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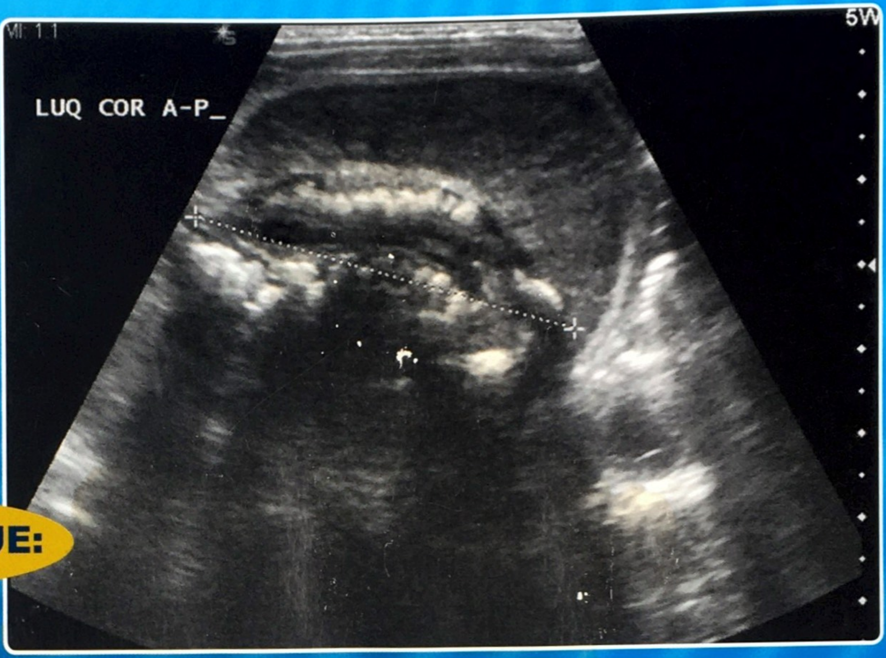
issue 4 2004

THE QUARTERLY PUBLICATION OF THE
AUSTRALIAN SONOGRAPHERS ASSOCIATION LTD.
Print Post Approved PP329295/000445



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ultrasound for biofeedback in physiotherapy

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When sonographers think of physiotherapists using ultrasound, it is usually the therapeutic variety. However an emerging field is the use of real time ultrasound to assist clients in 'turning on' specific muscle groups (visual biofeedback), which could have your local physio showing an unprecedented interest in your ultrasound machine!

Such has been the rapid expansion in this field that for the first time, the lecturers in both sonography and physiotherapy at the University of Sydney have collaborated to create a unit of study called 'Ultrasound for Physiotherapists'. The following article describes the current use of biofeedback real time ultrasound, which is primarily for patients with lower back pain. These patients learn, with the use of real-time ultrasound, to correctly exercise their transversus abdominis and multifidus muscles to treat their lower back pain.

Background

Chronic or recurrent low back pain (LBP) is a highly prevalent and costly problem in our society [1]. Increasing evidence is emerging that deep abdominal and paraspinal muscles including transversus abdominis (TA) and multifidus (MF) play important roles in supporting the spine and that dysfunction of these muscles arising after an episode of LBP may contribute to ongoing or recurrent symptoms [2]. These muscles have also been referred to as core muscles or spinal segmental stabilisers.

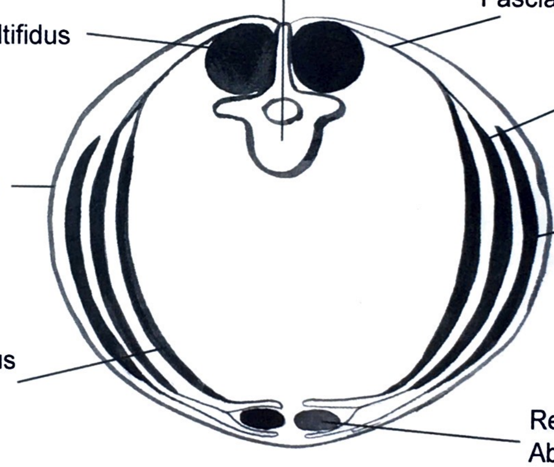

Fig 1. The relationship of the multifidus, the abdominal muscles and spine in cross-section.

Anatomy

The fibres of TA originate from the thoracolumbar fascia between the twelfth rib and the iliac crest posterolaterally and from the lower six costal cartilages to the lateral third of the inguinal ligament as it passes anteriorly [1,3]. Medially, the TA attachment is aponeurotic, forming part of the rectus sheath [3].

Multifidus is the most medial of the lumbar muscles. It is composed of five separate bands of fascicles, the deepest originating from the vertebral lamina and inserting into the mamillary process of the vertebra two levels caudad or just above the first dorsal sacral foramen in the case of the L5 fibres. The more superficial fibres arise from the spinous processes and insert into the mamillary process three to five levels inferiorly and to the posterior superior iliac spine. There are also attachments of some of the deeper multifidus fibres to the capsules of the zygapophyseal joints [2]. The relationship of the multifidus, the abdominal muscles and the spine are shown in cross-section in figure 1.

Segmental Stabilising Function

There are a number of proposed mechanisms by which TA and MF stabilise the spine and research is ongoing into fully understanding these mechanisms (see [2] for review). TA and MF contraction may both contribute to tensioning the thoracolumbar fascia which in turn reduces unwanted intersegmental motion in the spine (ie: movement between two adjacent vertebrae) through its attachments to the vertebrae. Intra-abdominal pressure (IAP) has also been hypothesised to increase rigidity of the spine. The level of IAP will relate to the tension in the abdominal and lumbar walls and therefore to the function of the muscles in these areas.

Hides [4] describes the features of an optimal TA activation pattern as symmetrical TA shortening and tensioning the anterior abdominal fascia, thickening slightly and wrapping around the waistline without significant change in the dimensions of internal and external oblique. MF contraction is detected by increase in the muscle depth which can be measured as the distance from the thoracolumbar fascia to the vertebral transverse process underlying the multifidus segment of interest. The contraction should be slow and controlled [4].

Changes in Stabiliser Function in LBP

In LBP sufferers, variations in muscle morphology and function have been noted that affect their ability to produce segmental stability. Reduced shortening of TA, increased activity of the oblique abdominals and asymmetry of contraction has been noted [4]. Wasting of MF has been demonstrated ipsilateral to the lumbar level responsible for symptoms in acute LBP [5] and it has been shown that this does not recover spontaneously after symptom resolution even with return to normal activity [6]. Impaired MF function may be evident as a failure to contract the muscle or variations in the quality of the contraction. For example, the superficial MF fascicles may dominate the deep fibres producing spinal movement rather than stability or the muscle may contract with brief bursts of activity (phasic activation) rather than a sustained slow contraction (tonic activation) [4].

Benefits of Retraining

Targeted retraining of TA and MF has been shown to be an effective treatment strategy in a number of populations of LBP sufferers. While research in this area is in its infancy, the major studies to date have shown positive results. In a population of thirty-nine patients with acute first episode LBP, those who did not undertake TA and MF retraining had an 84% rate of recurrence in the first year and 75% recurrence in the following two years. By comparison, those who completed targeted TA and MF retraining had only a 30 to 35% recurrence rate during the three year follow-up [7]. In another patient group with radiologically confirmed spondylolysis or spondylolisthesis (structural defect in the pars interarticularis of the vertebral arch), significant reductions in symptoms and disability were evident after TA and MF retraining and were maintained during the 30 month follow-up period [8].

The retraining program advocated for LBP patients is based on a motor relearning approach with specific exercises taught by the physiotherapist to help the patient restore the function of their core muscles. The first step is for the patient to relearn how to activate the TA and MF without any undesirable compensatory strategies. This usually begins in a supine or sidelying position. As this skill is mastered, the complexity of the task is increased by superimposing movements of the limbs (which requires coordination between the stabilisers and prime mover muscles) and progressively increasing weight bearing from lying through sitting positions to standing. Finally, the patient learns to incorporate control of the spinal stabilisers into progressively more challenging functional activities [2].

Role of Biofeedback

When learning any new motor task, feedback is used by the learner to determine the success of each attempt. In some cases this feedback may come wholly from the body's internal sensory mechanisms. In other cases, such as with the retraining of the core muscles, the sensory feedback available to the learner may be insufficient for the learner to determine the appropriateness of their attempt. In this situation, learning may be enhanced by the availability of augmented feedback [9]. Previously used methods of providing biofeedback during core muscle retraining all have significant practical limitations.

The biofeedback method most commonly employed by physiotherapists in retraining the core muscles at present is pressure biofeedback. This involves an air filled "balloon" being placed between the subject's spine and a hard opposing surface while the subject's spinal control is challenged through different limb movements. The "balloon" is attached to a pressure gauge and a change in the reading on the gauge is indicative of spinal movement and therefore a loss of stability. The difficulties with this method lie in the indirectness of the measure and the compensatory strategies that subjects can employ (often subconsciously) to keep the pressure reading constant. For example, if the subject were to overactivate the oblique abdominals in a 'bracing' action, they may be able to limit pressure fluctuations with a particular challenge, but they will not be learning the correct stabilising corset action which is known to optimally control the spinal segments and improve function and symptoms.

Other methods of providing biofeedback include electromyography (EMG) in which electrodes are used to detect the electrical activity in muscles as they are activated. Surface EMG (in which the electrodes are adhered to the skin) is non-specific, being unable to reliably differentiate signals from the target muscles and other overlying or adjacent muscles. Needle EMG overcomes this lack of specificity and has been used experimentally but is generally considered too invasive and impractical in the physiotherapy clinical setting. Magnetic Resonance Imaging is able to dynamically demonstrate the corset-like function of the stabilising muscles but the costs involved again preclude its widespread application in the clinical setting. Also the subject position during assessment is significantly restricted thereby limiting the functional progression of training.

Role of Ultrasound

Hides and colleagues [10] suggested that the visual feedback provided by real time ultrasound (RTU) scanning "could be an innovative addition to .... muscle re-education programs". RTU provides the ability to dynamically image deep muscle structures such as TA and MF during activation. This provides a useful assessment tool for the physiotherapist as well as an immediate source of feedback for the training subject. As ultrasound can be used with the subject in virtually any posture (including lying, sitting and standing), it provides the flexibility to be used throughout training to check the muscle activation as the exercise complexity is increased.

In order to assess the quality of a TA contraction, the image must show the central fascial connection of the TA and as much of the muscle bellies of TA and the abdominal obliques as possible. A transverse transducer placement roughly ten centimetres lateral to the midline at the

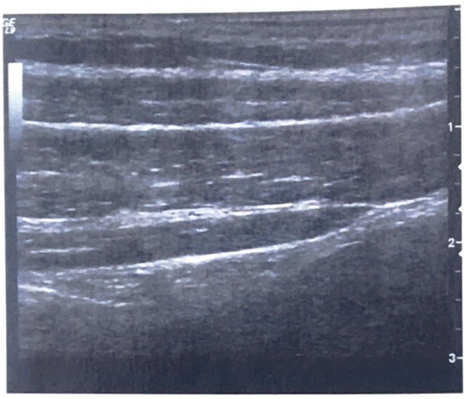

Fig 2. Transversus Abdominis muscle at rest showing fascial connection of the TA medially and internal and external obliques anteriorly.

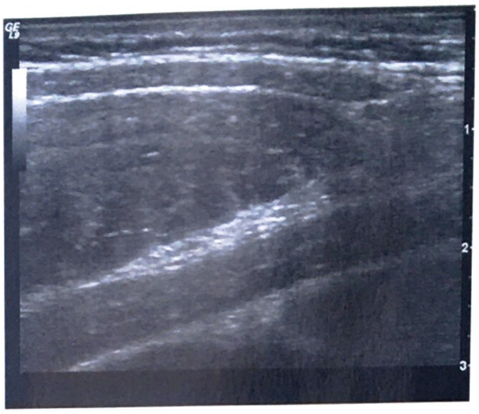

Fig 4. Thickening of the internal oblique shown in this image is a 'poor' result; the physiotherapist will ask the client to try a different exercise strategy to gain TA contraction with minimal internal oblique contraction.

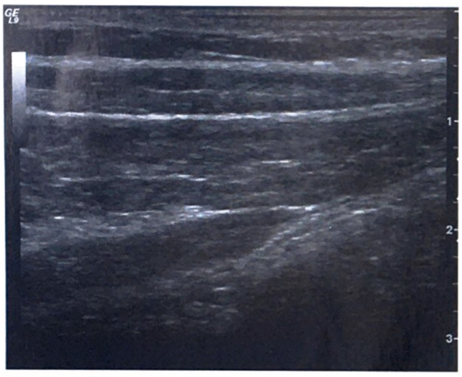

Fig 3. Transversus Abdominis contraction. Note, in comparison to fig 2, the thickening of the TA and lateral movement which tensions the antero-medial abdominal fascia.

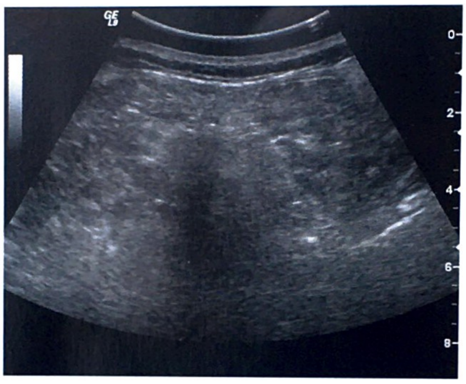

Fig 5. Transverse midline over spine with patient in prone position, to compare left and right multifidus muscle bellies.

level of the umbilicus has been found to fulfil these criteria [11, 4], (fig 2).

Transverse scanning over the midline adjacent to the umbilicus can also be employed to assess the symmetry of abdominal muscle contraction. Any divergence of the linea alba and surrounding structures to one side during TA activation would suggest an inequality in the level of contraction of the two sides of the abdominal muscles. While subjective assessment of TA muscle thickening and movement is easily observed by the patient (figs 3 & 4), objective indicators of muscle function can be attained from linear measures of the thickness of TA and the obliques and the length of the central fascia at rest and during contraction.

For assessment of MF, a transverse midline scan with the patient prone allows for comparison of left and right muscle bellies at each lumbar level (fig 5).

This can be employed to detect any localised wasting that has been found to occur in LBP patients [5]. Parasagittal scanning allows concurrent visualisation of multiple lumbar levels of MF and can be useful in detecting variations between levels in quality of contraction. Both cross-sectional area and muscle depth can be used as objective indicators of MF size and function.

Due to the necessity of both the patient and operator being able to see the ultrasound image as they perform the exercises, the positioning of the display is an important consideration in RTU biofeedback retraining. Often a second external display that can be positioned as required for the patient is the only way to achieve this without compromising the patient position required to achieve the desired muscle activation.

Both linear array and curvilinear transducers have been successfully employed for TA and MF biofeedback. Hides and colleagues [12] advocate the use of a 5MHz transducer for most patients although higher frequencies may be suitable for many patients due to the superficiality of the muscles of interest.

Future directions and challenges

As with any new tool in health care, if ultrasound biofeedback is to be widely applied as a physiotherapy clinical tool, it is important that physiotherapists are educated and skilled in obtaining quality images. Until recently, no specific training courses were offered in Australia for physiotherapists wishing to utilise RTU for biofeedback of trunk muscles. The University of Queensland has incorporated limited exposure to the technology in their undergraduate physiotherapy degree and to a greater extent in some of their Masters programs. In semester one of 2004, The University of Sydney Schools of Medical Radiation Sciences and Physiotherapy jointly offered an "Ultrasound for Physiotherapists" course as a miscellaneous subject of one semester's duration. The course focussed on equipping the enrolled students with an understanding of the theoretical and practical elements of diagnostic real time ultrasound specifically aimed at being able to image the abdominal wall and multifidus for assessment and biofeedback of these spinal stabilising muscles. Hopefully the availability of such courses will continue to grow.

There appears to be growing interest in RTU biofeedback within the physiotherapy profession, but for many physiotherapists the investment in equipment and training is considered high when the market for this service is relatively untested. As availability of RTU biofeedback increases, however, awareness of the benefits should grow among patients and referrers. In parallel, the more physiotherapists involved in providing RTU biofeedback, the greater the scope for ongoing research. There are a number of directions that this may take. Firstly, a deeper understanding of how TA, MF and other muscles specifically function to stabilise the spine should develop. The contraction of the pelvic floor, for example, has been shown to induce co-contraction of TA [13], and it seems likely that it and other muscle groups may have synergistic roles in segmentally stabilising the spine. Secondly, the most effective training methods to improve segmental stabilisation will become more apparent with increased clinical usage and research investigation. Also, further research demonstrating the cost effectiveness of this treatment will help to confirm the value of RTU biofeedback to patients and referrers.

Certainly, as the use of RTU by the physiotherapy profession grows, the scope for interaction and collaboration between ultrasonographers and physiotherapists will increase. The benefits of this are likely to be seen further afield than in the management of LBP, as the potential for knowledge sharing in such areas as tissue pathology and recovery can only benefit members of both professions and their clients.

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