

## Regional morphology of the transversus abdominis and obliquus internus and externus abdominis muscles

Donna M Urquhart<sup>a,\*</sup>, Priscilla J Barker<sup>b</sup>, Paul W Hodges<sup>c,d</sup>,  
Ian H Story<sup>a</sup>, Christopher A Briggs<sup>b</sup>

<sup>a</sup> School of Physiotherapy, The University of Melbourne, Victoria 3010, Australia

<sup>b</sup> Department of Anatomy and Cell Biology, The University of Melbourne, Victoria 3010, Australia

<sup>c</sup> Prince of Wales Medical Research Institute, New South Wales 2031, Australia

<sup>d</sup> Division of Physiotherapy, The University of Queensland, Queensland 4072, Australia

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### Abstract

**Background.** The mechanisms by which the abdominal muscles move and control the lumbosacral spine are not clearly understood. Descriptions of abdominal morphology are also conflicting and the regional anatomy of these muscles has not been comprehensively examined. The aim of this study was to investigate the morphology of regions of transversus abdominis and obliquus internus and externus abdominis.

**Methods.** Anterior and posterolateral abdominal walls were dissected bilaterally in 26 embalmed human cadavers. The orientation, thickness and length of the upper, middle and lower fascicles of transversus abdominis and obliquus internus abdominis, and the upper and middle fascicles of obliquus externus abdominis were measured.

**Findings.** Differences in fascicle orientation, thickness and length were documented between the abdominal muscles and between regions of each muscle. The fascicles of transversus abdominis were horizontal in the upper region, with increasing inferomedial orientation in the middle and lower regions. The upper and middle fascicles of obliquus internus abdominis were oriented superomedially and the lower fascicles inferomedially. The mean vertical dimension of transversus abdominis that attaches to the lumbar spine via the thoracolumbar fascia was 5.2 (SD 2.1) cm. Intramuscular septa were observed between regions of transversus abdominis, and obliquus internus abdominis could be separated into two distinct layers in the lower and middle regions.

**Interpretation.** This study provides quantitative data of morphological differences between regions of the abdominal muscles, which suggest variation in function between muscle regions. Precise understanding of abdominal muscle anatomy is required for incorporation of these muscles into biomechanical models. Furthermore, regional variation in their morphology may reflect differences in function.

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### 1. Introduction

There is increasing evidence to indicate the importance of the anterolateral abdominal muscles in control and movement of the lumbar spine and pelvis (Cholewicki et al., 1999; Cresswell et al., 1992; Hodges and Gandevia, 2000). However, few studies have

\* Corresponding author. Address: Department of Epidemiology and Preventive Medicine, Central and Eastern Clinical School, Monash University, Alfred Hospital, Commercial Road, Melbourne 3004, Vic., Australia.

E-mail address: [donna.urquhart@med.monash.edu.au](mailto:donna.urquhart@med.monash.edu.au) (D.M Urquhart).

comprehensively investigated the morphology of these muscles. Transversus abdominis (TrA), obliquus internus abdominis (OI) and obliquus externus abdominis (OE) have a number of primary fibro-osseous attachments that include the costal cartilages, the lumbar spine via the thoracolumbar fascia (TLF), and the iliac crest and pubis (Williams et al., 1999). It is hypothesised that the muscle fascicles originating from these different structures may have different functions. For example, the upper fascicles of TrA arising from the costal cartilages may stabilise the rib cage, the middle fascicles attaching to the TLF may contribute to control of the lumbar spine, and the lower fascicles arising from the iliac crest may support the abdominal contents and generate forces that compress the sacroiliac joints (Richardson et al., 2002 and Snijders et al., 1995).

Recent evidence from electromyographic (EMG) studies suggests there is regional variation in abdominal muscle function. During upper limb movements, greater tonic activity of the lower region of TrA was reported compared to middle region (Hodges et al., 1999). The superficial abdominal muscles of the lower abdominal wall were also more active in erect standing than those of the upper abdominal wall (Strohl et al., 1981). Furthermore, differences in the recruitment of regions of OI and OE have been documented during trunk extension and rotation (Davis and Mirka, 2000; Mirka et al., 1997).

While these studies provide preliminary evidence of regional differences in function, investigation of regional morphology is critical for evaluation of the mechanical effect of each region on the lumbar spine, pelvis and rib cage. Although one study has described the fascicle orientation of regions of TrA, OI and OE (Askar, 1977), there has been no detailed, quantitative investigation of regional morphology of the abdominal muscles. The aims of this study were to compare the morphology (fascicle orientation, thickness and length) of the abdominal muscles and regions of these muscles.

## 2. Methods

Twenty-six human cadavers, embalmed in a solution of 4% formaldehyde, were serially dissected to investigate the morphology of TrA, OI and OE. Twenty-four sides of 12 specimens (6 female, 6 male, mean age: 84 (73–95) years) were dissected to investigate the anterior abdominal wall, and 28 sides of 14 specimens (6 female, 8 male, mean age: 83 (60–96) years) to expose the inner aspect of the posterolateral wall. A midline incision was made from the xiphoid process to the pubic symphysis, and OE, OI and TrA were separated and reflected. The abdominal viscera and overlying fascia were subsequently removed to reveal the posterolateral wall.

### 2.1. Regional anthropometric measures

Anthropometric measures were documented to define regions of the abdominal wall and to determine the extent to which TrA attaches to the costal cartilages (upper region), TLF (middle region) and the pelvis (lower region) (Fig. 1). The upper region was measured with a tape measure (accuracy  $\pm 0.1$  cm) from the 6th costal cartilage or the superior border of the T9 vertebral body to the inferior border of the rib cage. The T9 vertebral body is in close alignment to the notch of the 6th costal cartilage (Snell, 2000) and was selected in specimens where parts of the rib cage had been previously removed. The middle region was defined as the distance between the inferior border of the rib cage and a line connecting the superior borders of the iliac crest, and the lower region was measured from this line to the pubic symphysis.

### 2.2. Fascicle orientation

The orientation of fascicles of TrA, OI and OE was examined in the anteriorly dissected specimens with reference to a line connecting the left and right anterior superior iliac spines (ASIS). Fascicles parallel to this reference line were considered to be horizontal. The upper, middle and lower regional measures of TrA and OI were documented bilaterally at the level of the 11th costal cartilage, halfway between the iliac crest and rib cage, and adjacent to the ASIS. Additional orientation measures were reported for TrA, 2 cm below the ASIS, and for OI, halfway between the ASIS and pubic symphysis. The fascicle orientation of OE was calculated at the level of the 8th costal cartilage (upper region) and halfway between the iliac crest and the rib cage (middle region). The fascicles of OE did not extend below the ASIS and therefore no measurements for a lower region of

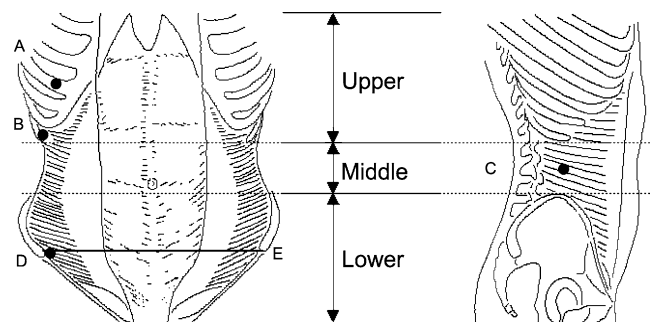


Fig. 1. Anterior and lateral view of the upper, middle and lower regions of the abdominal wall. Horizontal lines show the borders of the regions. Key landmarks for the measurement of muscle length and fascicle orientation are indicated by A (8th costal cartilage), B (11th costal cartilage), C (halfway between the iliac crest and rib cage), D (ASIS) and E (a line connecting the left and right ASIS). Note the different fibro-osseous attachments for each region of TrA; the costal cartilages in the upper region, the TLF in the middle region, and the pelvis in the lower region.

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