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Original article

Abdominal muscle recruitment during a range of voluntary exercises

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Abstract

Various exercises are used to retrain the abdominal muscles in the management of low back pain and other musculoskeletal disorders. However, few studies have directly investigated the activity of all the abdominal muscles or the recruitment of regions of the abdominal muscles during these manoeuvres. This study examined the activity of different regions of transversus abdominis (TrA), obliquus internus (OI) and externus abdominis (OE), and rectus abdominis (RA), and movement of the lumbar spine, pelvis and abdomen during inward movement of the lower abdominal wall, abdominal bracing, pelvic tilting, and inward movement of the lower and upper abdominal wall. Inward movement of the lower abdominal wall in supine produced greater activity of TrA compared to OI, OE and RA. During posterior pelvic tilting, middle OI was most active and with abdominal bracing, OE was predominately recruited. Regions of TrA were recruited differentially and an inverse relationship between lumbopelvic motion and TrA electromyography (EMG) was found. This study indicates that inward movement of the lower abdominal wall in supine produces the most independent activity of TrA relative to the other abdominal muscles, recruitment varies between regions of TrA, and observation of abdominal and lumbopelvic motion may assist in evaluation of exercise performance.

Keywords: Exercises; Abdominal muscles; Transversus abdominis; Low back pain

1. Introduction

A diverse range of exercises is used clinically to retrain the trunk muscles. However, recruitment of the abdominal muscles during exercises that aim to restore motor control have not been clearly defined. Most studies have used surface electromyography (EMG) to investigate these techniques (Partridge and Walters, 1960; Kennedy, 1980; Richardson et al., 1990; Jull et al., 1995; Allison et al., 1998; O'Sullivan et al., 1998; Vezina and Hubley-Kozey, 2000) and the results of the small number of intramuscular EMG studies are inconclusive (Carman et al., 1972; Strohl et al., 1981; Goldman et al., 1987; De Troyer et al., 1990). For example, three different recruitment patterns were reported when six subjects were instructed to "pull in" their abdominal wall (De Troyer et al., 1990).

A contemporary approach for low back pain (LBP) involves recruitment of transversus abdominis (TrA) with minimal activity of the superficial abdominal muscles in the early stages of rehabilitation. This approach is based on evidence that activity of TrA contributes to spinal control (Cresswell et al., 1992; Hodges et al., 1999) and dysfunction of this muscle occurs in people with LBP (Hodges and Richardson, 1996b, 1998; Hodges, 2001). Although recruitment of TrA is emphasized initially, all of the trunk muscles are considered to be important for the restoration of normal function and progression involves strategies for

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re-education of the whole muscle system (Richardson et al., 1999). The efficacy of this method has been established in randomized control trials with acute and chronic LBP patients (Hides et al., 1996; O'Sullivan et al., 1997b,c). The technique involves inward movement of the lower abdominal wall without movement of the spine or pelvis (Richardson et al., 1999). Surface EMG studies indicate that activity of the superficial abdominal muscles is minimal during this manoeuvre (Jull et al., 1995), and indirect measurements of TrA activity with a pressure cuff under the abdomen to indicate movement of the abdominal wall, are related to direct EMG measures of TrA motor control (Hodges et al., 1996a). However, no study has directly investigated TrA activity during this, or other exercise approaches.

Other exercise strategies have also been argued to be beneficial in LBP management. Abdominal bracing (lateral flaring of the abdominal wall) (Kennedy, 1980) and posterior pelvic tilting have been proposed to improve lumbopelvic control by elevation of intra-abdominal pressure and by reduction of the lumbar lordosis, respectively (Kennedy, 1980; Vezina and Hubley-Kozey, 2000). However, there is controversy regarding the specific patterns of abdominal muscle recruitment during these exercises. A recent review concluded that muscle activation patterns during pelvic tilting are not clearly defined in people with or without LBP (Vezina et al., 1998).

An additional consideration is that there are differences in the morphology and recruitment of regions of TrA and obliquus internus abdominis (OI) (Askar, 1977; Rizk, 1980; Hodges et al., 1999; Urquhart et al., 2001, 2004). Upper fascicles of TrA that attach to the rib cage are horizontal, and middle and lower fascicles that fuse with the thoracolumbar fascia and the iliac crest are inferomedial (Urquhart et al., 2001). Fibres of upper TrA are also active with the opposite direction of trunk rotation to lower and middle fibres (Urquhart et al., 2004), and activity of lower and upper fibres of OI vary during posterior pelvic tilting (Carman et al., 1972). Although these reports suggest regional differences in activity of the abdominal muscles, their recruitment has not been comprehensively investigated during voluntary exercises. The aims of this study were to investigate recruitment of regions of the abdominal muscles during exercises used in LBP management, and to determine if common clinical techniques, such as observation of abdominal, spinal and pelvic motion, assist differentiation of patterns of abdominal muscle recruitment.

2. Methods

2.1. Subjects

Seven subjects (4 male, 3 female), with a mean (SD) age, height, and weight of 30(4) years, 174(9) cm, and 68(15) kg, participated in the study. Subjects were excluded if they had a history of low back or leg pain that affected function in the preceding 2 years, or any abdominal, gastrointestinal, neurological or respiratory condition. All subjects had an 'average' activity level, as determined by the habitual physical activity questionnaire (Baecke et al., 1982). Five subjects had performed the exercises previously and all subjects were involved in another study (Urquhart et al., 2004). All procedures were approved by the institutional research ethics committee and conducted in accordance with the declaration of Helsinki.

2.2. Electromyography

Recordings of EMG were made using bipolar fine-wire electrodes inserted into three regions of the abdominal wall under the guidance of real-time ultrasound imaging (5 MHz curved array transducer) (128XP/4, Acuson, Mountain View, CA). Electrodes were fabricated from two strands of Teflon-coated stainless steel wire (75 μm) (A-M Systems Inc., Everett, Washington, USA), with 1 mm of Teflon removed from the ends. The electrodes were threaded into a hypodermic needle (0.70×38 mm) and the tips bent back 1–2 mm to form hooks. Electrodes were inserted into the upper region of TrA (adjacent to the 8th rib), the middle region of TrA, OI and obliquus externus abdominis (OE) (midway between the iliac crest and inferior border of the rib cage), and the lower region of TrA and OI (adjacent to the anterior superior iliac spine (ASIS)) (De Troyer et al., 1990; Cresswell et al., 1992; Hodges and Richardson, 1997; Urquhart et al., 2004). Pairs of surface EMG electrodes (Ag/AgCl discs, 1 cm diameter and 2 cm inter-electrode distance) were placed over rectus abdominis (RA), halfway between the umbilicus and the pubic symphysis. A ground electrode was placed on the iliac crest. EMG data were bandpass filtered between 50 Hz and 1 kHz and sampled at 2 kHz using a Power1401 data acquisition system and Spike2 software (Cambridge Electronic Design, Cambridge, UK). The data was exported and analysed using Matlab 6 (release 12; MathWorks, Natick, MA, USA).

2.3. Video motion analysis

A video motion analysis system was used to quantify displacement of the upper, middle and lower regions of the abdominal wall and movement of the lumbar spine and pelvis in prone. Data were captured with a digital video camera (Sony DCR TRV20, Tokyo, Japan), positioned 2 m away and perpendicular to the subject. A diffuse light source, placed under the subject's abdomen, and a black background were used to highlight the edge of the abdominal wall in the video image (Fig. 1). A marker was placed on the spinous