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A neuromuscular strategy to prevent spinal torsion: Backward perturbation alters asymmetry of transversus abdominis muscle thickness into symmetry☆

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ABSTRACT

Symmetric co-contraction of the transversus abdominis (TrA) muscle is beneficial in terms of increasing trunk stability. The aim of this study was to investigate the symmetry of lateral abdominal muscle thickness during static and dynamic conditions. Fifteen male subjects (27.13 ± 5.51 years old) were instructed to sit on a chair and maintain upright posture. Every individual subject wore a jacket harness that could be backwardly attached to a 9-kg weight through a pulley system. An unexpected drop of the weight induced the transition from static to dynamic condition. The thickness of external oblique, internal oblique, and TrA muscles was measured with ultrasonography. Our results revealed more symmetry of TrA thickness during the dynamic condition (21% vs. 13%, $p = 0.019$) compared with the static. The symmetric muscle thickness of TrA during the dynamic condition is considered a result of more contraction on the non-dominant side. This phenomenon could be a possible strategy of deep abdominal muscles to prevent spinal torsion during sudden trunk perturbation.

1. Introduction

Recent biomechanical studies have suggested that transversely oriented muscles around the spine play a critical role in stabilization of the trunk [1,2]. In particular, co-activation of the lateral abdominal muscles such as transversus abdominis (TrA) and external oblique (EO) stabilizes the trunk against external perturbation [1]. These lateral abdominal muscles are classified into superficial and deep muscles depending on their locations and roles [3–5]. The deep muscle (e.g., TrA) is responsible for the maintenance of neutral curvature and stiffness of the lumbar spine, whereas the superficial muscle (e.g., EO) is dependent on the direction of external force and produces a greater magnitude of torque to maintain trunk stability [3,5]. Above all, the co-activation of TrA is critical for efficient muscular stabilization of the spine [6].

Asymmetrical co-activation of the lateral abdominal muscles, however, can potentially lead to negative consequences such as torsion of the intervertebral joints with high compression force. Previous studies have shown the asymmetry of abdominal muscle thickness between the left and right side with respect to the sagittal plane during various postural tasks [7–9]. When asymmetric activation occurs during trunk stabilization, an imbalance in the torque might occur. Consequently, repetitive imbalanced torque can induce pain, causing microtrauma-related inflammation in the tissue surrounding the facet joints or intervertebral discs [10,11]. Moreover, the high magnitude of external load on the trunk would increase the microtrauma caused by increased joint compression force [11]. Hence, it has been reported that asymmetric activation in trunk muscles can easily result in structural changes of muscle thickness along with low back pain [12,13]. Nevertheless, it is still not clear whether the contractile patterns of lateral abdominal muscles are symmetric or asymmetric during trunk stabilization.

Ultrasound imaging techniques have often been employed in previous studies for quantification of lateral abdominal muscle thickness [14–16]. It has been demonstrated that muscle thickness quantified through ultrasound imaging is closely correlated with the level of electromyographic activities [17]. Previous ultrasound imaging studies have shown little variation between left and right abdominal muscle thickness in the supine position [18]. However, since supine position involves relatively low muscular activities, it is hard to elucidate contraction patterns of abdominal muscles during dynamic movements [19]. The current study investigates the thickness characteristics of the lateral abdominal muscles during both static and dynamic conditions through unexpected backward pulling of the trunk.

☆ This experiment was performed at the Department of Physical Therapy, Korea University. The Ethics Committee of the University of Korea granted ethical approval for this study (KU-IRB-10-06-A-2).

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Previous studies have revealed that the muscle activation of TrA was different and independent of that of other abdominal muscles during backward trunk perturbation [18,20]. In addition, in an electromyographic study, the deep abdominal muscles showed symmetric activation during lifting task in contrast to global muscles [21]. The purpose of the present investigation was to study the symmetry of the TrA abdominal muscle during trunk stabilization. We hypothesized that the asymmetry of the left and right TrA muscle thickness, induced through an unexpected backward perturbation, decreases in the dynamic condition compared with the static condition because this symmetrical strategy would create more rotational stabilization and less of a chance for the backward force to create a force couple about the low back region.

2. Methods

2.1. Subjects

Fifteen healthy right-handed young males (age: 27.13 ± 5.51 years, body mass: 68.53 ± 6.42 kg, height: 174 ± 0.52 cm, BMI: 22.42 ± 1.45) participated in this study. Subjects with back pain, internal diseases, a surgical history, or neurologic abnormalities were excluded from the investigation. Written informed consent was obtained from all the subjects after the procedures of the study were explained to them. The experimental protocol was approved by Korea University Institutional Review Board.

2.2. Experimental setup

We selected the unexpected sudden perturbation method to identify the pattern of lateral abdominal muscles. The basic experimental setup was similar to the one designed in the previous study for investigation of spinal reflex motor control [22]. Subjects were asked to sit on the edge of a chair with their knees on a 30° incline position (see Fig. 1). A strap was tied around the pelvis to mechanically isolate the lower body from the upper body. To equalize the pressure of the strap on both hip bones, a single strap was anchored to the seat on both sides of the subject. The subjects wore a harness jacket with a ring attached near the position of the T9 and T10 vertebrae. The rings were connected to external loads of 9 kg through a pulley system with an electromagnet set at the opposite end.

The experimental measurements consisted of two parts. First, in the static condition, subjects maintained an upright sitting posture without any other forces pulling the upper body. Second, in the dynamic condition, subjects initially maintained the upright sitting posture with no force applied to the upper body. Then, a backward force was suddenly induced as soon as the electric current from the electric magnets was disconnected. The displacement of the weight was minimal. For both static and dynamic conditions, the subjects were asked to maintain the upright sitting posture. The trial was repeated thrice with a resting period of 2–3 min between each trial. The order of static and dynamic condition was balanced among the subjects.

2.3. Ultrasound imaging

Two brightness mode (B-mode) ultrasonography machines (Volusion I, GE Medical Systems, UK) were used to simultaneously capture images of EO, IO, and TrA muscles. The placement of the linear volume transducers (5.6–18.4 MHz, RSP6-16-RS, GE Medical Systems, UK), determined using a tape measure, was the midpoint between the anterior superior iliac spine and the lower border of the ribcage (Fig. 2), where the EO, IO, and TrA muscles lie at the same level [8]. The two machines, each with their own transducer, were attached to the left and right abdominal regions and used simultaneously. We identified whether the two transducers captured ultrasound images simultaneously using the progress time displayed on the computer monitors. The head of each transducer was adjusted to ensure their exact location for detecting muscle activity. Custom-made foam blocks were wrapped around the transducers to minimize their movement. Subsequently, the transducers were fixed to the abdomen using Velcro straps. The ultrasonography images were stored as 50 Hz video files and analyzed offline.

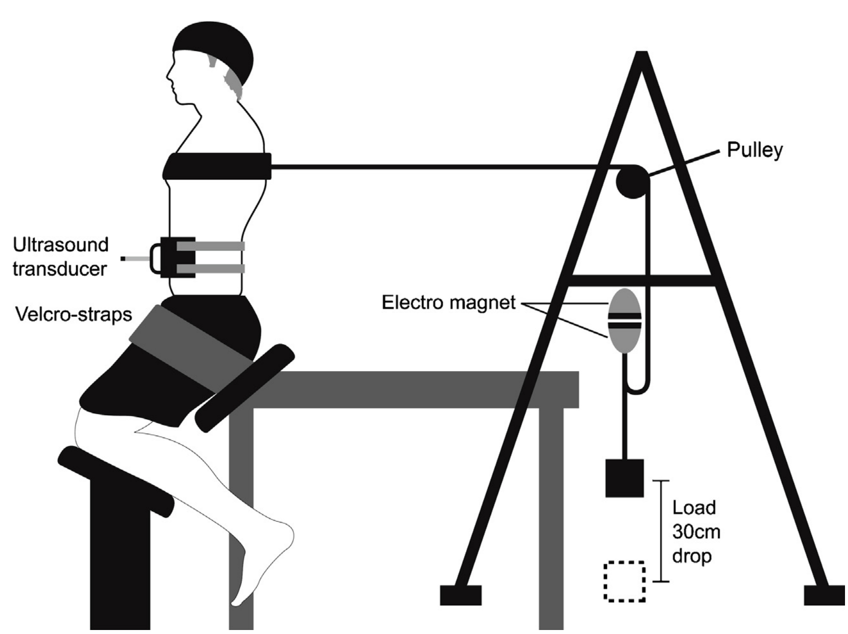

Fig. 1. Experimental setup. Subjects were seated with their knees on a 30° inclined wedge; a strap was used to fix the pelvis. A string holding an external load was connected in line with the 9–10th thoracic vertebrae. In the dynamic condition, the external load was suddenly dropped from a height of 30 cm toward the ground to induce unexpected trunk perturbation.