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Effects of augmented trunk stabilization with external compression support on shoulder and scapular muscle activity and maximum strength during isometric shoulder abduction

Hyun-jeong Jang [a], Suhn-yeop Kim [a], Duck-won Oh [b,*]

[a] Dept. of Physical Therapy, College of Natural Science, Daejeon University, 62 Daehak-ro, Dong-gu, Daejeon 300-716, Republic of Korea
[b] Dept. of Physical Therapy, College of Health Science, Cheongju University, 298 Daesung-ro, Cheongwon-gu, Cheongju, Chungbuk 360-764, Republic of Korea

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ABSTRACT

The aim of the present study was to investigate the effects of augmented trunk stabilization with external compression support (ECS) on the electromyography (EMG) activity of shoulder and scapular muscles and shoulder abductor strength during isometric shoulder abduction. Twenty-six women volunteered for the study. Surface EMG was used to monitor the activity of the upper trapezius (UT), lower trapezius (LT), serratus anterior (SA), and middle deltoid (MD), and shoulder abductor strength was measured using a dynamometer during three experimental conditions: (1) no external support (condition-1), (2) pelvic support (condition-2), and (3) pelvic and thoracic supports (condition-3) in an active therapeutic movement device. EMG activities were significantly lower for UT and higher for MD during condition 3 than during condition 1 ($p < 0.05$). The MD/UT ratio was significantly higher during condition 3 than during conditions 1 and 2, and higher during condition 2 than during condition 1 ($p < 0.05$). Shoulder abductor strength was significantly higher during condition 3 than during condition 1 ($p < 0.05$). These findings suggest that augmented trunk stabilization with the ECS may be advantageous with regard to reducing the compensatory muscle effort of the UT during isometric shoulder abduction and increasing shoulder abductor strength.

1. Introduction

Trunk stabilization is necessary for maintaining efficient load transfer to the limbs, coordinating distal and proximal movements, and regulating force or energy during integrated kinetic chain activities (Cools et al., 2007a,b). The active and passive control systems work synergistically to maintain optimal body posture for stability, mobility, and performance during daily activities (Vleeming et al., 2007). Well-organized trunk muscles corresponding with these systems are fundamental for selecting movement strategies that optimize recruitment patterns and temporal sequences in limb muscles.

Trunk-stabilizing muscles play an important role in maintaining spinal and pelvic stabilities, and in helping the generation and transfer of force from large to small parts of the body during functional limb movements (Baechle et al., 2000). The central location of these muscles is suitable for regulating the stabilizing function during specific movements of distal segments, which are associated with proximal stability that is essential for successful distal mobility. Given that almost all kinetic chains contribute to the control of core strength, motion, and balance, this contribution is essential for effectively utilizing all the kinetic chains associated with the function of upper and lower limbs.

The shoulder has a large range of motion and the coordinated control of shoulder muscles depends on the extent of scapular stability, which is based on trunk stabilization efforts during movement (Borstad, 2006). Coordinated shoulder and scapular muscle activity is necessary to increase dynamic stability during shoulder movement; therefore, altered muscle activity can lead to inappropriate glenohumeral and scapulothoracic joint movement rhythm which can cause various shoulder pathologies (Wong, 2006). Most scapular joint prime movers attach to the spinal column; therefore, changes in spinal alignment greatly influence shoulder and scapular position, muscle activity, and kinematics.

An altered spinal alignment influences scapular position and stability directly, thereby changing the action of shoulder and scapular muscles (Hsu et al., 2009). Therefore, clinical observation

* Corresponding author at: Dept. of Physical Therapy, College of Health Science, Cheongju University, 298 Daesung-ro, Cheongwon-gu, Cheongju, Chungbuk 360-764, Republic of Korea. Tel.: +82 43 229 8679; fax: +82 43 229 8969.
E-mail address: odduck@cju.ac.kr (D.-w. Oh).

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of specific shoulder movements and activities should take into consideration trunk alignment and stability, and the influence on structural, neuromuscular, and functional efficiencies. Inadequate control of the muscles supporting upper trunk impedes effective load transfer to the upper limb, and the activity of shoulder girdle muscles such as the upper trapezius (UT) may be modified by changes in the length-tension relationship when spinal alignment is altered, which has been recognized as a possible cause of abnormal scapular motion (Ludewig and Cook, 2000).

Previous studies have found that either rehabilitative exercises and/or therapeutic aids, such as a compression belt, may be beneficial to reinforce trunk stability (Stuge et al., 2004; Lee, 2004). Clinicians have used a therapeutic belt to provide external trunk support with compression to individual spinal segments, which facilitates trunk stability by delivering biomechanical force potential (Takasaki et al., 2009). Commonly, clinical use represents clinical reasoning and decision making processes to manage a variety of musculoskeletal discomforts, demonstrating current concept with an emphasis on trunk stabilization in clinical setting. However, previous studies have not investigated various options for trunk stabilization, although this results in beneficial effects that promote the efficiency of upper and lower limb movements (Putnam, 1993); therefore, the present study aimed to determine the effects of augmented trunk stabilization with external compression support (ECS) on the electromyography (EMG) activity of shoulder and scapular muscles and shoulder abductor strength during isometric shoulder abduction.

2. Methods

2.1. Subjects

Twenty-six healthy women (age: mean [SD], 19.71 [1.4] years; weight: 53.00 [5.7] kg; height: 160.33 [4.45] cm) were recruited for the study. Inclusion criteria were as follows: (1) no orthopedic, neurological, cardiopulmonary, or psychological disease that could hinder shoulder abduction during standing, (2) no significant shoulder and scapular muscle weakness, and (3) no shoulder joint contracture. Pregnant women were excluded from the study. Prior to initiation of the study, a description of the entire experimental procedure and its safety was provided to the subjects. All the participants signed a written consent form. The study was approved by the university institutional review board.

2.2. Procedures

Isometric shoulder abduction was performed under three conditions: (1) no external support (condition-1), (2) pelvic support (condition-2), and (3) pelvic and thoracic supports (condition-3). The external support to augment trunk stability was provided by the active therapeutic movement version 2 (ATM2) (BackProject Corporation, San Jose, California), which consists of two adjustable pads (upper and lower pads) and four compression belts. Subjects stood contacting the pads on anterior chest with feet shoulder length apart. The pad height was adjusted for each subject. Isometric shoulder abduction during condition-1 was performed without any external support to increase trunk stability. For condition-2 and -3, a pelvic support was applied by fastening two belts across the posterior superior iliac spines and the greater trochanters. For condition-3, pelvic supports were used along with thoracic supports by fastening the belts across the T7 and T11 regions horizontally (Lewis et al., 2008) (Fig. 1). The belts were adequately fastened within a tolerable level for each subject. Subjects were asked to perform isometric shoulder abduction in each condition without any movement of the head and trunk.

2.3. Measurements

2.3.1. EMG recording and data processing

EMG data were obtained from the dominant side UT, lower trapezius (LT), lower serratus anterior (SA), and middle deltoid (MD) using an 8-channel portable system featuring a signal conditioner (Myosystem 1400A; Noraxon Inc., Scottsdale, AZ, USA). After shaving and scrubbing the skin with alcohol, disposable Ag/AgCl surface electrodes (15×15 mm Ag–AgCl, Seedtech Inc., Bucheon, Korea) were attached 2 cm apart to each muscle, based on ‘Surface EMG for Non-Invasive Assessment of Muscles (SENIAM)’ guidelines (Hermens et al., 2000).

UT electrodes were placed on an oblique line on the upper back halfway between the acromion process and spinous process of C7. LT electrodes were placed on an oblique angle outside the medial border of the scapula and 5 cm inferior to the scapular spine (Kibler et al., 2008). SA electrodes were placed just below the axillary region at the level of the scapular inferior angle (Kibler et al., 2008). MD electrodes were placed midway between the acromion process and deltoid tuberosity (Minning et al., 2007). A ground electrode was placed on the ipsilateral acromion process. Short, shield wires were used to attach electrodes to on-site preamplifiers.

The EMG data were recorded with a correction of DC bias, bandpass filtered from 20 to 450 Hz and 60 Hz by using notch filters with a correction of zero offset, and full-wave rectification; the data were then stored for further analysis. The overall gain for the EMG signal was set at 2000 with an input impedance of 100 kΩ. Sampling rate for the raw EMG signal was 1024 Hz and the common mode rejection ratio was 90 dB. Data were recorded

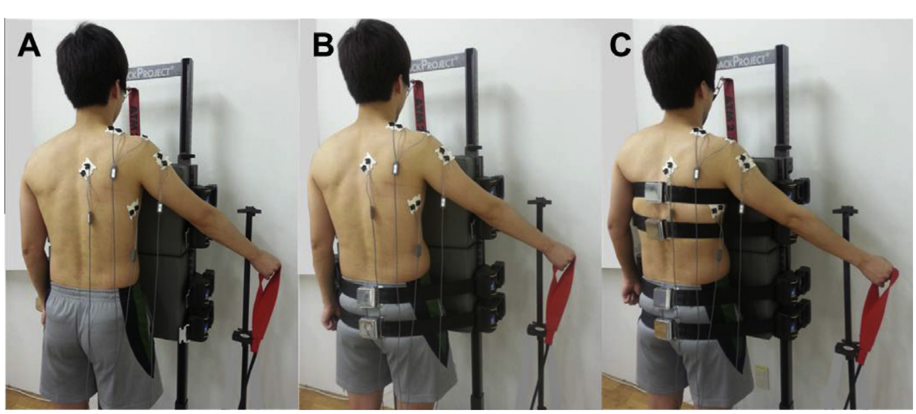

Fig. 1. Experimental procedure using the ATM2. (A) No external support (condition-1), (B) pelvic support (condition-2), and (C) pelvic and thoracic supports (condition-3).