However, there were no study investigated the effect of movement planes and arm elevation angles of the pull down exertion on muscular activation, both of the inferior fibers of trapezius and latissimus dorsi.

Some previous studies have performed pull down as an isotonic exercise, which is the general form. However, difficulty remains in adjusting the exercise to patients who need rehabilitation exercises at an early stage. It is considered that isometric exercise for shoulder rehabilitation is a more stable way of initiating muscular activation without increasing load at the glenohumeral joint, especially in patients with limitations in shoulder mobility (Ellenbecker and Cools, 2010; Millett et al., 2006). Although one previous study has suggested activation of the shoulder muscle, including latissimus dorsi, under isometric conditions and various angles and planes, there remains a lack of evidence about which shoulder angle and movement plane are effective for activating the latissimus dorsi and the inferior fibers of trapezius during the pull down exercise (Anders et al., 2004). This previous study did not statistically compare the muscular difference according to shoulder angle and movement plane but compared sex differences.

Therefore, the present study is to investigate the activation of the latissimus dorsi and the inferior fibers of trapezius under conditions of various shoulder angles (60°, 90° and 120°), and three planes of movement (sagittal, scapular, and frontal plane) during pull down exercise. The purpose was to find out effective means of isometric pull down exercise for activating the musculatures. We hypothesized that the inferior fibers of the trapezius might be activated with increased shoulder elevation angles and closer proximity to the frontal plane, while the latissimus dorsi might be activated with decreased shoulder elevation angles and closer proximity to the sagittal plane.

## 2. Methods

### 2.1. Population

This study was performed on 14 asymptomatic men aged 20–22 years (mean ± SD: 21.8 ± 1.4 years), whose height and weight were 175.4 ± 5.2 cm and 68.1 ± 2.1 kg, respectively. Subjects with a history of upper extremity pain or discomfort in the past 6 months were excluded. For consistency, all subjects were right-hand dominant, which the dominance was defined as the one used for writing. Ethical 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

A Trigno wireless system (Delsys, Boston, MA, USA) was used for obtaining electromyography (EMG) signals; the Trigno electrodes (Delsys, Boston, MA, USA) was set as band pass of 20–450 Hz and a common mode rejection ratio of 80 dB. The sensor (27 mm × 37 mm × 15 mm) included four skin contacts (5 × 1 mm) made of pure silver (99.9%), which contain two patent-pending stabilizing references and distance between skin contacts is 1 cm. The EMG data were corrected with EMG-Works-Acquisition (Delsys) at 2000 Hz, which simultaneously showed data display. Two surface electrodes were placed on the following muscles of the right side: latissimus dorsi, ~4 cm below the inferior tip of the scapula, half the distance between the spine and lateral edge of the torso. The electrode was placed at an oblique angle of ~25°; and the inferior fibers of trapezius, at 1.5 cm lateral and oblique to the T6 spinal process (Cram et al., 1998). Because there were differences between size of the participants, muscle belly of the latissimus dorsi and the inferior fibers trapeizus were identified with the manual muscle testing (Kendall et al., 2005). To exclude any influence of electrical noise, the skin was prepared for EMG measurement by cleaning the electrode site with alcohol, and lightly abrading the skin with fine sandpaper.

### 2.3. Exercise procedure

Prior to the pull-down exercises, maximal voluntary isometric contractions (MVCs) for each muscle were performed to normalize the individual differences. The following EMG normalizing procedure was suggested previously (Cram et al., 1998; Kendall et al., 2005). A 5-s MVC was done for each muscle using three trials. The first and last second of each trial was excluded and the mean value of the middle 3 s was used for normalization.

Subjects performed three trials of pull down exercise for each of nine conditions in randomized order: three planes (sagittal, scapular, and frontal plane) * three shoulder angles (60°, 90°, and 120°). The load for pull down was not controlled, but determined as maximal isometric exertion against a fixed pull down bar. From a standing position, subjects grasped the bar as pronated and with a wide grip. Shoulder angle and planes for each condition were determined by measuring with a goniometer and inclinometer, and stacking wooden plates under the participant's feet (Fig. 1). One researcher fixed the participant's pelvis so as not to be rotated or translated in an upward direction. Each isometric exertion was maintained for 5 s, and the middle 3 s were used for further analysis. Three seconds of EMG data during the pull down were averaged, and the data were expressed as %MVC value against normalized data. The 5 s of isometric contraction was controlled by a 60-Hz metronome. Prior to measurement, each participant was instructed verbally and visually about how to perform a pull down, and given a 5-min practice time for each condition for familiarization of exertion. Three minutes of rest time was given to each participant between trials and conditions.

### 2.4. Data analysis

PASW Statistics (version 18.0; SPSS, Chicago, IL, USA) was used to analyze significant differences in the %MVC of each muscle. A two-way repeated measures analysis of variance was used to determine the effect of planes (frontal, scapular, and sagittal) and shoulder angles (60°, 90°, and 120°) on the EMG data. Preliminary analysis revealed there was no interaction between planes of exertion and shoulder angles. Specific pair-wise comparison between conditions of shoulder angles and between those of planes were done through Bonferroni correction, and a significant difference was revealed ($p = 0.05$).