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Masterclass

Muscle control – pain control. What exercises would you prescribe?

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SUMMARY. **A very specific type of exercise has been devised which is proving to provide effective pain relief for chronic and recurrent back pain sufferers. The exercise approach focuses on retraining a precise co-contraction pattern of the deep trunk muscles, the transversus abdominis and lumbar multifidus. The approach is based on the knowledge of how muscles provide stability for the spine in normal situations. It has been further developed according to research evidence which has demonstrated dysfunction in the deep trunk muscles in patients with back pain. The mechanism for pain relief with this specific exercise approach is believed to be through enhanced stability of the lumbar spine segments.**

INTRODUCTION

Therapeutic exercise encompasses many well known exercise strategies such as rehabilitating the functional demands of the muscle system, enhancing cardiovascular fitness or improving joint and muscle flexibility. Exercise can also be used to assist in pain relief through several local or general physiological effects (McArdle et al 1991). Our particular interest has been in the use of exercise for pain control in spinal pain patients. It is our hypothesis that control of back pain and prevention of its recurrence can be assisted by enhancing muscle control of the spinal segment. The aim is to improve active segmental stabilisation thereby protecting the joints from painful strains and reinjury.

In recent times, several different exercise programmes have been proposed to promote lumbar stabilisation (Robison 1992, Saal & Saal 1989). The ability of such programmes to improve stabilisation of the lumbar spine has been difficult to evaluate because of a lack of appropriate measurement methods. Current programmes consist of a variety of general trunk and girdle exercises and, for the most part, they seem to have some success (Saal & Saal 1989). However, within these general programmes, it is difficult to ascertain which particular features of the exercise tasks or facilitation techniques are responsible for the more successful outcomes in some patients compared to others. Therefore it is sometimes difficult for the clinician to know where to place the emphasis in their retraining of a back pain patient.

Our work with spinal pain patients both in the clinic and in the laboratory has led to the development of some quite specific exercise techniques for the rehabilitation of lumbar segmental control. Research is beginning to vindicate these approaches. In presenting these particular exercise techniques, it is appropriate to consider several issues. These include the mechanisms involved in providing muscle support for the lumbar motion segment and why muscle control is needed to enhance segmental stabilisation in back pain patients. It is also necessary to understand which muscles are vital for segmental stabilisation as well as those which demonstrate dysfunction in back pain patients. This provides a basis for identifying features to consider in exercise design for specific methods of rehabilitation of active lumbar segmental control.

MECHANISMS FOR MUSCULAR SUPPORT OF THE LUMBAR MOTION SEGMENT

The muscle system in its function of stability, provides protection to articular structures. It can help minimise unwanted joint displacement, aid stress absorption and generally prolong the 'cartilage serving time' of the joint (Baratta et al 1988).

The development of active joint stabilisation has been attributed to several muscle recruitment strategies. One strategy is the early pre-programmed recruitment of particular muscles. Specific muscles are recruited before an action is commenced to ensure that the joint is

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supported prior to a given movement. For example, during a jumping task, the leg extensor muscles are recruited prior to ground contact in preparation for the forces of landing (Gollhofer & Kyrolainen 1991).

The regulation of muscle stiffness is also important for the stabilisation of joints (Johansson et al 1991). A mechanism for increasing joint stability through enhanced muscle stiffness is co-contraction of agonist and antagonist muscles which lie each side of a joint (Andersson & Winters 1990). Recruiting muscles in co-contraction is considered to provide support and joint stabilisation even when contractions occur at very low levels. Hoffer & Andreassen (1981) contend that contractions as low as 25% maximum voluntary contraction (MVC) are able to provide maximal joint stiffness. In addition, feedback from the joint and ligament afferents, via their effects on the gamma spindle system, may help regulate muscle stiffness (Johansson et al 1991). This occurs through the gamma system's influence on the alpha motorneurones which control the tonic, slow twitch muscle fibres (Johansson & Sojka 1991). It appears that the tonic motor units are those most closely related to the control of joint stabilisation. This is commensurate with the proposed antigravity postural supporting role attributed to these motor units.

A major advance in our understanding of how muscles contribute to lumbar stabilisation came from recognising the significant functional difference between local and global muscles. Bergmark (1989) in his dissertation on lumbar spine stability proposed a difference between local and global muscles. Global describes the large torque producing muscles linking the pelvis to the thoracic cage. Their role is in providing general trunk stabilisation. Such muscles balance external loads and in that way help minimise the resulting forces on the spine. Local muscles refer to those attaching directly to the lumbar vertebrae. These muscles are considered to be responsible for segmental stability as well as controlling the positions of the lumbar segments.

Lumbar segmental stability

Lumbar segmental stability is provided by osseous, ligamentous and muscle restraints. Injury and degenerative disease can affect any structure of the motion segment and can result in both abnormal segmental movement and muscle dysfunction. Panjabi (1992) considers the segment's neutral zone is the sensitive region. This is the small range of displacement around the segment's neutral position where little resistance is offered by passive spinal restraints. The subtle movement in this region may increase with injury, disc degeneration and weakness of the muscles (Panjabi 1992).

Logically it is the muscles of the local system which have direct attachments to the lumbar vertebrae that have the greatest capacity to affect segmental stiffness through control of the neutral zone (Crisco & Panjabi 1990). The contributions of several of the back muscles to active segmental stabilisation have been investigated in *in vitro* studies (Goel et al 1993; Panjabi et al 1989; Steffen et al 1994; Wilke et al 1995). The lumbar multifidus in particular has been shown to contribute to the control of the neutral zone. Wilke et al (1995) in a biomechanical study demonstrated that the multifidus provided more than two-thirds of the stiffness increase at the L_{4-5} segment. This stabilising role of multifidus has been recently verified in vivo in animal research (Kaigle et al 1995).

The abdominal muscles are often ascribed an important role in the treatment of back pain. A muscle which could be described as part of the local system and which has not been studied extensively to date, is the transversus abdominis. Its possible importance in lumbar stabilisation was first addressed by Cresswell et al (1992). These researchers studied the muscles of the back and abdominal wall using fine wire EMG. They demonstrated that transversus abdominis had direct links with the development of intraabdominal pressure. Furthermore it contracted with all trunk movements regardless of the primary direction of movement and it was recruited prior to all other abdominal muscles with sudden perturbations of the trunk.

Recently, more concrete evidence has emerged demonstrating the importance of transversus abdominis in the motor control associated with lumbar stabilisation. Fine wire and surface EMG were used to study each abdominal muscle during three movements of the upper limb, flexion, abduction and extension (Hodges & Richardson 1995a). The onset of EMG activity for transversus abdominis occurred prior to any limb movement. Additionally the pattern of onset was similar for each of the three directions of arm movement. This was different to the activity pattern of other abdominal muscles. The rectus abdominis, external and internal oblique muscles rarely preceded limb movement and the onset of their activity varied with the movement direction. The authors concluded that in regard to stabilisation of the lumbar spine, this study provided evidence for a functional differentiation between the abdominal muscles.

The local muscle system has a primary responsibility for segmental stability. It appears that both multifidus and transversus abdominis are important components of this system.

Dysfunctions in the local muscle system

The stabilisation function of any antigravity trunk muscle is likely to be affected in low back pain patients. Their tonic fibres have an important antigravity, postural supportive role. These fibres can be affected by disuse (Richardson & Jull 1994) and by the reflex and pain inhibition associated with lumbar pain and injury (Baugher et al 1984). The nature of this dysfunction impacts on the type of exercise required to restore this stabilising or supporting role.

A link has been established between dysfunction in the local muscles and back pain. Several researchers have demonstrated dysfunctions in the multifidus muscle of back pain patients. Hides et al (1994) reported a significant reduction in segmental multifidus cross sectional area in patients with acute, first episode, unilateral back pain. It was proposed that this phenomenon was a result of pain and or reflex inhibition of the muscle. Rantanen et al (1993) demonstrated 'moth eaten' Type I muscle fibres in the multifidus muscle of patients with chronic back pain. Further evidence comes from Biederman et al (1991) who found that multifidus demonstrated greater fatiguability relative to other parts of the erector spinae in chronic back patients compared to a normal population.

Dysfunction of the transversus abdominis muscle has also been clearly shown in back pain patients. Hodges and Richardson (1995b) demonstrated a motor control deficit in the transversus abdominis muscle. In their EMG experiment analysing the onset of activity of the muscles of the abdominal wall in response to arm movements, the timing of onset of transversus abdominis was delayed in chronic low back pain sufferers compared with individuals who had never experienced back pain. Notably no significant change was detected between the two groups in any other muscle of the abdominal wall. The delayed action of transversus abdominis compared to its early recruitment prior to limb movement in normal individuals, has made a significant contribution to knowledge of the mechanisms involved in poor lumbar stabilisation associated with low back pain. The results are even more significant when one considers that the problem appears to be limited to the muscle which forms the deepest layer of the abdominal wall.

Evidence of the importance of the local muscles in stabilisation of the lumbar spine as well as their proven dysfunction in the back pain population, has led us to focus on these muscles in the rehabilitation of active stabilisation of the lumbar spine. Indeed, a completely new type of therapeutic exercise has been developed aimed at reversing the dysfunction known to occur in the local muscle system.

EXERCISE DESIGN

In the process of developing a new concept in therapeutic exercise to enhance lumbar stabilisation, each facet of the exercise was reasoned on a knowledge of stabilisation as well as a knowledge of the muscle dysfunction found in back pain patients. Several decisions had to be made to design the most suitable exercise. These included the type of muscle contraction (i.e. concentric, eccentric, isometric), the body position, the level of resistance or load, the number of repetitions and subsequently the methods of progression. These decisions were based on extensive work in the clinic as well as a number of EMG studies (Jull et al 1993, Richardson et al 1990, Richardson et al 1992, Richardson et al 1995).

Type of muscle contraction

Functional differences between the global and local muscle systems help direct which type of muscle contraction is needed in re-education of the local system. The length-tension relationships of these muscles differ during trunk movements. The global muscles span the lumbar area and they shorten or lengthen eccentrically as they produce the torque to move the trunk. The local muscles attach from vertebra to vertebra and are responsible for maintaining the position of the lumbar segments during functional trunk movement. McGill (1991) confirmed their primary segmental stabilisation role in a study of the geometry of the multifidus muscle. He showed that the operational length of multifidus was virtually unchanged through a range of trunk postures.

These functional demands indicate that isometric exercise is most beneficial for re-educating the stabilising role of these deep local muscles of the lumbar spine. At a later stage, isometric exercises for these deep lumbar muscles can be combined with dynamic functional exercise for other parts of the body.

Exercise involving co-contraction of the deep abdominal and back muscles is also in line with stabilisation. Co-contraction of agonist and antagonist has been considered by several researchers in relation to joint stabilisation strategies (Andersson & Winters 1990). This type of muscle activity is linked to increasing joint stiffness and support independent of the torque producing role of muscles (Carter et al 1993). A simultaneous isometric co-contraction of transversus and multifidus, while maintaining the spine in a static neutral position, should help re-educate the stabilising role of these muscles.

As argued previously, the tonic motor units are those most closely related to control of joint stabilisation. In addition, both disuse and reflex inhibition are likely to affect the slow twitch or tonic fibre function within the muscle. Therefore a prolonged tonic holding contraction at a low level of MVC would be most effective in retraining the stability function of these muscles.

In summary, the evidence presented indicates that a programme for the transversus abdominis and multifidus is required for specific lumbar segmental stabilisation training. It should include activating an isometric co-contraction of these muscles and training the patient to hold a low level tonic contraction. There is one other factor in exercise design. There are patients in whom the more active global muscles such as rectus abdominis, external oblique or thoracic erector spinae predominate in general exercise techniques. In these patients it is almost impossible to detect if local muscle activation is occurring during general exercise. Therefore specific exercises which isolate the local muscles as much as possible from contraction of the global muscles have proved to be the most beneficial way of targeting them in rehabilitation programmes and ensuring that the correct muscles are being reactivated.

Body position and level of resistance

The local muscles function to control segmental stiffness independent of the global muscle system which is responsible for balancing the external loads. There is no need for high loaded exercise and it is logical to reduce external loading during initial rehabilitation of the local system. This is achieved by using exercise positions such as four point kneeling or prone lying where body weight is supported and no additional external resistance is applied. Such positions and exercises involving minimal external loading also reduce the chance of pain and reflex inhibition which could be increased if high load exercises were given early in rehabilitation.

Low loads have another benefit in therapeutic exercise aimed at restoring joint stabilisation. The restoration of tonic function in the muscles only requires low levels of muscle contraction as tonic fibres operate at levels below approximately 30–40% MVC (McArdle et al 1991). Additionally it has been argued that only low levels of muscle force, approximately 25% MVC, are needed to develop the increased muscle stiffness required for enhancing spinal stability. Therefore the addition of high external loading which is required for strength changes, is not suitable for the development of muscle stiffness for joint support. For these reasons, positions and exercises involving minimal external loading are the ideal when rehabilitating the local muscles for lumbar spine stabilisation.

Number of repetitions, holding ability

A localized and specific isometric setting exercise was developed to improve the stability role of the local muscles. This isometric co-contraction of transversus and multifidus involves retraining a specific motor skill. In order to gain maximum benefit, the exercise needs to be repeated as many times as possible throughout the day.

Methods of progression

Progression of this new type of exercise can be taken through several stages. At first, it involves increasing the holding time of the isometric co-contraction as well as the number of repetitions. The setting exercise can then be progressed from low loads with minimal body weight to more functional body positions with gradually increasing external loads. In addition, advances need to be made from performing the exercise with a static neutral lumbar spine to other static positions at more extremes of range. Finally, patients should be able to hold a co-contraction of the deep muscles during dynamic functional movements of the trunk.

SPECIFIC METHODS OF REHABILITATION

Teaching the isolated setting action of transversus abdominis and multifidus is not easy when patients have marked dysfunction in their local muscle system. The therapist needs to develop a high level of teaching skill for successful treatments. For this reason quite detailed descriptions of the exercise programme will be given. As with all therapeutic exercise, methods have to be used to detect if the correct muscles are contracting during the exercise. The dysfunction occurs in the deep muscles of the abdominal wall and back and this can present some challenges especially in patients whose more active global muscles attempt to substitute for the correct muscle action. Several strategies including specific palpation, careful observation of changes in body shape and the use of pressure biofeedback were developed for this purpose.

Methods of teaching an isometric co-contraction of transversus abdominis and multifidus with a static neutral spine

There are only a few methods of achieving an isometric co-contraction of the local muscles independent of the global muscles. The method we have developed from our clinical and research work involves the re-education of the co-contraction of transversus abdominis and multifidus as the basic functional unit of a movement skill. The isolated action of these local muscles is taught by asking the patient to gently draw in the abdominal wall especially in the lower abdominal area. This is an action similar to that described by Lacote et al (1987) for the muscle test action of the transversus abdominis muscle. The patient also learns to simultaneously contract their multifidus muscle in an isometric setting action. This ensures the maintenance of a static neutral spine position.

Active persons without a history of chronic low back pain have little difficulty in performing this task (Richardson et al 1995). However it is not easily achieved by patients with low back pain, both acute and chronic. If the patient is unable to perform the setting action, other techniques of facilitation and skill learning are employed. These include:

- Visualising the correct muscle action. The local muscles form a corset like structure which acts to tighten around the waist. The physiotherapist should demonstrate and describe the muscle action to the patient. Anatomical illustrations of the muscles involved are an effective teaching aid.
- Using instructions which cue the correct action. Several different phrases such as 'draw your lower abdomen up and in' or 'pull your navel up towards your spine' can be used to cue the patient to the muscle action required.
- Focussing on precision. The patient has to concen-

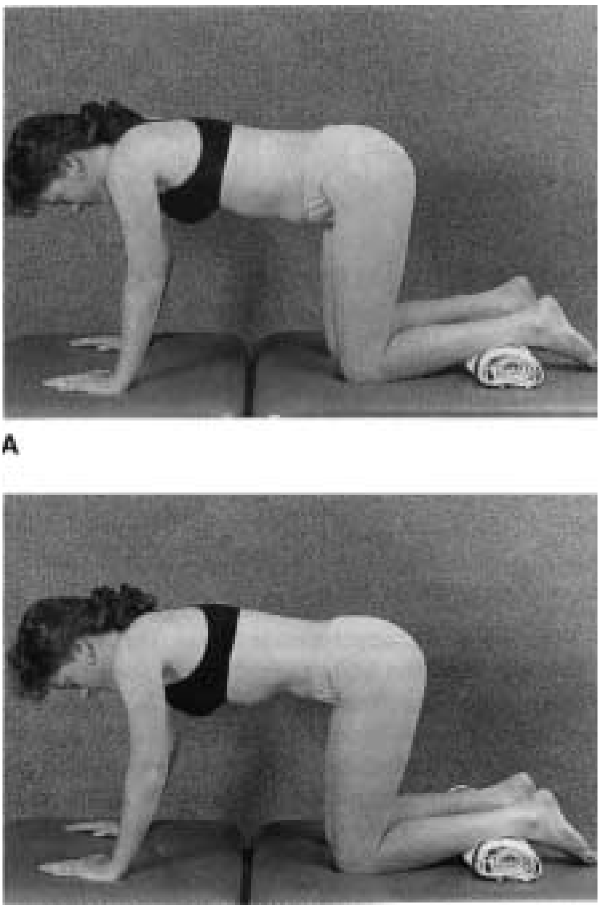
trate and focus on the precise muscle action to be achieved. It should be stressed that the co-activation of the deep muscles is a gentle action. Other muscles of the body are to remain relaxed during this localised exercise.

- Facilitation techniques. Facilitation techniques can help the patient feel the muscle action required. These can include a deep but gentle manual pressure on the transversus abdominis or manual contact on multifidus. Another facilitation strategy is to combine the co-contraction with a contraction of pelvic floor muscles.

Body positions for re-education

There are several different positions in which the isometric co-contraction exercise can be activated while keeping the global muscles relaxed and maintaining the spine in a static neutral position. Each position allows different opportunities for teaching, testing and retraining this technique. Re-education of the isometric co-contraction is commenced in the four point kneeling and prone positions. One of the major advantages of these positions, as is revealed when monitoring the abdominal wall with multichannel EMG, is that they seem to be inhibitory for a major global muscle, the rectus abdominis. These positions help to isolate the exercise to the deep local muscles.

Fig. 2—The pressure biofeedback unit.



A

B

Fig. 1—Re-education in four point kneeling (A) the relaxed abdominal wall; (B) the abdominal drawing in action.

Re-education in four point kneeling

The first position for the patient to learn to contract their local muscles is in four point kneeling (Figs 1A & B). Learning the action of drawing in the abdominal wall and holding this position is easiest in this position. This is probably due to the facilitatory stretch of the deep abdominal muscles resulting from the forward drift of the abdominal contents. The patient is taught to locate and maintain normal thoracic and lumbar curves for the isometric exercise. The rib cage and pelvis should remain still and the patient must continue to breathe normally throughout the abdominal 'drawing in' and holding contraction.

Re-education and testing in the prone position

The prone position is a major testing and training position. It is in this position that some quantifiable evaluation of the patient's ability to co-contract the deep muscles can be made. While multichannel needle and surface EMG can be used in research to gain precise measures and descriptions of the muscle dysfunction, they cannot be readily used in the clinic. Yet some quantification of exercise performance is needed to assess the level of the patient's ability and to monitor the effectiveness of training. The pressure biofeedback has proved to be a useful clinical tool for assessment and to enhance training and learning in this position (Fig. 2). The co-contraction of the transversus abdominis and multifidus involves a drawing in action of the abdominal wall. The pressure biofeedback unit can indirectly monitor the movement of the abdominal wall by recording a decrease in pressure as the muscles contract and support some of the

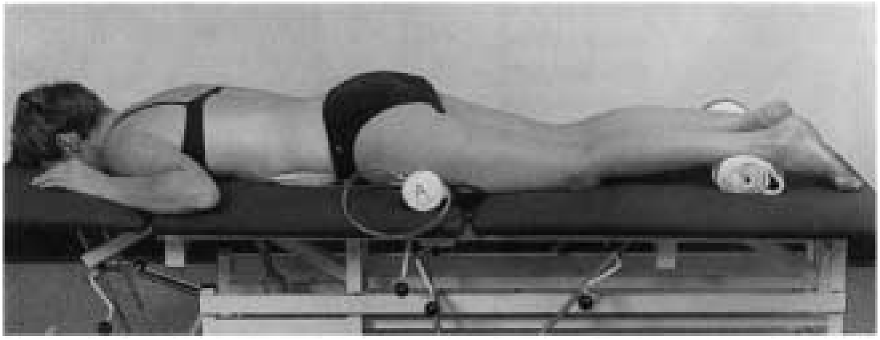


Fig. 3—The test of the abdominal drawing in action in prone lying, monitoring the co-contraction with the pressure biofeedback unit.

weight of the abdominal contents off the sensor.

The patient is asked to lie with the pressure sensor under the lower abdomen, the lower edge in line with the anterior superior iliac spine (Fig. 3). It is inflated to 70 mmHg pressure. The instruction given to the patient is to draw the lower stomach gently off the pressure sensor and hold the position. When the correct localised contraction is performed, pressure decreases by approximately 6–8 mmHg up to a maximum of 10 mmHg in the holding position.

The simultaneous contraction of multifidus can be palpated close to the lumbar spine in the low lumbar area. Once the patient has learnt the setting action, the pressure biofeedback is invaluable in monitoring the patient's retraining of holding time of the co-contraction.

Re-education in upright positions

Retraining the co-contraction in the upright standing and sitting positions is a necessary prerequisite for postural retraining and for later retraining in functional activities. The appearance of the abdominal wall when it is relaxed and when the correct action is performed is illustrated from an anterior view (Figs 4A & B) and from a side view (Figs 5A & B). The contraction of the transversus abdominis can be palpated just medial to the anterior superior iliac spines (Fig. 4B). Alternatively, facilitation of the co-contraction can be provided through multifidus (Figs 5A & B).

Substitution strategies

The efficacy of training will relate to the accuracy with which a patient can activate and hold the deep muscle co-contraction. This setting exercise is a movement skill and patients have lesser or greater difficulty in activating the correct muscle action. When they have problems, it is not uncommon for them to use substitution strategies to mimic the correct action. The physiotherapist must be vigilant and observe or monitor substitution with the pressure biofeedback and correct the action.

As a basic guide the rib cage, shoulders and pelvis should remain in a constant position during the setting action to minimise the contribution of the global muscles. Some of the substitution strategies commonly used by patients can be identified in the upright position by careful observation. One substitution manoeuvre

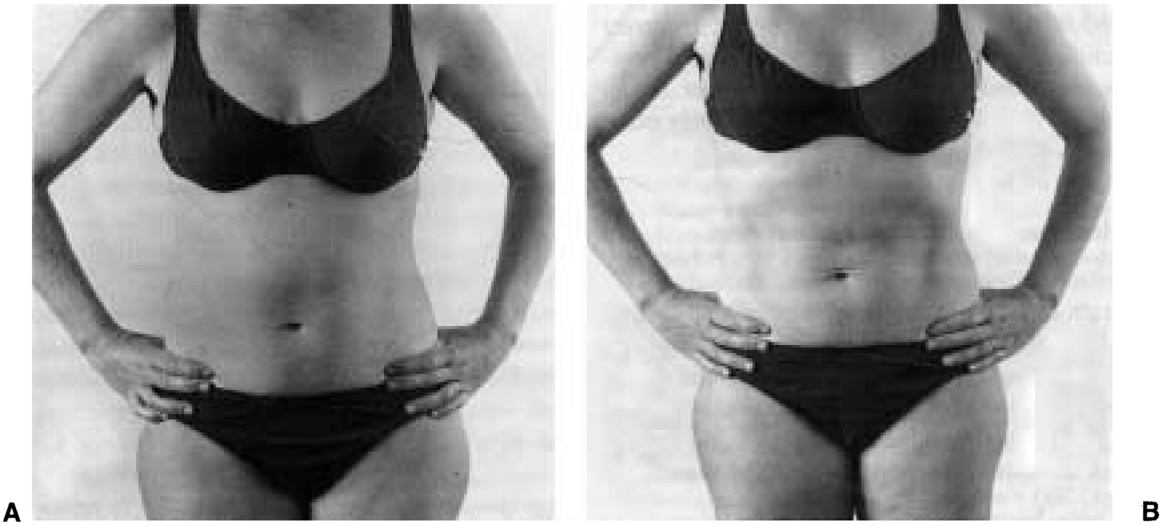


Fig. 4—The anterior view of the co-contraction (a) the relaxed abdominal wall; (b) the abdominal drawing in action.

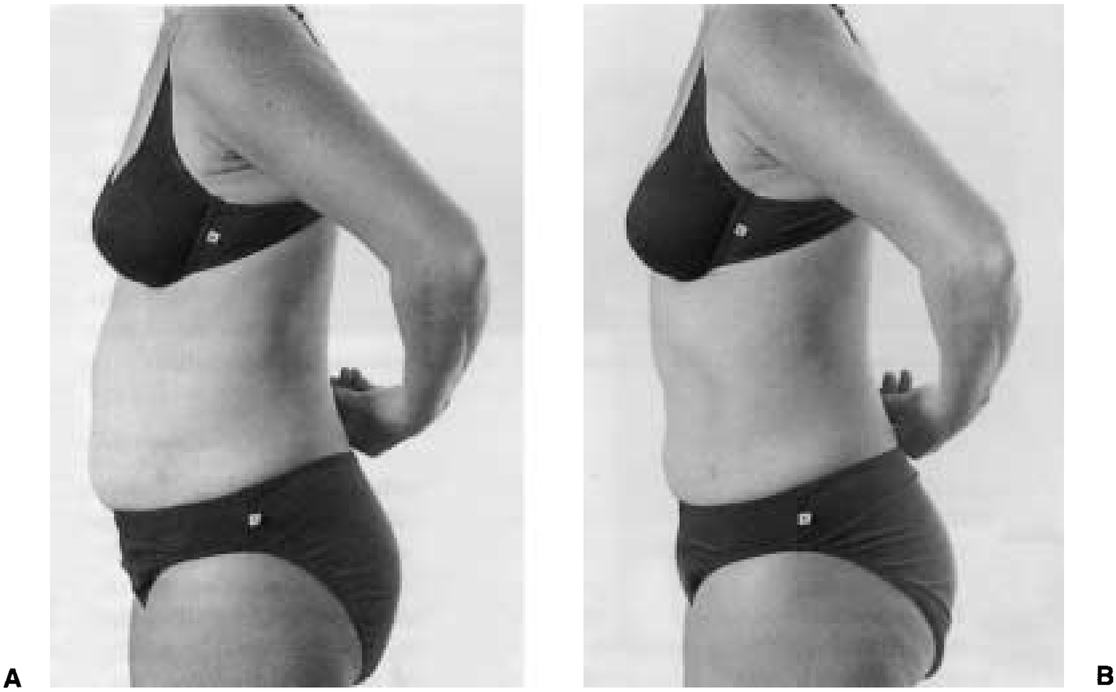


Fig. 5—The lateral view of the co-contraction (A) the relaxed abdominal wall; (B) the drawing in action.

involves sucking in the upper abdomen by taking in and holding a deep breath (Fig. 6). This can be done with virtually no abdominal muscle activity. If this manoeuvre is performed in the prone position with the pressure biofeedback, there can be a drop in pressure of 1–2 mmHg which may be mistaken for the beginnings of a correct muscle action. Observation of the abdominal wall, asking the patient to breathe normally and palpating the contraction of either transversus abdominis or multifidus will help identify the incorrect action.

Another strategy sometimes used instead of the drawing in action, is an abnormal bracing action involving the external obliques. In the upright position, the depression of the rib cage and the appearance of an horizontal abdominal skin crease point to the incorrect muscle action (Fig. 7). If performed in the prone position with pressure biofeedback, this incorrect action does not result in a decrease in pressure. In most cases the pressure will increase by 1–2 mmHg.

Progression from positions of minimal external loading

Patients train in the minimally loaded prone and upright positions until they can hold an isolated contraction of the deep local muscles. An arbitrary target is the ability to perform 10 by 10 second holds in succession without fatiguing. Once this is achieved, the exercise can be progressed to slowly increase loads and functional demands.

The aim of this next stage is to integrate the local and global muscle systems. Most of the traditional stabilisation programmes involving general trunk muscle co-contraction and added load are applicable at this stage (Jull & Richardson 1994). It is important that increases in load are introduced gradually with constant monitoring of the deep muscle system to ensure its continued action.

Link between exercises and pain relief

The key aim of the abdominal drawing in or setting

Fig. 6—A substitution strategy utilising breath holding and rib elevation. Note the different shape of the abdomen and rib cage compared to the correct action.

Fig. 7—A substitution strategy of an abnormal bracing action utilising predominantly the external oblique muscle. Note the depressed rib cage and the skin crease across the upper-middle abdomen.

exercise is to isolate the correct muscle action in all exercise positions and develop holding ability. Pain relief is usually concomitant with the patient mastering this task. The time taken to achieve this is variable and depends on the level of dysfunction. It may take one or two treatment sessions to help the patient master it or it may take several weeks of practice for the patient to reach this stage.

The reason for the importance of isolating the muscle action is not fully understood. Our working hypothesis is that it relates to motor control issues which are independent of the prime mover muscle action. Hodges and Richardson (1995 a & b) have demonstrated that during limb movement, there is a separate control system for the deep abdominal muscle, transversus abdominis. This could explain the need to first train the deep muscles independently of the main torque producers which are used to perform the functional tasks.

Evidence of efficacy of this new concept in therapeutic exercise

Evidence of the link between this concept of motor control and training the deep muscles to increase segmental stability and subsequent pain relief is beginning to emerge. O'Sullivan and Twomey (1994) studied the effects of this type of exercise on patients suffering from chronic low back pain with the radiological diagnosis of spondylolysis or spondylolisthesis. On completion of the treatment period, the specific exercise group demonstrated a significant reduction in pain intensity and increase in functional mobility when compared to the control group who undertook general exercises.

The effect of this exercise on acute, first episode unilateral back pain was also studied in recent research on the multifidus muscle. Hides et al (1995) demonstrated in a prospective controlled trial that inhibition of the lumbar multifidus did not resolve automatically as back pain resolved. A programme of re-education of co-contraction of the deep muscles, gradually increasing the holding time, was needed to restore the segmental multifidus to its pre injury size. Preliminary data from a 9-month follow up suggests that the exercise group may have suffered less recurrence of back pain in this period. This is an exciting new area of clinical research which will be the focus of our future research efforts.

CONCLUSION

A very specific type of therapeutic exercise has been devised which provides effective pain relief for chronic and recurrent back pain sufferers probably through enhanced segmental stabilisation. This approach was developed over the span of several years and is based on knowledge of how muscles stabilise the spine and the dysfunction which occurs in these muscles in back pain sufferers. The success of such programmes should provide the impetus for further basic scientific research on the function of the deep muscles and the dysfunction that occurs within this system of muscles in back pain patients. As a result of increased knowledge in the area, rehabilitation exercise can be further developed and refined for more efficient and effective pain relief. In this way the scientific foundation for the practice of physiotherapy can be firmly established.

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