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Trunk muscle activation during stabilization exercises with single and double leg support

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ABSTRACT

The aim of this study was to analyze trunk muscle activity during bridge style stabilization exercises, when combined with single and double leg support strategies. Twenty-nine healthy volunteers performed bridge exercises in 3 different positions (back, front and side bridges), with and without an elevated leg, and a quadruped exercise with contralateral arm and leg raise ("bird-dog"). Surface EMG was bilaterally recorded from rectus abdominis (RA), external and internal oblique (EO, IO), and erector spinae (ES). Back, front and side bridges primarily activated the ES (approximately 17% MVC), RA (approximately 30% MVC) and muscles required to support the lateral moment (mostly obliques), respectively. Compared with conventional bridge exercises, single leg support produced higher levels of trunk activation, predominantly in the oblique muscles. The bird-dog exercise produced greatest activity in IO on the side of the elevated arm and in the contralateral ES. In conclusion, during a common bridge with double leg support, the antigravity muscles were the most active. When performed with an elevated leg, however, rotation torques increased the activation of the trunk rotators, especially IO. This information may be useful for clinicians and rehabilitation specialists in determining appropriate exercise progression for the trunk stabilizers.

1. Introduction

Spine stabilization is dependent upon coordinated neural control of the passive and active trunk structures (Panjabi, 1992). In that the ligamentous spine is mechanically unstable under compressive loads as low as 90 N (Crisco and Panjabi, 1992; Lucas and Bresler, 1961), co-activation of the trunk musculature provides a stiffening mechanism to the vertebral joints, thus ensuring stability when the spine is exposed to higher loads (Cholewicki and McGill, 1996; Cholewicki et al., 1999; Gardner-Morse and Stokes, 1998, 2001; Vera-Garcia et al., 2006, 2007).

A variety of trunk stabilization exercises are broadly used to develop trunk co-activation patterns that promote spine stability (McGill, 2002). Many of these exercises consist of maintaining the spine in a "neutral" position with minimal associated trunk motion, while internal or external forces are applied using one of the following strategies: (a) holding the pelvis lifted off the floor in supine, prone or lateral positions, commonly known as "bridge" exercises (Bjerkefors et al., 2010; Ekstrom et al., 2007; Imai et al., 2010; Kavcic et al., 2004; Lehman et al., 2005; McGill and Karpowicz, 2009; Stevens et al., 2006); (b) executing different limb movements in quadruped or lying positions, frequently referred to as "bird-dog" or "dead-bug" exercises (Bjerkefors et al., 2010; Ekstrom et al., 2007, 2008; Kavcic et al., 2004; Hall et al., 2009; McGill and Karpowicz, 2009; Stevens et al., 2007a, 2007b); (c) using unstable surfaces (Imai et al., 2010; Lehman et al., 2005; Stevens et al., 2006; Vera-Garcia et al., 2000), oscillation poles, such as a Bodyblade® (Moreside et al., 2007; Sánchez-Zuriaga et al., 2009) or Propriomed® (Anders et al., 2008), or other devices; and (d) combining any of the above strategies.

Electromyographic and mechanical studies have shown that bridge and bird-dog exercises challenge the trunk musculature without applying large compressive forces to the lumbar spine (Axler and McGill, 1997; Kavcic et al., 2004). Bridge exercises performed in supine position ("back bridges"), prone position ("front or ventral bridges") and lateral position ("side bridges") mainly activate the trunk extensor muscles (Bjerkefors et al., 2010; Ekstrom et al., 2007; Imai et al., 2010; Kavcic et al., 2004; Lehman et al., 2005; Stevens et al., 2006), sagittal flexor muscles (Ekstrom et al., 2007; Imai et al., 2010; Lehman et al., 2005; McGill and Karpowicz, 2009) and lateral bend muscles (Ekstrom et al., 2007;

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Imai et al., 2010; Kavcic et al., 2004; Lehman et al., 2005; McGill and Karpowicz, 2009), respectively.

Despite the large number of electromyographic studies that have analyzed the trunk muscular response during conventional bridge exercises, the assessment of trunk muscle challenge during bridge exercises with single leg support strategies (i.e., bridges with one leg elevated) is lacking. To our knowledge, the effect of these strategies has only been studied for back bridge exercises (Bjerkefors et al., 2010; Ekstrom et al., 2007; Kavcic et al., 2004; Stevens et al., 2006, 2007a). On the basis of these studies, single leg support while bridging supposes a major challenge to the neuromuscular system and possibly higher loads on the spine (Kavcic et al., 2004). Further research is needed to clarify the effect of single leg support strategies during stabilization exercises, in order to provide guidance for rehabilitation specialists when determining progressive exercise protocols for the trunk musculature.

The purpose of this study was to analyze the trunk muscle activity during common stabilization exercises performed in bridging and quadruped positions, combined with single and double leg support strategies. The hypothesis of this study was that single leg support strategies will increase trunk muscular co-activation, especially in the oblique muscles, as they must counteract the rotation torque produced during unilateral limb elevations.

2. Methods

2.1. Participants

Twenty-nine asymptomatic subjects volunteered in this study: 18 men (age: 24.22 ± 5.23 years, mass: 72.28 ± 5.41 kg, height: 178.44 ± 4.34 cm) and 11 women (age: 22 ± 2.93 years, mass: 57.9 ± 6.55 kg, height: 166.36 ± 4.48 cm). All participants signed an informed consent document approved by the Ethics Committee of the University. Individuals with known medical problems, histories of spinal or abdominal surgery, or episodes of back, shoulder or hip pain requiring treatment 6 months prior to this study were excluded.

2.2. Instrumentation and data collection

During the recording session, subjects performed 4 common bridge exercises, 6 bridges performed with an elevated leg, and 2 bird-dog exercises:

Front bridge (FB in Fig. 1): The subject maintained the pelvis lifted off the bench in a prone position, resting on his/her elbows-forearms and toes, with the trunk fully aligned with the lower limbs. The arms were perpendicular to the bench and the palms of the hands joined. The feet were placed at the width of the hips.

Front bridge with elevated right or left leg (R FB and L FB in Fig. 1): The subject performed the front bridge position, while holding one leg elevated (hip extension). The toes of the elevated foot reached the height of the heel of the support leg. The exercise was randomly ordered with right or left leg lifted.

Back bridge (BB in Fig. 1): The subject maintained the pelvis lifted off the bench in a supine position, resting on his/her shoulders and feet, with the knees bent and the trunk fully aligned with the thighs. The feet were hips-width apart and the arms were extended at the sides of the trunk, palms facing down.

Back bridge with elevated right or left leg (R BB and L BB in Fig. 1): The subject performed the back bridge position while maintaining one leg lifted off the bench (knee extension). The exercise was randomly ordered with right or left leg lifted.

Right and left side bridge (R SB and L SB in Fig. 1): The subject maintained the pelvis lifted off the bench in a lateral position, resting on the elbow and lateral aspect of the foot of the lowermost side, and with the trunk fully aligned with the lower limbs. The arm of the lowermost side was perpendicular to the bench, and the uppermost arm rested along the side of the trunk. The exercise was randomly ordered on the right or left elbow.

Side bridge with hip flexion and hip extension (SB-F and SB-E in Fig. 1): The subject performed the right and left side bridge positions with both hip flexion (leg forward) and hip extension (leg backward) for the uppermost leg, maintaining the lowermost leg in line with the trunk. During the side bridge with hip flexion, the heel of the uppermost leg was aligned with the toes of the support foot. In the side bridge with hip extension, the toes of the uppermost leg were aligned with the support leg heel.

Bird-dog (Fig. 2): The subject maintained a quadruped position in a 2-point stance, with contralateral arm and leg elevated (parallel to the bench). The exercise was randomly performed with elevated right arm and left leg (BD R-L in Fig. 2) or with elevated left arm and right leg (BD L-R in Fig. 2).

Prior to data collection, participants were verbally and visually instructed by the researchers on correct exercise technique. Trials were then executed under the instruction that trunk motion was to be kept to a minimum, while maintaining the spine in a neutral position. During the electromyographic recording, subjects performed a single repetition of each isometric task with 5 s duration and a 1 min rest between exercises. Order of exercises was randomized between subjects.

Surface electromyographic (EMG) signals were collected on each subject using the *Muscle Tester ME6000*® (Mega Electronics Ltd., Kuopio, Finland). This is an eight-channel portable microcomputer with an 8-channel A/D conversion (14 bit resolution), a CMRR of 110 dB and a band-pass filter of 8–500 Hz. Sampling frequency was programmed at 1000 Hz. The EMG signals were transferred via an optical cable to a compatible computer where it was monitored by Megawin® 2.5 program (Mega Electronics Ltd., Kuopio, Finland).

The EMG signals were recorded bilaterally (R = right, L = left) in the following muscles and locations: rectus abdominis (RA), approximately 3 cm lateral to the umbilicus; external oblique (EO), approximately 15 cm lateral to the umbilicus; internal oblique (IO), the geometric center of the triangle formed by the inguinal ligament, the outer edge of the rectus sheath and the imaginary line joining the anterior superior iliac spine and the umbilicus (Ng et al., 1998; Urquhart, 2005); and erector spinae (ES), 3 cm lateral to the spinous process of L3. Skin zones for electrode placements were shaved and cleaned with an alcohol swab in order to reduce impedance. Pre-gelled disposable bipolar Ag–AgCl surface electrodes (Arbo Infant Electrodes, Tyco Healthcare, Germany) were positioned parallel to the muscle fibers with a center-to-center spacing of 3 cm.

Prior to the stabilization exercises, maximal voluntary isometric contractions (MVCs) against manual resistance were carried out to obtain reference values to normalize the EMG signals. For the abdominal muscles, the participant produced two sets of maximal isometric efforts in trunk flexion, right lateral bend, left lateral bend, right twist and left twist. For the ES, maximal isometric trunk extensions were performed in the *Biering-Sorensen* position. Maximal efforts were maintained during an isometric 3–4 s hold. In order to avoid muscular fatigue, 5 min rest was allowed between each MVC series. This MVC protocol has been described elsewhere in more detail (Vera-Garcia et al., 2010).

2.3. Data reduction and statistical analyses

After visual inspection to remove possible artifacts, raw EMG signals were full wave rectified, averaged every 0.01 s and normalized to maximum EMG values obtained during the MVCs. Mean activation levels from the center 3 s window of normalized EMG