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Original research

Morphology of the abdominal muscles in ballet dancers with and without low back pain: A magnetic resonance imaging study☆

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ABSTRACT

Objectives: To evaluate the morphology of transversus abdominis and obliquus internus abdominis muscles and the ability to "draw in" the abdominal wall, in professional ballet dancers without low back pain, with low back pain or both hip region and low back pain.
Design: Observational study.
Methods: Magnetic resonance images of 31 dancers were taken at rest and during voluntary abdominal muscle contraction. Measurements included the thickness of transversus abdominis and obliquus internus abdominis muscles, lateral slide of the anterior extent of the transversus abdominis muscles (transversus abdominis slide) and reduction in total cross sectional area of the trunk.
Results: The transversus abdominis and obliquus internus abdominis muscles were thicker in male dancers and the right side was thicker than the left in both genders. There was no difference in muscle thickness as a proportion of the total thickness, between dancers with and without pain, although there was a trend for female dancers with low back pain only to have a smaller change in transversus abdominis muscle thickness with contraction than those without pain. Transversus abdominis slide was less in female dancers than in male dancers. When gender was ignored, the extent of transversus abdominis slide was less in dancers with low back pain only. Reduction in trunk cross sectional area with contraction was not different between genders or groups.
Conclusions: This study provides evidence that the abdominal muscles (transversus abdominis and obliquus internus abdominis) are asymmetrical in dancers and although the abdominal muscles are not different in structure (resting thickness) in dancers with LBP, there is preliminary evidence for the behavioural change of reduced slide of transversus abdominis during the 'draw in' of the abdominal wall.

1. Introduction

Despite the effortless grace of classical ballet there is a high prevalence and incidence of low back pain (LBP).[1] The spine is the most common site of chronic pain in professional dancers with the majority of injuries occurring in the lumbar region.[2] Abdominal muscle weakness has been cited as a contributing factor to LBP in professional dancers.[3] However in dancers, peak trunk flexion torque is not correlated with LBP[4] and the association between abdominal endurance and LBP in athletes (including dancers) is weak.[5] Abdominal muscle strength is also a poor predictor of risk for development of LBP in athletes.[6] In contrast, morphology and behaviour of the abdominal muscles has been suggested to have a more consistent relationship to LBP.

In non-dancers with LBP, altered motor control of abdominal muscles has been observed.[7,8] Electromyography (EMG) recordings have demonstrated delayed activation[7] and reduced amplitude of activity in transversus abdominis (TrA) muscles in people with LBP.[9] Consistent with EMG changes, a smaller increase in TrA muscle thickness with contraction has also been observed with ultrasound imaging.[9]

Delayed and reduced activation of the TrA muscle may compromise spinal control.[7,10] The TrA muscle contributes to spinal control via its attachment to the thoracolumbar fascia,[11] and by modulation of intra-abdominal pressure.[12] Changes in cross-sectional area (CSA) of the trunk, observed with ultrasound and magnetic resonance imaging (MRI) during the voluntary task of "drawing-in" the abdominal wall has been used as a clinical muscle test of

☆ Magnetic resonance images were made at the UQ/Wesley Centre for Advanced Imaging.

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the TrA muscle.[13] During this manoeuvre, as the muscle bellies of TrA thicken and shorten, there is an associated lateral slide of the anterior extent of the TrA muscle (TrA muscle slide) and reduced trunk CSA.[14] These actions are consistent with descriptions of TrA muscle function from anatomical studies.[11] Less TrA muscle slide and smaller reduction in trunk CSA have been observed in people with LBP than those without LBP.[15] Reduced ability to decrease the CSA of the trunk by "drawing-in" the abdominal wall has also been observed in elite cricketers and footballers with LBP.[16,17] These parameters have been argued to primarily reflect TrA activation.

Studies of trunk muscle geometry have reported symmetry of the abdominal muscles between sides in participants without LBP,[18,19] irrespective of hand dominance or gender.[18] Bilateral contraction is argued to have a greater affect on spine control than unilateral contraction.[12] Asymmetry of the TrA muscle slide has been observed in cricketers with LBP.[16] Cricketers also had larger resting thickness of the OI muscle on the side of the non-dominant hand and there was a non-significant tendency for greater OI muscle thickness in those with LBP than those without LBP.[16]

Maintenance of an aesthetically symmetrical body structure and equal ability to perform tasks on either leg and to either side is a key objective in ballet.[20] The symmetrical emphasis of classical ballet would be predicted to encourage symmetrical abdominal muscle development in dancers, although an asymmetrical bias in teaching[21] and some specific dance tasks[22] has been observed. As changes in muscle morphology, symmetry and behaviour are related to LBP in non-dancers it is possible that dancers with LBP could also have changes in these trunk muscle parameters.

This study aimed to investigate, in professional ballet dancers, the size and symmetry of the TrA and OI muscles and the lateral slide of the anterior extent of the TrA muscle, changes in thickness of TrA and OI muscles, and trunk CSA with voluntary contraction of the abdominal muscles. A second aim was to compare these parameters between dancers with and without LBP.

2. Methods

Seventeen female dancers aged 23(3) years, weighing 51(4) kg with heights of 165(4) cm; and 14 male dancers aged 24(4) years, weighing 74(6) kg, with heights of 183(5) cm volunteered from 49 dancers on tour for The Australian Ballet production of Giselle in Brisbane, Australia. All dancers, including corps de ballet to principals were on full workloads. The majority of the dancers nominated that they were right hand (94%) and right leg (97%) dominant. Demographic data, hypermobility scores,[23] site and degree of spinal curvature[24] and functional lower leg turnout[25] were collected by an experienced physiotherapist. Dancers completed a general health and injury questionnaire (which included a body chart), the International Physical Activity Questionnaire long form[26] and a laterality profile.[22] All dancers who completed the physical activity questionnaire ($n = 27$) scored in the 'high' physical activity category.[26] Dancers were excluded if they had LBP of non-musculoskeletal aetiology, neurological or respiratory disorders, a history of spinal surgery, or contraindications to MRI (magnetic resonance imaging). One dancer was excluded due to pregnancy. The number of participants in the study was determined by availability rather than by a power analysis.

LBP was investigated several ways. Dancers who indicated on the body chart that they had pain in the region of the lower back, pelvis or hip completed a detailed questionnaire. Presentation was discussed with the physiotherapy team who provided ongoing care for the dancers, to determine whether, based on comprehensive physical assessment, pain was reproduced by provocation of the low back only or structures other than the low back i.e. the hip or pelvis. As 10 dancers were reported to have hip region pain in addition to LBP, and there were no cases of hip region pain without LBP, dancers were divided into three groups for comparison; no history of hip region or LBP ($n = 8$); history of or current LBP ($n = 13$); history of or current hip region and LBP ($n = 10$). Severity of pain in both the low back and hip regions was measured using a 10 cm Visual Analogue Scale (VAS). Participants with LBP also completed a Roland-Morris Disability questionnaire and Oswestry Disability questionnaire. Except for pain, there was no difference in demographic data among groups (ANOVA).

The Institutional Medical Research Ethics Committee approved the study. Participants gave informed consent and the study was undertaken in accordance with the Declaration of Helsinki.

After a medical practitioner had screened the participants for MRI contraindications they were positioned in supine with the hips and knees resting in slight flexion on a foam wedge. Measures were made at rest and during abdominal muscle contraction. Dancers were instructed to gently "draw-in" the abdominal wall without moving the spine and without breathing. Dancers were familiar with this manoeuvre from their dance training. Images were taken at rest and after completion of the contraction (which was cued by the operator) with the subject holding the breath at mid expiration. Images were made using a Siemens Sonata MR system (1.5 T) with true fast imaging and a steady-state precession (TrueFISP) sequence of 14 mm × 7 mm contiguous slices centred on the L3-4 disc. MRI images were saved for later analysis and de-identified prior to measurement.

Measurements were made from the MRI images using Image J (version 1.42q, http://rsb.info.nih.gov/ij) (Fig. 1). In all measurements the cursor was placed at the inside edge of the fascia. Measures were: thickness of the TrA and OI muscles on the right and left sides at the muscle's widest point at rest and at the same location during contraction; the CSA of the entire trunk excluding skin and subcutaneous fat at rest and during contraction; and the lateral slide of the anterior extent (defined as the point at which the muscle attaches to the anterior fascia) of the TrA muscle with contraction, on both sides. Repeatability and reliability of measurements of trunk CSA from MRI scans have been reported.[17]

STATISTICA, Version 9 (StatSoft Pacific Pty Ltd.) was used for data analysis. Preliminary analysis was conducted to reduce the large range of potential variables. The mix of participants with unilateral and bilateral pain precluded investigation of the side of pain in the analysis. This decision was validated by the absence of main effect for side of back or hip region pain on the muscle parameters. Age, height, hypermobility score, range of 'functional turnout', years of dance training, years of professional dancing, leg length difference and site and degrees of spinal curvature were eliminated from the analysis as they did not influence muscle thickness, trunk CSA or TrA muscle slide in a preliminary ANCOVA (all: $p > 0.05$). As all the dancers were of slim build, height provided the main variance across participants so weight and body mass index were not included in the analysis.

For the analysis of change in muscle thickness with contraction, ANCOVAs using a general linear model were undertaken separately to compare the proportional change from rest to after contraction in the linear measurements of TrA and OI muscle thickness between right and left sides (repeated measure) and between the three groups. One-way ANOVAs were used to compare the TrA muscle slide, and the CSA of the entire trunk between rest and contraction. Post hoc analysis was undertaken using Duncan's test. Significance was set at $p < 0.05$.

3. Results

At rest the thickness of OI was larger than that of TrA (main effect – muscle: $p < 0.01$). Male dancers had thicker TrA (interaction