Strengthening Transversus Abdominis in Subjects with a History of Lower Back Pain and Asymptomatic Individuals: The FLEXI-BAR V's Stabilization Training

By

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ABSTRACT

Background: The neuromuscular system acts to maintain spinal stability and reduce the impact of complex loading patterns associated with activities of daily living. During the past decade, exercising of the abdominal muscles has become widely used in the management of low back pain (LBP) in order to provide this supplement to spinal stability. Several exercise programs have been advocated to promote lumbar stabilisation but evaluation is difficult. As new training methods are emerging, a clear understanding of the efficacy of modern interventions used to strengthen neuromuscular structures to provide stability and to prevent future complications is currently considered an important area of research.

Objective: The study aims to establish the strengthening effect of the transversus abdominis muscle (TrA), comparing the application of stabilization training with vibration training in the form of the FLEXI-BAR, whose normal function is regarded as significant in spinal stability.

Methods: A convenience sample of seventeen subjects, were classified into two groups; those with a history of LBP, and those without a history of LBP. Nine subjects formed the FLEXI-BAR training group and eight the stabilisation training group, both performed an exercise program for a training period of four weeks. A pressure biofeedback unit (PBU) was used to assess the performance of the TrA muscle adopting a test-retest (pre-test and post-test) design. The statistical significance of the changes between TrA function before and after the program was analysed by performing a mixed between-within subjects analysis of variance (ANOVA). Furthermore, another ANOVA was produced to investigate whether the impact is different for HLBP and NLBP subjects

Results: Although not statistically significant, increases in strength were observed in subjects involved with the FLEXI-BAR program. In particular greater strengthening of the TrA muscle was seen in the history of LBP group.

Conclusion: This study provides one step forward in the knowledge concerning the efficacy of exercise programs to strengthen the core stability system. The results seem to indicate that the FLEXI-BAR has an ability to strengthen the TrA, and could provide an application to aid the rehabilitation of LBP individuals.

Keywords: Transversus abdominis; Lower back pain; FLEXI-BAR; Stabilization training; Vibration training; Pressure biofeedback unit

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CHAPTER 1 INTRODUCTION

The stability of the spine is determined by the osseoligamentous armour that encapsulates the spine (Panjabi, 1992; Norris 1995a). The complex loading patterns associated with activities of daily living, act on these structures and if unprotected, can expose spinal vulnerability, predisposing musculoskeletal injuries, such as lower back pain (LBP) (Renkawitz et al. 2006). The growing awareness of LBP as a major clinical problem has promoted increased interest and research into this continuing epidemic (Cairns et al. 2000).

Recent epidemiological research has focussed primarily on the local stability system, which acts as a 'corset like' structure to tighten the waist, when the spine is in a loaded position (Hides et al. 1996; O'Sullivan et al. 1997; Danneels et al. 2001; Hides et al. 2001). The correct alignment required to stabilize and accommodate movements depends on adequate strength and endurance of the abdominal musculature (Hodges and Richardson, 1997a; 1997b; Zedka and Prochazka, 1997; Beith and Harrison, 1999a; 1999b; 1999c). It is the activation of the dynamic spinal support system that is exposed and which provides the basis for the concept of stabilization training (Hides et al. 1996; O'Sullivan et al. 1997; Danneels et al. 2001; Hides et al. 2001).

The heightened interest in abdominal muscle development has resulted in an explosion of exercise devices, although only moderate scientific evidence is available regarding their efficacy (Carriere, 1999; Vera-Garcia et al. 2000; Hildenbrand and Noble, 2004; Marshall and Murphy, 2005; Marshall and Murphy, 2006). Although not a contemporary concept, vibration training, has received little empirical attention for its strengthening potential. An oscillating device such as the FLEXI-BAR, targets the smaller muscles of the back and abdominal region, enabling the lumbar and abdominal muscles to produce the stiffness required to optimize the loading on the lumbar spine and to prevent injury (Callaghan and McGill, 1995; Kaigle et al. 1995; McGill, 1997; Gardner-Morse and Stokes, 1998).

As new training methods are emerging, a clear understanding of the efficacy of modern interventions and exercise programs used to strengthen neuromuscular structures to provide stability and to prevent future complications is currently considered an important area of research (Chartered Society of Physiotherapy 1999; American Physical Therapy Association, 2000).

The purpose of this study was to investigate the strengthening effect of the transversus abdominis muscle (TrA), by comparing the application of stabilization training with vibration training in the form of the FLEXI-BAR, over the course of a four week training program. The aim of the research was to evaluate its capacity to support the existing literature with regards to the effectiveness of stabilization training and to evaluate vibration training on the ability to supplement spinal stability, in order to consider both applications in the management of LBP.

The novelty of this study will provide information regarding the efficacy of the FLEXI-BAR and its strengthening potential on core stability, in a population with a history of LBP and also with a comparison of training modality which is at the forefront of current research. To date, the author is not aware of any studies that have evaluated this. Secondly, by virtue of the outcome measure used, it will enable determination of the level of strength demonstrated by improvement in the study subjects, indicative of the effect that vibration training can produce, adding to prescriptive knowledge of this form of training.

CHAPTER 2 LITERATURE REVIEW

Introduction

To gain an appreciation of the complex and evolving principles that underpin core stability, unequivocal aspects of this topic should be identified and considered in isolation, in which five main areas have been identified. Firstly, spinal pathology is considered, specifically within the context of the local stability system, followed by a discussion on LBP and the approaches for rehabilitation in line with clinical guidelines. Thirdly, the role of stabilization training will be analyzed and its relevance within the clinical setting. Finally the concept of the FLEXI-BAR is introduced, which will attempt to address and analyze the relationship between vibration training and its ability to strengthen the core stability system.

Spinal Pathology

The human spine devoid of its musculature is inherently unstable (Norris, 1995c). The traditional model of biomechanics considered the spinal ligaments, intervertebral disc and osseous elements to be the structures solely responsible for stabilization of the vertebral column (Knuttson, 1944; White and Panjabi, 1978). However, in vitro studies have revealed the non-pathologic osseoligamentous spine to be incapable of tolerating normal physiological loads (Lucas and Bresler, 1961; Cynn et al. 2006). Cholewicki and McGill (1996) described spinal loads associated with occupational and recreational activities ranging from 6,000 to 18,000 N. In vitro studies of the osseoligamentous lumbar spine, it has been found that the spinal pathology develops at loads between approximately 20 and 90 N (Lucas and Bresler, 1961; Crisco, 1989; Jemmett et al. 2004).

Further biomechanical research has demonstrated that lumbar motion segments display bi-phasic stiffness properties across the physiological range of motion (ROM) (Panjabi, 1992a; Jemmett et al. 2004) (See Appendix I). In which such findings have led to the development of a more comprehensive model of spinal function in which the central nervous system, skeletal muscle and osseoligamentous structures are considered to be inter-reliant mechanisms of a spinal stabilization system (Panjabi, 2003). Given the inability of the osseoligamentous spine to tolerate the loads associated with normal activities, spinal muscles are now deliberated as key to the maintenance of adequate spinal stability, in which co-ordinated muscular activity is mandatory to prevent excessive loading, leading to injury.

The evolution of the spinal stability model has prompted much research, focusing particularly on the functional set of (deep) muscles (transversus abdominis (TrA), psoas, quadratus lumborum and lumbar multifidus) with segmental patterns of attachment in the lumbar region conducive to the maintenance of intersegmental stiffness. They have been hypothesized, to be architecturally capable of developing the intersegmental stiffness required for spinal stability (Bergmark, 1989; Quint et al. 1998; Hodges et al., 2003; Jemmett et al. 2004), in which a number of studies have reported on the anatomical, biomechanical or neurophysiological characteristics of these muscles in context with spinal stability (McGill, 1991; Wilke et al. 1995; Andersson et al. 1996; Penning, 2000; Hodges et al. 2003).

Despite this significant body of work, a review of the literature failed to identify, the fundamental anatomy and architecture of the deep lumbar muscles, an area which has not, in all cases been fully established (Bogduk and MacIntosh, 1984; Barker et al. 2001). In vivo, the stabilizing role of the spinal muscles cannot be easily studied by EMG measurement, because EMG recording does not provide a quantative measure of muscle force (Panjabi, 2003). Furthermore, the deep spinal muscles ('stabilizers') are difficult to reach. However, a recent in vitro study (Jemmett et al. 2004), limited to the examination of a single specimen, found evidence that the TrA attaches only via the anterior layer of the thoracolumbar fascia (TLF). This is in contrast with previous work (Bogduk and MacIntosh, 1984; Barker et al. 2001). The findings could be indicative of simple variation in the normal anatomy. Regardless, an understanding of the extent of this variation may be important from a therapeutic perspective, given the recent clinical emphasis on motor re-education of the TrA in individuals with low back pain (Richardson et al. 1999). The lack of large studies which comprehensively detail the attachments of this important muscle in context of lumbar stability represents a gap in the literature.

The Role of TrA and Multifidus

TrA and lumbar multifidus are important components of the local stability system, in which a number of studies have reported on the anatomical, biomechanical or neurophysiological characteristics, in the context of spinal stability (McGill, 1991; Wilke et al. 1995; Anderson et al. 1996; Hodges, 1999; Penning, 2000; Hodges et al. 2003). EMG studies have revealed that the multifidus along with TrA are the only muscles active during all trunk movements (Cresswell et al. 1994; Wilke et al. 1995). So can it be proposed that these muscles co-contract simultaneously?

Functionally, the proposed co-contraction of lumbar multifidus and TrA is unlikely to be obligatory, although there is evidence that TrA is continuously active (with amplitude modulation) during gait (Saunders et al. 2004) and in static postures (Cresswell et al. 1992), whilst lumbar multifidus is active with phasic bursts. However there is research to suggest similarities between TrA and lumbar multifidus. For example both muscles are active in a non-directional-specific feedforward manner in preparation for the perturbation of the spine from arm movements. Although contraction may not be simultaneous, the mechanical effects may occur more or less simultaneously because the electromechanical delay of TrA takes longer than lumber multifidus due to the long-elastic anterior fascias. Earlier activity of TrA may compensate for this delay (MacDonald et al. 2006).

Several EMG studies have previously reported that muscle recruitment patterns in patients with LBP differ from healthy subjects (Richardson et al. 1992; Hodges et al. 1996; Richardson, 1996; Lariviere et al. 2000; O'Sullivan, 2000; Marras et al. 2001; Hodges and Hides, 2004b). The dysfunction of the TrA has been demonstrated as a motor control deficit (Hodges and Richardson, 1995; 1996; 1997). The EMG analysis of the experiment by Hodges and Bui (1996) showed, that the onset of activity of the muscles of the abdominal wall in response to upper and lower limb movements, indicated that the timing of onset of TrA was delayed in LBP sufferers, compared with individuals who have never experienced back pain (Hodges and Richardson, 1995).

Changes in activation patterns and cross sectional area of the segmental portion of the lumbar multifidus has also been suggested (Hides, 2004b). Several studies have demonstrated morphological changes in lumbar multifidus in LBP, which show a degree of type I muscle fibre atrophy (Hultman et al. 1993; Parkkola et al. 1993; Rantanen et al. 1993; Sihvonen et al. 1993; Mattila et al. 1999). Consequently the muscle is weaker (Mayor et al. 1989; Cassisi et al. 1993) and exhibits excessive fatigue (Mayor et al. 1989; Biedermann et al. 1991; Klein et al. 1991; Roy et al. 1995; McGill, 1998; Chok et al. 1999).

It is also worth noting that TrA and multifidus are often difficult to activate and may weaken in both sedentary individuals and those with LBP (Soderberg and Barr, 1983; Herrington and Davies, 2005). Therefore evidence exists that these muscles may not be optimally recruited, or may fatigue in their stabilizing role, even in normal, currently asymptomatic individuals (Parnianpou et al. 1988). Therefore, asymptomatic individuals with dysfunctional TrA and multifidus muscles may be in a ‘at risk’ group of developing LBP symptoms, because of their failure to fully activate their dynamic spinal support system.

Lower Back Pain

Current biomechanical understanding about the pathogenesis of LBP is still incomplete. Billions of pounds are spent annually on the treatment of LBP and low back injuries (Coyle and Richardson, 1994; Ellis, 1995; Waddell, 1996), affecting up to 80% of people at some point during their lifetime (Katz, 2002; van Tulder et al. 2002; Ehrlich, 2003;

Woolf and Pfleger, 2003). It is reported that despite the "large numbers of pathological conditions that can give rise to LBP, 85% of these are without a detected patho-anatomical/radiological abnormality" (Dankaerts et al. 2006a, p.1). It is this 'non-specific' population which often develops into a chronic fluctuating problem with intermittent flares (Croft et al. 1998; Burton et al. 2004).

Intense research efforts have been made to understand the complex and unique structures of the spine (Waddell, 1987; 2004; Dillingham, 1995; Wimmers et al. 2003; Dankaerts et al. 2006a). The evidence suggests that spinal muscles provide stability (Van Dieen et al. 2003) and muscle recruitment patterns significantly affect loading on the intervertebral joints (Mirka and Marras, 1993; Marras et al. 2001). Therefore imbalanced muscle activation can theoretically load the spine incorrectly and induce LBP and musculoskeletal injury (Price et al. 1948; Grabiner et al. 1992; Renkawitz et al. 2006). One of the highest research priorities should be to determine the best strategies for treating individuals with a history of LBP (Abenhaimet et al. 2000).

There are many treatment options for LBP, in which a recent review (Assendelft et al. 2007) comparing spinal manipulation, manual therapy, physiotherapy, exercises, back school and analgesics, concluded that the optimal treatment remains largely enigmatic. The review which compared 'sub-groups' of LBP subjects, highlighted the uneven quantity and methodological quality of the randomised controlled trials (RCT's). A criticism of the review was that for the 'exercise' intervention, trials were formulated into this broad cluster, with insufficient detailing of the exact treatment that was applied for this intervention. The generalization of 'exercise therapy' as a single form of treatment detracts greatly from the interpretation of the results. Exercise therapy is a multi-faceted modality that requires specific prescription, in which randomised controlled trials need to be narrowed in definition (Hayden et al. 2007).

However a review of the literature reveals that a shift can be observed in the choice of interventions to a more active approach (Koes et al. 2001; Rasmussen-Barr et al. 2003; Koumantakis et al. 2005; Groenendijk et al. 2007), being one of the key determinants of improvement for many sufferers (van Tulder, 2002). In contrast to Assendelft et al. (2007), recent systematic reviews have concluded that exercise is a safe, effective therapy, when compared to usual care (van Tulder et al. 2000; Liddle et al. 2004; Rainville et al. 2004; van Tulder and Koes, 2004a). Furthermore positive results have been documented with different types of exercise, such as low-stress aerobic exercise (Manniche, 1999; Mannion et al. 2001; Koumantakis et al. 2005), flexion-extension movement modalities (Chok et al. 1999; Leinonen et al. 2000; Byrne et al. 2006), strengthening (O'Sullivan et al. 1997; Carpenter and Nelson, 1999; Petersen et al. 2002; Byrne et al. 2006; Ferreira et al. 2007), flexibility (Herrington and Davis, 2005; Sherman et al. 2005), advice to 'stay active (CSAG, 1994; Koes et al. 2001) utilised by physiotherapists, suggesting there is little evidence that a particular 'type' of exercise is any better than another, both with respect to their duration and their physical intensity (van Tulder et al. 2000; Hayden et al. 2007). Furthermore, there appears to be no direct dose-response relationship (Campello et al. 1996; Arokoski et al. 2004).

In coherence with other reviewers (Hilde, 1998; Abenhaim, 2000; Tugwell, 2001), contemporary recommendations should focus research not on general exercise therapy, but instead on trials that investigate specific exercise intervention strategies (Hayden et al. 2007).

A better understanding regarding the extent of physiological and functional effects of more modern exercise techniques used in LBP rehabilitation, like stabilization exercise training, is currently considered an important area of research (Chartered Society of Physiotherapy, 1999; American Physical Therapy Association, 2000). Although there are several randomised controlled trials on the usefulness of classic trunk exercises, which activate the abdominal and paraspinal muscles as a whole, at relatively high contraction levels (Kellett et al. 1991; Hansen et al. 1993; Risch et al. 1993), recently increasing attention has been paid to preferential re-training of the local stabilizing muscles of the spine (Hides et al. 1996; O'Sullivan et al. 1997; Danneels et al. 2001; Hides et al. 2001).

Although some clinical research has demonstrated that re-training these muscles leads to a decrease in short-term and long term LBP symptoms in some special populations with apparent instability pre-dispositions (Hides et al. 1996; O'Sullivan et al. 1997; Hides et al. 2001), it is still generally unclear whether stabilization exercises can be generally applied to any individual with LBP (Nachemson, 1985; O'Sullivan, 2000; Koumantakis et al. 2005; Ferreira et al. 2007).

Nonetheless, the gap between evidence-based guidelines and the physiotherapy management of LBP is well recognised in the literature (Foster et al. 1999; Hurley et al. 2000; Li and Bombardier, 2001; Gracey et al. 2002; Armstrong et al. 2003).

Stabilization Training

Biomechanical models suggest that all muscles with intervertebral attachments are better suited for intersegmental stability provision (multifidus, transversus abdominis), as opposed to the larger trunk muscles (erector spinae, rectus abdominis), which are dedicated to movement generation (Bergmark, 1989). Inadequate activation of the local stabilising trunk muscles may lead to instability of the lumbar spine (Panjabi, 1992a).

The evidence presented indicates that a program for the TrA and multifidus is required for specific lumbar segmental stabilization training, which is reasoned as a knowledge of the muscle dysfunction found in individuals with a history of lower back problems (Jull et al. 1995).

Recruitment of the abdominal muscles during exercises to restore motor control has not been clearly defined. The basic concept of an isolated action of these local muscles is taught by asking the individual to gently draw in the abdominal wall, especially in the lower abdominal area (Richardson and Jull, 1995). Most studies have used surface electromyography (EMG) to investigate these techniques (Patridge and Walters, 1960; Kennedy, 1980; Richardson et al. 1990; Jull et al. 1995; Allison et al. 1998; O'Sullivan et al. 1998; Vezina and Hubley-Kozey, 2000) and the results of the small number of intramuscular EMG studies are inconclusive (Carmen et al. 1972; Strohl et al. 1981; Goldman et al. 1987; De Troyer et al. 1990). For example three different recruitment patterns were reported when six subjects were instructed to 'pull in' their abdominal wall (De Troyer et al. 1990).

There are only a few methods of achieving an isometric co-contraction of the local muscles independent of the global. In the study by Norris (1995a) abdominal hollowing was reported to be achieved in two different ways, by dynamic abdominal bracing (DAB) and abdominal hollowing (AH) which have been shown to give muscle activity suitable for lumbar stabilization (Richardson et al. 1990; Norris, 1995c; 2001). It was the latter, that most subjects found easier to learn. Importantly, a recent study (Urquhart et al. 2005) which standardized the instructions for the procedure of the voluntary exercise provided further EMG evidence to validate that the recruitment of TrA, with minimal activity of other abdominal muscles, may be best achieved during the inward movement of the lower abdominal wall (Richardson et al. 1992).

Active persons without a history of LBP have little difficulty in performing this task (Richardson and Jull. 1995). However it has been reported that it is not easily achieved by patients with LBP (Richardson and Jull, 1995; O'Sullivan, 2000; Norris, 2001). It should also be noted that, stability muscles have been described as better suited to endurance and better recruited at low resistance levels (Richardson and Jull, 1995; Liebenson, 1998; O'Sullivan, 2000; Norris, 2001; Urquhart et al. 2005).

Evidence supports the use of four point kneeling or prone lying as the best positions to perform the abdominal 'drawing in' manoeuvre (ADIM) for training (Richardson et al. 1992; Richardson and Jull, 1995). It has been shown that a facilitatory stretch of the deep abdominal muscles resulting from the forward drift of abdominal contents (Richardson et al. 1992; Beith et al. 2001; Norris, 2001) is aided in these positions and that EMG activity reveals an inhibitory activity of global muscle, rectus abdominis (Richardson and Jull, 1995; O'Sullivan, 1998; Beith et al. 2001).

Once the individual is able to preactivate and maintain the co-contraction pattern, the individual can hold the position while 'load is added via the weight of the lower limbs' into a loaded position (Liebenson, 1998). In which the progression of this technique can be taken through several stages (Jull and Richardson, 1995; O'Sullivan, 2000; Norris, 2001; Koumantakis, 2005), which is based on the motor learning model (Saunders, 2004).

The research supporting the efficacy of stabilization training has been insubstantial and inconclusive. Recently widely publicized trials supporting specific stabilization exercises from laboratory based research (Hodges and Mosely, 2003), and small-scale RCT's with pre-defined subgroups of LBP patients have provided positive evidence (O'Sullivan et al. 1997; Hides et al. 2001). However subsequent larger trials in hospital settings with non-specific LBP subjects have found conflicting evidence of the effects of these exercises compared to advice and manual therapy (Cairns et al. 2000; Golby et al. 2000)

The study by Sung (2003) looked at the effect that a stabilization exercise program had on the endurance of the multifidi muscle. Results suggest that exercise training emphasized the role that lumbar multifidi muscle plays on stabilizing the spine during functional movement, but had no effect on EMG determinants of fatigue. Suggesting that spinal stabilization exercises affect back muscle function by mechanisms other than improved endurance of the stability musculature. Although the pattern of results from the longlitudinal study suggested positive treatment effects, the limitations involved reduced specificity of training, with regards to an insufficient number of exercises used in the program, a short exercise period, and no control group, which must be viewed as relatively weak evidence for the effect. Macdonald et al. (2006) however reiterated that training the co-contraction of multifidus and TrA as part of a therapeutic exercise program was unlikely to restore typical activation patterns, but may be required to compensate for an underlying osseoligamentous deficit to restore intervertebral control.

Although it is evident that these inconsistencies exist within the literature, within a clinical setting it appears that stabilization training has been accepted and is presently a popular treatment choice for LBP patients. The cross-sectional survey (Bryne et al. 2006) that investigated the current use of a range of exercise therapy approaches for LBP by outpatient's physiotherapists, found that specific spinal stabilization exercises to be the most popular (51%). Although a relatively modest sample size used, this evidence conflicts with the lack of endorsement from LBP clinical guidelines (Koes et al. 2001; van Tulder et al. 2002).

The methodological quality of the studies that are amongst the literature, at large, makes evaluation problematic, because of the lack of appropriate measurement techniques, partly due to the anatomical position of the local musculature system.

Clinical trials require explicit and repeatable measures (Hayden et al. 2007). A snapshot of empirical evidence exists with regards to the high quality trials, (Hodges, Richardson, Jull, Hides) overtly highlighting the efficacy of stabilization exercises. Although subordinately on the success of TrA and multifidus retraining in treatment of LBP, the concept has been ignored by a large proportion of the medical community (Hayden et al. 2007). Although currently at the forefront of research, as new training methods, modalities and new marketing tools are emerging, a better understanding of the effects of such techniques is considered an important area to focus (Koumantakis et al. 2005).

FLEXI-BAR

The heightened interest in abdominal muscle development has resulted in an explosion of abdominal exercise devices in recent years, such as the Ab Roller, Ab Trainer and the FitBall are just a few to mention that have appeared on the market, although little scientific evidence is available regarding their efficacy (Carriere, 1999; Vera-Garcia et al. 2000; Marshall et al. 2005; Marshall et al. 2006). Hildenbrand and Noble (2004) conducted a study investigating the activity of the abdominal musculature by comparing these exercise devices with the traditional trunk curl. Eliciting both a statistically and practically significant difference, in the electric activity of the abdominal musculature when exercising with the different types of exercise devices.

The FLEXI-BAR is a device that has been used for many years in Germany for rehabilitation purposes and is used in the recreational training environment, yet its application in a rehabilitation setting in the United Kingdom (UK) has received little empirical attention. Adapted from the Proprio-bend, developed 30 years ago, the FLEXI-BAR works on the basis of vibration training, by superimposing a 5 Hz vibration-like stimulus to the muscles during movement. The FLEXI-BAR is marketed to effectively target and stabilize the deep muscles of the body. The vibrations are created when a shaking action is maintained, triggering a passive response from the deep muscles allowing the agonist and antagonist muscles to work together in response to the vibrations that forces them to start working. Thus an unstable environment is created as the vibrations disrupt the stability of the spine.

The FLEXI-BAR can be used to target muscles of the whole body, with the assertion that the device balances out neuromuscular dysfunctions, improves proprioception and body co-ordination, activates the pelvic floor muscles, stimulates connective tissue structures and improves sensory motor activity. Studies on patients with chronic low back pain have found that an oscillating tool such as the FLEXI-BAR stabilizes the smaller muscles of the back (multifidi, rotators, semispinalis), and the abdominal muscles (TrA). Theory suggests that the vibrations produced by the FLEXI-BAR automatically switch the core musculature on.

Current research is sparse and as late, has focused on muscle strength and neuromuscular activation of the large, superficial muscle groups. A study conducted by Amin et al. (2006) looked at the effects of a FLEXI-BAR exercise session on neuromuscular function (muscle activation and strength) measured by surface EMG, on a number of muscles located proximally and distally to the origin of the stimulus, in comparison to performing the same exercises using a sham bar. Significant differences between muscle activity during FLEXI-BAR vs. sham bar exercises were observed only in the muscles close to the FLEXI-BAR (triceps, biceps from the upper limb). No statistically significant results were found in the activity of any of the other muscle groups between the FLEXI-BAR and the sham bar. A non-statistically significant sample size was used and due to the different dimensions which existed between the non-vibratory control bar and the FLEXI-BAR, results may have been affected and contributed to an inconclusive trial. The majority of research carried out on the FLEXI-BAR has been done in Germany. With only a handful of trials investigating the activation of the core stability system, however these trials have not been translated into English. Due to the location of the local musculature system, future assessment of muscle activity would require intra-muscular EMG studies to be conducted, which would involve ethical consideration and could affect subject participation levels. To date, it is not clear the strengthening effect that the FLEXI-BAR exhibits on the core stability muscles, and to the author's knowledge, its effectiveness as a rehabilitation tool for selected populations e.g. LBP is an area of research that has not been tackled.

The Effects of Vibration Training

Vibration training is not a new concept, in which much research has investigated the mechanisms related to structural adaptation and muscular response. The focus of the research is based on outcome measures of muscular strength and power, in which evidence suggests, can be illicitly improved with vibration training.

Consistent with other trials, research conducted by Bosco et al. (1998) found that the improvement in muscle performance after vibration training was similar to that occurring after several weeks of heavy resistance training (Ikai and Fukunnaa 1970; Coyle et al. 1981; Hakkinen and Komi, 1985). Enhancement of the neurogenic functions of the leg extensor muscles after 3 weeks with seen. The vibration application period of 10 minutes and the perturbation of gravitational field consistent (5.4g), "an equivalent length and intensity of training stimulus can be reached only by performing 150 leg press or half-squat exercises with extra loads of three times the body mass, twice a week for 5 weeks" (Bosco et al. 1992). This is reiterated by Diemen (2006), who found that the same effect can be achieved with vibration training, which requires a modest training effort, as with that of weight training, requiring maximal effort. This illustrates that it is not just the effect which is of relevance, but ones motivational preferences to take part in physical activity can be inhibited by not only the length of time it takes to undergo physical activity, but also the effort that is required. This could have significant relevance within the clinical setting.

Whole body vibration (WBV) has been used as a method of training to increase strength. Once again it is mainly the large muscles that have been investigated. A review of the literature highlights conflicting and inconclusive results for this type of training. From the twelve studies that were reviewed (Schlumberger et al. 2001; Torvinen et al. 2001; Delecluse et al. 2003; Roelants et al. 2004a; 2004b; 2006; Ronnestead, 2004; Verschueren et al. 2004; Delecluse et al. 2005; Cormie et al. 2006; Fagnani et al. 2006; Mahieu et al. 2006) all studies had a control group, although the activities used in this group varied. In five of the studies control groups performed identical exercises to the WBV group (Schlumberger et al. 2001; Delecluse et al. 2003; Ronnestead, 2004; Mahieu et al. 2006; Roelants et al. 2006). WBV strength training effects were found in eight of the studies (Schlumberger et al. 2001; Torvinen et al. 2001; Delecluse et al. 2003; Roelants et al. 2004a; Roelants, 2004b; Verschueren et al.

2004; Cormie et al. 2006; Fagnani et al. 2006;), when compared to the passive control groups. However Torvinem et al. (2001) found there was no improvement in the WBV or passive control group in leg press force and grip strength. Also Cormie et al. (2006) found no difference in peak force and peak power comparing the WBV and passive control group. Furthermore, Delecluse et al. (2005), who used a different study design, using a different subject population and methodology to the other trials, found that with WBV no surplus value to conventional training was indicated, when WBV training was additionally performed.

Comparison of these inconclusive results could be related to the methodological short comings. Studies used different subject populations (trained and untrained), different exercises were performed between and within trials, and various outcome measures (dynameter, high box test, surface EMG, contact mat force plate) were used. The studies reviewed suggest further research is required using different measuring techniques with potential to look at muscle recruitment, comparing identical exercises between the control and WBV groups. Branching into new territory to objectively investigate the concept of vibration training and its efficacy to target the deep intrinsic muscles of the body.

Aims of Study

The available research provides little evidence to clinicians who need to decide which interventions to implement for the treatment of LBP. There is evidence to support the use of stabilization training, although there is little basis on which to substantiate the use of alternative modes of exercise, such as the FLEXI-BAR, which is currently based on conceptual vibration theory. Few studies have examined the muscle activity levels following therapeutic exercises in subjects with LBP, and the results obtained in the studies controversial (Alexiev, 1994; Ng et al. 2002). Consequently, a pilot study has been conducted to compare the effects of stabilization training and the FLEXI-BAR for individuals with and without a history of LBP.

Secondary aims of the study were:

- To consider the reproducibility and reliability of the pressure biofeedback unit (PBU) as a tool designed to facilitate the assessment of the absence or presence of LBP and TrA dysfunction, against published guidelines.
- To consider any association between subjects with a history of LBP and level of abdominal functioning.
- To identify the most effective form of exercise to potentially change any motor deficit of the TrA in subjects with a history of LBP.

CHAPTER 3 METHODOLOGY

Design

An experimental methodology was adopted using a test-retest design. This enabled subjects to act as their own controls (Kinnear and Gray, 2000). The experimental study combines two approaches, using between-subjects and within-subjects variables, in one analysis, facilitating an investigation into the impact of two different modes of exercise on their ability to strengthen core stability (using pre-test and post-test), and in addition, consider whether the impact is different for subjects with and without a history of LBP (Hodges et al. 1996; Hodges and Richardson, 1996; 1997; Cairns et al. 2000). An outline of the study structure is shown in Appendix IV.

All subjects were randomly assigned to each of the experimental conditions, reducing the problem associated with non-equivalent groups in between-groups design (Stevens, 1996; Tabachnick and Fidell, 1996; Sim and Wright, 2000). Randomization was performed independently. Pilot testing was conducted to enhance familiarity with the procedures required to use the PBU and to address temporal stability and intra-rater reliability (Pallant, 2002). The format of the exercise program, together with the exercises selected for use, were also piloted to limit contaminating factors that might influence the results (Goodwin, 1998; Stangor, 1998). The intervention period was four weeks (Hides et al. 1996) and the expected study hypotheses were as follows;

I. Strength training significantly increases TrA strength

II. FLEXI-BAR training has a significantly different effect on TrA strength to stabilization training
III. LBP groups TrA strength is significantly different to non-LBP groups
IV. The LBP and non-LBP groups response to exercise is significantly different

Subjects

The subjects were seventeen (10 female and 7 male) students recruited from the University of Birmingham, of which all volunteers were undergoing a health related study program. Subjects received verbal and written information about the trial and each participant signed informed consent (CSP, 2002) (Appendix II). The inclusion criteria were men and women 18 to 65 years of age, who had a history of LBP and who were not receiving either specific abdominal stabilization training nor performing an organised regime of flexi-bar training, at the time of testing. This ensures that the validity of the data obtained is not influenced by external factors (Marshall and Murphy, 2006). Exclusion criteria were a history of postural or skeletal abnormalities, neuromuscular disorders or spinal damage (Hodges, 1996). Trials based on subjects with serious spinal pathology have found that they are not considered representative of the majority of LBP patients (Teasell and Harth, 1996; Snook et al. 1998). No one subject was experiencing lower back pain in his/her body while testing and no subject had experienced a *significant* episode of LBP in the last 6 months, as permitted by the university.

The age of the subjects ranged from 20 to 56 years with a mean age of 28.5 years (SD = 8.4). The mean age of the male subjects was 28.4 years (SD = 4.5), while for females, the mean was 28.6 years (SD = 9.8). Of the seventeen subjects in the sample nine reported a history of non-specific lower back pain. Subjects' LBP history is shown in Table 1. The remaining eight subjects were asymptomatic.

Table 1: Subjects LBP Characteristics

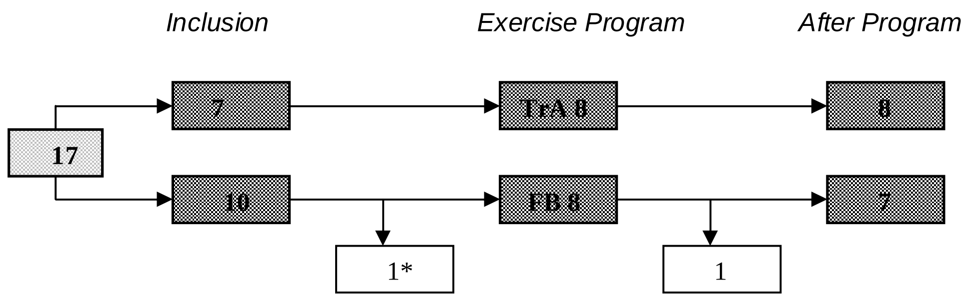
	FB-group (n = 5)	*TrA-group* (n =4)
Age (year) Median (SD)	29 (4.5)	36.5 (13.9)
Gender (female/male)	3/2	3/1
Exercise Habits (seldom/weekly)	0/5	0/4
Previous treatment for LBP	(3)60%*	(1) 25%*
History of LBP (≤ 6 months/ 6 months-2 year/2-5 yrs/5yrs +)	1/2/2	1/1/1/1
Diagnosis given (yes/no)	60%/40%*	25%/75%*

FB = FLEXI-BAR training group, TrA = stabilization training group
* Number of individuals (% of individuals in the group)

Subjects were classified initially into two groups: those with a history of lumbar spine pain, which were the symptomatic individuals (HLBP) and those without a history of lumbar spine pain, the asymptomatic individuals (NLBP), which formed the control group. After, subjects were randomised into either of two groups: A training group using the FLEXI-BAR (FB) (n=9) and a stabilization group (TrA) (n=8) taught using the ADIM. The first HLBP subject and the first NLBP subject included in the study were randomised to one of the groups by lot (9 HLBP cards and 8 NLBP cards in a box). The HLBP and NLBP individuals were then separately and consistently randomised to either group (Rasmussen-Barr et al. 2003).

Two subjects (both in HLBP-FB group) dropped out of the trial. One immediately after inclusion, before the first PBU testing, associated with personal commitments and the other due to a shoulder injury, not related to the trial (Fig. 1). The groups were thus: HLBP-FB n=3, NLBP-FB n=4, HLBP-TrA n=4, NLBP-TrA n=4. All dropouts are included in the baseline data.

Figure 1: Flow chart showing study flow, number of subjects and number of dropouts



The open boxes represent the subjects that dropped out of the study.
* Subjects that dropped out before the exercise program.

Ethical Consideration

All subject identification information that has been collected during research activity has been kept strictly confidential, with the assurance of subject anonymity where possible.

A review of the ethical principles underpinning the study highlighted a potential issue surrounding the sample population. Strict criteria prohibited the author to use a sample population who at the time of the trial had an episode of LBP. Clearance of this issue is addressed in the exclusion criteria of the trial. Also, with any exercise application, the potential for training to cause harm was minimised by frequent interaction with subjects, teaching of correct technique and supplementary printed guidelines to accompany the exercise program. Any subject exhibiting any adverse effects to the exercise prescribed were prohibited from continuing with the study. Ethics Committee at the University of Birmingham approved the study.

Procedure

Before and after the intervention, assessments were made. Prior to the intervention, the subjects filled out a health questionnaire, regarding age, gender, exercise habits, LBP history and treatment and general health status (Skargren, 1998; Smidt et al. 2005) (Appendix III).

One week before the exercise program was taught, each subject attended a one hour mandatory training session to become familiar with the exercise technique, the equipment and protocol. An information pack was also administered to each subject, containing the protocol (Appendix IV), training diaries (Appendix V), the exercise program (Appendix VI) and a self-efficacy home exercise questionnaire (Appendix VII).

Subjects were encouraged to perform a training program, designed to take 10-15 minutes, at home, three times a week (FLEXI-BAR, 2007). A training diary was kept to control compliance (Descarreaux et al. 2002; Kolt and McEvoy, 2003) (Appendix V). Total workload, based on the number of repetitions performed, was filled in for each set performed for each exercise, for each exercise session performed by the subject (Marshall and Murphy, 2006). This workload, as well as total physical activity (e.g. hours spent participating in other sporting or physical leisure activities) was collected at the end of the intervention. Many instruments are routinely used to assess adherence to exercise programs. The Home Exercise Compliance Assessment (HECA) facilitates self-assessment of various exercise forms. Although no previous reports of the psychometric properties of this adherence measure could be found in the literature, this self-report method of assessment for adherence to home exercise has been used in several previous investigations (Noyes et al. 1983; Almekinders and Almekinders, 1994; Brewer et al. 1994; May and Taylor, 1994). Adapted from the HECA, subjects completed a Self-efficacy Home Exercise Questionnaire (Appendix VII) administered at the end of the intervention to access compliance related data.

Progress was regulated through supervision at the initial introductory training, at two weeks (drop in session) and via phone contact at 1.5 and 3 weeks initiated by the author, and throughout the intervention as dictated by the subjects, to augment adherence to the home exercise component (Jackson, 1994; Friendrich et al. 1996; Brewer, 1998; Friendrich et al. 1998; Schneiders, 1998; Spetch and Kolt, 2001).

Exercise Instruction Sheets

Exercise instruction sheets (produced using the ‘Physiotools’ computer program, Chattanooga Group and FLEXI-BAR images [FLEXI-BAR, 2007]) with written and illustrated instructions were also used to enhance adherence, by increasing understanding, stimulating memory processes, and encouraging information recall (Ley, 1988; Sneiders et al. 1998). Supplementary printed material used to support exercise programs, has shown in previous research (Spelman, 1984; May and Taylor, 1994; Schneiders et al. 1998) to strongly increase rates of adherence in home-exercise programs (Kolt and McEvoy, 2003).

Two different exercise programs were formulated, with comparable exercises between the FB and TrA groups. The exercise sheets included clear diagrams and standard instructions (Appendix VI). The aim of the exercises were to strengthen the core stability system, specifically TrA and because no clear identification of any specific, superior exercises could be drawn from the literature, seven comparable, commonly used back rehabilitation exercises were generated by an experienced personal trainer and FLEXI-BAR instructor and a sport scientist (Richardson and Jull, 1995; Hides et al. 1996; 2001; O'Sullivan et al. 1997; Richardson et al. 1999; Koumantakis et al. 2005;). The exercise programmes were not periodized. Pilot work indicated that the seven exercises would take approximately 13 minutes to complete.

Pressure Biofeedback Unit (PBU)

A stabilizer pressure biofeedback unit (Chattanooga Group, Inc.) and a stopwatch (Heuer Microsplit 1000) were used to indirectly measure the subject's ability to perform a TrA isolation test (Cole et al. 1994; Cairns et al. 2000). Previous studies support the use of the PBU as a reliable and valid clinical instrument to act as an indicator of deep abdominal function (Cole et al. 1994; Richardson and Jull, 1995; Hodges et al. 1996; Richardson et al. 1999; Cairns et al. 2000), although arguably the low intra-tester reproducibility, highlights uncertainties regarding its use as an outcome measure for scientific purposes (Storheim et al. 2002). Due to the anatomical location of the TrA, invasive procedures, in the form of fine wires, impregnated through the skin, would be required to achieve scientific accuracy, although queries regarding ethical approval are noted and would not be appropriate for this study. With this regard and the acknowledgment of the explicitly small sample sizes used in previous studies, standardization of the test procedure is considered central to the validity of the results (Appendix VIII).

The subjects were familiarised with the abdominal drawing-in manoeuvre (ADIM), by a previously developed technique (Teyhen et al. 2005). The subject was first instructed in the ADIM via traditional training techniques (Richardson et al. 1999). The subjects were instructed to gently pull the abdominals in toward the spine as they exhaled and then to maintain this contracted state for 10 seconds. The initial training included tactile cueing with the subject's fingers palpating 1 inch medial and inferior to the anterior superior iliac spine (ASIS) to help confirm contraction of the TrA. After the subject understood the intent of the ADIM, and the investigator felt that an optimum level had been achieved, but no more than six practice tries were allowed in an attempt to prevent premature fatigue (Cairns et al. 2000), the subjects underwent testing.

The testing position is lying prone as recommended by Richardson and Jull (1995) and Hodges et al (1996). Due to the localisation and the function of the TrA muscle, this position inhibits the rectus abdominis and involves minimal external loading. The inflatable cell was placed centrally beneath the abdomen with the lower edge at the level of the ASIS. Readings were taken at the start and finish of a 10-second contraction, over three consecutive contractions, with one minutes rest between contractions (Cairns et al. 2000). The highest score over the 10 second contraction was also recorded. Subjects performed the manoeuvre using standard instructions (Table 2); inward movement of the abdominal wall (Richardson et al. 1999). Subjects adopted a breath-holding strategy, where the TrA was set at the end of expiration. Previous research has identified this as an important strategy to reduce contamination of results (Hodges and Richardson, 1997b). Changes in pressure readings were calculated from the baseline of 70 mm Hg. The mean change in pressure at the end of the three contractions was calculated and used further in analysis. The mean final change in pressure was used, as the prone test examines endurance rather than ability purely to activate a muscle.

Readings were taken at full expiration and the PBU was 'zeroed' to 70 mmHg before each contraction. No feedback was given to the subjects during data collection.

Table 2: Standardized instructions used for the voluntary PBU

EXERCISE	*INSTRUCTIONS **
Inward movement of the lower abdominal wall	Breath in and out. Gently and slowly draw in your lower abdomen below your navel without moving your upper stomach, back or pelvis.

* Subjects were instructed to perform each exercise with 'mild' effort (a rating of 2 on the Borg scale)

A correctly performed abdominal drawing-in action will result in pressure reduction. Although inconsistency within the literature exists regarding what a normal pressure reduction response is during the test, reflecting on the findings from Herrington and

Davies (2005), the adjusted figures of Hodges et al. (1996) will be used (Cairns et al. 2000) (Appendix IX). According to the manufacturer, the accuracy of the apparatus is ± 3mm Hg (Storheim et al. 2002).

Training Intervention

FB Group

The FB-group subjects (n = 7) underwent a 4 week training program, meeting initially for the pre-training session, recommended by FLEXI-BAR that a week is required for subjects to familiarise themselves with the equipment and correct technique (Appendix X). A week later, the subjects were taught the exercise program (Appendix X). Both sessions were done in a group environment. Subjects were not explicitly taught how to train the isometric contraction of the TrA muscle through the ADIM.

Exercise

The subjects were taught to perform the seven different exercises by practicing them under the guidance of a FLEXI-BAR instructor. Subjects had no experience using the FLEXI-BAR, but were all leading an active lifestyle, which incorporated exercise on a weekly basis. Training guidelines recommend that for maximum results, the bar should be used three times per week, 10-15 minutes each session (FLEXI-BAR, 2007). Subjects were able to perform all of the exercises and are arranged in Appendix VI.

TrA Group

The TrA-group subjects (n = 8) underwent a 4 week training program. The mandatory session (Appendix XI) required subjects to be taught how to train an isometric contraction of the TrA muscle through the ADIM, together with relaxed breathing, in the four point kneeling position (Norris, 1995b; Richardson and Jull, 1995; Beth et al. 2001; Herrington and Davis, 2005), introducing the first phase of lumbar stabilization (Norris, 1995; Richardson and Jull, 1995; Koumantakis et al. 2005). Once mastered, different positions were practised (e.g. supine and crooked-lying). The subjects were instructed in a group.

The week separating the pre-training session and the teaching of the exercise program, subjects were asked to practice the precise repetition of the isolated isometric-specific contraction of (TrA of) the stabilizing muscle, increasing their contracting time up to 10 seconds (Koumantakis et al. 2005). With 10 seconds being the optimal amount of time to hold the contraction (Norris, 1995b). Within the literature there is no consensus as to the frequency of each exercise, therefore eight repetitions were sustained, guided by standard Pilates training principles (Herrington and Davies, 2005).

Exercise

The subjects were taught to perform the seven exercises by practising under the guidance of a Sports and Exercise Scientist (qualified at degree level) (Appendix XI). Most of the subjects had experience performing these exercises and all participated in weekly exercise or physical activities.

The exercises involved static positions and contraction with movement (Richardson and Jull, 1995; Komantakis et al. 2005). Only low levels of muscle contraction is required as tonic fibres operate at levels below 30-40 % MVC (Hoffer and Andreassen, 1981; McArdle et al. 1991; Norris, 1995b; Cholewicki and McGill, 1996). Additionally it has been argued that only low levels of muscle force, approximately 25% MVC, are needed to develop the increased stiffness required for enhancing spinal stability. Thus, the subjects were instructed to perform each exercise with 'mild' effort, which is equivalent to a rating of 2 on the Borg scale (Borg, 1982; Urquhart et al. 2005) (Appendix XII). Subjects were able to perform all of the exercises, which are arranged in Appendix VI.

Risk Assessment

Demonstrating good practice, a risk assessment was carried out for both laboratory and home exercise program environments, prior to data collection (Appendix XIII).

Analysis

All statistical analysis was undertaken using SPSS Software (Version 14.0). The statistical significance of the changes between TrA function before (Time 1) and after (Time 2) the program was analysed by performing a mixed between-within subjects analysis of variance (ANOVA). Furthermore, another ANOVA was produced to investigate whether the impact is different for HLBP and NLBP subjects.

Additionally, Individual pressure changes were compared against published guidelines to classify subjects into groups based on the result of their prone test (Hodges et al.

1996; Cairns et al. 2000). (Appendix IX), and compliance rates graphically represented for each mode of exercise.

CHAPTER 5 RESULTS

FLEXI-BAR V's Stabilization Training

A difference in PBU scores before and after training was observed (Fig. 2.). During the FLEXI-BAR intervention, PBU scores decreased considerably from M=68.00 before the intervention to M=65.57 after intervention (Table 3). Whereas, PBU measurements for the stabilization intervention, hardly decreased after the four week exercise program (accounting for the margin of error there is no difference in this group), indicating a stronger strengthening effect of the TrA muscle in subjects undergoing vibration training.

Table 3 Descriptive statistics; means and standard deviations categorized by group history.

	Group History	Training Regime	Mean	Std. Deviation
Before Training	HLBP	FLEXI-BAR	67.35	1.45
		TrA	68.25	.928
		Total	67.86	1.17
	NLBP	FLEXI-BAR	68.50	1.37
		TrA	69.67	1.61
		Total	69.09	1.52
	Total	FLEXI-BAR	68.00	1.42
		TrA	68.96	1.43
		Total	68.51	1.46
After Training	HLBP	FLEXI-BAR	64.12	2.41
		TrA	68.00	1.36
		Total	66.34	2.68
	NLBP	FLEXI-BAR	66.67	2.48
		TrA	68.58	1.75
		Total	67.63	2.23
	Total	FLEXI-BAR	65.57	2.62
		TrA	68.29	1.48
		Total	67.02	2.45

Estimated marginal means data of Time is shown in Fig 2. Amongst the distribution of scores, greater variance post training in the FLEXI-BAR group is indicated by the standard deviation (SD=2.62) (Appendix XIV).

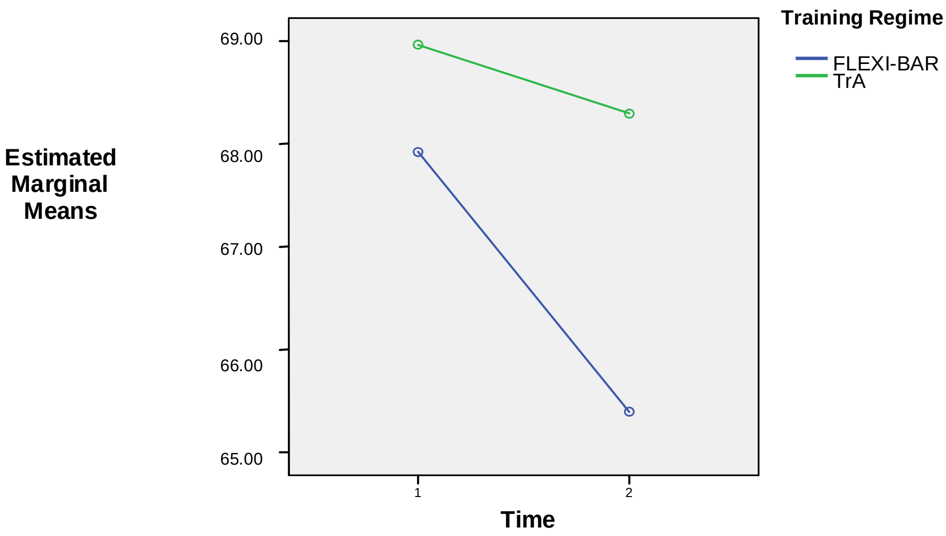


Fig. 2 Estimated marginal means of PBU scores before (Time 1) and after (Time 2) the exercise program.

The distribution of PBU measurements before and after training indicates a greater variability in scores in the FLEXI-BAR group. There is one outlier at the high values for PBU measurements for stabilization training. A greater difference between the training regimes PBU scores is considerably illustrative after training (Fig. 3 and 4).

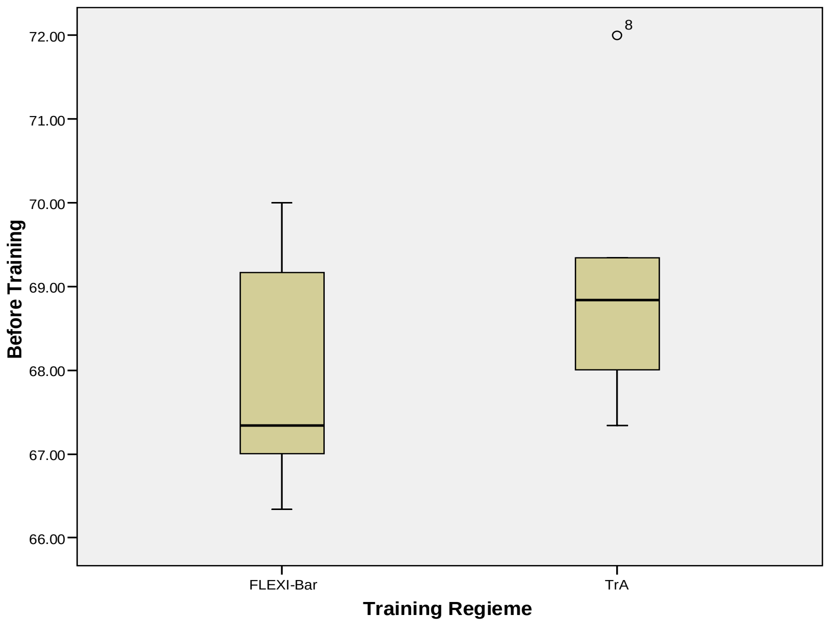


Fig. 3 A Box plot representing PBU measurements for both training regimes before training.

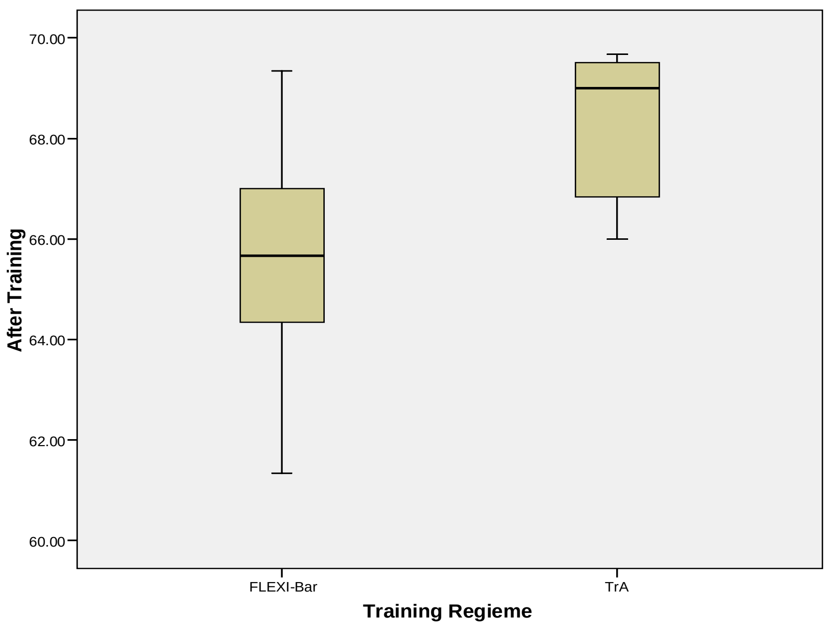


Fig. 4 A Box plot representing PBU measurements for both training regimes after training.

Results of Analysis

Strength Training Effects

There was a statistically significant main effect for Time, Wilks' Lambda=.497, F(1, 14)= 13.14, p=.003, with a very large effect size (eta squared=.503). Suggesting, a responsive change in TrA strength, between before and after the exercise program, therefore supports the hypothesis that strength training increases TrA strength. Results for multivariate tests are shown in Appendix XIV.

Training Regime

The main effect for training regime [F (1, 14) = 5.01, p=.04] was statistically significant, with the effect size being relatively large (eta squared=.278). Indicating that there was a significant difference in TrA strength between those who received FLEXI-BAR training, and those who received Stabilization training (Appendix XIV). However the interaction effect [F(1, 14)= 4.56, p=.06] did not reach statistical significance. Highlighting that there was no difference in TrA strength between the two conditions, before or after the exercise programs. Consequently, the hypothesis that FLEXI-BAR training has a different effect on TrA strength to stabilization training must be rejected.

Group History

Baseline data of PBU measurements were observed to be lower in the FLEXI-BAR group, in both conditions (HLBP and NLBP). Indicating that subjects in this group were initially able to contract their TrA muscle better than the stabilization group. Overall, It was perceived that a greater TrA strength, was distinguished in the HLBP-FB group (from M=67.34 before intervention to M=64.12 after intervention), than that of the between-subject factors of the stabilization group. The distribution of PBU measurements before and after training indicates the vast variability in scores within each group (HLBP and NLBP) and also accentuates considerably differences between the groups (Fig. 5 and 6).

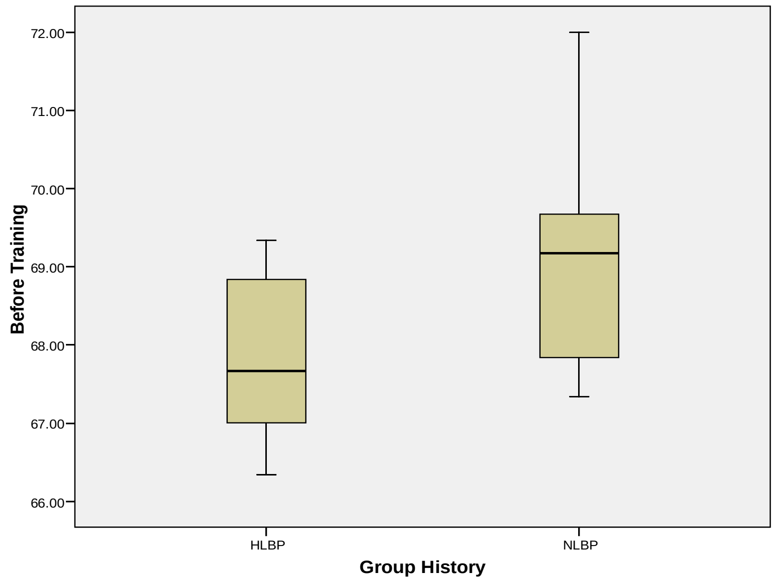


Fig. 5 A Box plot representing PBU measurements, categorized by group history before training.

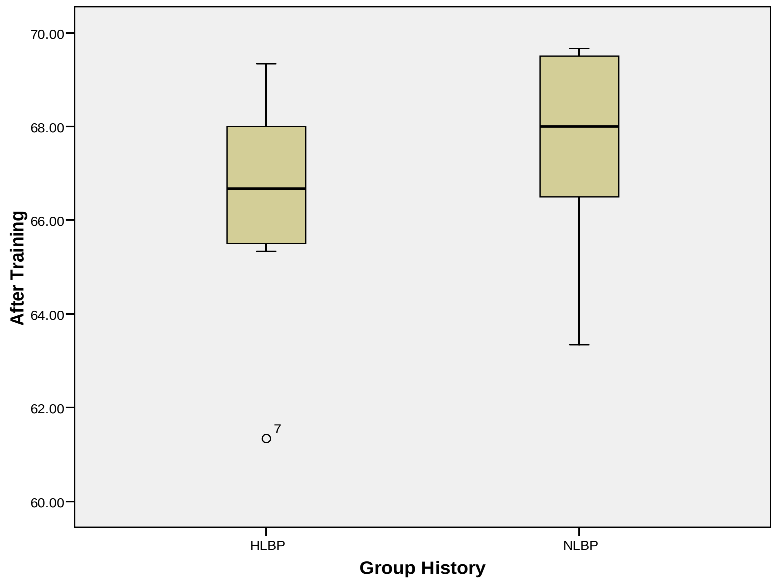


Fig. 6 A Box plot representing PBU measurements, categorized by group history after training.

Results of Analysis

HLBP and Non-LBP TrA Strength

As indicated by PBU scores, TrA strength, for both HLBP and NLBP groups, demonstrated no between-or within-group effects. The main effect for Group (HLBP and NLBP) [F (1, 14) = 3.34, p=.09] and the interaction effect [F (1, 14) = .304, p=.59] did not reach statistical significance (Appendix XIV). Signifying that there was no difference between the HLBP and NLBP groups between vibration and stabilization training. As a result, the hypothesis that LBP TrA strength is different to the non-LBP group is rejected.

LBP and Non-LBP Response to Exercise

Additionally, there was no statistical significant interaction effect [F(1,14)= 1.623, p=.23] found connecting the HLBP and NLBP groups between vibration training and stabilization training, before and after the exercise program (Appendix XIV). Dismissing the final hypothesis, that the LBP and non-LBP groups' response to exercise is different.

Power Analysis

Due to a moderate sample size, the non-significant results indicate insufficient power of the test (Appendix XIV). The low power values (<.80) indicated by the power analysis indicates a low level of confidence that there is no real difference between the groups.

PBU Results in Accordance to Guidelines

According to the guidelines by Hodges (1996), the statistics highlight that the subjects in the NLBP group represent a higher proportion of PBU scores cumulating in the ‘abnormal’ category, both before (63% [FB=25%, TrA=38%]) and after (50% [FB=13%, TrA=37%]) the exercise program, when compared to the HLBP group (Before; 43% [FB=14%, TrA=29%] , After; 29% [TrA=29%]. Results shown in Fig. 7.

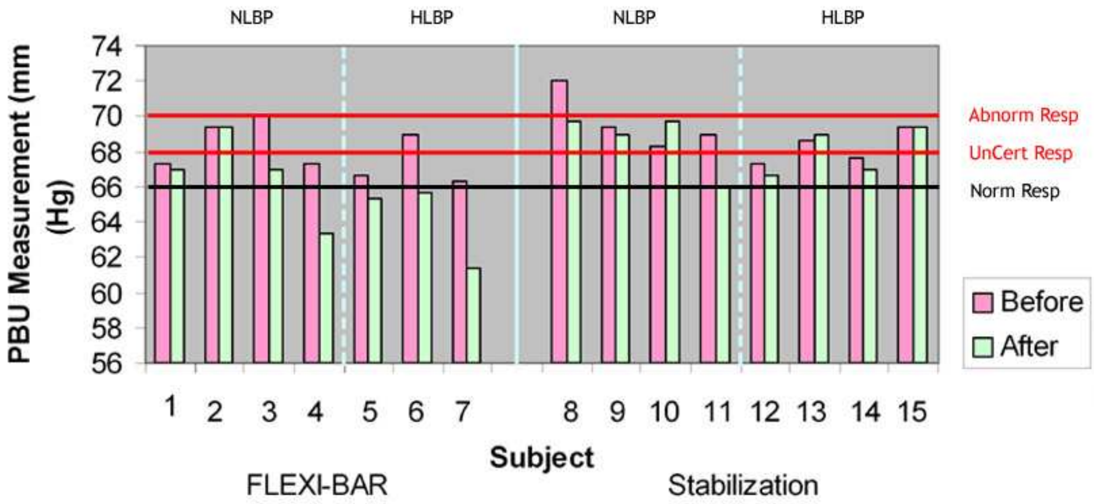


Fig. 7 A bar chart to show the PBU results in accordance to guidelines, prior to and following the exercise program for both FLEXI-BAR and stabilization training for each subject.

In contrast, the HLBP group has a higher proportion of subjects with PBU scores in the ‘uncertain’ category before (57% [FB=29.5%, TrA=29.5%] and after (29% [TrA=29%]), when compared to the NLBP group (Before; 25% [FB=25%], After; 25% [FB=25%]).

However following the exercise program, 43% (FB=43%) of PBU scores can be seen to come under the ‘normal’ category, which is represented highly in the HLBP (NLBP=25% [FB=12.5%, TrA=12.5%]).

Exercise Program Compliance

A similar trend can be denoted for both the FLEXI-BAR and the stabilization group (Fig. 8). Throughout the four weeks of training no participant missed all three sessions in one week. During week one compliance was high, with 86% [FLEXI-BAR] and 87.5% [TrA] of subjects undertaking all three sessions. In week two, a percentage decline with 71% [FLEXI-BAR] and 75% [TrA] undertaking all three sessions, with 12.5% [TrA] only performing the exercises once a week.

As the weeks progress there is was a tendency for compliance rates to become significantly lower. Results suggest that in the final week, ⅔ less compliance was observed in the stabilization group (subjects adhering to the exercise program 3 times per week), when compared to week 1. Following suit, in comparison to the beginning week of the FLEXI-BAR program, only ½ of those subjects performed the exercises three times per week, during the final week of the program.

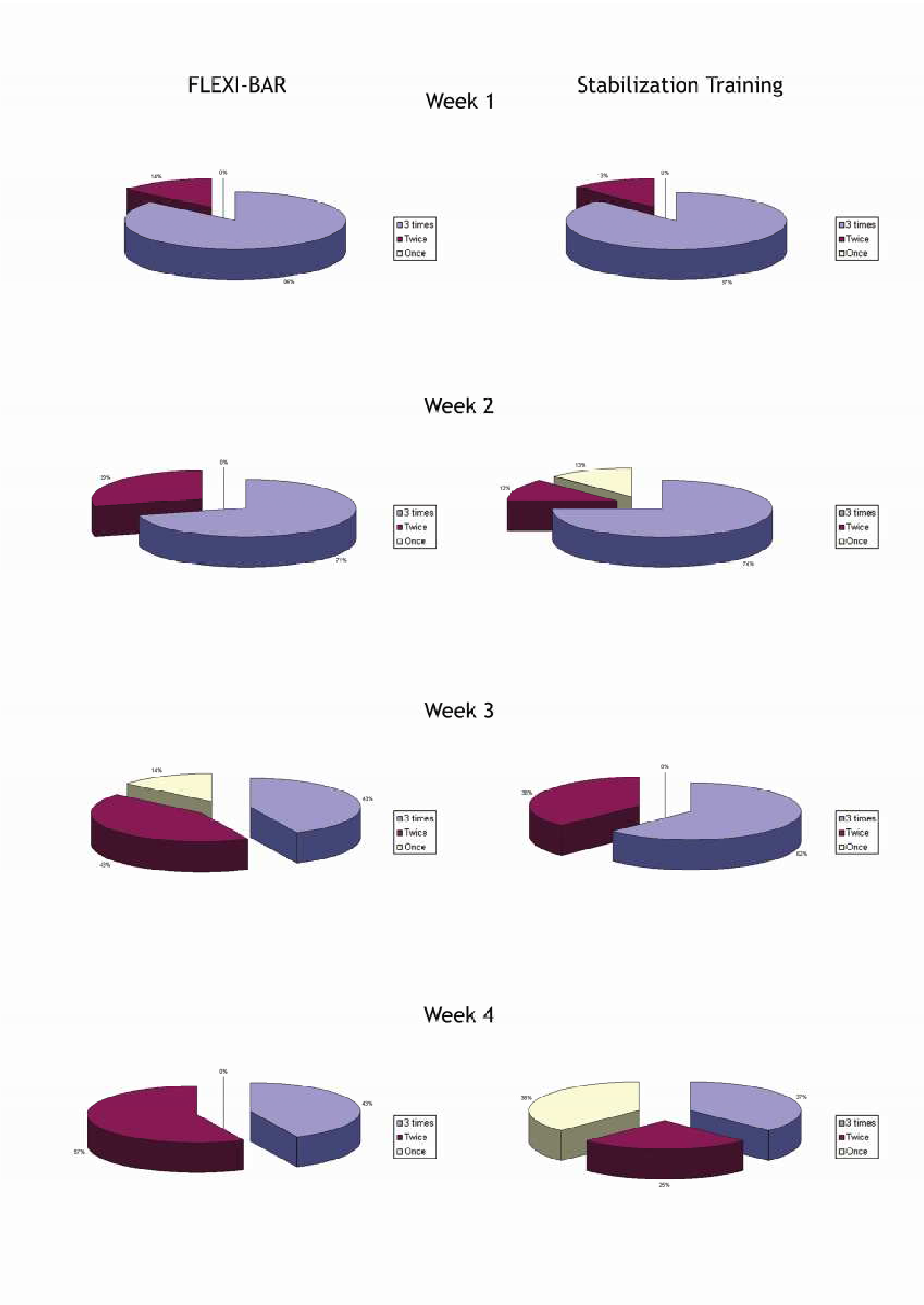


Fig. 8 Pie charts to represent the number of times per week (%) that subjects undertook the exercise programs.

CHAPTER 5 DISCUSSION

Training Regime Comparison

Strengthening the spines musculature is a current concept at the forefront of research, in which there are many exercise options available to support core stability and target specifically the TrA (Koumantakis et al. 2005).

In this study, a large effect size was demonstrated between those who received FLEXI-BAR training and those who received stabilization training, however no difference was statistically found within the subjects of the two training modes, at baseline and following the exercise programs. Analysis of subject's means from the descriptive data detects that greater strength increases were observed in the FLEXI-BAR group (reduction of 3mmHg) following the four week exercise program. In contrast to this, subjects in the stabilization group were reported to exhibit a minimal improvement (reduction of 1mmHg) in TrA strength between baseline and after four weeks of training. During the pre-session training, the FLEXI-BAR group were not explicitly taught to perform the ADIM whilst exercising with the bar, but encouraged to 'tighten' the abdominals. The enhancement of the TrA muscle demonstrated by the FLEXI-BAR, supports the hypothesis that the bar has the effect to automatically switch on the core musculature when the bar vibrates, thus confirming strengthening of the relevant appendshire.

It could be proposed that the inhibitory effect of strength identified amongst the stabilization group, could be explained by a number of reasons. Although Hides et al (1996) reported long-term effects of stabilization training following four weeks of training

(Hides et al. 2001), the training period in this study prior to the subjects undergoing the exercise program may not have been considered sufficient. Findings from previous studies, report that several weeks of practice may be required to learn to contact the TrA correctly (Richardson and Jull, 1995; O'Sullivan et al. 1997). In the present study a week separated the pre-session training and the exercise program and although between this time subjects were encouraged to practice not only the exercises taught, but urged to activate the stabilizing muscles in all activities of daily living (Rasmussen-Barr et al. 2003), the teaching augmented in a group environment, meant that apart from palpating the TrA contraction in the subjects, there was no means of verifying whether these muscles were recruited appropriately. Taking an individualistic approach to the stabilization-enhanced exercise group, may have benefited this group.

The FLEXI-BAR also encompassed the largest training effect on an individual subject. It is worth noting that the individual reported a 100% compliance rate throughout the exercise program, reinforcing that the exercise dose prescribed was correct. An abundance of research has investigated the concept of vibration training and the mechanisms related to structural adaptation and muscular response. In comparison to stabilization training, the FLEXI-BAR produced greater strengthening effects over the same time period. This can be demonstrated by observing the dose-response relationship. Although both groups were prescribed the same amount of exercise e.g. number of times per week, the time to perform the exercises per session, it appears that the strengthening response was tripled by the FLEXI-BAR users, in comparison to that reported by stabilization training. Consistent with other authors, Bosco et al. (1998) concluded that in their study, improvement in muscle performance after vibration training was similar to that occurring after several weeks of heavy resistant training (Ikai and Fukunnaa 1970; Coyle et al. 1981; Hakkinen and Komi, 1985). What may have been of interest in this study was to compare the two modes of exercise at two weeks, to see if any strength differences could be observed.

Throughout the exercise program compliance rates were comparable between the exercise groups on a week to week basis. Subjects reported completing 60.7% (FLEXI-BAR) and 65% (TrA) of their prescribed exercise sessions (3 times per week) over the four-week period. Despite limited literature on exercise compliance rates for LBP patients, the data recorded supports the earlier findings of Schniders et al. (1998), who observed low compliance rates when issuing a home exercise program. The self-efficacy questionnaire (Appendix VII) highlighted time limitations to be a strong indicator for subjects not adhering to the program. Also space was considered an issue when trying to replicate the exercises within the home environment for the FLEXI-BAR group.

It has been well documented that compliance rates tend to be higher than those in studies where supplementary printed material is not used to support exercise programs (Ferguson and Bole, 1979; Deyo, 1982; May and Taylor, 1984; Spelman, 1984; Schneiders et al. 1998), in which could have been a residing factor in this study and should be an approach that is strongly considered, especially in clinical practice.

The expectation of exercise compliance with regards to the length of time required to perform the exercises in any one session and the overall duration of the exercise program may have had a positive effect.

"*Motivation, which is primarily concerned with activation and persistence of behaviour, is seen to be cognitively based and through cognitive representation of future outcomes, individuals can generate current motivators of behaviour*" (Schneiders et al. 1998; p.151).

It could be perceived that for the FLEXI-BAR subjects, undertaking a form of training that they had not done before or been aware of as a training tool, played a predominant role in the acquisition and retention of new behaviour patterns such as the instigation of an exercise regimen, such as the FLEXI-BAR (Sherman et al. 2005). Additionally it could be apparent that any superior effect obtained from using the FLEXI-BAR, could have derived from actual physiological improvements in muscle strength or was it just liked more and therefore used more (effectively) than the stabilization method?

Subjective report of compliance is at present, the pre-eminent that can be achieved with home-based exercise programs and has a capricious degree of accuracy depending on its implementation. Despite the widespread use of this approach, it is prone to recall and bias problems (Kolt and McEvoy, 2003). Due to the subjective nature of the compliance data collection in this study, it is emphasised, that the compliance rates analyzed are reported data only and therefore still subject to validation.

Established exercise habits have previously been identified as predictor variables of compliance (Baecke et al. 1982; Oldridge, 1982). In this study, habitual physical exercise comprised of 73% of subjects performing additional leisure/sport activities ≥

twice a week. Within the active population sample, the program did not require a modification in behaviour patterns, although a conflict between the training program and an individuals established exercise regime may have been evident.

An interesting finding was the subject's perception of whether they thought that over the four weeks there core stability had improved. 100% of the subjects in the FLEXI-BAR group strongly or generally agreed that a perceived improvement in their core stability was evident at the end of the program. In contrast to this, 63% of the stabilization group were not sure whether their core stability had been improved. It could be hypothesized that because stabilization training is primarily a concentrated slower activity which focuses on postural as well as abdominal core movements, in contrast the FLEXI-BAR exhibits a combination of a higher intensity cardiovascular workout with the strengthening component.

Group Relevance

The present study was conducted with students within the field of a health related program, a group with a high degree of body awareness and co-ordination skills than sedentary men and women. However, the results showed great variation in the ability to contract the TrA. Research advocates that dysfunction of TrA muscle, relates to instability of the spinal osseoligamentous system, therefore, the incidence of LBP (Richardson et al. 1992; Jull et al. 1993). A dysfunction in the recruitment of TrA in the current study did not appear to indicate pathological level of instability, as the baseline PBU scores demonstrate that the NLBP group had weaker TrA functions. Due to the variability in individual scores, it could be proposed that the individual's deep stabilizing muscles may not be optimally recruited, due to difficulties in gaining a perception of the required contraction. However, another explanation could be that a dysfunction exists in automatic motor control of stability in the non-LBP population, which supports the current work by Herrington and Davies (2005).

The results suggest that no difference was seen between the group status (HLBP, NLBP) and the PBU scores prior to and following the intervention. However, it can be seen that strength differences were found to be greatest in the HLBP-FB group, with 57% (of HLBP) of subjects classified as having a 'normal' PBU response following the completion of the four week exercise program, in contrast to the stabilization group (12.5%). Potentially, signifying the beginning of an enhancement in the activation of TrA. A recent review (MacDonald et al. 2006) suggested that multifidus and TrA exercise programs are unlikely to restore typical activation pattern, but may be required to compensate for an underlying osseoligamentous deficit to restore intervertebral control. However, in this study, without investigating the recruitment patterns of the TrA muscle, it is not possibly to suggest that the correct muscle recruitment strategies was adopted to help to stabilize the spine and address any motor deficit or 'instability' symptoms that may have been present in this population (Nachemson, 1985; O'Sullivan, 2000).

TrA Function

The finding that the HLBP group was not statistically different from the NLBP was surprising. Although studies such as Hodges et al. (1996) and Cairns et al. (2000) have found that subjects with LBP have severe problems with conducting the abdominal drawing-in action and reducing the pressure measured by the PBU, this was not found in the present study, as quantifiable changes in functioning of the TrA were not denoted between the groups (Jull et al. 1995; Richardson et al. 1995; Hodges et al. 1996). Regardless of the present condition of the population used (subjects used had no significant episode of LBP in the past six months), previous research have reported that despite resolution of symptoms, neuromuscular dysfunction of lumbar multifidus may persist (Hides et al. 1996; Cairns et al. 2000), indicating that a distinction should have been visible in the results. Although, drawing a comparison between the present study and previous research indicates that a difference in sample populations were used, depicting that a younger, more active sample were recruited in this study.

As mentioned previously, the PBU scores for the HLBP groups identify that the subjects were able to contract the TrA better than the NLBP, in which the one recorded failed attempt (+70mmHg) was conducted among the NLBP subjects. In essence, the lack of association between group status (HLBP/NLBP) and measured abdominal function was not expected, even though previous studies have recognised that the changes in motor control in this population (non-specific) are highly variable (O'Sullivan et al. 1997; Hodges and Moseley, 2003; van Dieen et al. 2003).

The inclusion of subjects with a history of non-specific LBP was important, as they constitute a significant clinical group. In spite of the “large numbers of pathological conditions that can give rise to LBP, 85% of these are without detected pathoanatomcal/radiological abnormality” (Dankaerts et al. 2006a, p.1). It must not be underestimated that this ‘LBP group’ conceals a large heterogeneous group of subjects (McKenzie, 1981; Spitzer, 1987; Borkan et al. 1998; Bouter et al. 1998; Leboeuf and Manniche, 2001). It should be noted that a methodological flaw in the current study was not using a homogenous sample. Although a complicated and obstinate task, further screening of the subjects could have eliminated the potential for inconsistent results i.e. specific exercises applied to a falsely assumed homogenous sample, may result in either aggravation of the condition or failure to respond (Binkley et al. 1993; Fritz et al. 2000; LeBoeuf-Yde and Manniche, 2001; Fritz et al. 2003).

However, a challenge for future research is to evaluate the capacity to define sub-groups of the population, in support of a classification system for LBP. Although current research is investigating this problem, it is required a prerequisite to the validation of future studies, enabling quantification of clinical changes in motor control, secondary to the implication of specific ‘targeted’ interventions (Elvey and O’Sullivan, 2004; Dankaerts et al. 2006a; Dankaerts et al. 2006b), to subsequently enhance treatment efficacy as suggested by Leboeuf-Yde et al. (1997; 2001).

TrA Isolation Test

It has been advocated that the prone lying TrA isolation test can accurately classify subjects into LBP and painless groups in 80% of subjects (Hodges et al. 1996). However there is an inconsistency within the literature regarding what a normal pressure reduction response is during this test. When using the guidelines by Hodges et al. (1996), it was considered a normal change to be greater than or equal to 4mmHg. Hodges et al. (1996) found that in their study, 33% of non-LBP subjects were deemed as having a TrA dysfunction. When Richardson and Jull (1995) tested a group of subjects, by classifying normal to be a 6-10mmHg change, dysfunction was found in 44% of the asymptomatic subjects.

Moreover, a study by Cairns et al. (2000), using the adjusted figures of Hodges et al. (1996), discovered that 59.9% of the subjects were identified as a correct classification, as measured by the PBU. In spite of the variability in facilitating a correct TrA contraction across groups and that only an asymptomatic population was used, data from a recent study (Herrington and Davies, 2005), found that the TrA isolation test identified 52.7% of all subjects with an incorrect TrA contraction.

In the present study, using the adjusted figures of Hodges et al. (1996), 80% of all subjects baseline readings, were identified with an incorrect TrA contraction as measured by the PBU. These findings are high compared with previous studies. However, methodological factors may have contributed to these differences, as Hodges et al. (1996) converted pressure data from analogue to digital and recorded it electronically. While an improvement in internal validity of the study, the operation of computerised recording with a measurement tool designed for manual recording reduces its clinical applicability and generalisability of any results (Sim and Arnell, 1993). "The removal of human error and contamination from parallax[1] or miss-reading of the gauge scale can make research unrepresentative of current clinical practice" (Cairns et al. 2000; 133).

Clinical Relevance

Although it is agreed that exercise should be part of the management of LBP, there is significant variation in the type of exercise and the proposed mechanisms of effect for each exercise. Comparing a technique which is currently at the forefront of research and which is the most commonly used treatment among UK physiotherapist (Jackson, 2001), with a training tool which is very much unfounded in this country has highlighted an abundance of questions surrounding their efficacy within a rehabilitation setting.

The results indicated that subjects did not show a vast improvement in TrA strength in the stabilization group. What is currently not clear is whether stabilization exercises are better suited to certain types of populations or whether they can be generally applied to any population with LBP. Unsubstantiated suggestions that stabilization training maybe useful in reducing pain and disability for all populace with non-specific LBP have appeared in the literature (Goldby, 1996; Panjabi, 1992; Richardson et al. 1999; Norris, 2001).

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[1] An apparent change in the position of an object resulting from a change in the position of the observer (Oxford English Dictionary, page 274).

The issue must be raised that using a population with a history of LBP, although no subject should have been experiencing any pain during testing, the very nature of the condition is that episodes of symptoms do reoccur. It must be remembered that the presence of symptoms during testing is important when examining a subject population as the role of pain and reflex inhibition of the muscle must always be considered (Grabiner et al. 1992). With this in mind, drawing a conclusion regarding the role of stabilisation training amongst this population is unjustifiable, considering the inconclusive results found.

Strength enhancement was observed in subjects involved with the FLEXI-BAR program. The FLEXI-BAR within Europe has established its application as a rehabilitation tool for many years. However, within the UK it has received little empirical attention. It became apparent that in this study prior to undertaking the exercise program, none of the subjects involved were aware of or had heard of the FLEXI-BAR, which may account for its profile, thus its application within the clinical environment.

Although inconclusive, the design of the study provides a foundation for other researchers to consider the application of the FLEXI-BAR and the principles that underpin vibration training, which may provide an invested benefit to a population in which 80% of adults will experience back pain over the course of there lives and with reoccurrence rates of up to 85% (Binkley et al. 1993; Lanes et al. 1995; van Tulder et al. 2002; Ehrlich, 2003; Katz, 2003; Woolf and Pfleger, 2003), it is proposed that this client group should be targeted with the aim of prevention of chronic disability (CSAG, 1994).

Limitations and Recommendations for Future Research

Acknowledged limitations of the study involve the inclusion of relatively functional subjects. In which, the modest sample size, as indicated by insufficient power, precludes any definite conclusion, as the results can be therefore classed as preliminary. A long-term study design could have provided knowledge concerning the efficacy of the exercise modes and the management potential for the LBP population. It can also be recognised that the PBU was found to be not reproducible enough to be used as an outcome measurement for purposes of LBP classification. Although an inherent strength recording measurements manually, introducing human error has the potential to threaten the reliability of the readings. Due to the deep location of the TrA, invasive procedures would be required to obtain reliable data, which would involve ethical consideration. Also as with studies of other physical treatments, it was impossible to blind study participants to treatment group.

Although out of the realms of this study, a continuation of the work by Jull and Janda (1987), a shift to viewing LBP as a multi-factorial bio-psycho-social disorder is now well accepted and has important implications for re-education programs (Borkan et al. 2002; Ford et al. 2003; McCarthy et al. 2004; Waddell, 2004). Acknowledging underlying issues that could be associated with the physical attributes of the condition and that it is necessary to address these deficits before re-education takes place.

The inability to stabilise the spine during daily activities, may predispose individuals to future spinal pathology, suggesting that assumed 'asymptomatic' individuals have the potential to be affected by LBP. The study has recognised that the FLEXI-BAR exhibits strengthening effects on the TrA muscle, although the need to in cooperate additional outcome measures to assess pain, function and disability within the LBP population becomes essential for justification prior to its application within the rehabilitation setting in this particular population. The findings indicate that with the increase in use of stabilization regimes and training, the obligation for an accurate, affordable quantifiable measuring and monitoring system is mandatory to observe the activity of the local stability system. This would also allow conclusions to be draw regarding the efficacy of specific exercises which are appropriate for the use of LBP sufferers.

With this population reaching epidemic proportions (Dankaerts et al. 2006a; Dankaerts et al. 2006b), the efficacy of exercise programs to strengthen spinal structures to provide stability and to prevent future complications, is an area of research that requires further study.

CHAPTER 6 CONCLUSION

The study indicates that strength training does increase TrA strength. The preliminary work undertaken suggests that there is no difference in TrA strength between the training regimes and that there is no disparity in TrA strength between LBP and Non-LBP groups and their response to exercise. Notably, the modest sample size and population sample used precludes any definite conclusion.

The research accentuates the need for an accurate quantifiable measuring and monitoring system to observe the activity of the local stability system and that a long-term study design should be considered, to further explore the efficacy of exercise regimes and the management potential for the LBP population.

This study provides one step forward in the knowledge concerning the efficacy of exercise programs to strengthen the core stability system. The results are inconclusive, although suggests that the FLEXI-BAR has an ability to strengthen the TrA, and could provide an application to aid the rehabilitation of LBP individuals. More evidence in a larger study population is required to substantiate the findings of this study. This pilot study may be used to determine a design model for future research.

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