The role of the diaphragm during abdominal hollowing exercises

This study investigated the surface electromyographical (EMG) profiles of the diaphragm, anterolateral abdominals and rectus abdominis during abdominal hollowing exercises (AHE) in 20 healthy subjects. Muscle activity was assessed at 1000Hz over two seconds in crook lying at three incremental loads above a baseline of 40mmHg monitored by a pressure biofeedback unit. EMG amplitude increased significantly above resting for all muscles during correct performance of AHE at 5mmHg. At 15mmHg, all subjects were deemed to have performed AHE incorrectly and both the diaphragm and rectus abdominis activity were significantly elevated (p < 0.05). This supports the concept that the diaphragm plays a significant role in motor control strategies used by subjects performing different forms of AHE.

Key words: Abdominal Muscles; Diaphragm; Exercise; Spine

The role of the abdominal muscles in the provision of segmental stabilisation of the lumbar spine varies within the scientific and clinical literature. The intimate association between the activation of the abdominal muscles and mechanisms to increase intra-abdominal pressure and the subsequent role of intra-abdominal pressure in providing lumbar stabilisation has been well documented. Increases in intra-abdominal pressure have been shown to occur as a reflex response to external stresses placed on the spine. The primary muscles involved in perturbations of the lumbar spine are transversus abdominis, internal obliques, diaphragm and the pelvic floor (Cresswell et al 1994, Grew 1980, Kumar and Davis 1973). The external obliques and rectus abdominis (RA) are primarily active during lumbar spine flexion and extension, such as lifting and lowering, and have been demonstrated to influence intra-abdominal pressure (Cresswell et al 1992, McGill and Sharratt 1990).

The abdominal muscles make contributions to stabilisation of the lumbar spine via mechanisms other than maintaining intra-abdominal pressure (Gracovetsky et al 1985). Specifically, the internal obliques and transversus abdominis muscles attach to the lateral raphe of the thoracolumbar fascia and have been shown to generate a longitudinal tension within the fascia. This results in compressive forces through the vertebral column, decreasing the amplitude of the intervertebral shear force components. Moreover, a potential extension moment, which may increase the tendency of approximating the spinal processes, is generated, which may help reduce stress through the intervertebral joints (Gracovetsky et al 1981, Tesh et al 1987, Vleeming et al 1995).

Although the mechanisms remain unclear, abdominal hollowing exercises (AHE) have been advocated to improve lumbar spine stabilisation in patients with low back pain (Richardson and Jull 1995, Richardson et al 1992) and in patients with radiologically defined lumbar spine instability (spondylolisthesis) (O'Sullivan et al 1997). Such exercises have been utilised in physiotherapy management of lumbar spine instability (O'Sullivan et al 1997 and 1998), and aim to improve the recruitment and motor performance of the muscles responsible for stabilising the lumbar spine. To date, the literature has shown that transversus abdominis and internal obliques are the abdominal muscles primarily responsible for these mechanisms (Cresswell et al 1992, Gracovetsky et al 1985, Tesh et al 1987). Other authors have suggested that the diaphragm is important for maintaining or...
increasing intra-abdominal pressure together with the abdominal muscles (Cresswell et al 1994, Grew 1980, Kumar and Davis 1973, Williams et al 1989). Although it is recognised that the trunk muscles including all the abdominal muscles, the diaphragm and the pelvic floor are involved in altering the resistance (and impedance) to movement of the spine and chest wall (Barnes et al 1991), the role of the diaphragm during AHE has not been reported.

Abdominal hollowing exercises are a specific form of therapeutic exercise devised to teach patients to contract the anterolateral abdominal muscles, consisting of transversus abdominis and internal obliques, by hollowing the abdomen in towards the centre of the back without any substantial movement of the rib cage. Whilst some patients are able to perform the motor strategy correctly, illustrating a relative isolation of the anterolateral abdominal muscles, others attain the specific performance criteria using different motor patterns. These motor patterns have been defined as substitution patterns and may include flexing the trunk, deep inspiration with breath holding, posterior pelvic tilting utilising the RA, pushing through the feet, and bracing of the abdomen (Richardson and Jull 1995, Richardson et al 1992). Each of these movements has also been associated with subjective inferences of specific muscle activation patterns, for example recruitment of RA is reported to be commonly utilised by patients when attempting to perform ARE and this may be associated with a bracing manoeuvre or a pelvic tilt. Such strategies, have been qualified as “incorrect” (Richardson et al 1992) and may reflect dysfunction in the motor control strategies of muscles which may play a role in lumbar spine stabilisation.

Cresswell et al (1994) and Hodges and Richardson (1995) found that the abdominal muscles and most significantly transversus abdominis, pre-activate in anticipation of a known load or sudden perturbation to the trunk in individuals without back pain. It has been suggested by Cresswell et al (1994) that this indicates a feedforward strategy important for lumbar spine stabilisation. Hodges and Richardson (1995) reported that in response to upper limb perturbations (rapid arm movement) the onset of transversus abdominis activation was significantly delayed in subjects with low back pain by comparison with subjects with no history of back pain. The alterations in the recruitment of transversus abdominis may reflect neuromotor control deficiencies in patients with low back pain (Hodges and Richardson 1995). Any interpretation which purports the absence of the transversus abdominis onset during the pre-movement stabilisation phase presents the question: which element of the stabilisation system; active (muscle), passive (non-contractile), or a combination of both may fulfil a substitution role for the transversus abdominis during the pre-movement stabilisation phase? This issue remains unclear and warrants further investigation. Nevertheless, when teaching ARE to patients with chronic low back pain, the neuromotor control deficiency in the recruitment of transversus abdominis may precipitate the use of substitution patterns.

During a valsalver manoeuvre, RA and the erector spinae muscles are recruited to increase intra-abdominal pressure (Bearn 1961). Clinically, this is often seen in the form of a breath hold during AHE or abdominal bracing which incorporates co-contraction of all the abdominal muscles, in an effort to increase the resistance to movement or stabilise the trunk. The diaphragm, the principal muscle of inspiration, plays a significant role in the maintenance of intra-abdominal pressure (McGill and Sharratt 1990, Williams et al 1989). Therefore it could be postulated that activation of the diaphragm and RA may be involved in a multitude of motor control substitution patterns employed by the patient to meet the demands placed on them by the physiotherapist teaching them AHE.

McGill et al (1995) suggested that the trunk muscles are recruited to stabilise the lumbar spine and may assist in the mechanics of ventilation. During increased loading tasks, the trunk muscles are recruited to stabilise the spine and the diaphragm is required to control ventilation. Lumbar spine stabilisation may be sacrificed in those people with poor neuromotor control who are unable to differentiate and subsequently accommodate to, a dual requirement of breathing and provision of lumbar spine stabilisation. This further necessitates an understanding of the relationship between diaphragmatic and trunk muscle activation.

Therefore the aim of this study was to determine the relative activity of the diaphragm, RA and anterolateral abdominal muscles during AHE, at baseline and three incremental loads.

**Method**

The muscle activity of the diaphragm was determined using surface electrode placements as described by Gross et al (1979) and Sharp et al (1993). This is generally accepted in the area of respiratory function. Although there is a systematic change in the centroid frequency of the signal when compared with oesophageal electrode placement (Shar p et al 1993), this frequency shift would not significantly alter the EMG signal amplitudes for different incremental loads in a within-subjects study design. A pilot study was conducted to determine the validity of these electrode placements on the amplitude and onset of the subsequent EMG signal profile of the diaphragm.

One volunteer subject had the following transducers attached: an oesophageal electrode, gastric and pleural pressure balloons and four pairs of surface electrodes on the right (sixth and seventh intercostal spaces) and left (seventh and eighth intercostal spaces) mid-clavicular and lateral to the mid-clavicular lines (Gross et al 1979, Sharp et al 1993). While the subject performed a series of manoeuvres and tasks, the following EMG signal profiles were collected simultaneously: two differential oesophageal electrode configurations and four surface electrode configurations. Gastric and
pleural pressures were also recorded. All channels were collected at 1000Hz via power regulated amplifiers (Grass Instruments Co MA USA) and a 16-bit analogue to digital converter, for up to 10 seconds depending on the task, and stored and processed using Labview 4.0 Virtual Instruments software on a Power Macintosh (7500/100) computer. The data were visually inspected and the electrocardiographic artefact was extracted (no significant phase difference between channels was detected). The EMG signal data were then demeaned and band pass filtered (6Hz - 400Hz) using a 4th order zero lag Butterworth filter.

The subject performed the following tasks: deep breathing, upper limb perturbations (rapid arm movement), jumping, stepping and a series of Mueller manoeuvres (MM, static inspiratory effort without recruitment of the abdominal muscles) (Laporta and Grassino 1985) which the subject was specifically trained in performing.

The main part of the study involved a repeated measures design to investigate muscle recruitment of the anterolateral abdominal muscles, RA and diaphragm during ARE at incremental load increases of 5mmHg, 10mmHg and 15mmHg from a baseline level of 40mmHg as measured by a pressure biofeedback unit (PBU) (Chattanooga Australia Pty Ltd) placed between the lumbar spine and the plinth with the subject in crook lying. It is acknowledged that many therapists may use different protocols for setting the pressure of the device, however this was used to operationally define the motor control task for this study. Similarly, an operational definition of correct and incorrect performance of the ARE was determined by two experienced therapists and in accordance with similar interpretations of those by Richardson et al (1992). In the experimental setting, each subject was required to achieve and hold the required incremental load as determined by the PBU. In circumstances where substitution patterns were detected, the control strategy was defined as incorrect. Since the study focused on motor control changes as subjects moved from a correct performance to a substitution pattern, all subjects were required to be able to perform the ARE to the satisfaction of the therapists at an initial load increment of 5mmHg.

The dependent variable was muscle activity of the right lower RA, the right anterolateral abdominal muscles and the right side of the diaphragm.

Twenty-six healthy volunteers, 11 males and 15 females aged between 18 and 49 years were screened for the study. The subjects were recruited from the Perth metropolitan area and were excluded from the study if they: had a history of low back pain within the past six months; had neuromuscular or musculoskeletal disorders; had previous major abdominal surgery; were considered to be obese as categorised by a Body Mass Index > 27 (Bray et al 1976); or were unable to perform the ARE correctly, increasing the PBU by 5mmHg from a baseline level of 40mmHg (Richardson and Jull 1995; Richardson et al 1992).

Six subjects were excluded on the basis of the last exclusion criterion, consequently 20 subjects participated in the study.

Two 3M Ag/AgCl surface EMG electrodes were positioned at an inter-electrode distance of 25mm and aligned parallel to the muscle fibres for the right lower RA, anterolateral abdominal muscles and diaphragm. Surface EMG electrodes were positioned according to Ng et al (1995) for the right lower RA and the right internal oblique. As the internal oblique lies superficial to the transversus abdominis muscle, the relative contribution of each muscle to the surface EMG signal was unknown. Therefore the EMG signal was considered to represent a combined signal from the anterolateral abdominal muscles. The surface EMG electrodes for the right side of the diaphragm were positioned just lateral to the mid-clavicular line as per the pilot study (Gross et al 1979). The earth electrode was positioned over the left anterior superior iliac spine. The electrodes were connected to a preamplifier (Medelec PA63) and into an analogue to digital converter which sampled the EMG signal at 1000Hz.

Prior to testing, each subject was taught ARE in the four point kneeling position as described by Richardson and Jull (1995), and then in the crook lying position using the PBU as described by Richardson et al (1992). The skin was carefully prepared as described by Gilmore and Meyers (1983) and the surface EMG electrodes were applied to the skin. A multimeter was used to check that the skin impedance was below 5kΩ.

Electromyography testing was performed with the subjects positioned in crook lying on a plinth, with 70 degrees of hip flexion measured with a goniometer. A set of scales was positioned under the subject's feet to monitor if the subject pushed through the feet during the contraction, representing an incorrect motor pattern of abdominal hollowing. The PBU was positioned under the small of the back between L1 and S2. A submaximal contraction was selected for amplitude normalisation (Allison et al 1993, Allison et al in press). This was achieved by lifting both feet 1cm off the scales for a 10s period for amplitude normalisation. Subjects were then given a 3min rest period prior to formal testing. The formal testing protocol firstly involved a 10s period of quiet breathing to record a baseline EMG muscle activity level at rest. Subjects were then instructed to perform an abdominal hollowing contraction at one of the three incremental loads of 5mmHg, 10mmHg and 15mmHg maintaining each level of contraction for 10 seconds, during which the muscle activity was recorded. A 3min rest period was allowed between each load increment. Therapists performing the testing protocol were blind to the total root mean square (RMS) output during the testing.

The data were visually inspected and
the electrocardiographic artefact was extracted (no significant phase difference between channels was detected and therefore a windowing subtraction technique was used across all channels). The EMG signal data were then demeaned and band pass filtering (6Hz - 400Hz using a 4th order zero lag Butterworth filter). The RMS was calculated for two seconds (7th and 8th seconds) for the three abdominal hollowing contractions at 5mmHg, 10mmHg and 15mmHg, the amplitude normalisation double leg lift task and the baseline data of quiet breathing. The EMG signal data for each muscle for all the abdominal contractions and the baseline data were then amplitude normalised.

The SuperANOVA statistical package on a Power Macintosh computer was utilised for statistical analyses. A probability level of $\alpha < 0.05$ was determined to represent a statistically significant difference. Three one-way repeated measures ANOVAs with contrasts were used to determine if there was a significant interaction between the normalised muscle activity at the 5mmHg, 10mmHg and 15mmHg load increases for each muscle during the AHE. For the analysis of muscle recruitment during correct performance of abdominal hollowing, a one-way ANOVA and post hoc contrast analyses determined whether significant differences occurred in the relative increase in normalised EMG muscle activity during deep breathing, sudden upper limb flexion and a MM are illustrated in Figure 1. The MM activates the diaphragm against a relaxed abdominal wall. The two signals demonstrate a high association between the amplitude characteristics. It was determined that this was consistent with the current use of this protocol as reported in the literature and deemed as a valid interpretation of the amplitude of the diaphragm for the purposes of this study. Subsequent studies at Curtin University of Technology (O'Sullivan 1997), using this same protocol of surface electrode placement for the diaphragm and other surface electrode placements for the external oblique have demonstrated different amplitude and onset latencies during upper limb perturbations and abdominal hollowing protocols. Therefore, the electrode configurations for the diaphragm in these testing protocols were not detecting a significant crosstalk artefact from the external oblique. Nevertheless, it is likely that the intercostals, if acting in synergy with the diaphragm, would have contributed to the amplitude of the derived signal using this electrode configuration.

Results
Methodological issues
The EMG profiles of the diaphragm from an oesophageal and surface electrode configuration during deep breathing, sudden upper limb flexion and a MM are illustrated in Figure 1. The MM activates the diaphragm against a relaxed abdominal wall. The two signals demonstrate a high association between the amplitude characteristics. It was determined that this was consistent with the current use of this protocol as reported in the literature and deemed as a valid interpretation of the amplitude of the diaphragm for the purposes of this study. Subsequent studies at Curtin University of Technology (O'Sullivan 1997), using this same protocol of surface electrode placement for the diaphragm and other surface electrode placements for the external oblique have demonstrated different amplitude and onset latencies during upper limb perturbations and abdominal hollowing protocols. Therefore, the electrode configurations for the diaphragm in these testing protocols were not detecting a significant crosstalk artefact from the external oblique. Nevertheless, it is likely that the intercostals, if acting in synergy with the diaphragm, would have contributed to the amplitude of the derived signal using this electrode configuration.

Figure 2 illustrates raw data held over 10 seconds for the double leg lift (used for amplitude normalisation) for each of the three muscles. It would seem that the raw data have similar amplitude profiles and that the phasic characteristics of the diaphragm are of little influence on the overall data.

Main study
Figure 3 displays the mean and standard deviations of the normalised EMG signal of the diaphragm, RA and anterolateral abdominal muscles at the baseline level, 5mmHg, 10mmHg and 15mmHg load increments. An example of the raw data for one subject for one trial is illustrated in Figure 4 and clearly reflects the trends noted in the group means. Note cardiac artefact is seen in the baseline data for diaphragm and RA and that little increase in anterolateral abdominal muscles
amplitude is demonstrated at incremental loads. Table 1 illustrates that significant differences occurred between the normalised muscle activity of the RA and diaphragm at the 5mmHg, 10mmHg and 15mmHg load increments. No significant difference was shown between the load increments for the anterolateral abdominal muscles. Contrary analyses revealed that the normalised EMG signal of the diaphragm and RA significantly increased between the 5mmHg and 15mmHg load increment; no significant difference was shown for the baseline to 5mmHg increment during the correct performance of abdominal hollowing.

Figure 5 displays the relative increase in normalised EMG signal of the diaphragm, RA and anterolateral abdominal muscles from the baseline level to the 5mmHg load during correct abdominal hollowing. A one-way ANOVA and post hoc analyses revealed that the relative increase in muscle activity of the anterolateral abdominal muscles was significantly greater than that of the RA \( F_{1,119} = 10.2, p = 0.003 \). Statistically, this suggests that the subjects were performing the correct pattern of abdominal hollowing as determined clinically by the two physiotherapists for inclusion in the study. There was no significant difference in the relative increase in muscle activity between the anterolateral abdominal muscles and the diaphragm \( F_{1,119} = 3.86, p = 0.057 \) or the RA and the diaphragm \( F_{1,119} = 1.53, p = 0.224 \).

**Discussion**

**Methodological issues**

This preliminary study seems to suggest that it is possible to identify the amplitude of the diaphragm using surface electrode configurations. The difference between the two signals would seem to represent a low pass filtering effect of the soft tissues, differences between the costal and crural components of the diaphragm and cross talk from more superficial muscles. However, from our visual inspection, it would seem that the signal amplitude is very similar for tasks such as deep breathing and Mueller manoeuvres and any cross talk from muscles such as external obliquis makes a small contribution to the overall signal. This is critical in the fact that authors have identified specific substitution patterns which involve the external oblique.

Many criticisms of EMG single amplitude assessments are based on the issue of amplitude normalisation of the signals. It is clear that studies involving individuals with dysfunction associated with pain syndromes are unable to normalise the EMG signal profiles utilising maximal effort (Allison et al. 1993, Allison et al. in press). This study has nominated to use a double leg lift which provides a similar raw EMG amplitude profile of the muscles investigated and represents a stable motor strategy over the duration of the 10s hold. This would support the inferences by Allison and co-workers (1993 in press) that amplitude normalisation procedures need to be applicable to the population being tested and that protocols should be examined carefully since selection of the normalisation protocol influences the variance and consequently the power of the subsequent statistical analysis. This study would support the use of the double leg lift on the basis that the amplitude of the signal was great enough to exceed the ECG artefact; that the signal amplitude is similar to the activity being tested; and that it is consistent across trials (O’Sullivan 1997) and during the 10s duration.
Abdominal hollowing exercises

It has been well established that the anterolateral abdominal muscles are recruited to stabilise the lumbar spine by the interaction of at least two mechanisms such as increasing intra-abdominal pressure and via the thoracolumbar fascia (Cresswell et al 1992, Gracovetsky et al 1985, Tesh et al 1987). Abdominal hollowing exercises taught by physiotherapists have been shown to be effective for the recruitment of the anterolateral abdominal muscles (Richardson et al 1992). However, it is possible that the significance of the motor control pattern lies in the isolation of the anterolateral abdominal muscles as reflected by a motor control strategy of decreasing the activity of some muscles (ie RA) and the facilitation of others (anterolateral abdominal muscles). In this study, the muscle activity of the anterolateral abdominal muscles significantly increased from the baseline level to the 5mmHg load increment, when the subjects were deemed to be performing the correct AHE pattern.

The role of the diaphragm during the correct performance of AHE has not been reported. The results of this study demonstrated that the muscle activity of the diaphragm significantly increased from a baseline level of quiet breathing to the 5mmHg load increment. During the correct performance of abdominal hollowing at the 5mmHg load increment, subjects were required to continue breathing normally. However, it is clear that breath holding, identified as a substitution pattern, is an unsatisfactory description of a multitude of strategies which result in a pattern of substitution. In the simplest sense, breath holding may infer closing of the glottis, yet significant differences in the function of the diaphragm can be seen while maintaining an open glottis and where the subject uses an upper chest breathing pattern. This study seems to reflect this position since all the subjects kept breathing normally but the phasic characteristics and the activity of the diaphragm were noticeably different from quiet breathing. This provides an example where our initial perception of a muscle centered substitution pattern, that is breath holding, would seem less stereotypical than previously considered. Further examination of possible interactions between different muscles is warranted on the basis of assisting the interpretation of motor control strategies in the clinical setting.

The increase in the EMG signal of the diaphragm could reflect a change in the degree of activity or excursion of the diaphragm. This may be used to alter any of the possible mechanisms associated with altering the stability of the trunk or lumbar spine. However, it is clear that when subjects are deemed to be performing the correct motor strategy of AHE, it would seem that there is an increase in the activation of the diaphragm as measured by surface EMG. Figure 5 illustrates the fact that the phasic characteristics of quiet breathing were altered during AHE even at the lowest of loads. It is only speculation that this increase in activity of the diaphragm altered the stability of the lumbar spine. However, such speculations are consistent with previous studies that describe a synergistic action of transversus abdominis, internal obliques, diaphragm and the pelvic floor to increase intra-abdominal pressure for lumbar spine stabilisation in response to an external load placed on the spine (Cresswell et al 1994, Grew 1980, Kumar and Davis 1973). In addition, Williams et al (1989) describe an

<table>
<thead>
<tr>
<th>Repeated measures ANOVA</th>
<th>Baseline / 5 (mmHg)</th>
<th>5 / 10 / 15 (mmHg)</th>
<th>Post hoc analyses</th>
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<tr>
<td>ALA</td>
<td>p = 0.724</td>
<td>*p &lt; 0.001</td>
<td>p = 0.703</td>
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<tr>
<td>Diaphragm</td>
<td>*p = 0.038</td>
<td>*p &lt; 0.001</td>
<td>p = 0.212</td>
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<td>RA</td>
<td>*p &lt; 0.001</td>
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* Significant difference between the mean normalised EMG signal (p < 0.05) n = 20, df (19).
anatomical relationship between the costal portion of the diaphragm interdigitating with transversus abdominis which may suggest a possible neurological/motor control link.

The muscle recruitment of the diaphragm, anterolateral abdominal muscles and RA was further investigated during ARE at load increments of 5mmHg, 10mmHg and 15mmHg above a baseline of 40mmHg monitored by a pressure biofeedback unit. Clinical inspection by two experienced physiotherapists revealed that the subjects performed the AHE correctly at a load of 5mmHg yet none were considered able to perform the task without substitution patterns at the highest load.

The diaphragm and RA muscle activity significantly increased from the 5mmHg load increment to the 15mmHg load increment, however there was no significant change in the activity of the anterolateral abdominal muscles. This would infer that the anterolateral abdominal muscles were recruited at the 5mmHg load increment and the diaphragm and RA were further recruited to achieve the load increase of 15mmHg. It is unclear whether a) the anterolateral abdominal muscles were maximally recruited and therefore the diaphragm and RA were substituted to achieve the additional load or b) the optimal motor strategy for this task was to recruit the diaphragm and RA rather than increase activation of the anterolateral abdominal muscles. Nevertheless, the muscle activity of the diaphragm increased with the recruitment of RA, as the subjects used alternative motor patterns to achieve the 15mmHg load increment.

Clinically, during attempted performances of abdominal hollowing which were deemed to be incorrect, the increase in RA muscle activity may be explained by the subjects posteriorly tilting their pelvis and bracing the abdomen, however it is possible to tilt the pelvis without increases in RA activity. The fact that specific substitution patterns have been identified belies the diversity of the possible control strategies. Moreover, the associations between the movement patterns and the level of muscle activity as recorded by EMG is yet to be objectively explained in the clinical or experimental setting.

The increase in diaphragmatic activity may be explained by the subjects maintaining a larger than normal inspiratory volume and then sustaining this lung volume (with glottis open) against an increasing intra-abdominal pressure due to simultaneous contraction of the abdominal muscles reflected here in the activity of the RA (and probably the pelvic floor). It is therefore probable that the synergistic activation of the diaphragm and RA are an attempt to maintain the higher intra-abdominal pressure. Clinically, physiotherapists are aware that breath holding is associated with the recruitment of substitution patterns during incorrect performance of AHE. However, an upper chest breathing pattern may also facilitate the use of the diaphragm during such manoeuvres. It is possible that altered breathing patterns may be present in a certain proportion of individuals with chronic back pain due to the specific utilisation of the diaphragm as a means of adjusting mechanisms which may influence the trunk stability and more specifically segmental stability of the lumbar spine. This study provides evidence that increased diaphragmatic activity is associated with the performance of AHE.

Finally, this study, in the experimental setting, utilised operationally defined incremental loads, as recorded by the PBU, as a form of perturbing the possible motor control strategies. The ability to generalise to activities of daily living and to individuals with motor dysfunction or spinal pathology is the focus of further research at this institution.

Conclusion

This study demonstrates that the diaphragm plays a role during AHE. During the correct performance of abdominal hollowing, the activity of the diaphragm increased with recruitment of the anterolateral abdominal muscles. Clinically, the subjects were not considered to be breath holding, or breathing in an obviously abnormal manner or with recruitment of accessory muscles. It is postulated that the increased muscle activity of the diaphragm and the anterolateral abdominal muscles is associated with an important mechanism of lumbar spine stabilisation. This is yet to be verified.

During incorrect performance of abdominal hollowing at the higher load increments, muscle activity of the diaphragm further increased with the recruitment of RA. Clinically, this coincided with various substitution patterns. It is probable that the increased activity of the diaphragm with RA is an attempt to flatten the lumbar spine to attain the increased load. It remains unclear how the incremental changes in pressure in the PBU actually reflect movement or translation of the lumbar spine. What is clear is that the increasing load places additional demands on the muscles of the trunk and diaphragm which may play a significant role in the stabilisation of the lumbar spine.

The results of this study indicate that when teaching AHE to patients, physiotherapists should consider the diversity of different motor control strategies and that muscle recruitment during AHE at increasing loads may be associated with increased activity of the diaphragm. Teaching the motor strategy in functional positions is therefore critical and if subjects are dependent on the diaphragm to achieve this strategy then they may resort to incorrect motor strategies when placed under some form of increased ventilatory or aerobic load. This is a critical consideration in individuals who need to maintain lumbar spine stability during work and sporting activities and in return to work programs or functional rehabilitation regimens.

Further research is necessary to evaluate the possible dual role of the diaphragm in the provision of trunk
stability and appropriate ventilation in individuals with and without chronic low back pain.

Footnote.

A summary of these data were presented in poster form at the 10th Biennial Conference of the Manipulative Physiotherapists’ Association in Melbourne, November 1997.

References


