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Original Article

Abdominal muscle activity during abdominal hollowing in four starting positions

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ABSTRACT

The aim of this study was to investigate the activity of the rectus abdominis (RA), external abdominal oblique (EO), and transversus abdominis/internal abdominal oblique (TrA/IO) muscles during abdominal hollowing (AH) in four positions: crook lying, prone lying, four-point kneeling, and wall support standing. Thirty-two healthy participants, aged 21.3 ± 0.8 years were recruited. They were instructed to perform maximal voluntary contraction (MVC) and AH. The electromyography (EMG) data of each muscle during AH were normalized as a percentage of MVC. During AH in all four starting positions, significant differences were found in the EMG activity of RA, EO, and TrA/IO ($p < 0.001$). The TrA/IO exhibited the highest while the RA exhibited the lowest EMG activity. Among the four different starting positions, only the TrA/IO showed significant difference in mean EMG activity ($p < 0.001$). The results suggest that all four starting positions can facilitate TrA/IO activity with minimal activity from RA and EO.

1. Introduction

Low back pain (LBP) is a common problem that occurs in the general population. One year prevalence of LBP has been reported to range from 40.5 percent to 64 percent (Barrero et al., 2006; Ihlebaek et al., 2006). It has been found that approximately 60–80 percent of the population report LBP once in their life time (Manchikanti, 2000; Ihlebaek et al., 2006). One hypothesis for the development of LBP is that there is a dysfunction in the control of the abdominal and back muscles (Panjabi, 1992; Richardson and Jull, 1995; O'Sullivan et al., 1997; Hides et al., 2001). Specific exercises that aim to train these trunk muscles to function properly are, thus, a contemporary approach for treating LBP. Abdominal hollowing (AH) is one of these exercises that is widely used in patients suffering from LBP (O'Sullivan et al., 1997; Hides et al., 2001; Rasmussen-Barr et al., 2003; Shaughnessy and Caulfield, 2004; Goldby et al., 2006).

To learn how to perform AH, it is recommended that a patient with LBP should start practising AH in a position that facilitates the co-contraction of the deep abdominal and back muscles. When the patient can master AH, the starting position can be changed. The muscles that should be activated during AH are the transversus abdominis (TrA), the internal abdominal oblique (IO) (lower fibres), and the lumbar multifidus (deep fibres) which have been proposed to function synergistically (Richardson et al., 2004). To be effective, co-contraction of these deep trunk muscles should occur in isolation from the rectus abdominis (RA) and the external abdominal oblique (EO) which lie superficially. Empirically, four positions have been suggested by clinicians as the starting positions for performing AH. These positions are crook lying (O'Sullivan, 2000), prone lying (Richardson and Jull, 1995; O'Sullivan, 2000), four-point kneeling (Richardson and Jull, 1995; Norris, 1999; O'Sullivan, 2000), and wall support standing (Norris, 1999).

To date, there have been only two studies that have compared the effectiveness of the starting positions for performing AH (Beith et al., 2001; Urquhart et al., 2005). Beith et al. (2001) compared the prone lying to the four-point kneeling position and found no statistical difference in the activity of IO between positions. However, an isolated activation of IO tended to occur more easily in the four-point kneeling position than in prone lying position. Urquhart et al. (2005) compared crook lying with prone lying positions. They found that crook lying could encourage the TrA to work in isolation better than the prone lying position.

The aims of this study were to determine 1) whether there was any significant difference in electromyography (EMG) activity among the three abdominal muscles in each of the four starting positions (crook lying, prone lying, four-point kneeling, and wall support standing); 2) whether there was any significant difference in the EMG activity of each muscle among the four different starting positions; and 3) whether there was any difference in the frequency of non-activation and isolation of three abdominal muscles among the four starting positions.

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2. Methods

2.1. Participants

A convenience sample of 32 asymptomatic LBP (14 male, 18 female) took part in this study. Their mean ± standard deviation of age was 21.3 ± 0.8 years, their weight 50.2 ± 8.2 kg, their height 1.64 ± 0.08 m, and their body mass index was 18.6 ± 1.8 kg/m^2. The participants were recruited from the students and staff of the Faculty of Allied Health Sciences at the Chulalongkorn University. Participant recruitment commenced in September 2005 and continued until January 2006. They were excluded if they had a history of LBP, practised AH, or any abnormalities of the spinal column or abdominal region such as fractures, surgery, burns, or cancer. Moreover, participants with a skinfold thickness in the abdominal and supra-iliac area greater than 20 mm were also excluded. This aimed to decrease the EMG artifact due to adipose tissue lying between the surface electrodes and the tested muscles (Neumann and Gill, 2002). All the participants had thin skinfold (abdominal skinfold thickness was 16 ± 4 mm and supra-iliac skinfold thickness was 9 ± 3 mm). Ethical approval for the study was granted by the Research Ethics Committee, Chulalongkorn University, Thailand.

2.2. Procedure

Participants gave written informed consent prior to participation in the study. Initially, all participants were trained to perform AH in four positions. The standard protocol suggested by Richardson and Jull (1995) as described below was practised until they were able to correctly perform the AH. After the training session, only the participants who could perform AH correctly continued with the study. Then, they were instructed to perform maximal voluntary contraction (MVC) and AH. The order of the position was randomly assigned using a 4 × 4 balanced Latin square (Portney and Watkins, 2000). All participants were tested in the afternoon.

2.2.1. Maximal voluntary contraction

All participants were asked to perform three manoeuvres which were expected to generate maximal EMG activity for each of the three abdominal muscles. These manoeuvres were trunk flexion, trunk flexion with rotation to the left, and trunk flexion with rotation to the right. Each manoeuvre was performed against manual resistance once in crook lying and then in sitting (Beith et al., 2001). During the performances, the participants were instructed to avoid any jerky contractions in order to decrease the chance of injury. Each manoeuvre was held for 5 s with a 2-min rest between trials to prevent muscle fatigue (Ng et al., 2002). For each muscle, the greater EMG that was produced either in the crook lying or sitting position was chosen as a reference value for normalization.

2.2.2. Abdominal hollowing

All participants were required to perform AH for 10 s, three times in each position, with a 1-min rest between each time. For the crook lying position, the knees were flexed at 90° (Drysdale et al., 2004). For the prone lying position, a small pillow was placed under the ankles (Richardson and Jull, 1995). For the four-point kneeling position, the participants were asked to look at the floor with their ears in horizontal line to the shoulder joints, their knees directly below their hips and their wrists directly below the shoulders (Norris, 1999). A small pillow was placed under their ankles (Richardson and Jull, 1995). For the wall support standing position, participants were asked to stand with their backs against the wall while their hips were slightly flexed and their knees were extended. The distance from the wall to their heels was 6 inches (Norris, 1995).

Briefly, the AH was performed by gently pulling the navel in and up while not allowing any movement at the spine, rib, or pelvis (Norris, 1995; Richardson and Jull, 1995; O'Sullivan, 2000). After the navel has been drawn close to the spine, the participants were instructed to hold the abdominal contraction for 10 s while continually breathing normally. This aimed to activate the TrA at a low level of muscle contraction which should be approximately 25 percent of its MVC (Richardson and Jull, 1995). The lumbar spine was kept in a neutral position such that the anterior superior iliac spine and posterior superior iliac spine were aligned vertically (Richardson et al., 2004). The duration of training for each participant varied from 10 to 40 min.

2.3. Measurement

EMG recordings were made using silver/silver chloride surface electrodes of 1 cm in diameter which were placed with a centre-to-centre spacing of 2.2 cm (Ng et al., 1998). The three channels method was used in which a reference electrode for each muscle was placed adjacent to the paired electrodes of that muscle. All abdominal muscles were recorded on the right side by positioning the surface electrodes in parallel to the muscle fibres (Fig. 1).

All EMG placements followed those recommended by Ng et al. (1998). For the RA, the electrodes were placed in a cephalad/caudad orientation at 2 cm inferior to the navel and 1 cm lateral to the midline. For the EO, the electrodes were placed diagonally on the inferior edge along a line connecting the most inferior point of the costal margin and the contralateral pubic tubercle. For the TrA and IO, the electrodes were placed in the area where the TrA and IO fuse together and this was called TrA/IO. The TrA/IO electrodes were placed horizontally at 2 cm inferior and medial to the anterior superior iliac spine (Marshall and Murphy, 2003). EMG were sampled at 1000 Hz over a bandwidth of 8–500 Hz using the ME3000P8 EMG system® (Mega Electronics Ltd, Kuopio, Finland):

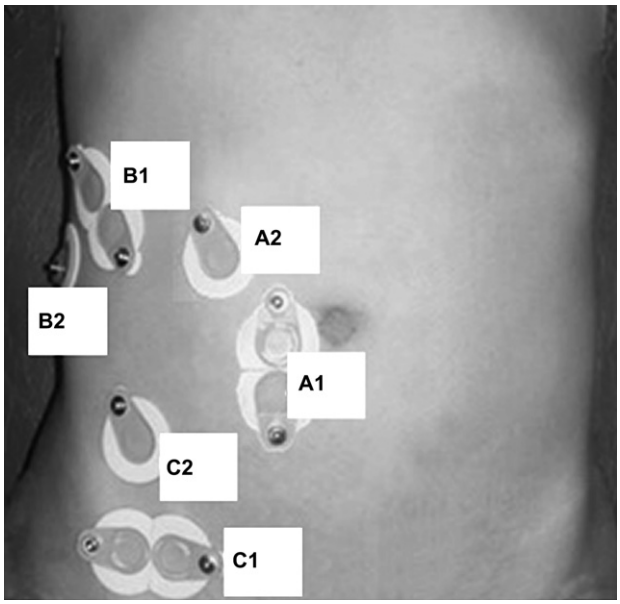

Fig. 1. Location for attaching surface electrodes to the abdominal wall. (A1 = Paired electrode of the rectus abdominis muscle, A2 = Reference electrode of the rectus abdominis muscle, B1 = Paired electrode of the external abdominal oblique, B2 = Reference electrode of the external abdominal oblique, C1 = Paired electrode of the transversus abdominis/internal abdominal oblique, and C2 = Reference electrode of the transversus abdominis/internal abdominal oblique).