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Original article

Instruction and feedback for conscious contraction of the abdominal muscles increases the scapular muscles activation during shoulder exercises

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ABSTRACT

Purpose: The study aimed to investigate the effect of the instruction for conscious contraction of the abdominal muscles on the scapulothoracic muscles activation during shoulder exercises.
Design: Repeated measures design in a single group, pre-post instruction.
Methods: Sixty healthy male and female subjects (mean age 23.5 ± 3 years) volunteered for this study. Two isometric and three dynamic exercises for the scapulothoracic muscles, focusing on the serratus anterior muscle were assessed before and after familiarization training, standardized verbal, and tactile feedback applied to encourage abdominal muscle contraction. Repeated measures ANOVA and Bonferroni post-hoc test were used to compare normalized EMG amplitudes.
Results: Instruction increased EMG amplitude only for serratus anterior muscle during isometric exercises (Inferior Glide and Isometric Low Row). Conscious contraction of the abdominal muscles resulted in significant increase ($p < 0.05$) in the serratus anterior, upper, middle and lower trapezius EMG amplitude, during dynamic exercises (Wall Slide, Wall Press, and Knee Push-Up).
Conclusion: Conscious contraction of the abdominal muscle increased the activation of the serratus anterior e the three parts of the trapezius during dynamic shoulder exercises with moderate to minimal levels of EMG activation. In the other hand, abdominal muscles contraction was effective to increase the activation of the serratus anterior during isometric exercises but did not increase the trapezius activation. So, Inferior Glide and Isometric Low Row performed along with encouraged abdominal muscle contraction are compatible to initial phases of the serratus anterior strengthening with low levels of upper trapezius muscle activation.

1. Introduction

Activation of the scapulothoracic muscles is considered a significant aspect of shoulder complex rehabilitation (Kibler et al., 2008; Kibler and Sciascia, 2010). Exercises minimizing the upper trapezius (UT) muscle activation in relation to the serratus anterior (SA) are recommended to improve scapular stabilization by promoting selective SA strengthening (Martins et al., 2008). Strengthening and facilitation of the abdominal muscles are also recommended as requisite for the restoration of the scapular muscle force couples (Kibler and Sciascia, 2010).

From a mechanical point of view, trunk and pelvis stability are required to transmit force and energy to the upper limbs during function or sports activities (Hirashima et al., 2002; Kibler et al., 2006; Jang et al., 2015). Scapulothoracic joints and its muscles are an anatomofunctional linkage between the trunk and the upper extremities (Kibler and Sciascia, 2010).

Previous studies suggest muscle synergy between the oblique external (OE) muscle and SA during knee push up plus with ipsilateral leg extension (Maenhout et al., 2010; Kim et al., 2011). As a result of the leg extension and gluteus maximus activity, the thoracolumbar fascia is tightened and the lumbar spine extended. Compensatory ipsilateral OE muscle tension is created and transferred to the proximal tendon of the SA, leading to greater muscle fiber recruitment in the scapulothoracic muscle (Maenhout et al., 2010; Kim et al., 2011).

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The influence of adding pelvic and thoracic supports on the surface electromyographic (EMG) activity of the scapulothoracic (UT, SA, and lower trapezius – LT) and middle deltoid muscles was already tested (Jang et al., 2015). Trunk stabilization was provided by an external support consisting of pads and belts to the pelvic and the thoracic regions. Participants performed isometric contractions at 45° of shoulder abduction in the scapular plane with pelvic support, with pelvic and trunk support and with no external support. Adding support to the trunk and pelvic regions did not significantly increase the SA and LT activations, but increased the middle deltoid and decreased UT EMG. However, the decrease in UT activation did no significantly decreased the UT/SA ratio which ranged from 0.9 (without stabilization) to 0.94 (both stabilizations) (Jang et al., 2015).

Thus, the influence of trunk stabilization created by conscious contraction of the abdominal muscles on the scapulothoracic muscles activity during shoulder exercises with low UT/SA ratios has not yet been studied. Therefore, the purpose of this study was to investigate the effect of the instruction for conscious activation of the abdominal muscles, encouraged by verbal and tactile feedback, on the EMG activity of the scapular muscles during shoulder exercises commonly used in rehabilitation protocols. Our hypothesis is that adding active abdominal muscle contraction during exercises for the shoulder complex increases the EMG activity of the scapulothoracic muscles.

2. Methods

2.1. Participants

Healthy participants were recruited by verbal invitation and explanatory flyers distributed in campus facilities. Sixty-five healthy, right-handed, male (n = 27) and female (n = 38) subjects (mean age 23.52 ± 3.61 years and mean body mass 23.2 ± 2.34 kg/m^2) participated in the study protocol. All subjects volunteering signed a consent form according to the national regulation and approved by the institutional review board of the university hospital. Subjects were not included if they had previous trauma, neurological or musculoskeletal conditions in the shoulder complex, upper limb, spine or pelvic girdle; limited or painful range of motion in the shoulder complex, upper limb, spine or pelvic girdle; visually detectable spine misalignment, or reported intake of skeletal muscle relaxant drugs.

2.2. Instrumentation

The EMG signals were collected using the Trigno Wireless System (16-bit A/D converter resolution) and processed by EMG Works Acquisition (both from Delsys Inc. Boston, MA, USA). Data were acquired at 2 kHz of sampling rate per channel.

Trigno sensors (Delsys Inc. Boston, MA, USA) are built on a base for four parallel bars (99.9% Ag, 5 × 1 mm contact area and fixed inter-electrode distance of 10 mm), representing two active electrodes and two stabilizing references, eliminating the use of an external reference electrode. Trigno sensor's amplifier has a band pass filter of 20–450 Hz, the baseline noise of <750 nV RMS, with a full dynamic range of ±5 V and a common mode rejection ratio of 80 dB.

Before sensor placement, the skin was shaved, gently abraded and cleaned using alcohol wipes to reduce skin impedance (Hermens et al., 2000). Sensors were fixed using double sided adhesive tape. EMG signals were collected bilaterally from the SA, UT, middle trapezius (MT), LT, EO, internal oblique (IO) and rectus abdominis (RA).

The SA sensor was placed with bars aligned parallel to the length of the muscle fibers, below the axilla, to the lower level angle of the scapula, anterior to the latissimus dorsi muscle and posterior to the pectoralis major muscle (Maenhout et al., 2010). The UT muscle sensor was placed midway on a line between the acromion and the spinous process of the C7 vertebra (Maenhout et al., 2010). The MT sensor was placed at 50% of the horizontal distance between the medial border of the scapula and the spinous process of the T3 vertebra. The LT sensor was placed at 2/3 of the line between the trigonum spinae scapula and the spinous process of the T8 vertebra (Hermens et al., 1999). The OE muscle sensor was placed 15 cm lateral to the umbilicus with bars parallel-oriented to the muscle fiber's direction, just below the convexity of the 10th rib (Juker et al., 1998). The OI sensor was placed below the external oblique electrodes and just superior to the inguinal ligament (Juker et al., 1998). The RA muscle sensor was placed 3 cm lateral to the umbilicus (Juker et al., 1998).

2.3. Procedure

After sensor placement, the EMG signals were recorded bilaterally from maximal isometric voluntary contractions (MIVC) for all muscles investigated in a random sequence (muscle and side) defined by the drawing lot.

The MIVC task of each muscle was registered during five seconds of sustained effort. Each MIVC task was repeated three times. Participants rested at least 30 s between MIVC of the same muscle and two minutes between different MIVC tasks (Maenhout et al., 2010; De Araújo et al., 2011).

For the SA, the subject was seated with the shoulder in 130° forward flexion. The examiner applied manual resistance against further shoulder elevation (Maenhout et al., 2010). UT MIVC was acquired with the subject seated and shoulder abducted at 90°. The examiner applied manual resistance against further shoulder abduction (Maenhout et al., 2010). MT MIVC was recorded with the subject in prone position, 90° shoulder abduction, and humeral external rotation. The resistance was applied against horizontal abduction (Maenhout et al., 2010). LT muscle MIVC was also recorded with the subject in prone position; the shoulder was abducted to be aligned with the LT fiber's muscle direction. The resistance was applied against retraction and depression (De Mey et al., 2013).

EO and IO (contralateral) MIVC were recorded with the subject in supine position, arms crossed over the chest, 45° of hip flexion and 90° of knee flexion. The examiner applied resistance against the contraction of trunk flexion and rotation to the opposite side. RA MIVC was recorded in the supine sit-up exercise. Subjects performed trunk flexion with their arms crossed over the chest, 45° of hip flexion and 90° of knee flexion. The examiner applied manual resistance against the trunk flexion (Monfort, 2009).

After a resting period of 15 min, the subjects performed one trial of five repetitions of each of the five exercises. Participants rested 5 s between repetitions and two minutes between exercise's trials (Maenhout et al., 2010; De Mey et al., 2013).

The exercises (Table 1) were selected based on literature for being recommended for muscle strengthening with UT/SA ratio <1, or for scapular motor control improvement. Two exercises were performed as sustained contractions (isometric exercises): "Inferior Glide" and "Isometric Low Row" (Fig. 1) (Cricchio and Frazer, 2011; Kibler et al., 2008). Three exercises were performed dynamically: "Wall Slide", "Wall Press" and "Knee Push-Up" (Ludewig et al., 2004; Uhl et al., 2010; Maenhout et al., 2010; Cricchio and Frazer, 2011) (Fig. 2).

"Inferior Glide" and "Isometric Low Row" were performed in five repetitions maintained by five seconds. "Wall Slide", "Wall Press"