A Quantitative Investigation into the Effectiveness of a 2x2, Crossover, Randomized Control Trial, for Individuals Suffering from Non-specific Chronic Lower Back Pain, using a physical Exercise-Focused Clinical Intervention on the Transverse Abdominus/ Multifidus (Stability) and Rectus Abdominals/ Erector Spinae (Dynamic) Muscles.

A thesis

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Abstract

A plethora of research has been conducted on interventions to reduce non-specific lower back pain and improve the quality of life of sufferers. However, there is a lack of distinction on the complementary nature of these interventions. Our primary research goal was to assess the effectiveness of stability- and dynamic-style clinical interventions, focusing on exercises to strengthen specific trunk muscles, including the transverse abdominis/multifidus (stability-AB), and rectus abdominis/ erector spinae (dynamic). We aimed to determine the effectiveness of these interventions in reducing non-specific chronic lower back pain. Our research questions focused on whether a two-part clinical intervention targeting specific core muscle groups (dynamic or stability) improves pain outcomes, whether exercises targeting specific core muscle groups improve disability index physical impairment and overall low back pain rating scale scores, and if there is a difference between intervention groups and the sequential order of intervention for these outcomes. Additionally, we wanted to investigate the correlation between these outcome measures and trunk endurance strength scores. Seven participants were randomly assigned to either the stability (N =4) or dynamic (N = 3) exercise group. Outcome measures included back and leg pain, lower back pain visual analogue scale scores, disability index, physical impairment, and total Low Back Pain Rating Scale (LBPRS) scores. Four measures of trunk endurance strength were taken using Mcgill's Torso Endurance Test Battery (MTETB), which involves trunk extension, trunk flexor, and trunk lateral tests on both the left and right sides. Assessments were performed before the first clinical intervention, after the first intervention, and after the completion of the final intervention. Each intervention phase lasted 4 weeks for each participant before they switched to the opposing exercise group. The scores of back and leg pain, lower back pain, disability index, and physical impairment all improved significantly after both interventions. We found no difference between the groups during these intervention phases, or any potential crossover/sequential effect, except for the dynamic group showing a significant improvement in physical impairment scores after the first intervention, which remained consistent between interventions one and two. In conclusion, both exercise approaches were similar across all our outcome measures and may serve as complementary interventions for individuals suffering from non-specific chronic low back pain.

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Abbreviations

Low/ lower back pain	LBP
chronic lower back pain	CLBP
Non-specific chronic lower back pain	NSCLBP
Low Back Pain Rating Scale	LBPRS
McGill's Torso Endurance Test Battery	MTETB
Fear-avoidance model of pain	FAMP
Abdominal drawn-in manoeuvre	ADIM
Abdominal expansion manoeuvre	AEM
Transverse abdominals/ abdominus	TA
Rectus abdominals/ abdominus	RA
Flexion- relaxation phenomenon	RLF
Independent variable	IV
Dependant variable	DP
Visual Analog Scale	VAS
Non-steroidal anti-inflammatories	NSAID

Chapter 1: Introduction

Back pain, specifically nonspecific chronic low back pain (NSCLBP), is an ever-complicated burden on the affected individuals as well as society. While many potential intervention options exist, the overall effectiveness of these different interventions in conjunction with one another for improving pain and quality of life outcomes of the affected population is unclear. One of the potentially more effective interventions is core/trunk stability. This intervention focuses on engagement and strengthening the transverse abdominus (TA), the deepest layer of the abdominal muscles, and has been considered to have clinical significance regarding positive outcomes in the affected population (Hodges & Richardson, 1998a; Lynders, 2019; Miura et al., 2014). We argue that the multifidus, intentionally or not, will have a substantial role in the function and execution in TA stability exercise interventions (Cooley et al., 2024; Wong et al., 2014). Another cluster of interventions falls under the more dynamic style of movement, for example, pilates, or yoga, which has a focus on mobilizing and strengthening through all planes of movement, specifically, through the sagittal pane with spinal/trunk flexion and extension. These movements will engage the rectus abdominus and the erector spinae due to their biomechanical functions.

Research indicates changes in performance in overall trunk endurance strength tests are significantly negatively affected between healthy individuals and suffers of NSCLBP. (Jørgensen & Nicolaisen, 1987; McNeill et al., 1980; Nakata et al., 2024) Using the most recent meta-analysis, there is evidence that both styled interventions may prove beneficial for suffers of NSCLBP (Fernández-Rodríguez et al., 2022a). However, there is little evidence in the literature as to whether using these different styles of physical exercise has a complementary effects on each other.

Our primary research aim was to assess the effectiveness of stability and dynamic-styled exercises in a clinical intervention aimed at strengthening the muscles in the trunk, specifically the transverse abdominis/multifidus (stability- AB), rectus abdominis, and erector spinae (dynamic- BA) in reducing lower back pain in sufferers of NSCLBP. The research questions for our study are as follows:

1. Does a two-part, clinical intervention targeting specific core muscle groups (stability or dynamic) improve pain as an outcome?

2. Does exercise targeting specific core muscle groups (stability or dynamic) improve outcomes for disability index, physical impairment, and overall low back pain rating scale scores?

3. Is there a correlation between pain, disability, and physical impairment compared with the individual trunk measures from McGill's Torse Endurance Test Battery?

4. Is there a difference between the intervention groups for a two-stage core strengthening intervention and the sequential order of the interventions for improving pain, disability index, physical impairment, and total score of the Low Back Pain Rating Scale, as an outcome for non-specific chronic low back pain?

The scope of this study focuses on the change in lower back pain, the total score of the low back pain rating scale, and its variables: back and leg pain, disability index, and physical impairment, for individuals suffering from NSCLBP. We also look at the correlation between the change in person scores and the trunk strength metrics taken from Mcgill's Torso Endurance Test Battery (MTETB). Though we are interested in how the scores are related to the variables that are associated with quality of life, we were less interested in the overall trunk strength endurance changes alone. While we used aspects of a multidisciplinary design, such as providing and encouraging the use of heat application and pain education relating to fear avoidance and pain catastrophizing, we did not use any specific outcome measures relating to these. Due to a single researcher limitation in time and costs, a full multidisciplinary intervention was not considered. The greatest limitation of the study was our limited number of participants (N=7) due to difficulty in finding participants, our strict inclusion/ exclusion criteria, and four participant dropouts over the intervention period.

A crossover design was used to allow for participants to potentially get the benefits of both individual interventions. Using the above outcome measures, we conducted a 2x2, crossover randomized clinical trial, involving two intervention groups- split between a core stability style versus a dynamic style strengthening program. Participants were randomized into groups before the start of the clinical intervention. All participants started with an assessment that involved both the Low Back Pain Rating Scale (LBPRS) and Mcgill's Torse Endurance Test Battery, as well as performed a 4-week trunk strengthening programme. Participants performed a total of three strengthening sessions per week, with 4 exercises performed per session. Each of the four prescribed exercises had two additional variations provided, for 12 exercise variations in total for each intervention style. This was to account for individual

levels of capability due to pain and base level of strength and fitness. We additionally taught activation of the deep trunk muscles using the abdominal draw-in manoeuvre. At the completion of the first four-week intervention, a follow-up assessment was performed, and participants crossed over into the other interventions. Following the completion of the second four-week intervention, a final assessment was performed, for a total of three assessments (pre, post-1, post-2). The data was evaluated to determine if using two interventions in combination provides complimentary results transitioning from one to another. Due to the crossover design, we will be able to assess if they are complimentary, regardless of an intervention order, if starting with either stability of dynamic style trunk strengthening program has greater outcomes compared to the other (AB vs BA), and if this program has merit in a clinical setting.

The core chapters of the thesis are Chapter 2, Literature Review, which provides an overview of lower back pain and its impacts, anatomy and morphology changes relating to lower back pain and a review of relevant research regarding interventions for NSCLBP; Chapter 3, Research Methodology, which is a description and rationale of the methodology that was used for the research study; Chapter 4 Results, which is a report and analysis of results obtained over the randomized clinical trial, separated into four different research questions; Following this is Chapter 5, Discussion, in which contains a discourse of the results and how to they relate to the previously mentioned research; Finally Chapter 6, Conclusion, summarizes the research as a whole, and contains our overall insights and recommendations regarding what we have found.

Chapter 2: Literature Review

The following literature review provides an overview of lower back pain and its impacts, anatomy and morphology changes relating to lower back pain, and a review of relevant research regarding interventions for NSCLBP.

1.1 Lower Back Pain, Prevalence in Society, and its Impacts

Backpain, and specifically lower-back pain (LBP) is an ever-present and significant health concern in modern society, from the individuals who are directly affected through to the practitioners, clinicians, and physicians who attempt to treat said patients. It is one of the most common reasons an individual may visit a general practitioner and/or seek further medical advice (Darlow et al., 2014). Outcomes are often less than desirable regarding effective diagnoses and treatment options, for both practitioners and patients alike (Atlas & Deyo, 2001) and leaves many individuals with debilitating pain, disability, and compromised quality of life. The issues presented due to LBP are extremely wide, encompassing very mild (e.g. lumbar sprain) to very severe (e.g. spinal cord injury) disability and pain. Similarly, LBP may have a multitude of different potential causes (often unknown and without a clear incident) and is usually focused on the lumbar spine and sacroiliac joint. Alongside the substantial consequences LBP has on an individual's mental and physical health, LBP also creates a tremendous socio-economic burden on society. It is estimated that the costs LBP has on Western society is 1-2% of the gross national product, and a large portion of the costs (80-90%) is caused by the disability associated with LBP and productivity lost through inability to work (Dutmer et al., 2019); a considerably large figure for one subgroup of pathologies/injuries. This is reinforced by data out of Britain by Maniadakis & Gray, where the direct cost of back pain in 1998 was it was estimated to be 1,632 million pounds. This highlights the importance of establishing more cost-effective treatments to try and minimize the burden on the health sector (Maniadakis & Gray, 2000). The individual impact on healthcare costs and productivity dramatically increases when patients need to be referred to specialized treatment, regardless of whether these are surgical or conservative interventions (Solumsmoen et al., 2022).

A systematic review was conducted on the prevalence of lower back pain globally (165 studies were used) and found that the prevalence of LBP lasting for more than 1 week was 11.9% (minor, fast recovering pain) and LBP lasting more than one month to be 23.3% (not considered chronic but presenting as a more debilitating pathology/injury). Within the population, females with an age range of 40-80 years old are most at risk. (Hoy et al., 2012). This study also illustrates that the prevalence of LBP is going to become an ever more pressing issue; as the population gets older, the mean average age of the global population also gets older due to the change in global birth-rates (higher prevalence of more severe LBP in older individuals, with a drop in the prevalence in less-severe conditions). Indeed, years lived with a disability has increased by 54% between 1990 and 2015 with LBP as a direct cause (Dutmer et al., 2019), highlighting the importance of further research regarding assessing risk factors and identifying effective treatment/prevention of LBP (Hoy et al., 2012).

A potential compounding factor for the increasing prevalence of chronic lower back pain (CLBP) may be the decrease in overall physical activity and increase in sedentary lifestyles around the globe (Bontrup et al., 2019); though, the relationship between a sedentary lifestyle and CLBP is still a contentious issue. A systematic review performed by Chen et al. (2009; 15 studies) did not find an association between a sedentary lifestyle and the development of LBP when it is the only variable (Chen et al., 2009), while a study by Lemes et al. (2021) found an inverse relationship between leisure-time physical activity, sedentary behavior and LBP in obese participants, but not individuals within a normal weight/BMI range (Lemes et al., 2021); indicating a sedentary lifestyle and excess body weight may be confounding factors. This sentiment is reinforced by Okifuji and Hare, who found that for overweight patients suffering from chronic LBP, weight loss positively impacted their pain and can be an important function of the rehabilitation process.(or avoiding further weightgain) Okifuji and Hare also mention that weight-gain alone is not the direct cause of the condition/pain but can act as a significant comorbidity for the patients suffering from a chronic condition (Okifuji & Hare, 2015) . The largest concern is individuals who suffer from a chronic condition (spinal cord injury, for example) as they are most at risk of significant increases in BMI (specifically body; visceral, and adipose tissue), in turn, making the rehabilitation process even more difficult (Crane et al., 2013) and further exacerbating and/or complicating the symptoms of the chronic condition.

1.1.1 Chronic versus Acute

A large group of suffers of LBP fall under non-specific chronic lower back pain (NSCLBP), with no clear pathological or clear mechanism of injury. According to the National Library of Medicine, an acute condition is a sudden onset of symptoms that are often severe. Regarding LBP, this is often a lumbar sprain but could be something more severe such as a herniated/prolapsed disc. In contrast, a chronic condition is a long-developing syndrome that can be its own pathology or be a result of an acute injury. For LBP, it is considered a chronic condition if the patient has had daily pain/problems for over three months (Acute vs. chronic conditions: MedlinePlus Medical Encyclopaedia Image, n.d.). For acute LBP, a large majority of cases will improve on their own regardless of the intervention (Atlas & Deyo, 2001) and why an important aspect of treatment is educating patients on managing expectations of recovery time, prevention, and likelihood of recurrence (Atlas & Deyo, 2001). This is in line with research that has shown the only therapy with good evidence of efficacy regarding the treatment of acute LBP is superficial heat (Chou & Huffman, 2007). potentially because many cases involve musculoligamentous processes (Atlas & Deyo, 2001) Non-steroidal anti-inflammatories (NSAIDS) have benefits during the acute stage of nociplastic pain (Figure 2.) but recent research indicates the use of NSAIDS during an acute phase, negatively affects maturation and proliferation, and overall recovery outcomes (Fragomen et al., 2020;Wheatley et al., 2019); However, use of NSAIDS and other medications can be vital to enable rehabilitation/ normal function in life once the condition has moved from acute to chronic. Overall ineffectiveness of different interventions is supported by a 2005 meta-analysis that concluded that an exercise therapy intervention for populations with acute LBP is as effective as either no treatment or other conservative treatments/interventions; while the same research found exercise therapy to be slightly effective at reducing pain and improving function/movement in adults with chronic LBP (Hayden et al., 2005). NSCLBP and its current treatment, commonly recommended western interventions, such as (inappropriately) high use of opioid analogue medications, excessive rest, high use of imaging (to potentially get further away from the core issue), and surgical interventions results in many potential adverse side-affects. Many of these recommendations come from high-income countries, and with little data on their cost-effectiveness. Considering the already known difficulties in the treatment of NSCLBP, Foster et al. (2018) recommended more models start to adopt a biopsychosocial framework (Figure 1.). Such a framework involves a less invasive, multidisciplinary approach to back pain that reduces the

focus from spinal abnormalities and works towards increasing activity, function, and return to work (Foster et al., 2018). The majority of CLBP is diagnosed as NSCLBP due to the lack of injury/ pathological evidence for said pain.

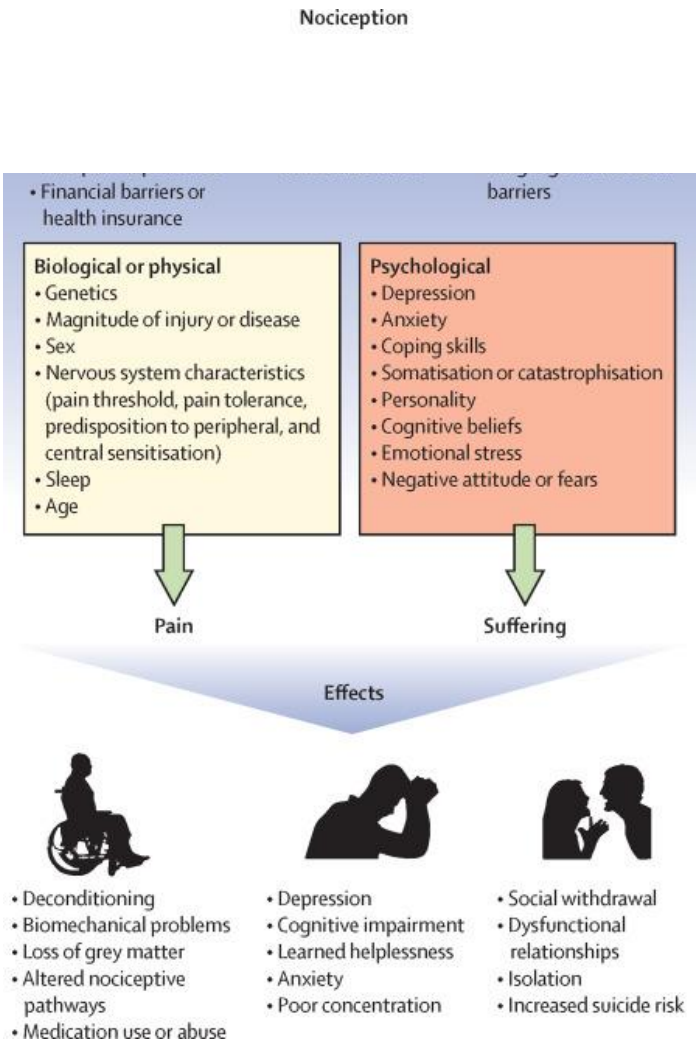


Figure 1. Illustration of the biopsychosocial model of pain, and the interaction between psychology, biology, and social factors may exacerbate and lead to chronic pain (*Cohen et al., 2021)*

abnormalities, and work towards increasing activity, function, and return to work (Foster et al., 2018). An example of the dynamics between psychology, biology, and social factors how they interact with chronic pain in cascading complexity (figure 1.)

1.1.2 Pain

At its core, pain can be defined as an unpleasant physical and/or emotional response, potentially involving damage to real tissue. Pain can be categorized into three types from a neurobiological perspective: nociceptive pain, inflammatory pain, and pathological pain. These categories can be expanded to include nociceptive pain, neuropathic pain, and nociplastic pain (Figure 2.), particularly in the context of chronic pain. The complex nature of pain involves significant overlap and interaction between these pathways, as well as individual variability. Various factors such as stress, disturbed sleep, and psychological distress can both influence and be influenced by pain. The Biopsychosocial model attempts to illustrate the complex interaction between these factors.(Cohen et al., 2021).

In the context of general lower back pain, determining the location of pain can be challenging, as it varies among individuals. Multiple potential reasons for deferred pain, such as issues with the spinal cord or nerve roots, can complicate diagnosis and lead to increased pain for sufferers. Issues like radiculopathy and stenosis can contribute to the difficulty in identifying the root cause of the pain.

When examining lower back pain pathology, leg pain is a crucial indicator that clinicians use to assess the possibility of sciatica originating from specific spinal segments. However, other conditions such as piriformis syndrome can also cause similar symptoms. Leg pain can stem from different sources, including centralized sensitization, denervation, axonal damage, peripheral nerve sensitization, and mechanosensitization, making it challenging to differentiate between these sources and diagnose more heinous spinal pathology (Schäfer et al., 2009). A key consideration in diagnosing spinal pathology is the distinction between various manifestations of neoplastic, nociceptive, and neuropathic pain, and understanding the treatment options for each according to Cohen et al. (2021).

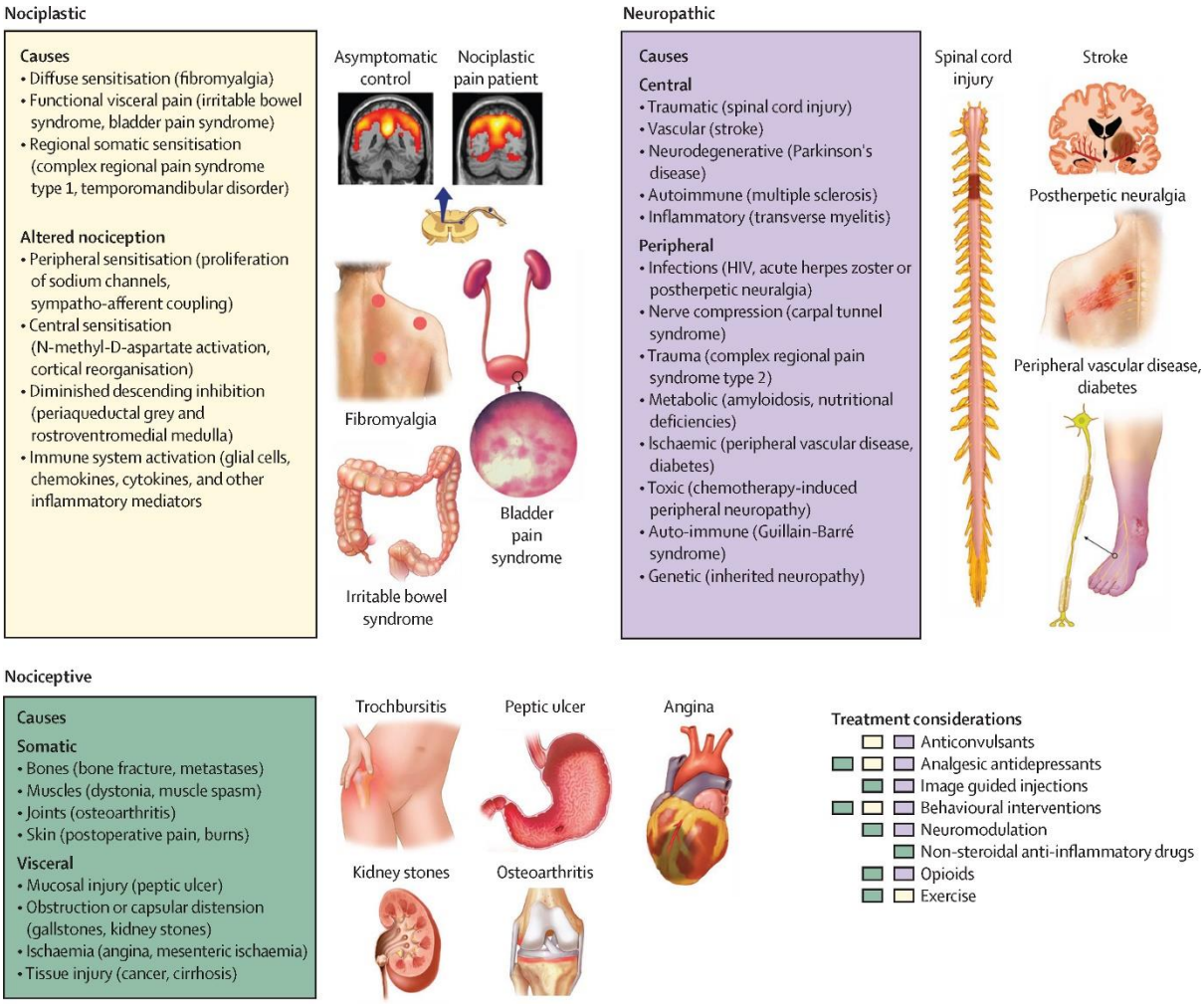


Figure 2. Examples of various manifestations of neoplastic, nociceptive, and neuropathic pain, with considerations of treatment. *(Cohen et al., 2021)*

1.1.3 Core and Spinal Stability

The concept of spinal stability is often discussed in the context of NSCLBP. Punjabi describes spinal instability as abnormal, undesired motions between the vertebrae, leading to compression, stretching, or deformation of spinal structures and resulting in increased pain. From a clinical perspective, stability is closely associated with three biomechanical functions of the spine: allowing movement between body parts, bearing and managing loads, and protecting the spinal cord and nerve roots. Panjabi (1993) conceptualizes a mechanical classification of spinal stability, comprising passive, active, and neural subsystems, each contributing to the overall stability of the spine. Dysfunction within any of these subsystems can lead to compensation patterns and chronic dysfunction, ultimately resulting in pain. (Panjabi, 1993). Panjabi conceptualizes a mechanical classification when discussing spinal stability as a passive musculoskeletal subsystem, an active musculoskeletal subsystem, and a

neural and feedback subsystem. The passive subsystems do not provide significant stability while in the proximity of neutral spinal positions, but more so toward the end range of motion in the trunk, that ligament structures resist spinal motions. The active subsystem composes of the muscle and the tendons of the connecting and surrounding spinal structures and is how the system generates force, and conversely, provides the required stability through the force generation. The neural subsystem is responsible for receiving information from the various transducers through the muscle and determines the required stability in conjunction with active subsystem. (Panjabi, 1993) at its most basic, Dysfunction among any of these three sub-systems may start a cascade of compensation patterns, and eventually, may result in chronic dysfunction and pain (Panjabi, 1993).

1.2 Trunk

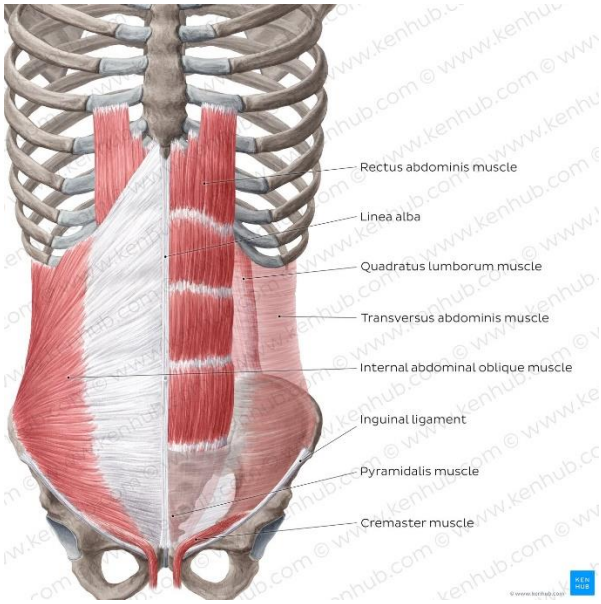


Figure 3. Diagram of the different layers/ muscles comprising of the trunk. *(Muscles of the Trunk: Anatomy, Diagram, Pictures | Kenhub, n.d.)*

The trunk, an anatomical catch-all term, describes multiple muscle groups both anterior, posterior, proximal to the pelvis, and distal to the clavicle; is the primary structure responsible in spinal and core stability, as well as movement through the sagittal, transverse and frontal plane (*Muscles of the Trunk: Anatomy, Diagram, Pictures | Kenhub*, n.d.). It seems to

be an area, that keeps significantly impacted by individuals suffering from NSCLBP. It has been found that compared to healthy individuals, the overall trunk strength of suffers was only 60% of their healthy counterparts, male and female; intriguingly, this disparagement in strength is not observed in other body parts (Jørgensen & Nicolaisen, 1987). The trunk muscles are divided between local (transverse abdominus and multifidus) and global structures (erector spinae, rectus abdominus, internal/ external obliques, latissimus dorsi, gluteus maximus, quadratus lumborum (figure 3.)). due to differences in biomechanical function (Bergmark, 2009) Considering this, many researchers have been focusing on interventions which address these trunk stabilisers specifically, such as the Transverse abdominus and multifidus.

1.2.1 Transverse Abdominis, Rectus Abdominus

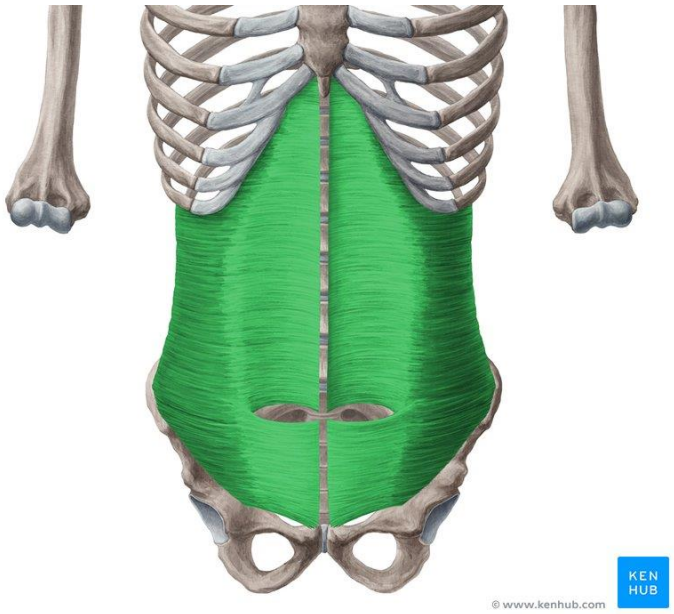


Figure 4. Anatomy of the Transverse Abdominus. (Transversus Abdominis: Origin, Insertion and Function | Kenhub, n.d.)

The transverse abdominals (TA) are the deepest abdominal muscles in the trunk that are primarily responsible for the stabilization of the trunk and spinal structures (*Transversus Abdominis: Origin, Insertion and Function | Kenhub*, n.d.) structures (Figure 4.). Many practitioners and researchers reference core and abdominal strength but there is often a lack

of distinguishment (or consideration) as to which part of the abdominals or spinal structures should be focused on as an intervention for back pain. One of the muscles it is combined with, is the superficial abdominal muscles, the rectus abdominus (RA). The RA is the most superficial of the abdominals (what is commonly understood as the 'abbs') the primary function is trunk flexion, resisting spinal extension and assisting in contraction to assist overall trunk stability and expiration (*Rectus Abdominis: Origin, Insertion, Innervation,Function | Kenhub*, n.d.). The RA originate on the pubic symphysis and pubic crest, and attach to the xiphoid process and the costal cartilage (figure 5.) The TA, RA and pyramidalis muscles make up the anterolateral abdominal wall.

A study by Lee (2013) et al did a chronic lower-back pain intervention with a specific focus on strengthening the TA. After the intervention, both male and female subjects had significant increases in transverse abdominals strength and in-turn, the strength of the lumbar extensors and flexors also increased, this led to an overall decrease in pain for the participants involved (S. Lee et al., 2013). Another piece of research looked at the activation of the different core muscles with individuals with lower-back pain (electro-magnetic resonance testing). It was found that activation of all major core muscles was delayed in specific movements (rectus abdominis, erector spinae, and obliques) while there was delayed activation of the transverse abdominals in each direction (Hodges & Richardson, 1998) potentially indicating the deeper stabilizing muscles are impacted more and have a larger effect of individuals with chronic lower back pain. When discussing individuals suffering from LBP, compensation for change in core recruitment may be exacerbated. Research by the Radebold et al. (2001) looked at the muscle response pattern to sudden trunk loading between patients with LBP and healthy participants. Investigators measured 12 trunk muscles while patients performed isometric contractions in trunk flexion, lateral bending, and extension, and found a significant change in the muscle response patterns in responses to a load release and could be considered either a compensation mechanism to attempt to stabilize the lumbar spine and could potentially act as a predisposing factor for the injury of the lower back (Radebold et al., 2001).

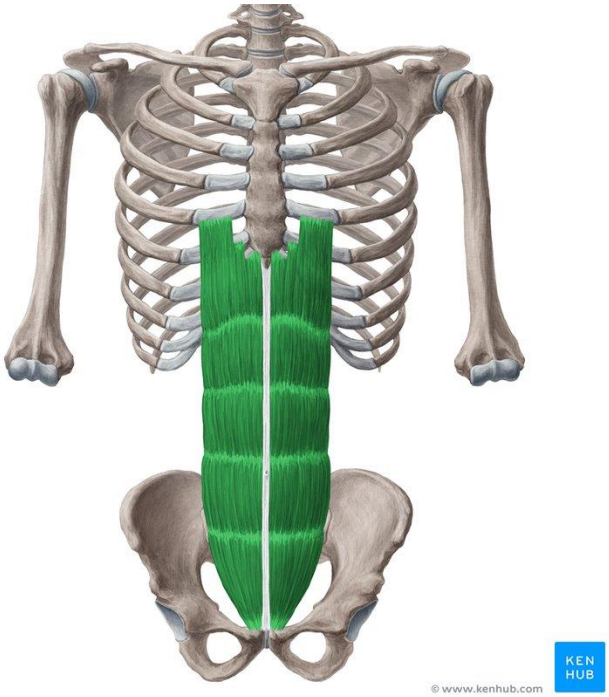


Figure 5. Anatomy of the Rectus Abdominus. *(Rectus Abdominis: Origin, Insertion, Innervation,Function | Kenhub, n.d.)*

Research by Radebold et al. (2000) reinforces the idea of overall trunk dysfunction by finding longer latencies in offsetting agonists of the trunk. NSCLBP suffers are observed to have simultaneous onset of antagonistic structures and have these agonist/antagonist structures concurrently contract. The authors conclude that it is not known is if these are predisposing factors that led to NSCLBP or if this is a pure compensatory mechanism the body uses as an attempt to stabilize the spine (Radebold et al., 2000). For those suffering of NSCLBP, especially those deconditioned, a point is made that it may be of benefit to start an intervention with a graduated progression of exercises that activate and challenge both the global and local muscles of the lumbar spine; and it could be best practice to start with exercises focusing on the contraction of the of local trunk muscle groups, then graduate to floor based exercises and eventually exercises requiring a higher level of muscle coordination and contraction (Nakata et al., 2024).

1.2.2 Multifidus and Erector Spinae

The multifidus is a part of the transversospinalis group and is some of the deepest muscles of the vertebral column and trunk. They attach bi-laterally spanning the length of the verterbral column (*Multifidus: Origin, Insertion, Innervation, Action | Kenhub*, n.d.).

Figure 6. Anatomy of the Multifidus *(Multifidus: Origin, Insertion, Innervation, Action | Kenhub, n.d.)*

The primary function of the multifidus is stability of the spine and trunk. For example, if the obliques contract to produce trunk flexion, the multifidus will contract to oppose the trunk flexion to maintain a pure axial rotation. The origin points of the multifidus are as follows: the dorsal surface of the sacrum, the erector spinae aponeurosis, the posterior, superior, iliac spine, the sacroiliac process, mammillary processes, thoracic transverse processes, and the cervical articular processes. The insertion sites of the multifidus are the spinous process of the associated superior vertebrae (2-5 segments above origin, (Figure 6.)) over the entire vertebrae (*Multifidus: Origin, Insertion, Innervation, Action | Kenhub*, n.d.). Interestingly, it is now considered that the multifidus has relevant clinical application to the treatment practices physiotherapy practices but has widely been under-discussed from physician to patient. Regarding its association with the transverse abdominus and its role in a core

stabilization programme, there is evidence that they are likely engaged in most, if not all 'stabilization' programs. The study "Multifidus Atrophy Is Localized and Bilateral in Active Persons with Chronic Unilateral Low Back Pain" looked at whether there was measurable atrophy of the multifidus muscles of individuals suffering from chronic lower back pain (Beneck & Kulig, 2012). Of importance, the study found evidence of Atrophy of the multifidus as well as the erector spinae in individuals with NSCLBP, but also more severe conditions such as facet joint osteoarthritis and disc herniations (Beneck & Kulig, 2012). Additional studies have supported this degeneration of the multifidus by finding that pattern of atrophy in NSCLBP is localized to the specific region of pain and asymmetry could be seen in patients who had uni-lateral pain compared to bi-lateral (Hides et al., 2008). Individuals suffering atrophy of the multifidus may independently affect clinical outcomes. Research that has investigated the relationship between degeneration and change of muscle quality of the lumbar multifidus and spinal degradation found that an increase muscle quality alone did not have a significant reduction on pathologies and leg pain intensity. Increases specifically in the lumbar multifidus did have a positive effect on disability outcomes, while it did not have a mediating effect between the leg pain and pathology. This research reinforces the complexity of specific CLBP and how the pathways leading to pain can be different among individuals with similar lumbar multifidus atrophy (Cooley et al., 2024). Interestingly, changes in trunk and spinal muscle activation may lead to additional compensation from the erector spinae to assist in spinal stability due to the previously mentioned dysfunction and overall neuromuscular control. Evidence suggests that as deep trunk and abdominal stabilization starts to diminish, spinal structures start to take on additional loading, and an inability to relax from contraction.

Assisted involuntary contraction of the multifidus may also be of benefit in reducing NSCLBP. Individuals who suffer from NSCLBP with no prior back surgery and pathological evidence for the cause of the back pain, despite physical therapy and medication interventions, found a benefit to use of commercially available pulse generators to induce stimulation and contraction of the multifidus. Episodic simulation of the lumbar multifidus was beneficial in reducing the NSCLBP (>50% reduction of VAS score), and improving the outcomes of disability, quality of life (84% of patients), and ability to return to work (45% returned to work with three months; Deckers et al., 2015). Interestingly, this intervention did not cause any patients pain to increase, and potentially reinforces the importance of activation/contraction of the multifidus, regardless of the stimuli; it also potentially highlights that externally stimulating the lumbar multifidus was beneficial because of pain and fear

avoidance can cause patients to avoid voluntary contraction and movement of the lumbar structures (Cooley et al., 2023).

Figure 7. **Anatomy of the Erector Spinae group.** *(Erector Spinae: Attachments, Innervation and Function | Kenhub, n.d.)*

The spinal erectors-erector spinae are a grouping of muscles that include the spinalis capitals, thoracis, and cervicis; the longissimus capitas, thoracis, and cervices and the Iliocostalis colli, thoracis, and lumborum. The spinalis group can simply be described as three separate muscles, which has three compartments to them each, a lumbar, thoracic and cervical. (*Erector Spinae: Attachments, Innervation and Function | Kenhub*, n.d.) and have attachments from the distal portion of the sacrum to the mastoid process of the temporal bone, with attachment ranging through each the vertebrae column (see figure 7.) During any anterior load, the spinal erectors will additionally provide support by resisting trunk flexion. Due to its function primarily being trunk and spinal extension, its association with overall

back endurance, and role in NSCLBP, an argument could be made that the erector spinae should be considered in the exercise prescription for any trunk intervention in this population group, especially when we consider the implications of the flexion-relation phenomenon.

1.2.3 The 'Erector Spinae flexion- Relaxation Phenomenon'

When healthy individuals move, the erector spinae can relax in a full range from upright to complete lumbar flexion, and a myoelectric silence of the musculature can be observed (Gupta, 2001); this is considered the flexion-relaxation phenomenon (FRP). During this relaxation of the erectors, the multifidus acts as the primary stabilizer during trunk flexion. In comparison, for individuals who suffer from LBP, and specifically NSCLBP, this relaxation is completely absent. An argument is made that the persistent activation and contraction of the erector spinae musculature may be an attempt of the body to try stabilizing injured and/or diseased spinal structures through reflexogenic ligament-muscular activation and potentially assisting in helping individuals suffering from NSCLBP to protect from further injury and pain (Gupta, 2001); It may be considered a biomechanical consequence of FRP to attempt to accommodate and transfer loads onto the more passive elements of the spine to attempt equilibrium (Gupta, 2001). A review into the biomechanical and clinical significance of the lumbar erectors on FRP concluded that FRP can be a valuable clinical tool to assist in diagnosing and treating individuals with NSCLBP, and that the myoelectric silencing or the erector spinae and subsequent load-sharing of passive structures, which fail under higher loads, can be a source for NSCLBP (Colloca & Hinrichs, 2005).

1.3 Interventions for Lower back pain

There are different two subsets of individuals with nonspecific back pain. One subset is individuals who are likely to have improvement regardless of intervention. The other (estimated at 20%) are individuals who are more likely/prone to have the nonspecific back pain develop into a chronic lower-back problem (Deyo & Phillips, 1996). Overall, less than 28% of all LBP cases fall into a chronic and/or severe diagnosis category but are responsible for 77% of all years lived with disabilities (Dutmer et al., 2019), illustrating the severe disparity of pain and symptoms between individuals who have NSCLBP. Some of the common interventions for treating NSCLBP and general back pain are as follows:

1.3.1 Exercise/physical activity

Exercise prescription, specifically abdominal and core exercise, have been common interventions that medical professionals and practitioners have attempted to use to manage acute and chronic LBP conditions, injuries and pathologies, to mixed results. Searle et al. (2104) performed a systemic review and meta-analysis (45 studies) regarding the efficacy of exercise interventions and the effectiveness of different treatments for LBP. It was found that the exercise groups had significantly less LBP compared to the control and different treatment groups, and that strength/resistance work and coordination/stabilization both had a beneficial effect in reducing LBP. Interestingly, cardiorespiratory and combined exercise programs were found to be less effective and/or ineffective (Searle et al., 2015). Research presented by Slade et al. (2006) reinforces this notion, in which a systematic review (13 high-quality studies used) found that strengthening of the trunk was more effective than no exercise for the reduction of pain and improving overall body function/range of movement. Greater benefits were also found with more intensive programs rather than simple strengthening programs, and show more promise as effective rehabilitation tools for chronic LBP as well as after lumbar surgery (Slade et al., 2006); This could reinforce the importance of a more robust and extensive trunk resistance training once a less invasive training can be achieved without flare-up of pain symptoms. Not only has general physical exercise been shown to be an effective intervention, but so has more advanced, high-intensity aerobic exercise. In a study by Chatzitheodorou et al. (2007) comparing the effects of high-intensity exercise versus a passive intervention on pain and disability in individuals with chronic LBP, it was found that high-intensity exercise was effective at reducing the pain compared to a passive control group (Chatzitheodorou et al., 2007).

Dynamic movement interventions are also sometimes put into a similar category of physical/physiotherapy interventions. A main point of contention, irrespective of best practices, is that different physicians/clinicians' personal experiences, beliefs, and biases, may result in widely different treatments for the same reported pain; interestingly, though it is found to be an effective intervention for some with CLBP, it is not currently clear if it is superior to any other exercise-specific intervention (Lewis et al., 1995) There are some interesting comparisons between core stability and dynamic movement with respect to NSCLBP. In a clinical intervention involving three groups, core stability, dynamic, and control, it was found that both core stability and dynamic interventions were successful in

improving outcomes of pain level, range of motion of the thoracolumbar, and functional disability in sufferers of NSCLBP (Mohamed et al., 201.It could be argued that, depending on the base level of muscle endurance and strength in the lumbar/ trunk region, even dynamic stretching may act as a function-strengthening intervention that could eventually be graduated into more demanding/ higher intensity physical activities/ interventions (Mohamed et al., 2019). An argument could be made that the effectiveness of exercise interventions such as pilates, would fall under the classification of 'dynamic', but with a less clinical focus. A systematic review and meta-analysis conducted on the prevention of low back pain and the success of different interventions (exercise, back bracers, education, shoe insoles), either independently or in conjunction with each other, concluded that only exercise alone or in conjunction with education was effective in preventing LBP (Steffens et al., 2016).

One of the major difficulties with determining if exercise interventions are effective for treating NSCLBP is the adherence to, or non-compliance with, the required exercise program. Helewa et al. (1999), for example, found that strength and exercise instruction and back education did not prevent the likelihood of LBP episodes; and non-compliance was the main consideration (Helewa et al., 1999). The biggest concern with any exercise is that many individuals suffering from NSCLBP are unable and/or struggle to engage with high-intensity exercise, or exercise in general. Research by Hayden et al.(2005) indicates that this might account for why acute conditions do not have the same response to exercise compared with chronic LBP (Hayden et al., 2005), and suggests that the introduction of high-intensity exercise regarding chronic patients should be done tentatively and after a period engaging with an exercise program (with professional supervision).

1.3.2 Surgery

Drastic differences in health outcomes for LBP may be achieved by surgery (Spoor & Öner, 2013). However, depending on the country an individual resides, and the medical and healthcare system that lies within that society, an individual's ability to either have access to (wait times, appropriate services), or the financial means (ability to pay for required surgery) may differ. For a large majority of individuals suffering from LBP, surgery is not an available intervention, nor would it be the appropriate one; albeit for a small subset of patients in which it can be vital. Regardless, if an individual needs surgery, an exercise program should always

be recommended and prescribed once rehabilitation can begin (usually physiotherapy). The largest concern for individuals who suffer from NSCLBP is that the diagnosis itself is essentially given based on the exclusions of a specific pathology or injury. Thus, if they have neither the means nor the opportunity to get appropriate imaging or diagnostics, and do have a specific pathology or injury that would recommended surgery, they remain classified as NSCLBP (Koes et al., 2006). An additional argument can be made, that if an individual moves from non-specific to diagnosed, they are removed from the classification of NSCLBP; however due to the potentially high risk of complications from spinal surgery, the probability that the root cause of the CLBP does not get addressed, and considering the difficulties involved in acute rehabilitation from surgery, patients can be left in a worse state than they were pre-operation; due to this, and overall average ineffectiveness of surgical treatments surrounding NSCLBP may be why the reductionist approach to treatment has persisted, dispute its criticism. Proponents argue that a pathoanatomical diagnosis is essential for target-specific treatment while putting less emphasis on the biopsychosocial aspects of chronic pain.

1.3.3 Psychological and Multidisciplinary Approach -

A multidisciplinary LBP intervention will primarily involve a physical rehabilitation component, a psychological component, and/or a social-focused component, delivered by healthcare professionals with at least two separate fields/backgrounds. A systematic review and meta-analysis performed by Kamper et al. (2015) examining the effectiveness of a multidisciplinary rehabilitation approach found moderate evidence that it was more effective than traditional/usual care and low proof that it may be more effective than physical treatments in reducing pain and disability with individuals suffering with chronic LBP (Kamper et al., 2015). This is reinforced by the research by Hoffman et al. (2007), which did a meta-analysis (22 studies) to evaluate the efficacy of different psychological interventions, specifically regarding chronic LBP (non-cancerous). Their research found that specific psychological interventions such as cognitive-behavioural therapy and self-regulatory interventions were particularly effective, reinforcing the previous research regarding the efficacy of using a multidisciplinary approach (Hoffman et al., 2007). These studies are also supported by research using applied behavioural analysis, specifically a changing criterion design, in which may be effective in improving performance in physical domains (Moore et al., 2017) but also provides a benefit for individuals recovering and working through the rehabilitation of chronic conditions (Nary, 2010) and specifically patients with LBP (Sculco

et al., 2001). Due to the limitations of access to good psychological services and support, there can be a substantial benefit to clinicians who can educate patients on pain in conjunction with their physical interventions.

1.3.4 Fear-Avoidance Model of Pain

The fear-avoidance model was introduced by Lethem et al. in 1983, and is a psychiatric model that aims to provide potential reasoning for how some individuals move from acute injuries into chronic musculoskeletal pain without any recurring mechanism of injury or pathology (Lethem et al., 1983). The model describes that if an individual suffers an acute injury, or something that results in them suffering pain, they can start catastrophizing over pain following the acute phase. This can lead to a cognitive distortion that prompts suffering individuals to start believing in worst-case scenarios and/or believe the pain/injury is more severe than the initial cause of the acute pain. If catastrophizing happens, this can cause a follow-on effect of actively fearing and avoiding movement that exacerbates or causes pain, eventually leading to hypervigilance and eventually a disuse disability and depression (Lethem et al., 1983). It is claimed that pain catastrophizing is the most consistent psychosocial factor regarding the prediction of adjustment of chronic pain and could be a factor that contributes to the development and eventually maintenance of chronic pain (Martinez-Calderon et al., 2019). A systematic review and meta-analysis looking at pain catastrophizing and function with chronic musculoskeletal pain (CMP) analysed 85 observational studies, which included a total sample of 13,628 participants who suffered from CMP. It was found higher levels of pain catastrophizing were significantly associated with chronic pain intensity, as well as disability in general (Martinez-Calderon et al., 2019). Maybe due to the wide range of severity associated with CLBP, education regarding the Fear Avoidance Model of Pain (FAMOP) may, or may not be beneficial in improving outcomes for individuals with LBP alone. Regarding the multidisciplinary approach discussed above, this type of pain education in conjunction with clinical intervention, may provide better overall quality of life outcomes for those suffering from chronic lower back pain, non-specific or pathology-based. A narrative review by the Department of Experimental-Clinical and Health Psychology, Ghent University, highlights that some of the burdens with the FAMOP regarding chronic injuries are its inherent roots in psychopathology, and its need to integrate and address the dynamics and multiple complexities involved with disability, and functional recovery interventions for individuals suffering with chronic pain (Crombez et al., 2012);this

idea is reinforced by a systematic review conducted to review fear avoidance as a prognostic factor for outcomes regarding patients with NSCLBP; The authors found that that fear-avoidance beliefs, for individuals suffering with LBP, have poorer outcomes in the subacute phase of the pain or injury, and early treatment to address this may have an impact in reducing the transition into chronicity and additional delays to the recovery process (Wertli et al., 2014). Some argue that pain-related fear and far avoidance tend to occur in the context of multiple and/or competing personnel goals and an overall exacerbation of symptoms and affected quality of life (Crombez et al., 2012). The paper "Pain-related fear, disability, and the fear-avoidance model of chronic pain" concluded numerous cross-studies have shown consistently the associations between pain-related fear and disability. The latest meta-analytic estimates are that the relations are quite stable over different socio-demographic conditions (Zale & Ditre, 2015). Interrelations between pain-related fear and disability have empirically

Figure 8. Fear-avoidance model of pain (Crombez et al., 2012)

become of higher clinical and empirical interest and there seems to be sufficient evidence that it could be a beneficial addition to already best practices for chronic pain and development and eventually maintenance of chronic pain (Martinez-Calderon et al., 2019). A systematic review and meta-analysis looking at pain catastrophizing and function with chronic Musculoskeletal pain (CMP) analysed 85 observational studies, which included a total sample of 13,628 participants who suffered from CMP. It was found often, higher levels

1.4 Abdominal Draw-in Manoeuvre

The abdominal draw-in manoeuvre (ADIM) is an exercise that is characterised bu a draw-in and isometric contraction of the transverse abdominals. Ques that a beneficial for suffers is to “suck in” the belly button. It is also helpful to show where to find the TA, (pressing the fingers on the inside of the iliac crest, which can provide proprioceptive feedback of directly feeling the deep abdominals contract (Lynders, 2019). A main benefit of teaching this movement is teaching suffers to correctly contract the abdominals, and results in co-contraction of the deepest trunk stabilizers/ activation oof the local trunk muscles, and has more commonly accepted benefit for suffers of NSCLBP (Lynders, 2019). A point of interest regarding the draw-in manor is the ability to change the affected neuromuscular control in the trunk of individuals suffering from NSCLBP (Osuka et al., 2020). Research from Lee and Kim (2005) made a comparison between the ADIM and the abdominal expansion manoeuvre (AEM), which is an expansion/ lengthening of the abdominals to brace. It was found that individuals suffering from CLBP found larger benefit to the AEM than the ADIM for reducing CLBP.; this could further reinforce that a focus on any type of trunk and abdominal contraction, can provide benefits to address the coordination and neuromuscular changes that can be seen with sufferers of CLBP (H. Lee & Kim, 2015)
In addition to the changes in neuromuscular control that can be addressed, there is evidence that it is comparable, or better than traditional dynamic core exercises for addressing the morphology of the trunk, and specifically the TrA thickness. A study by Park and Yu (2013) found that for patients suffering from CLBP, using the ADIM resulted in a significant increase in the thickness of internal and external obliques for both groups, but only the ADIM group found an additional significant increase in TrA thickness (Park & Yu, 2013). A study that used real-time ultrasound imaging on subjects while doing the ADIM found validity in the idea of ADIM causing a preferential activation of the TrA in individuals suffering from CLBP (Park & Yu, 2013). Interestingly, in follow-up assessments, the ADIM may have the larger benefit to subjects at the initial stage of intervention, potentially due to the low overall stimulus. Using the ADIM could be a cost-negative additive to interventions for individuals with CLBP (Teyhen et al., 2005)

It should be considered that even in the interventions that only look at core strengthening and stability alone, different muscles of the of spinal segment will also be used due to overall function of trunk flexion and extension. For example, a traditional plank is

primarily a core strengthening and endurance exercise; however, as an individual comes closer to mechanical failure and compensation mechanisms change in exercise form (e.g. change of hip height), the engagement of muscles such as the multifidus and erector spinae will start to be engaged more. An argument could be made that most core stabilization programmes would have significant activation of the multifidus, even if not intentional. Regardless, research indicates that improvements in overall trunk strength can reduce pain, and improve the range of motion and function of an individual's lower back, but is not a complete tool for addressing overall complications from chronic LBP (Slade et al., 2006).

1.5 Reliability Measures and Testing

Research by Biering-Sørensen has looked at physical measurements as risk indicators for lower back pathology. The primary findings from the study demonstrated that good isometric endurance of the back muscles may assist in preventing acute/first-time LBP, while recurrence of the LBP was primarily correlated to space of time since the last incident happened; the more severe the LBP was reported, the less time between incidents was found (Biering-Sorensen, 1984). This research is reinforced by Alaranta et al. (1994), who found that overall trunk muscular endurance, such as isometric extension, sit-ups, and arch-ups, in suffers of NSCLBP exhibit negative performance compared with individuals who had suffered acute flares of LBP previously. The American council of Exercise uses the Mcgill's torso endurance battery to assess overall trunk strength, and the relationship between the trunk structures, using four different measures of trunk endurance strength. Though this is an accepted test of the structures of the trunk, and provides potential risk indicators for LBP (*Low Back Disorders: Evidence-Based Prevention and Rehabilitation - Stuart McGill - Google Books*, n.d.), it is acknowledged that depending on the severity of lower back pain, prior surgery in the lumbar or trunk region, or a lower back pain flareup, these exercises may not be suitable and/or difficult for an individual to complete (Mcgill's Torso Endurance Test Battery, n.d.). This highlights a potential difficulty regarding trunk measures. While the research indicates that trunk extension and trunk endurance does correlate with, or at least potentially predict the chance of, LBP, the movement dysfunction in the suffering population can directly impact their ability to complete the tests (Alaranta et al., 1994). An argument could be made, using these measures during a clinical intervention could still be beneficial.If a participant could not complete a trunk endurance test (e.g, spinal extension test,) due to pain, but on repeated testing after or during intervention stage, and can at least perform the movement asked, even

if with an objectively low perceived strength, it would still indicate an improvement in pain/ associated LBP quality of life outcomes (or at least ability to move through pain). Abdelraouf and Abdel-aziem (2016) reinforces this idea by using the four trunk measures of the MTETB in a comparison of collegiate athletes who suffer with NSCLBP. Their conclusions were that there was a difference between healthy participants and suffers of NSCLBP, specifically in performance on the trunk flexor and trunk extension endurance tests and recommend this could be an important consideration in exercise prescription for these suffers. (Abdelraouf & Abdel-aziem, 2016)

1.6 The Myth of Spinal Stability

Dr Stuart McGill (who developed the Mcgill's Torso Endurance Test Battery) gave a presentation entitled "There is no such thing as non-specific lower back pain". A patient who had non-specific lower back pain was provided as an example, who was eventually given a diagnosis as degenerative disc disease (DDD). Individualized and tailored diagnostic testing led to a specific diagnosis of 'pain triggered by flexion intolerance', which is expanded into posture-modulated load intolerance, rather than a generalized load intolerance to the spinal structure, and allowed for a better-tailored rehabilitation plan (ThelHMC, 2017).He concluded, "Good coaches don't create fear [avoidance], they create movement confidence." This highlights the need for not only a clinically proven rehabilitation plan but the ability to empower clients and patients with the ability to get better and address the psychosocial aspect of CLBP (ThelHMC, 2017). Furthermore, it highlights the potential need for some level of individualization during a randomized clinical trial, to try to increase the chance of improving suffering outcome measures, while maintaining a consistent research design.

1.7 Analysis and interpretation of Pain Scores.

Pain scales have been and are still regularly used in measuring individuals perceived level of pain, to mixed results. One of the primary issues that arise when using written or verbal pain scales is the differences of cultures, genetics, self-perception of pain, and propensity of catastrophizing between individuals. These lead to greatly different reported scores for potentially the same level of 'objective pain'. Another point of contention is the primacy and recency effect in psychology, and how that affects individuals reporting of pain levels. A Visual Analog Scale (VAS) is a modified pain scale, which, in conjunction with a numerical pain scale, has visual prompts to indicate the severity of pain. It is reported that the use of the visual aids (being the change in visual happiness of the picture) helps assist

individuals in perceiving their pain in conjunction with how it affects their overall well-being. Using the interpretation of VAS pain scale scores, it is “suggested that a 33% decrease in pain represents a reasonable standard for determining that a change in pain is meaningful from the patient's perspective” (Jensen et al., 2003)This is used as a baseline for minimal clinical important difference (MCID). Regarding medical clinical important change (MCIC) in LBP patients, it was found with a numerical-pain scale, a change of 1.5 or less is not considered significant for acute and chronic suffering (Jensen et al., 2003).7

1.8 Current Gaps in the Research

One of the major gaps in NSCLBP intervention research is that no study directly compares strengthening of the transverse abdominis versus the rectus abdominis in conjunction with the multifidus and erector spinae (with hypertrophy as a secondary goal, especially if there has been any atrophy in the muscle), and uses pain, strength, and quality of life measures as outcomes. There has been a plethora of research that compares a dynamic versus stability-styled spinal movement focused clinical intervention; for example pilates versus core stability (Bhadauria & Gurudut, 2017a; Fernández-Rodríguez et al., 2022a) but there is a lack of comparisons of using these different types of trunk muscle interventions as complimentary sequential interventions to each other,(Ulger et al., 2023) and if starting with one style of intervention provides a better base for follow up interventions using another style. Based on the previously mentioned research, targeted stability and dynamic exercise interventions that focus on strengthening the transverse abdominis, multifidus, and the rectus abdominis would strengthen the trunk and abdominals and present an effective intervention for individuals suffering LBP, and specifically chronic LBP (Helewa et al., 1999; Slade et al., 2006). At worst, the targeted exercise interventions may not help manage LBP outcomes, but may help address the trunk dysfunction mentioned, and help take additional load of the spinal support structures and reinforce trunk strength in general; if the patient presents with a weakness in this area, it may lead to excessive loading on the posterior chain and directly on the spine. This would be considered a stability intervention due to the TA relation with the multifidus as antagonists and synergists of trunk movement and overall stability of the spinal structure. This style of intervention has the advantage of potentially being able to strengthen the trunk structure without causing an increase in pain symptoms due to the avoidance of movements that cause a spike in suffers of NSCLBP. It is important to provide a comparison between the rectus and transverse abdominals as the rectus abdominals specifically assist in

the flexion and shortening of the angle between the pelvis and trunk, which inherently involves trunk flexion/extension specifically in the lumbar zone. This is a primary affected movement for individuals with LBP, and the reduction in trunk flexor could be directly linked with potential fear-avoidance behaviors that have developed as individuals' pain has become more chronic and/or severe. A direct comparison between the rectus abdominus, erector spinae, transverse abdominals, and multifidus as separate exercise interventions could help distinguish if there is a difference between muscle strengthening and/or hypertrophy as an intervention tool. Potentially, these muscles could also work positively in conjunction with each other; for example, strengthening the transverse abdominals can provide more stability in the trunk, which in turn allows more stimulus-loading rehabilitation physiotherapy exercises. Similarly, a dynamic, rectus abdominal and erector spinae-focused rehabilitation program can strengthen the trunk through troublesome and compromised movements. The dynamic intervention provides an opportunity for pain education and addressing potential fear-avoidance beliefs that have surfaced after struggling with chronic lower back pain through a slow and guided progression of movements that have been avoided and have become weaker due to pain. It is vital that part of the exercise intervention also involves activation and loading of the posterior chain, as the abdominals are only the anterior portion of the trunk and are a major component in trunk flexion; antagonist, agonist, and synergistic depending on the movement; while the stability intervention allows participants to do a large level of intensity while not causing the same amount of localized movement in the affected area. The stability intervention has more application for this type of exercise style of program, and may provide the benefits of more high-intensity workouts due more maximal and the associated potential drop in chronic pain (Chatzitheodorou et al., 2007) due to the ability to do maximal effort without the same concerns of injury; Simultaneously, it would provide the potential to burn more calories and promote weight loss, which would be specifically applicable for individuals with chronic LBP that can struggle to do a single exercise session during the day.

Both stability and dynamic interventions have been shown in recent meta-analyses to be beneficially to suffers of NSCLBP, even though no study has looked at whether they might be complimentary. A randomized controlled trial with a crossover-design, allowed for testing of both interventions independently, as well as in sequential order over time, using between, and withing-groups research design. This can be focused on individuals who suffer with NSCLBP and exclude acute cases (most acute cases should improve independently with time) and

individuals who suffer chronic LBP but have a clear pathology or injury that may require a surgical intervention. The application of a multidisciplinary intervention with the exercise programme may also be potentially beneficial, but due to the necessity of multiple specialists, it may not be realistic due to limited resources. However, one could consider providing additional complimentary tools that have been shown benefit, such as an apparatus for heat application and incorporate pain education in conjunction with the clinical interventions.

Chapter 3: Research Methodology

This chapter is an overview, justification and description of the methodology used for the randomized clinical trial. We will discuss the overall research/ experimental design, ethics, assesment procedures, equipment and the exercises given to participants during each intervention. Figure 9. Illustrates the progression of participants from the point of contact.

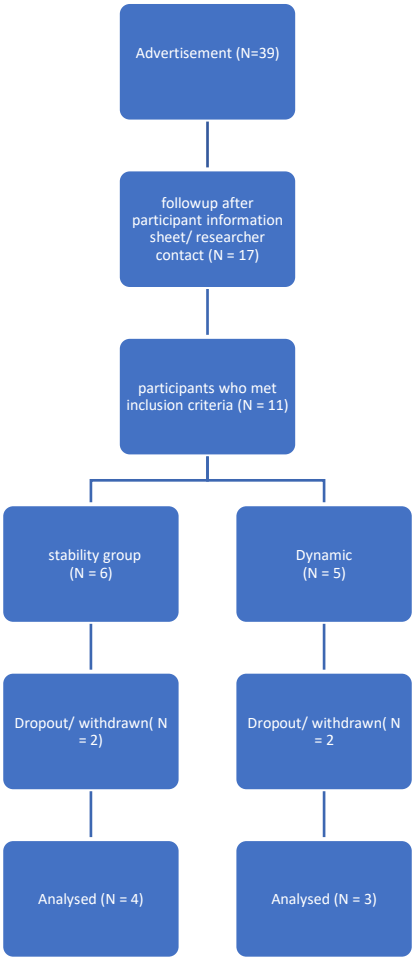


Figure 9. Flow chart of study design illustrating the progression of participant recruitment from advertisement, to contact, primary meeting and then completion of intervention.

1.9 Research Design

The research design was prospective, between, and within-subjects, 2 x 2 crossover randomized clinical trial.

1.9.1 Sample Size

The prevalence of individuals with CLBP between the ages of 20-59 as a population proportion is estimated to be 19.2% (Meucci et al., 2015). Using a confidence level of 95% and, margin of error of 5%, for this study, we aimed for 10-30 participants. This number considered sample size calculations as well as recommendations made by University of Waikato Human Ethics Research Committee, who provided ethical approval. Following recruitment, 39 potential participants expressed an interest in the study, of which 11 met inclusion criteria and were enrolled. Seven participants, in total, completed the clinical intervention (four participants dropped out for reasons unrelated to the study).

1.9.2 Characteristics

The main characteristics sought in the participant population suffering from NSCLBP for a period of more than 3 months (longer than 12 weeks total; that would carry the classification of chronic) and an age between 18 and 59 years old. The focus was to recruit general population rather than a specific group, aiming for an even percentage of male to female participants. By end of research period, two males and five females finished the clinical intervention.

1.9.3 Inclusion/ Exclusion Criteria

Participants were selected based on having non-specific chronic LBP. Pain in these individuals should be mild to moderate and without a clear or diagnosed reason, e.g. herniated disc, spinal stenosis, etc. Exclusion criteria for participating included: suffering from intermittent pain, severe pain, or disability-associated pain (>80% scored on numerical pain scale or disability index); an injury or diagnosed pathology associated with the pain; an injury or diagnosed pathology that may require specialist interventions (spinal surgery) or awaiting imaging for specialist referral; and previous surgery for a lower back injury or

pathology. Other exclusion criteria included <18 years old or >59 years old, currently engaged in two or more resistance trainings per week, or using a prescribed opioid (morphine analogues) medication.

1.9.4 Recruitment Method/ Time

Recruitment of participants was achieved through a recruitment flyer advertisement using various social media posts (including Facebook and Instagram) and presented at the University of Waikato community boards as well as physiotherapist clinics, with permission (e.g Habit Health). Any interested individuals who suffered from mild-moderate chronic lower back pain could scan a QR code from the flyer, which described the study in more detail (Participant Information Sheet) or contact the primary researcher (Adam Callaghan) through mobile phone or email communication for more information about the study and recruitment.

Once an individual expressed an interest in participating in the study, a time was organized to meet in person. At this meeting, the individual received a Participant Information Sheet to read and keep, and the study was discussed in detail. Any questions the participant had were answered. Finally, the individual was given a Consent Form and physical activity readiness questionnaire (PARQ+) and a time was arranged for collection of the Consent Form and a pre-assessment.

1.10 Informed Consent/Ethics

Participants provided consent by signing a Consent Form. Following the information meeting and provision of a Consent Form and PARQ+, participants were given at least two days to further consider whether or not to join the study. If they still wished to participate after this time, they then attended an enrolment and initial assessment meeting where they were reminded of the study and their rights and could ask any further questions before signing the Consent Form and beginning the study.

Ethical approval for this study was granted by the University of Waikato Human Research Ethics Committee (HREC) on the 24th of April, 2023: Approval # HREC(Health)2023#06 - *Strengthening transverse abdominus/multifidus (TA) versus rectus abdominus/spinal erector (RA) muscles for non-specific chronic lower-back pain*.

1.11 Experimental Design

In summary, the intervention took place over a total of 8 weeks (4 weeks per intervention) and involved three separate assessment/training sessions with researcher and 24 exercise program sessions. The assessment/training sessions took approximately 45 minutes per participant. This included 30 minutes for explanation and assessment, and 15 minutes for illustration and testing of initial exercise interventions. The exercise program sessions took participants 40-60 minutes to complete and were performed a total of three times per week, with a minimum of 48 hours between sessions.

The experimental dependent variables were back and leg pain, lower back pain, disability index, and physical impairment. The two instruments used during the assessments were the Low Back Pain Scale (LBPS) and the McGill's Torso Muscular Endurance Test Battery (MTETB). Variables measured in the low back pain scale include pain, disability index, physical limitation, and medications used. The LBPS and MTETB were performed with participants at each of the three assessment/training sessions: initial meeting; after completion of the first intervention stage; and after completion of the second intervention stage/end of the experiment.

The LBPS is comprised of three individual parts: the Visual Analogue Scale (VAS), Disability Index, and physical impairment. The VAS measured back and leg pain. The disability index had a variety of questions relating to how NSCLBP impacts their life and physical impairment was measured using the modified Schobers test, Back endurance test and a overall mobility test. When performing the modified Schober's test, the flexion distance is measured in Centimetres. A visual analogue scale was used to assess pain used a numerical pain scale, with a higher score indicating a greater intensity of pain. The disability index asks 15 questions that can be answered 'yes', 'no' or 'maybe/sometimes', which is then scored from 0-2 for a maximum score of 30. The physical impairment involves three physical tests: endurance of the back/lumbar; the modified Schober's test; and the overall mobility test. Physical assessments were all recorded in seconds, and a longer recorded time indicated less severity/ lower score. The additional medication question asked about the use and dose of non-steroidal anti-inflammatory, non-narcotic analgesics, or morphine analogues per week. The maximum score for the physical impairment is 40 points, and the maximum score for the LBPS is 124 (normally 130, but due to exclusion criteria for morphine analogues, these questions were not included in the total score). The higher the score, the greater the level of disability and impairment related to participants' lower back pain.

The MTETB uses three individual tests: the trunk flexor endurance test; the trunk lateral endurance test; and the trunk extensor endurance test. The tests were to assess trunk muscular endurance of the deep core muscles. Each of the tests was performed until participant failure and was measured in seconds. A nominal scale of either good or poor is then provided for a flexion:extension ratio, right-side bridge:left-side bridge ratio, and a side bridge (each side) extension ratio.

Participants were randomly assigned to a TA intervention (stability) or RA intervention (dynamic) experimental group. Interventions lasted 4 weeks with an assessment/training session. After this midway assessment (post-intervention 1), participants switched to the alternating intervention (RA intervention (dynamic) or TA intervention (stability), respectively). Each intervention had two warm-up exercise sets and four sets of four exercises to be completed. The repetition range was between 8-20 repetitions per set to maximize stress to stress-to-fatigue ratio while minimizing overall loading. If the participant could not perform eight repetitions of the exercise, a focus was given on one of the exercise variations given; each of the four exercises had 2 variations to accommodate for individual's physical capabilities. Regarding the RA intervention (dynamic), depending on and the amount of localised spinal flexion/extension, week one was 4 repetitions in reserve (RIR), the second week was 2 RIR, and the third and fourth week was completion until either muscular fatigue or researcher/self-selected stoppage due to increase in pain. Rest time between sets was dependent on participants fatigue and self-reported pain levels. Participants were provided with a generic wheat bag to keep and encouraged to use it regularly and explained the benefits of heat application of chronic back pain.

The following is a list of the exercises and descriptions given to participants to be performed during each intervention during the experiment. Each exercise grouping has additional notes provided regarding the individuation of the exercise and considerations depending on participant limitations. These were also provided to the participant as exercise workout templates. Participants were taught the ADIM during the start of the stability intervention.

1.11.1 Exercises for the Transverse Abdominus/ Multifidus Intervention (Stability)

(See appendix 8.5, 8.6, 8.7, and 8.8)

Exercise- Loaded hold shoulder raise.

Using any type of load (dumbbell, medicine ball, or plate) raise weight up until shoulder height. Maintain a braced trunk while weight is elevated. Hold the weight until shoulders begin to drop the weight or trunk begins to lose stability and round forward.

Exercise- Alternating front raise.

Sitting or standing, start with arms on both sides while holding a weight (thumbs up with dumbbells, palms down if holding a resistance weight). While keeping the arms straight, lift arms to shoulder level or above, while having arms roughly at a 30 degree angle (point the arms slightly away from you). While holding the position slowly drop one arm to the starting position and raise it back to shoulder level.

Exercise- Steering wheel plate shoulder raises hands.

Stand up tall with a plate in your hands. Brace your core and bend the knees slightly. Lift the plate to shoulder level with arms stretched out as far as possible. Begin turning the plate as if you were turning a steering wheel of a car until shoulders allow and turn the plate the opposite way. Continue this movement until lower back discomfort occurs or you cannot maintain a straight trunk posture.

Exercise- Side plank on the wall.

Stand next to a wall at an appreciable distance (the further away the harder the movement) so your forearm can be on the wall; you will be at an angle to activate your abdominals. Put your feet next to each other and put your forearm at shoulder height while holding the position of your feet while keeping a straight line. Hold the position as long as possible and return to standing without moving feet for resting position.

Exercise- Side plank with abduction.

Lie on your side with knees bent roughly at 90 degrees and one elbow on the ground. Push yourself up against your elbow until your head, shoulders, hips and knees are all in a straight line. Lift the top leg up and down while maintaining spine angle and return to starting position (legs may be extended further to increase the difficulty).

Exercise- Side plank.

Start by lying on your side, with one elbow lying on the ground and the other flat against your side, legs in a straight line with a slight bent in the knee. While engaging the core, squeeze your glutes and lift your trunk into a straight line while pushing your hips forward. The top position should have the body in a straight line. Slowly return to the starting position (to make it easier, you may use to other arm to help stabilize or bend your knees if the movement cannot be performed). Hold the position until trunk stability fails and cannot maintain straight spine angle.

Exercise- Seated good mornings.

Sit at the end of the bench and feet at the position which allows the most hip movement. Using a stick, keep the trunk straight and tight while moving it as far as you can before spinal flexion occurs. Return to start position.

Exercise- Loaded good mornings.

Stand with legs at hip-width and bar placed behind the upper back. Holding the bar with your hands, bend over from the hips, making sure that the truck and lower back keeps the same spinal angle through the movement, trying to keep the same knee bend that you had starting the movement. Return to starting position and repeat the movement (this can be performed holding a dumbbell or weight if shoulder mobility/training location does not allow).

Exercise- Romanian deadlift.

Begin the movement with your knees slightly bent and pushing your hips back while keeping your back as straight as possible and head position forward. Continue the movement as far as you can without rounding your back, when you get to the point of restriction bend your knees to lower the weight further. While lifting the weight up, push your knees and hips forward before elevating your spine to the starting position.

Exercise- Abdominal plank.

Start with all four limbs on the ground and then push yourself up with your forearms and your toes, with your chin tucked in. Your body should be a straight line and maintain position for as long as possible.

Exercise- Modified plank with leg lift.

In a plank position with elbows or hands on the ground. Contract the abdominal muscles and elevate one leg off the ground, try and think of pushing the legs backs while maintaining trunk stability. Do not allow the trunk or pelvis to move while the leg is moved backwards (if possible). Return leg to starting position and repeat with the opposite leg.

Exercise- Superman, arms forward plank.

Start in a plank or push-up position (whatever is easier) and brace the body. Lift one leg while lifting the opposite arm at the same time without letting the trunk or pelvis rotate. Reach as far as you can away from the body with both opposite arm and a leg and hold the contraction at the top of the movement. Return to start position and repeat with the opposite limbs; keep the trunk braced through the entire movement.

1.11.2 Exercise for Rectus Abdominus/Spinal Erector RA (Dynamic) Intervention

(See appendix 8.1, 8.2,8.3, and 8.4)

Exercise- Lumbar extension.

Lie down flat on your stomach, with arms tucked underneath the chest or directly in front, depending on what is most comfortable. While maintaining the pelvis and hips on the floor, try and arch your lumbar so your head is looking forward. You may slightly assist with your arms if extension (arching) cannot be performed alone. Slowly return to the starting position.

Exercise- Passive lumbar extension.

Lie on your stomach with your hand close to face at shoulder-width distance. Begin the movement by pushing yourself up against the floor with your arms slowly, allowing for your head, upper back and lumbar to begin arching one at a time. Keep the glutes relaxed and pelvis/hips against the floor during the movement.

Exercise- Lumbar flexion and extension.

Lie on your stomach with your hand close to face at shoulder-width distance. Begin the movement by pushing yourself up against the floor with your arms slowly, allowing for your head, upper back and lumbar to begin arching one at a time. Keep the glutes relaxed and pelvis/hips against the floor during the movement.

Exercise- Jefferson unloaded.

Start with a stick with hands at shoulder width. Begin rounding the spine, bending and rolling one vertebra at a time until you are at the bottom of your maximal range of motion/pain limit. Reverse the motion starting with your lower back and return to the starting position. Try to keep your knees as straight as possible. A step to increase range of motion is optional.

Exercise- Standing abdominal crunch.

Using a band above the head, grab the band with both arms out front above the head. Start with arms straight, bend your trunk forward by contracting your abdominals and bringing your rib cage towards your hip. Allow the hips to move back slightly to facilitate the movement. Hold the position for 1-3 seconds. Focus on the abdominals creating the movement rather than your arms. Return to the starting position slowly allowing the band to bring you upright.

Exercise- Loaded Jefferson curl.

Follow the same procedures as the unloaded Jefferson curl. If using a barbell, hold a shoulder width and if holding a weight, keep it in line with the middle of your body. If progressed from the unloaded variation, loading is to be done extremely slowly and only in supervised sessions.

Exercise- Modified superman.

Lie face down on the floor with arms folded, under the forehead or in the most comfortable position. Tuck in chin and slowly lift your legs off the floor without lifting up the hips, while slightly elevating the chest if needed to allow the movement. Slowly lower the legs to the starting position

Exercise- Stabilization superman.

Lie on the floor with arms and legs stretched straight in front, with your ear touching your inner arm. Push belly button towards the floor to activate abdominals. At the same time lift one arm and one leg (opposites) while maintaining core stability. Return arm and leg to starting position and perform the next repetition with the opposite limbs that were not raised.

Exercise- Superman strengthening.

Lie on your stomach with arms and legs stretched out as far as possible; think of having as long of a body as possible. at the same time lift your arms and legs off the floor and reaching with both legs. Try and hold the position for one second before returning to start position.

Exercise- Active pelvic tilt.

Sit on a chair with thighs parallel to the ground or below (this may be done standing if it is easier to perform the movement initially). Maintaining steady breathing and abdominal pressure, slowly move your hips and let your lower back arch, and then push your hips forward allowing your back to round. Alternate between these two positions within your available range of motion.

Exercise - Seated cat-camel.

Sit up in a chair with your back away from the backrest (if it has one) and place your hands on your knees. Start with a strong vertical posture and gently bend forward with your chin down until you feel a slight stretch in your back. Slowly reverse to movement and try and arch your back until you either feel a stretch in your lower back or abdominals. Alternate between these two positions for as many repetitions as comfortable.

Exercise-Cat-Camel

Start with all fours on the ground, palms facing down, head looking forward and hands underneath shoulders. Attempt to lift the chest and head at the same time by arching your lower back while letting the stomach drop. Reverse this movement into rounding the back into your comfortable range of motion. Hold each position for 5 seconds before alternating. Do not force the end range of motion, this is not a stretch like the seated variation.

-All movements were displayed and overseen by the primary experiment who is working as a clinician in rehabilitation.

1.12 Assessment Procedures

Every participant assessment started with an introduction to experimenters and explanation of the experimental design; this included a reminder of what will be done during the assessment and where participants will need to be touched (for example, top of the iliac

crest and midpoint of iliac spine, around L5/S1 vertebrae section, for the modified Schober's test). Once the participant was comfortable, the Researcher would begin the start of the assessment. The Researcher began by asking the initial back and leg pain questions of the visual analogue scale (VAS) from the low back pain rating scale. Participants were explained that severity from 0 to 10; 0 being the least amount of pain (considered no pain) and 10 being maximal amount of pain (most pain possible). The following are the questions that were asked during the examination:

1. Back pain at the time of the examination.
2. Leg pain at the time of the examination.
3. The worst back pain within the last 2 weeks.
4. The worst leg pain within the last 2 weeks.
5. Average level of back pain during the last 2 weeks.
6. Average level of leg pain during the past 2 weeks.

Following the back and leg pain visual analogue scale questions being answered and recorded, the researcher moved to the disability index portion of the low back pain scale. The following are the questions asked to the participants:

1. Can you sleep at night without low back pain interfering?
2. Can you do the easy chores at home such as watering flowers or cleaning?
3. Can you do your daily work without low back pain reducing your activities?
4. Can you put on shoes and stockings by yourself?
5. Can you do the easy chores at home such as watering flowers or cleaning the table?
6. Can you carry two full shopping bags (10 kilograms total)?
7. Can you bend over the wash basin to brush your teeth?
8. Can you climb stairs from one floor to another without resting because of low back pain?
9. Can you walk 400 meters without resting because of low back pain?
10. Can you run 100 meters without resting because of low back pain?
11. Can you ride a bike or drive a car without feeling any low back pain?
12. Does low back pain influence your emotional relationship to your nearest family?
13. Did you have to give up contact with other people within the last 2 weeks because of low back pain?

14. If it was a present interest, do you think that there are certain jobs which you would not be able to manage because of your back trouble?
15. Do you think that the low back pain will influence your future? (*Low Back Pain Rating Scale | RehabMeasures Database*, n.d.)

Following the end of the disability index questions being answered and recorded, the final portion of the questions involved asking the amount of analgesic usage. Participants were asked if they have taken any non-steroidal anti-inflammatory or non-narcotic analgesics, and if they had, the amount used per week. The amount of morphine or morphine analogs was not asked as it was an exclusion criterion for the research participants. This completed the verbal portion of the assessment and researcher then started the physical impairment tests. The modified Schober's test was performed in a private room of the gym, once researcher had applied examination gloves and the participant has been asked to raise the bottom of their shirt, the test protocol for the modified Schober's test is as follows**:**

The pre-test protocol was as follows:

1. Researcher showed participant where they will be finding the iliac crest to find the correct position on the iliac spine.
2. Apply examination gloves.
3. Participants were asked for verbal consent before being touched and the start of the test.

The test protocol was as follows:

1. Draw a line between the posterior iliac spines.
2. Mark a point a point 10 cm above the midpoint of the line on the lumbar spine.
3. Ask the participant to bend forward as far as comfortably possible.
4. While bending forward, measure the distance from that point to the midpoint of the line connecting the posterior iliac spines.
5. Determine the distraction = increase in measurement while bending forward.
6. Record distraction on the data sheet. (Low back Pain rating scale, 2017)

Record the change of distance and move on to the physical performance/endurance tests. The first test was performed for the overall mobility in the fastest time possible.

The test protocol was as follows:

Fastest time taken to go from (a) lying supine on a flat couch 80 cm above the floor to (b) standing beside the couch then (c) walking to the end of the couch (or equivalent length) (d) a deep knee bend (bodyweight squat) is done and then (e) return to the starting position. (Low back Pain rating scale, 2017).

Time is recorded and participants are moved to the last physical test (endurance of back muscles) in the LBPS - length of time that the patient can lie horizontally above the floor with the legs strapped to a bench, and the trunk unsupported from the level of the iliac crest. This is also the start of the MTETB section of the assessment.

The pre-test protocol was as follows*:*

1. After explaining the purpose of the test, the participant was shown the proper body position prior to trying to assume the position.
2. The starting position required the participant to be prone, positioning the iliac crests at the table edge (participant is shown where the iliac crest is) while supporting the upper extremity on the arms, which are placed on the floor.
3. While the participant is supporting the weight of his or her upper body, anchor the participant's lower legs by applying counterweight.
4. The goal of the test was to hold a horizontal, prone position for as long as possible. Once the participant fell below horizontal, the test was terminated. (Low back Pain rating scale, 2017)

The test protocol was as follows:

1. When ready, the participant lifted/extended the torso until it was parallel to the floor with his or her arms crossed over the chest.
2. A timer was started as soon as the participant assumed the position.
3. The test was terminated when the participant could no longer maintain the position.
4. The participant's time was recorded on the record sheet.

Following the completion of the trunk extensor endurance test, the participants were allowed to rest, and when self-reporting that they were ready, the trunk flexor endurance test was performed.

The pre-test procedure was as follows:

1. After explaining the purpose of the test, the participant was shown the proper body position prior to trying to assume the position.

2. The starting position required the participant to be seated, with the hips and knees bent to 90 degrees, aligning the hips, knees, and second toe.
3. The participant was instructed to fold his or her arms across the chest, touching each hand to the opposite shoulder, and to lean against a board positioned at a 60-degree incline, and keep the head in a neutral position (*Mgill's Torso Endurance Test Battery*, n.d.).
4. The participant was asked to press the shoulders into the board and maintain this position throughout the test once the board was removed.
5. The participant was instructed to engage the abdominals to maintain a flat-to-neutral spine. The back was not allowed to arch during the test.
6. The Researcher anchored the toes under a strap or manually stabilized the feet if necessary.

The test protocol is as follows:

1. Researcher counted down and started the timer when the board was removed from the back, while the participant maintained the 60-degree, suspended position.
2. The test was terminated when there was a noticeable change in the trunk position, this included the shoulders rounding forward or an increase in lower back arch angle or if a 60-degree angle is lost.
3. The participant time was recorded on the record sheet. (*Mgill's Torso Endurance Test Battery*, n.d.)

Following the completion of the trunk flexor endurance test, the participants were allowed to rest, and when self-reported that they were ready, the trunk lateral endurance test was performed.

The pre-test procedure was as follows:

1. The starting position required the participant to be on his or her side with extended legs, aligning the feet on top of each other or a heel-to-toe position. The Researcher demonstrated a full side-plank position that participant could replicate.
2. The participant was asked to place the lower arm under the body and the upper arm on the side of the body.
3. When the participant was ready, he or she was instructed to assume a full side-bridge position, keeping both legs extended and the sides of the feet on the floor. The elbow

of the lower arm was positioned directly under the shoulder and the upper arm was resting along the side of the body or across the chest to the opposite shoulder.

4. The hips should were elevated off the mat and the body was in a straight alignment with shoulders and head before starting the timer. (*Mgill's Torso Endurance Test Battery*, n.d.)

The test protocol is as follows:

1. The researcher started the timer as the client moved into the side-bridge position.
2. The test was terminated when there was a noticeable change in the trunk position; a deviation from the neutral spine including the hips shifting forward or backward, or a lateral shift up and down.
3. The participant time was recorded the on the record sheet.
4. The test was repeated on the opposite side when participant has had sufficient rest.

The completion of the trunk flexor endurance test marked the end of the assessment.

1.13 Equipment

Initial pain measures, mobility, and strength were obtained using the low back pain rating scale (Low back Pain rating scale, 2017), which was found to have a high level of reliability for assessing individuals with lower back pain (ICC = 0.98) (Manniche et al., 1994). Endurance and strength of the trunk structures was assessed using the Mcgill's Muscular endurance test battery. Range of motion (change of back flexion) was assessed by a generic measuring tape. A Samsung galaxy S20 mobile phone was be used for time measurements during training. Assessments were performed in an allocated room in the TT building at the University of Waikato, and a private room at the IronHouse Gym, Hamilton, New Zealand. Exercise routines and illustration of routines were performed in the allocated room in the TT building at the University of Waikato or within the recreational space of the gymnasium. All participants were provided with a free access to the gym during the study. A generic polyester wheat heat bagthat the participant could keep was provided to each participant at the start of first intervention period. A physiotherapy examination table was used for the tests during assessments. Labserv, single use, nitrile examination gloves used by researcher during modified Schober test. Cleaning of surfaces and equipment was done using TriGene advance concentrate, hospital-grade surface disinfectant, Tristel solutions limited,

snainwell, United kingdom. Individual 5, 10, and 15 KG weight plates and a 20 KG dumbbell was used for weighted exercises.

1.13.1 Data Processing

All data processing and analysis was performed using Microsoft Excel for Microsoft 365 MSO (Version 2205 Build 16.0.15225.20172) 64-bit and IBM Corp. Released 2023. IBM SPSS Statistics for Windows, Version 29.0.2.0 Armonk, NY: IBM Corp.

1.13.2 Statistical Analysis

The research data was analysed using a one-way Repeated Measures ANOVA, to compare the outcomes of suffers of NSCLBP, regardless of the intervention order, and two-way repeated measures MANOVA was used to compare the interaction effect between groups, and to assess for any potential sequential/crossover effect from the crossover design. Correlation effects were measured using Pearson bi-variant analysis for comparisons of continuous data and a point bi-serial correlation was performed to find a correlation between one continuous variable (e.g back and leg pain) and numerical data (good vs poor trunk ratio scores).

Chapter 4: Results

The overarching research objective of this study was to evaluate the effectiveness of different core strength/exercise interventions in reducing pain in individuals suffering from non-specific chronic LBP. Secondary to this, the study's objectives are to determine if strengthening the transverse abdominus/multifidus (stability- AB) and/or the rectus abdominus/spinal erectors (dynamic-BA) has greater efficacy, and whether sequentially targeting both (i.e. targeting one (TA or RA) provides a stronger foundation for the other) of these may impact the positive outcomes in sufferers of chronic LBP. Considering the previously established relationships between trunk/ core endurance and association/ prediction of CLBP, we also wanted to assess whether our participants followed these same correlations between the variables in the lower back pain scale and scores from the McGill's Torso Endurance Battery Tests' and the rating that is provided.

A total of 11 participants fit the inclusion criteria and were willing to participate. 7 total participants finished the overall study (2 male, 5 female). The average age for participants was 35.286. the range for total LBPRS total mean scores was 22. Range for LBP was 8.749 and BLP 13.429. the range for disability index was 7.714 and physical impairment was 14.571. Weight and height were not included descriptive statistics for the research.

1.14 Does a Two-Part, Clinical Intervention Targeting Specific Core Muscle Groups (TA or RA) Improve pain as an Outcome?

1.14.1 Back and Leg Pain

Results from participant scores of VAS, assessing back and leg pain, for assessment 1 (pre-intervention) was (Mean (M) = 13.439, Standard Deviation (SD) = 8.017), assessment 2 (post-intervention 1) (M = 9.571 SD = 6.705) and assessment 3 (post-intervention 2) (M = 3.0, SD=2.517). Individual participant scores and analyses are reported in Table 1 and Figure 10. The result of the one-way repeated ANOVA yielded there was a statistical difference in the combined sum of back and leg VAS pain scores between the three assessment periods; Wilks' $\Lambda = 0.207$, $F(2,5) = 9.560$, $p = 0.02$, partial n^2 = 793, observed power 0.809. Based on these results, there was sufficient evidence to reject the null hypothesis that there would be

no affect on participants back and leg pain over the clinical intervention. and conclude that participants' reported pain levels, as measured by the LBPRS, differed significantly over the three assessment periods. The effect size was large. Observed power was 0.809, indicating over 80% that results may have come out significant and above the accepted 0.8 value.

Post-hoc tests between the intervention phases did not find significance in VAS scores for back and leg pain between assessment 1 and assessment 2 (MD = 3.857, SE= 3.820, p = 1.0) or assessment 2 and assessment 3 (MD = 6.571, SE=1.288, p = 0.098) but significance was found between assessment 1 and assessment 3 (MD = 10.429, SE = 2.819, p = 0.030).

Table 1. Total scores and statistical analysis of participants' reported back and leg pain over the three assessments

Participant	BLP-A1	BLP-A2	BLP-A3	D A1-A2	D%	SD A A1-A2	D A1-A3	DS%	SD A1-A3
1	6	17	0	-11	-183%	5.50	6	100%	3.00
2	8	3	2	5	63%	2.50	6	75%	3.00
3	20	0	0	20	100%	10.00	20	100%	10.00
4	27	14	6	13	48%	6.50	21	78%	10.50
5	13	14	3	-1	-8%	0.50	10	77%	5.00
6	15	14	6	1	7%	0.50	9	60%	4.50
7	5	5	4	0	0	0.00	1	20%	0.50

Note. Negative values indicate an increase in score and increase in severity of pain, back and leg pain (BLP) over the three assessment periods (A1, A2, A3), the difference (D), difference percentage (D%), and standard deviation (SD).

Regarding the individual participants' back and leg pain scores, only two participants (participant 1 and participant 5) were seen to have an increase in pain during the clinical intervention (Table 1; Figure 10). Both of the participants had an increase between interventions 1 and 2, but at assessment 3, and by the end of the clinical intervention, these pain values had decreased to lower than pre-intervention (assessment 1) levels for an overall reduction of pain. Every participant except one met the minimally important clinical difference (MD% = 73, SD = 0.253). Participant Seven only had a 20% clinically significant change in back and leg pain scores over the intervention (D% = 20, SD = 0.05). This

participant also had the lowest scores before starting the clinical intervention of 5 points of maximum 30.

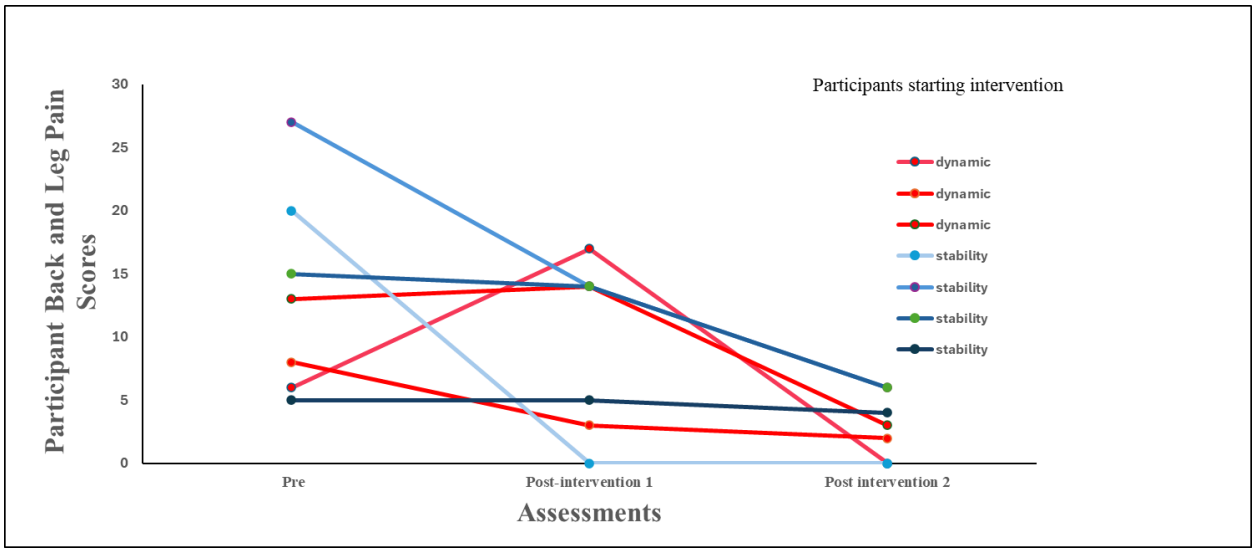


Figure 10. Back and leg pain scores of participants, over the three assessment periods.

Note. Participants have been coded by the intervention they started at intervention one period.

1.14.2 Lower Back Pain

Results from scores of the adjusted VAS (assessing only lower back pain) for assessment 1 were (M=11.286, SD = 2.265), assessment 2 (M=6.143, SD= 1.639), and assessment 3 (M = 2.571, SD = .812). Individual participant scores and analyses are reported in Table 2. The result of the one-way repeated ANOVA yielded there was a statistical difference in the combined sum of lower back pain (adjusted VAS scale) between the three assessment periods; Wilks' $\Lambda = 0.200$, $F(2,5) = 10.026$, $p = 0.018$, partial n^2 = 0.800, observed power = 0.827. Based on these results, there was sufficient evidence to reject the null hypothesis that there would be no effect on participants lower back pain over the clinical intervention and conclude that participants' reported LBP levels, as measured by the LBPRS, differed significantly over the three assessment periods. The effect size was large. Observed power was 0.809, indicating over 80% that results may have come out significant and above the accepted 0.8 value.

Pos-hoc tests between the intervention phases for VAS adjusted scores did not find significance between assessment 1and assessment 2 (MD= 5.143, SE= 3.066, p= 0.433) or

assessment 2 and assessment 3 (MD=3.57, SE 1.288, *P*= 0.97) but significance was found between assessment 1 and assessment 3 (MD = 8.714, SE = 2.542, *p*= 0.042).

Table 2. Total scores and statistical analysis of participants reported lower back pain over the three assessment periods

Participant	LBP-A1	LBP-A2	LBP-A3	D A1-A2	D%	SD A A1-A2	D A1-A3	DS%	SD A1-A3
1	6	5	0	1	17%	0.50	6	100%	3.00
2	8	3	2	5	63%	2.50	6	75%	3.00
3	20	0	0	20	100%	10.00	20	100%	10.00
4	19	7	3	12	63%	6.00	16	84%	8.00
5	10	13	3	-3	-30%	1.50	7	70%	3.50
6	11	10	6	1	9%	0.50	5	45%	2.50
7	5	5	4	0	0	0.00	1	20%	0.50

Note. Negative values indicate an increase in score and an increase in the severity of pain. Lower back pain (LBP) over the three assessment 1,2,3 (A1, A2, A3), difference (D), difference percentage (D%) and standard deviation (SD)

Regarding the individual participant's LBP scores, when an adjusted VAS was used, which removes leg pain as a variable, only participant 5 was seen to have an increase in pain during the clinical intervention, while participant 1 did not have the same increase of pain seen when leg pain is included, indicating the spike in pain during their dynamic intervention was primarily perceived sciatica pain down the leg. (Table 2. Vs Table 1.). Participant 5 had an increase between assessment 1 and 2, but by the end of the clinical intervention and assessment 3, these pain values had decreased to lower than pre-intervention (assessment 1) levels for an overall reduction of pain. Every participant except one met the minimally important clinical difference (MD% = 71, SD = 0.271). Participant 7 only had a 20%

clinically significant change in LBP scores over the intervention (D% = 20, SD = 0.05), which is the same as the back and leg pain values. These scores are relatively similar among each participant (except for participant 1) to the back and leg pain scale, indicating the majority of the pain scored by the participants during the study were primarily from LBP.

1.15 Does Exercise Targeting Specific Core Muscle Groups (TA or RA) Improve Outcomes for Disability Index, Physical Impairment, and Overall Low Back Pain Rating Scale Scores?

1.15.1 Disability Index

Results of the disability index scores for assessment 1 were (M = 7.714, SD = 3.302), assessment 2 (M=2.714, SD = 1.799) and assessment 3 (1.71, SD = 1.496). Together, these scores show a linear drop in disability index between each assessment period. The result of the one-way repeated ANOVA yielded there was a statistical difference in disability index scores between the three assessment periods; Wilks' $\Lambda = 0.125$, $F(2,5) = 17.500$, $p = 0.006$, partial n^2 = 0.875, observed power = 0.969. Based on these results, there is sufficient evidence to reject the null hypothesis that there would be no effect on participants disability index scores over the clinical intervention. We conclude that participants' disability index, measured by the LBPRS over the clinical intervention, differed significantly over the three assessment periods. The effect size was large. Observed power was 0.809, indicating over 96% that results may have come out significant and above the accepted 0.8 value.

Post-hoc tests between the intervention phases did not find significance in disability index scores between assessment 2 and assessment 3 (MD= 1.0, SE= 0.577, $p = 0.402$) but did find significance for assessment 1 and assessment 2 (MD = 5.0, SE = 0.951, $p = 0.006$) and assessment 1 and assessment 3 (MD = 6.0, SE = 0.926, $p = 0.002$).

1.15.2 Physical Impairment

Results from physical impairment scores for assessment 1 were (M=14.571, SD± 2.225), assessment 2 (M = 10.0, SD = 3.367), and assessment 3 (M = 8.857, SD = 2.795). The result of the one-way repeated ANOVA yielded there was a statistical difference in combined physical impairment scores between the three assessment periods; Wilks' $\Lambda =$ 0.080, $F(2,5) = 28.764$, $p = 0.002$, partial n^2 = 0.920, observed power 0.998. Based on these results, there is sufficient evidence to reject the null hypothesis that there would be no effect on participants physical impairment scores over the clinical intervention and conclude that participants' physical impairment scores, measured by the LBPRS over the clinical intervention, differed significantly over the three assessment periods. The effect size was

large. Observed power was 0.998, indicating over almost 100% that results may have come out significant and above the accepted 0.8 value.

Post-hoc tests between the intervention phases did not find significance in physical impairment scores between assessment 2 and assessment 3 (MD = 1.143, SE = 1.204, p = 0.10) but did find significance for assessment 1 and assessment 2 (MD = 4.571, SE = 0.808, p = 0.009) and assessment 1 and assessment 3 (MD=5.714, SE= .808, p= .001).

1.15.3 Low Back Pain Rating Scale -Combined Back and Leg Pain, Disability Index, and Physical Impairment Scores

Results from the LBPRS for assessment 1 were (M = 34.714, SD = 9.827), assessment 2 (M = 20.286, SD = 6.945), and assessment 3 (M = 12.714, SD = 3.147; Figure 11). The result of the one-way repeated ANOVA yielded d there was a statistical difference in LBPRS scores (back and leg pain, disability index, and physical impairment scores) between the three assessment periods; Wilks' Λ= 0.095, F (2,5) =23.891, p = 0.003, partial n^2 = 0.905, observed power 0.994. Based on these results, there is sufficient evidence to reject the null hypothesis that there would be no effect on participants total LBPS scores over the clinical intervention. We conclude that participants' combined back and leg pain, disability index, and physical impairment scores, as measured by the LBPRS, differed significantly over the three assessment periods. The effect size was large. Observed power was 0.994, indicating over almost 100% that results may have come out significant and above the accepted 0.8 value.

Post-hoc tests between the intervention phases did not find significance in LBPRS scores between assessment 1 and assessment 2 (MD = 14.429, SE= 4.577, p = 0.059) or assessment 2 and assessment 3 (MD =7.571, SE 2.496, p= 0.69) but did find significance between assessment 1 and assessment 3 (MD = 22.0, SE = 4.577, p = 0.002).

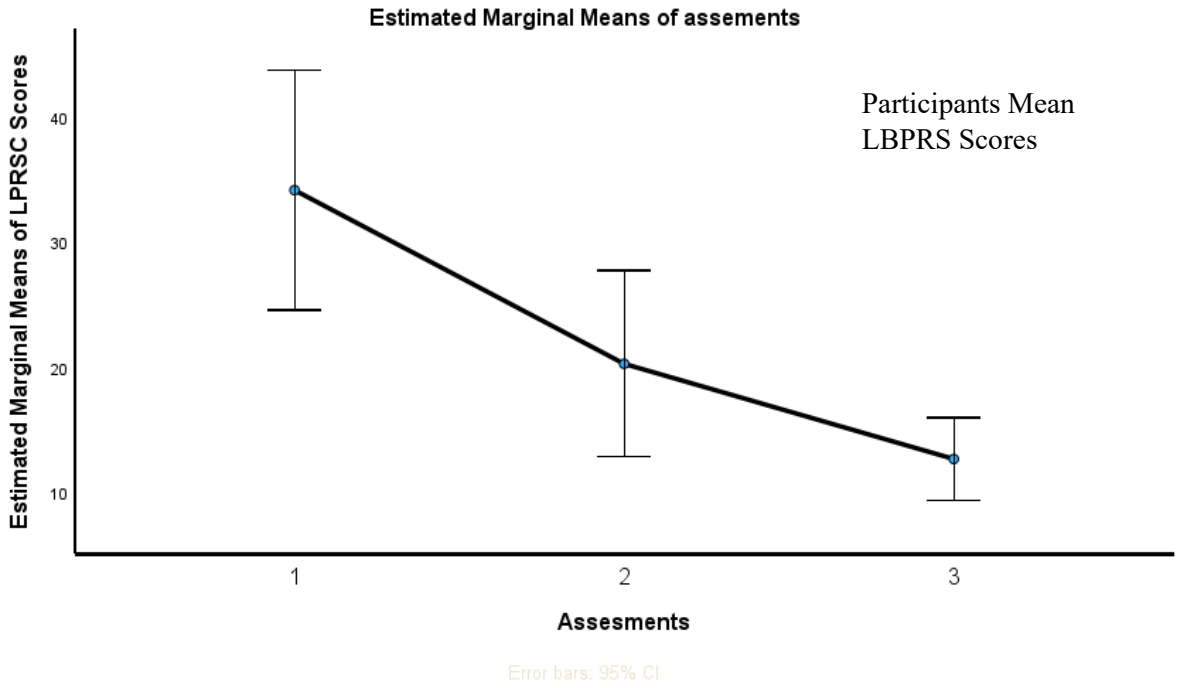


Figure 11. Changes in marginal mean scores of the combined low back pain rating scale over the clinical intervention period.

1.16 Is There a Difference Between the Intervention Groups for a Two-Stage Core Strengthening Intervention and the Sequential Order of the Interventions for Improving Pain, Disability Index, Physical Impairment, and Total Score of the LBPRS, as an Outcome for Non-Specific Chronic LBP?

1.16.1 Back and Leg Pain

When we separated the participants into their respective intervention groups, we saw that the Dynamic (BA) intervention (Table 3.) had a small mean increase in pain between assessment one, and assessment two, post-intervention-1. Among all other variables, back and leg pain, lower back pain, disability index, and total LBPRS scores, and a decrease among all variable scores between assessment 1-pre and assessment 3, post-intervention 2. When the leg pain variables are removed, we don't see a mean increase in pain scores across any of the intervention periods.

A two-way repeated measures ANOVA was run with the different intervention groups (stability-AB or dynamic-BA) as the IV and the back and leg pain VAS scores from the LBPRS as the DV, over the three assessment periods as the DV. Results of the within-groups ANOVA, confirmed the previous one-way ANOVSA'S, and found a significant reduction in back and leg pain for within-group comparisons Wilks' $\Lambda = .211$, $F(2,4) = 7.478$, $p = 0.045$, partial n^2 = .789, observed power = 0.632. We can conclude that participants' reported pain levels over the clinical intervention, as measured by the adjusted VAS, differed significantly over the three assessment periods, regardless of the intervention group. The effect size was large. The observed power was below the accepted 0.8 (Figure 12.)

There was no statistical significance found between the two intervention groups on overall back and leg pain scores over the clinical intervention period, $f = .517$, $p = .504$, partial n^2 = .094, observed power = .091.

There was not a statistical difference between the intervention groups, with time as an interaction effect Wilks' $\Lambda = .662$, $F(2,4) = 1.021$, $p = .438$, partial n^2 = .338, observed power = 0.134. Based on these results, we accept the null hypothesis and conclude that participants' reported pain levels over the clinical intervention, as measured by the adjusted VAS, did not differ significantly over the intervention period.

Table 3. Outcomes measures, between intervention groups, over the three assessments

DV	Assessment 1		Assessment 2		Assessment 3	
	Intervention group		Intervention group		Intervention group	
	AB	*BA*	*AB*	*BA*	*AB*	*BA*
Back and leg pain	16.75 ± 9.251	9.0 ± 3.601	8.25 ± 6.946	11.333 ± 7.371	4.0 ± 2.828	1.667 ± 1.528
Lower back pain	13.15 ± 7.089	8.0 ± 2.0	5.5 ± 4.203	7.0 ± 5.292	3.250 ± 2.50	1.667 ± 1.528
Disability index	7.750 ± 4.50	7.667 ± 1.528	3.250 ± 2.217	2.0 ± 1.0	7.750 ± 1.915	7.667 ± 1.0
Physical impairment	15.250 ± 2.872	13.667 ± .577	12.5 ± 1.732	6.667 ±.577	9.250 ± 2.986	8.333 ± 3.055
Total LBPRS score	38.0 ± 12.36	30.333 ± 3.21	20.5 ±7.371	20 ± 7.937	13.25 ± 4.113	12 ± 1.732

Note. **Standard deviation *(±)***

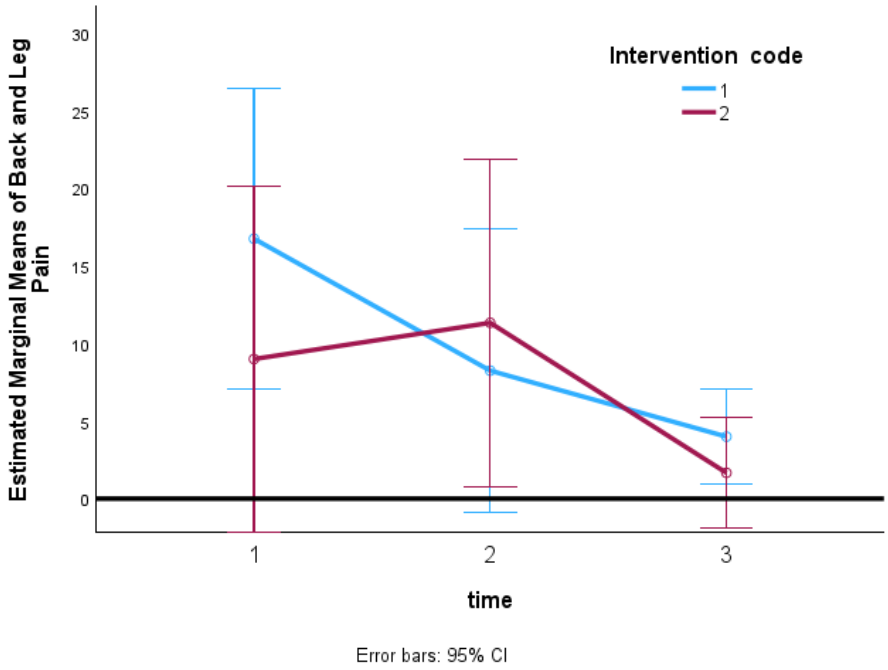


Figure 12. Changes in back and leg pain comparing intervention groups over the clinical intervention period.

Note. Intervention code 1 = stability (AB), 2 = dynamic (BA)

1.16.2 Lower Back Pain

A two-way repeated measures ANOVA was run with the different intervention groups (stability or dynamic) as the IV and the adjusted pain scale (just lower back pain) VAS scores over the three assessment periods as the DV. Results of the within-subjects MANOVA confirmed the previous one-way MANOVSA'S and found a significant reduction in LBP for within-group comparisons Wilks' $\Lambda = .199$, $F(2,4) = 8.054$, $p = 0.040$, partial n^2 = .801, observed power = 0.664. Participants reported LBP levels over the clinical intervention, as measured by the adjusted VAS, differed significantly over the three assessment periods, regardless of the intervention group. The effect size was large. The observed power was below the accepted 0.8.

There was no statistical significance found between the two intervention groups on overall lower back pain scores over the clinical intervention period, $f = 1.066$, $p = .349$, partial n^2 = .176, observed power = .135.

There was not a statistical difference between the intervention groups, with time as an interaction effect Wilks' Λ = .708, F (2,4) = 708, *p* = .501, partial n^2 = .292, observed power = 0.827. Based on these results, we accept the null hypothesis and conclude that participants' reported LBP levels over the clinical intervention, as measured by the adjusted VAS, did not differ significantly over the intervention group, and a crossover effect over time was not observed.

1.16.3 Physical Impairment

A two-way repeated measures ANOVA was run with the different intervention groups (stability or dynamic) as the IV and disability index scores over the three assessment periods as the DV. Results of the within-subject ANOVA indicate, confirmed the previous one-way ANOVSA'S, and found a significant reduction in LBP for within-group comparisons Wilks' Λ = .40, F (2,4) = 48.550, *p* = 0.002, partial n^2 = .960, observed power = .1.0. Based on these results we can conclude that participants' disability index scores lowered significantly over the clinical intervention, as measured by the LBPRS, differed significantly over the three assessment periods (figure 13.), regardless of the intervention group. The effect size was large. The observed power was above the accepted 0.8 value.

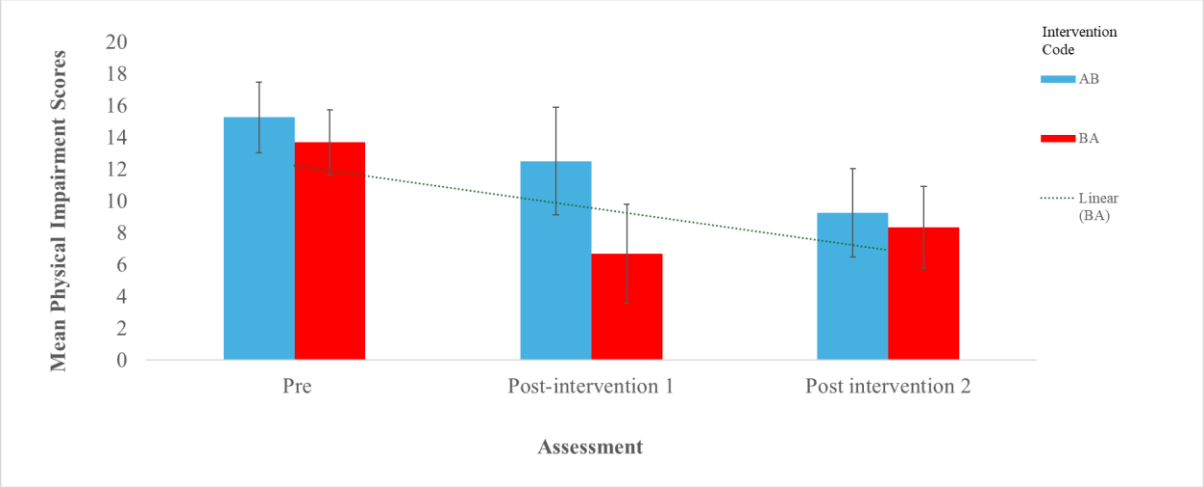


Figure 13. Changes in physical impairment scores, between the two intervention groups. Over the three assessment periods.

There was no statistical significance found between the two intervention groups on overall physical impairment scores over the clinical intervention period, p = .136, partial n^2 = .387, observed power = .304.

There was a statistical difference between the intervention groups over the three assessment periods, Wilks' Λ = .127, F (2,4) = 13.723, p = .016, partial n^2 = .873, observed power = 0.870. Based on these results, we reject the null hypothesis and conclude that participants' physical impairment scores over the clinical intervention, as measured by the LBPRS, did have an interaction/crossover effect. Further investigation (figure 13.) shows the majority of changes in disability index scores happened between assessments one and two for the BA intervention group (MD = 7.0, SE .671) and had a small increase in scores between assessments 2 and 3 (MD = -1.667, SD = 1.33), indicating there may be a crossover interaction the group starting with the dynamic intervention, as the significant changes persisted through the following intervention; this is reinforced by the majority of the changes in the disability index scores for the AB intervention group happening when participants started their dynamic portion, between assessment 2 and 3 (MD = 6.0, SE = 1.155) with minor changes through the stability portion of the intervention (MD = 2.750, SD = .581)

1.16.4 Disability Index

A two-way repeated measures ANOVA was run with the different intervention groups (stability or dynamic) as the IV and disability index scores over the three assessment periods as the DV. Results of the within-subject ANOVA indicate, confirmed the previous one-way ANOVSA'S, and found a significant improvement in physical impairment for within-group comparisons Wilks' Λ = .127, F (2,4) = 13.790, p = 0.016, partial n^2 = .873, observed power = .871. Based on these results, we conclude that participants' physical impairment scores over the clinical intervention, as measured by the LBPRS, differed significantly over the three assessment periods, regardless of the intervention group. The effect size was large. The observed power was above the accepted 0.8 value (figure 14.).

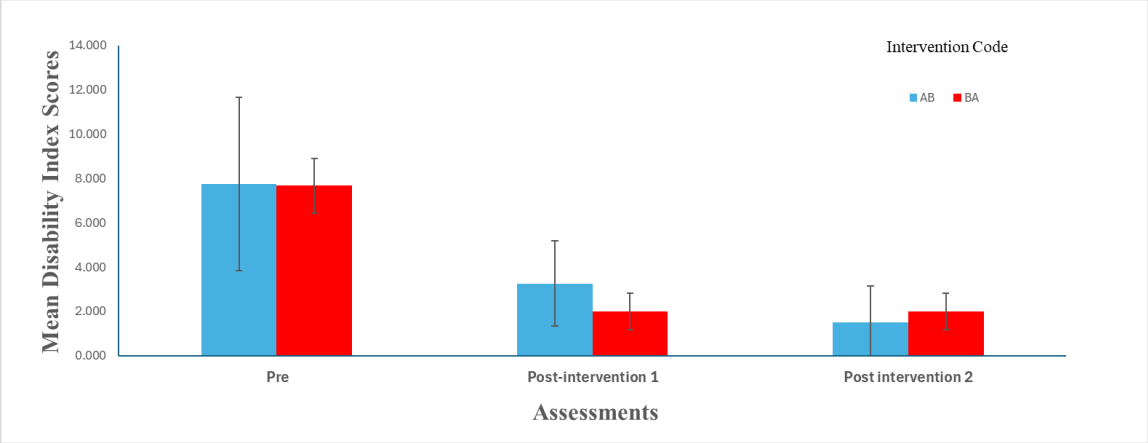


Figure 14. Changes in disability index scores, between intervention groups, over the three assessment periods.

There was no statistical significance found between the two intervention groups on overall disability index scores over the clinical intervention period, $f = .029$, $p = .872$, partial n^2 = .006, observed power = .052.

There was not a statistical difference between the intervention groups, with time as an interaction effect Wilks' $\Lambda = .624$, F (2,4) = 1.207, $p = .389$, partial n^2 = .376, observed power = 0.151. Based on these results, we accept the null hypothesis and conclude that participants' disability index scores over the clinical intervention, as measured by the LBPRS, did not differ significantly over the intervention period, and a crossover/ sequential effect over time was not observed. The majority of the drops in disability index scores for both groups were observed between assessment 1 and 2, but only the dynamic intervention (BA) was considered significant (MD = 5.667, SE = 1.542, $p = .043$, while both interventions were considered significant between assessment one and three, group AB (MD = 6.250, SE = 1.331, $p = .016$) and BA (MD = 5.667, SE = 1.537, P = .043) but scores were unchanged between assessment two (M = 2) and three (M = 2).

1.16.5 Low Back Pain Rating Scale

A two-way repeated measures MANOVA was run with the different intervention groups (stability or dynamic) as the IV and LBPRS (combined score of back and leg pain, disability index, and physical impairment) scores over the three assessment periods as the

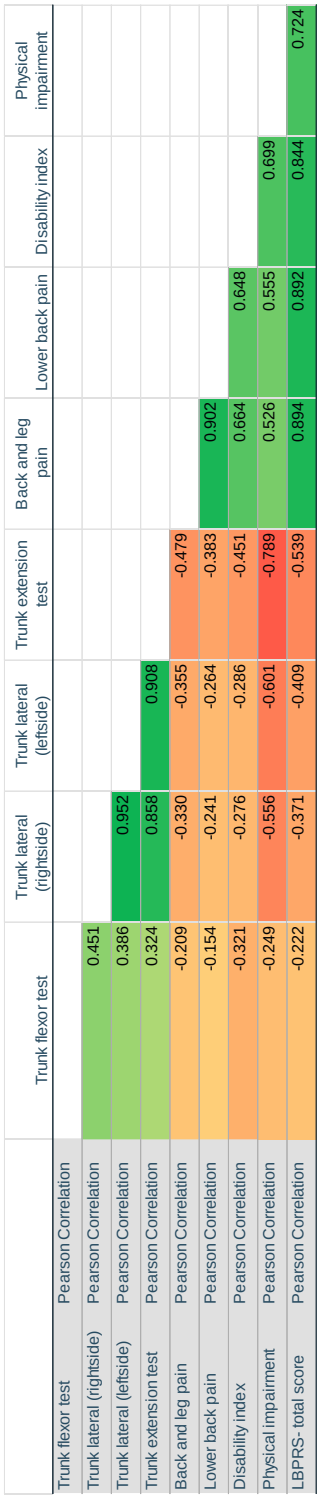
DV. Results of the within-ANOVA indicate, confirmed the previous one-way ANOVSA'S, and found a significant reduction in LBP for within-group comparisons Wilks' Λ = .090, F (2,4) = 20.24, *p* = 0.008, partial n^2 = .910, observed power = .960. Based on these results, there was sufficient evidence to conclude that participants' LBPRS scores over the clinical intervention, as measured by the adjusted VAS, differed significantly over the three assessment periods, regardless of the intervention group. The effect size was large. The observed power was below the accepted 0.8.

There was no statistical significance found between the two intervention groups on overall LBPRS scores over the clinical intervention period, *f* = .768, *p* = .421, partial n^2 = .133, observed power = .111.

There was not a statistical difference between the intervention groups, with time as an interaction effect, over the three assessment periods, Wilks' Λ = .708, F (2,4) = 708, *p* = .501, partial n^2 = .292, observed power = 0.827. Based on these results, they accept the null hypothesis and conclude that the effect between group and time, and LBPRS scores over the clinical intervention, did not differ significantly between the intervention groups, and the crossover/ sequential effect over time was not observed.

1.17 Was there a Correlation Between Pain, Disability, and Physical Impairment Compared with the Individual Trunk Measures from McGill's Torse Endurance Battery Test?

Table 4. Correlation matrix comparing outcomes scores from the individual variables from the MTETB, and LBPRS.



		Trunk flexor test	Trunk lateral (rightside)	Trunk lateral (leftside)	Trunk extension test	Back and leg pain	Lower back pain	Disability index	Physical impairment
Trunk flexor test	Pearson Correlation								
Trunk lateral (rightside)	Pearson Correlation	0.451							
Trunk lateral (leftside)	Pearson Correlation	0.386	0.952						
Trunk extension test	Pearson Correlation	0.324	0.858	0.908					
Back and leg pain	Pearson Correlation	-0.209	-0.330	-0.355	-0.479				
Lower back pain	Pearson Correlation	-0.154	-0.241	-0.264	-0.383	0.902			
Disability index	Pearson Correlation	-0.321	-0.276	-0.286	-0.451	0.664	0.648		
Physical impairment	Pearson Correlation	-0.249	-0.556	-0.601	-0.789	0.526	0.555	0.699	
LBPRS- total score	Pearson Correlation	-0.222	-0.371	-0.409	-0.539	0.894	0.892	0.844	0.724

1.17.1 Total-Metric Score Correlations

To conduct the correlations between the Low back pain rating scale and the Mgill's Torso Endurance Battery tests' performance results, a Pearson Bivariate analysis was used (Table 4). The scores for the 4 tests during the MGTEBT were then analysed and put into the classification of 'poor' or 'good' (good coded as 1, poor coded as 2), and a point bi-serial correlation was performed to see if there was a relationship to the LBPRS and its variables (back and leg pain, disability index and physical impairment) as well as the adjusted lower back pain scores.

A statistically significant strong negative correlation between total lower back pain rating scale score and the trunk extension test was observed; r (20) = -0.539, p = 0.012; indicating that the lower the muscular endurance score, the higher the associated LBPRS score. A significant negative correlation was also found between physical impairment scores and: the trunk lateral test (right side; r (20) = -0.556, p = 0.009); trunk lateral test (left side; r (20) = - .601, p = 0.004); and the trunk extension test (r (20) = -0.789, p = <0.001).

Regarding the individual tests of the MTEBT, compared against each other, a strong correlation was found between the trunk extension test with both the right-side lateral test (r (20) = 0.858, p = <0.001) and left-side lateral test (r (20) = 0.908, p = <0.001), and there was also a correlation between the left- and right-side lateral trunk tests (r (20) = - 0.952, p = 0.012). The only measure the trunk flexor test found that was significant was a moderate correlation with right side trunk lateral test (r (20) = 0.386, p =0 .040).

1.17.2 Good and Poor Rating Correlation

Using the ratings of good or poor, from the total scores of the individual test of the MTETB (Table 5.), the only statistically significant relationship found was a moderate correlation between the left-side/ right-side bridge ratio and physical impairment (r (20) = 0.457, p = 0.037). This indicates that there was a higher level of physical impairment scores for participants who had the score of 'good' compared to 'poor'. There was a moderate correlation between the flexion/extension score and physical impairment scores that almost statistical significance (r (20) = 0.432, p = 0.051).

Table 5. Correlation matrix comparing good and poor scores from the MTETB, and LBPRS Variables

		Back and leg pain	Lower back pain	Disability index	Physical impairment	LBPRS- total score	Flexiextension score	Leftside/ Rightside Bridge score	Right sidebridge/extension score
Back and leg pain	Pearson Correlation								
Lower back pain	Pearson Correlation	0.902							
Disability index	Pearson Correlation	0.664	0.648						
Physical impairment	Pearson Correlation	0.526	0.555	0.699					
LBPRS- total score	Pearson Correlation	0.894	0.892	0.844	0.724				
Flexiextension score	Pearson Correlation	0.255	0.156	0.393	0.432	0.273			
Leftside/ Rightside Bridge score	Pearson Correlation	0.223	0.109	0.369	0.457	0.335	0.208		
Right sidebridge/extension score	Pearson Correlation	0.314	0.210	0.376	0.308	0.251	0.277	-0.079	
left sidebridge/extension score	Pearson Correlation	-0.223	-0.258	-0.126	-0.086	-0.292	-0.010	-0.022	0.485

Note. Positive correlations are coded to green, negative correlations are coded to red with yellow representing neutral.

Chapter 5: Discussion

The following Chapter is a discussion of the results gathered and analysed over the research period. The analysed results are critically discussed: what was found and why, how it relates to already established literature, and the primary limitations and omissions.

1.18 Analysis of Research Findings

Our primary research goal was to assess the effectiveness of stability- and dynamic-style clinical interventions, focusing on exercises to strengthen specific trunk muscles, including the transverse abdominis/multifidus (stability-AB), and rectus abdominis/erector spinae (dynamic-BA). We aimed to determine the effectiveness of these interventions in reducing NSCLBP. The results confirm that using either the stability or dynamic intervention in conjunction with each other, regardless of the intervention order, may have a complementary effect in reducing lower back pain and its associated disability index, physical impairment, and total score from the LBPRS. This confirms the previous research that not only is core stability and dynamic intervention potentially useful for outcomes regarding lower back pain (Kim & Yim, 2020; Wang et al., 2012), but so is a dynamic styled interventions such as pilates, yoga or physical therapy (Bhadauria & Gurudut, 2017b; Fernández-Rodríguez et al., 2022b; Ulger et al., 2023). A point of interest was that we found significance across every single testing variable over the three assessment periods. Between assessment 1 (pre-intervention) compared to assessment 3 (final assessment) a clinical significance was observed for every individual. This also reinforces that regardless of intervention, resistance training focused on engagement and strengthening of local and global structures in the overall trunk can impact chronic lower back pain in sufferers (Bergmark, 2009).

Looking at all participants in the study, when we account for the back and leg pain VAS scores, two participants had an increase in pain in the dynamic stability intervention cohort, between assessment 1 and assessment 2. When we use the adjusted VAS, which removes the leg pain variances, this increase of pain is removed and every participant is shown to have a decrease in pain between each of the interventions 1, 2, and 3. The study did not find evidence of a crossover effect from either group, suggesting that a crossover or sequential effect did not impact the interventions. For future studies, a possible way to interrogate

crossover effects more fully would be to have two additional groups that would do only the dynamic stability intervention or the stability intervention over the eight weeks. One potential reason to consider for the lack of results regarding differences in efficacy between the intervention groups is the length of intervention. Evidence that time itself – i.e. carrying on of exercise post-intervention – is important for this population group (Manniche et al., 1991). This intervention was only 8 weeks (4 weeks per intervention) and is relatively short considering the minimal suffering time necessary for the classification of CLBP. Indeed, another consideration is that while we had an inclusion requirement of lower back pain for a minimum time of 12 weeks, we did not specifically ask, nor record how long each of the participants had suffered with LBP. This may be an additional variable that could be considered in the overall effectiveness of the interventions.

Although there was no significant crossover effect observed, performing the dynamic exercise intervention first in the order caused the only increase in pain among participants. While the difference was not statistically significant between intervention groups, and no clear indication that one intervention was better than the other, it reinforces the notion that sufferers of NSCLBP may benefit from starting the stability intervention before increasing into more difficult and pain-inducing movements, particularly if a trunk flexion and extension intolerance is observed. It could also be argued that the dynamic intervention also has merit starting first, as it was the only intervention to cause a statistically significant change in disability index scores that are required in a more dynamic intervention; however, considering that the only between-group effect we observed for the dynamic group between intervention 1 and 2 was for disability index scores. Considering these were the closest we had to psychological measures, the disability intervention may have slightly more validity in addressing these outcome measures.

When the initial literature review was performed and the associated research study planned, there were no crossover studies identified in the literature that followed a similar research design. During the end of 2023, while in the data collection phase of this study, a study was released that used a crossover clinical intervention with core stability and yoga. Although yoga would not have the same graduated load progression as this study, the body weight exercises performed provide a similarity to our study's dynamic intervention. The relevant finding of this study was both core stability and yoga exercise groups were found to have similar effects on improvements in pain, sleep quality, metabolic capacity and pain (Ulger et al., 2023).

The correlation matrix performed between the LBPRS and the MTETB ratios did not show what we were expecting to see based on the literature (Abdelraouf & Abdel-aziem, 2016). Of all the variables, we expected to see a high negative correlation with trunk flexor endurance strength and LBPRS due to the larger focus on the abdominals. However, in our results, the trunk flexor endurance test was the only variable measured that did not have a significant negative correlation with physical impairment scores.

The most statistically significant correlation we found was between the trunk extension test and the physical impairment scores. This is not unexpected, considering the trunk extension test in MTETB is the same as the back endurance test, which is one of the three measures of the physical impairment scores, in the LBPRS. Considering that they have an overlap of variables, it would be assumed that this would increase the correlation, nonetheless.

Overall, except for physical impairment: we only found a negative correlation between the trunk extension test and the total low back pain rating score. This is supported previous research that correlates LBP with weakness in the erector spinae and overall trunk extension ability (Abdelraouf & Abdel-aziem, 2016; Araújo et al., 2020; Jørgensen & Nicolaisen, 1987); however, due to having to hold a static spinal extension, this may highlight specific movement dysfunction-related patterns found with suffering individuals, and argue that the overall trunk flexion or side lateral tests do not have the same validity. What is more interesting, after seeing the negative correlations with overall performance and total scores relating to the back pain variables, are the point biserial correlations. These were calculated from the performance metrics and participants were either given a score of good or poor. The only statistically significant correlation we found was a moderate correlation between the left-side and right-side bridge ratio and physical impairment. Surprisingly, the correlation indicates that individuals who had a high number of good scores also had higher levels of physical impairment scores. We could speculate this was due to how these ratios are quantified. Regarding the ratio of left side:right side bridge, if a hypothetical participant was extremely weak and only scored one second on each side of the side lateral plank tests, due to the symmetry between the scores on the left and right, this would result in a classification of good for the ratio between the lateral trunk muscles. Due to the research indicating that atrophy and weakness is correlated with LBP (Beneck & Kulig, 2012; Cooley et al., 2023, 2024), it can be argued that the strength of the trunk muscles may be an indicator for non-sufferers or acute flares of LBP, but for individuals who have already crossed from acute to

sub-acute and now into a chronic classification, their overall performance of these trunk tests is a better correlator of pain.

1.19 limitations and Omissions

When designing the study, we focused on individuals who were less active and had low levels of resistance training. We excluded individuals who were already participating in heavy weight training to reduce the risk of acute injuries, such as lumbar sprains or strains, during the training intervention. We did not exclude individuals based on body weight or measure their body weight. However, considering the potential association between body weight and lower back pain (Okifuji & Hare, 2015b), it may have been valuable to measure body weight as a participant statistic at the beginning of the intervention. In hindsight, it would be valuable to use as an additional variable in a multivariate analysis.

Due to the focus on strengthening, participants in this study worked within a hypertrophy range for the stability-AB intervention; and we loaded participants in the dynamic-BA intervention a lot more than what a corresponding intervention such as yoga or pilates would. An additional consideration for increasing the scope of this study would be to either taking body composition measurements or diagnostic imaging, depending on financial limitations, to ascertain if hypertrophy had occurred over the eight weeks. Additionally, considering the flex and relaxation phenomena (Gupta, 2001), in conjunction with the trunk endurance strength, it could be interesting to take electromyography readings at each of the assessment points to assess if participants had measurable dysfunction regarding erector spinae contraction and the inability for muscular relaxation and if either of these interventions impacted this.

We had a total of 11 participants who expressed interest in participating in the research study, could commit to the requirements, and fit the inclusion criteria. Of these, seven participants in total finished the clinical intervention, while two dropped out and two had to be removed from the study. Of the two participants that dropped out, the first had completed six weeks of clinical intervention and two assessments. During week 7 they reported there was a family emergency and unfortunately had to move to a different region in the country and, as a consequence, could not finish the final two weeks and last assessment of the clinical intervention. The second participant dropped out after one assessment in the first week of training due to the inability to complete the training due to the level of pain. However, they

did clarify that this was not an exacerbation of lower back pain, but an unrelated pathology in their right leg, which resulted in them wearing a brace the majority of the working day. Of the two removed from the study, the first had completed seven weeks of exercise intervention and the second assessment at week 8. At this time they travelled to a different part of the country and although they expected to return, they did not. After two weeks they had missed a week of intervention training and also their final assessment, therefore had to be removed. The final participant was removed from the study during week 6, after two assessments and five weeks of intervention training. The participant had a sudden change in their home life situation, which required moving and a lot of lifting, subsequently resulting in an acute lower back pain flare-up during. This was reported during the second assessment and the participant was asked to see their GP. It was identified that the participant suffered from retrolothesis and osteopenia of the spinal structure and did not fall under the category of non-specific chronic lower back pain anymore. As a testimonial of the success of the interventions, two of the seven participants asked to continue working with primary researcher, once the study had completed, due to the change in Pain and outcomes.

Our primary goal was to design exercise programs targeting the sagittal, and frontal planes, considering the function of TA, RA, multifidus and erector spinae. However, we did have very minimal exercises that targeted the transverse plane, with the exception of exercise such has the modified superman, with uni-lateral leg and arm elevation, to resist rotation and train the multifidus. In hindsight, it may have been an oversight in overall design of the dynamic movement intervention to not include internal/ external oblique focused movements in the core muscle comparisons

Chapter 6

This final chapter contains a summation and final thoughts about the results we found during the study, how they link to prior studies, and our final recommendations.

1.20 Summation

This research study aimed to evaluate the effectiveness of different core strength exercise interventions in reducing pain in individuals with NSCLBP. Specifically, the study compares interventions targeting the transverse abdominus/multifidus (stability-AB) and the rectus abdominus/spinal erectors (dynamic-BA) and investigates whether sequentially targeting one muscle group before the other provides a better outcome. Regarding the effectiveness of core interventions as a whole, both the stability and dynamic interventions were effective in reducing pain and improving physical function in our participants suffering from NSCLBP. The primary success, other than finding significance, is the large effect sizes with each variable tested indicating the effectiveness of the intervention, and the improvements to pain were individually substantial.

Regarding the sequential nature of the research design, we did not find any statistically significant effects among all outcomes for either intervention sequence, with the exception of changes in physical impairment scores. This may indicate that exercise prescriptions targeting both muscle groups are important when considering interventions, but the ordering may be of much less importance and could come down to an individual-specific movement intolerance. Our participants had a negative correlation between their overall trunk strength and their levels of pain/LBPRS outcomes, in comparison to the trunk strength ratios of good and poor- which did not find much correlation overall; The participants had much more significant correlations regarding total endurance strength/ performance measures of the MTETB.

The greatest research limitation of this study was the small sample size. Fewer participants were recruited that expected despite several recruitment initiatives and thorough advertising through social media, physiotherapy clinics, and the University of Waikato community boards. While statistically significant results were obtained with, for the most part, robust effect sizes, the effect of the limited sample size is evident. In the dynamic-BA intervention, although there was an increase in pain in only one participant's data between

interventions 1 and 2, it led to the overall mean value for their associated group to have an increase in pain. It is therefore important to not over-reach when making conclusions when considering aspects of this study's findings. That said, that the participant experienced a temporary increase in pain over during the clinical intervention reinforces the need to have a level of exercise individualization to account for individuals' levels of varying pain or performance ability, and highlights the personalized approach needed for the management of NSCLBP and how it should be monitored.

Regarding future research, if we were to consider the present work a pilot study, based on its findings, a much larger study following a similar methodology is definitely merited. A larger participant sample size would be the most important factor, and could potentially allow for four interventions: Stability-A alone, dynamic-B alone, stability to dynamic-AB, and dynamic to stability-BA. Longer intervention periods could also be considered. Together, these changes could provide better resolution on whether or not one intervention is better than the other and/or whether one intervention supports the other. Certainly, based on the current study, there can be confidence that irrespective of the intervention, the participant should see some benefit.

Incorporating outcome measures relating to psychological factors and how they interact with different interventions could also help in providing a more robust understanding of the treatment and management of NSCLBP. Additional considerations could be incorporating a wash period between interventions to try to control for carryover effects. Additional consideration would be an intervention group that did a combination of stability and dynamic exercises simultaneously.

1.21 Final Recommendation

Considering the significance and large effect size found with the intervention as a whole, we conclude that an intervention targeting specific trunk/core muscles (stability or dynamic) regardless of intervention order may have an impact of considerable effect on reducing the level of lower back (and leg) pain. It may also positively impact disability index and physical impairment scores, and associated quality of life for individuals who suffer from non-specific, chronic lower back pain.

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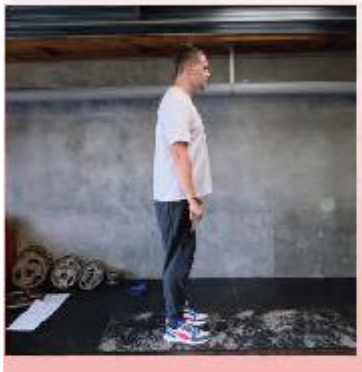
Appendices

1.22 Trunk flexion- Dynamic

Jefferson unloaded 1



Start with a stick with hands at shoulder width.
Begin rounding the spine, bending and rolling one vertebrae at a time until you are at the bottom of your maximal range of motion/pain limit.
Reverse the motion starting with your lower back and return to the starting position.
Try to keep your knees as straight as possible.
A step to increase range of motion is optional.

Standing abdominal crunch. 2

Using a band above the head, grab the band with both arms out front above the head.
Start with arms straight, bend your trunk forward by contracting your abdominals and bringing your rib cage towards your hip.
Allow the hips to move back slightly to facilitate the movement.
Hold the position for 1-3 seconds.
Focus on the abdominals creating the movement rather than your arms.
Return to the starting position slowly allowing the band to bring you upright.

Loaded jefferson curl. 3

Follow the same procedures as the unloaded jefferson curl.
If using a barbell, hold a shoulder width and if holding a weight, keep it in line with the middle of your body.
If progressed from the unloaded variation, loading is to be done extremely slowly and only in supervised sessions.

1.23 Trunk Extension- Dynamic

Lumbar extension 1

Lie down flat on your stomach, with arms tucked underneath the chest or directly in front,depending on what is most comfortable.
While maintaining the pelvis and hips on the floor, try and arch your lumbar so your head is looking forward. You may slightly assist with your arms if extension (arching) cannot be performed alone.
Slowly return to the starting position.

Passive lumbar extension 2

Lie on your stomach with your hand close to face at shoulder-width distance.
Begin the movement by pushing yourself up against the floor with your arms slowly, allowing for your head, upper back and lumbar to begin arching one at a time.
Keep the glutes relaxed and pelvis/hips against the floor during the movement.

Lumbar flexion and extension 3

Start with all fours on the ground with the spine in a neutral position.
Lower your glutes towards the floor with extending arms forward while rounding your spine.
Stretch as deep as possible until you can feel it through the trunk.
Hold the stretch for 3 seconds and (or as long as is comfortable) and slowly rock forward back into neutral position and slowly arch your spine into the previous exercise with the assistance of your arms.
Move between these two movements, holding the stretch at each point for 3 seconds or as long as comfortable.

1.24 Cat-Camel/ pelvic tilt- Dynamic

Active pelvic tilt 1

Sit on a chair with thighs parallel to the ground or below (this may be done standing if it is easier to perform the movement initially)
Maintaining steady breathing and abdominal pressure, slowly move your hips and let your lower back arch, and then push your hips forward allowing your back to round.
Alternate between these two positions within your available range of motion.

Seated cat-camel 2

Situp in a chair with you back away from the backrest (if it has one) and place your hands on your knees.
Start with a strong vertical posture and gently bend forward with your chin down until you feel a slight stretch in your back.
Slowly reverse to movement and try and arch your back until you either feel a stretch in your lower back or abdominals.
Alternate between these two positions for as many repetitions as comfortable.

Cat-camel 3

Start with all fours on the ground, palms facing down, head looking forward and hands underneath shoulders.
Attempt to lift the chest and head at the same time by arching your lower back while letting the stomach drop.
Reverse this movement into rounding the back into your comfortable range of motion.
Hold each position for 5 seconds before alternating.
Don't force the end range of motion, this is not not a stretch like the seated variation.

1.25 Modified Superman-Dynamic

Modified superman 1

Lie face down on the floor with arms folded, under the forehead or in the most comfortable position.
Tuck in chin and slowly lift your legs off the floor without lifting up the hips, while slightly elevating the chest if needed to allow the movement.
Slowly Lower the legs to the starting position.

Stabilization superman 2

Lie on the floor with arms and legs stretched straight in front, with your ear touching your inner arm.
Push belly button towards the floor to activate abdominals.
At the same time lift one arm and one leg (opposites) while maintaining core stability.
Return arm and leg to starting position and perform the next repetition with the opposite limbs that were not raised.

Superman strengthening 3

Lie on your stomach with arms and legs stretched out as far as possible; think of having as long of a body as possible.
at the same time lift your arms and legs off the floor and reaching with both legs.
try and hold the position for one second before returning to start position.

1.26 Anterior Hold- Stability

Loaded hold shoulder raise 1

Using any type of load (dumbbell, medicine ball, plate raise weight up until shoulder height.
Maintain a braced trunk while weight is elevated.
Hold the weight until shoulders begin to drop the weight or trunk begins to lose stability and round forward.

Alternating front raise 2

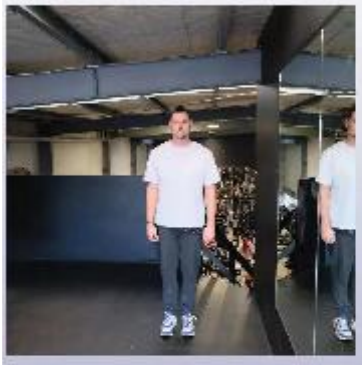
Sitting or standing, start with arms on both sides while holding a weight (thumbs up with dumbbells, palms down if holding a resistance weight).
While keeping the arms straight, lift arms to shoulder level or above, while having arms roughly at a 30 degree angle (point the arms slightly away from you)
While holding the position slowly drop one arm to the starting position and raise it back to shoulder level.

Steering wheel plate shoulder raise 3

Stand up tall with a plate in your hands. Brace your core and bend the knees slightly.
Lift the plate to shoulder level with arms stretched out as far as possible.
Begin turning the plate as if you were turning a steering wheel of a car until shoulders allo, and turn the plate the opposite way.
Continue this movement until lower back discomfort occurs or you cannot maintain a straight trunk posture.

1.27 Side plank- Stability

Side plank on the wall 1



Stand next to a wall at an appreciable distance (the further away the harder the movement) so your forearm can be on the wall; you will be at an angle to activate your abdominals.

Put your feet next to each other and put your forearm at shoulder height while holding the position of your feet while keeping a straight line.

Hold the position as long as possible and return to standing without moving feet for resting position

Side plank with abduction 2

Lie on your side with knees bent roughly at 90 degrees and one elbow on the ground.

Push yourself up against your elbow until your head, shoulders, hips and knees are all in a straight line.

Lift the top leg up and down while maintaining spine angle and return to starting position (legs may be extended further to increase the difficulty).

Side plank 3

Start lying on your side, with one elbow lying on the ground and the other flat against your side, legs in a straight line with a slight bent in the knee.
While engaging the core, squeeze your glutes and lift your trunk into a straight line while pushing your hips forward. The top position should have the body in a straight line."
Slowly return to the starting position(to make it easier, you may use to other arm to help stabilize or bend your knees if the movement cannot be performed)
Hold the position until trunk stability fails and cannot maintain straight spine angle

1.28 Hip-hinge – Stability

Seated goodmornings 1

Sit at the end of the bench and feet at the position which allows the most hip movement .Using a stick, keep the trunk straight and tight while moving it as far as you can before spinal flexion occurs. Return to start position.

Loaded goodmornings 2

Stand with legs at hip-width and bar placed behind the upper back.Holding the bar with your hands, bend over from the hips, making sure that the truck and lower keeps the same spinal angle through the movement, trying to keep the same knee bend that you had starting the movement. Return to starting position and repeat the movement.(this can be performed holding a dumbbell or weight if shoulder mobility/training location does not allow)

Romanian deadlift 3

Begin the movement with your knees slightly bent and pushing your hips back while keeping your back as straight as possible and head position forward. Continue the movement as far as you can without rounding your back, when you get to the point of restriction bend your knees to lower the weight further,
While lifting the weight up, push your knees and hips forward before elevating your spine to the starting position.

1.29 Plank Variations (Bird-dog)- Stability

Abdominal plank 1

Start with all four limbs on the ground and then push yourself up with your forearms and your toes, with your chin tucked in.
Your body should be a straight line and maintain position for as long as possible.

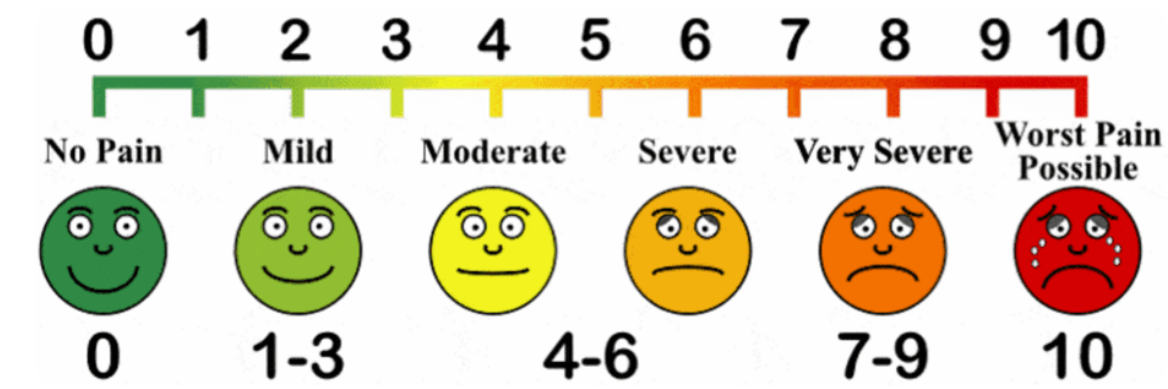
Modified plank with leg lift 2

Start in a plank position with elbows Or hands on the ground.
Contract the abdominal muscles and elevate one leg off the ground, try and think of pushing the legs backs while maintaining trunk stability.
Do not allow the trunk or pelvis to move while the leg is moved backwards (if possible).
Return leg to starting position and repeat with the opposite leg.

Superman arms forward plank 3

Start in a plank or push-up position (whatever is easier) and brace the body.
Lift one leg while lifting the opposite arm at the same time without letting the trunk or pelvis rotate.
Reach as far as you can away from the body with both opposite arm and a leg, and hold the contraction at the top of the movement.
Return to start position and repeat with the opposite limbs; keep the trunk braced through the entire movement.

1.30 Visual Analogue Scale



MCGILL'S TORSO MUSCULAR ENDURANCE TEST BATTERY

Trunk Flexor Endurance Test

The flexor endurance test is the first in the battery of three tests that assesses muscular endurance of the deep core muscles (i.e., transverse abdominis, quadratus lumborum, and erector spinae). It is a timed test involving a static, isometric contraction of the anterior muscles, stabilizing the spine until the individual exhibits fatigue and can no longer hold the assumed position.

Contraindications

This test may not be suitable for individuals who suffer from low-back pain, have had recent back surgery, and/or are in the midst of an acute low-back flare-up.

Equipment:

- Stopwatch
- Board (or step)
- Strap (optional)

Pre-test procedure:

- After explaining the purpose of the flexor endurance test, describe the proper body position.
  - ✓The starting position requires the client to be seated, with the hips and knees bent to 90 degrees, aligning the hips, knees, and second toe.
  - ✓Instruct the client to fold his or her arms across the chest, touching each hand to the opposite shoulder, knee against a board positioned at a 60-degree incline, and keep the head in a neutral position (Figure 1).
  - ✓It is important to ask the client to press the shoulders into the board and maintain this "open" position throughout the test after the board is removed.
  - ✓Instruct the client to engage the abdominals to maintain a flat-to-neutral spine. The back should never be allowed to arch during the test.
  - ✓The ACE® Certified Medical Exercise Specialist (CMES) can anchor the toes under a strap or manually stabilize the feet if necessary.
- The goal of the test is to hold this 60-degree position for as long as possible without the benefit of the back support.
- Encourage the client to practice this position prior to attempting the test.

Test protocol and administration:

- The CMES starts the stopwatch as he or she moves the board about 4 inches (10 cm) back, while the client maintains the 60-degree, suspended position.
- Terminate the test when there is a noticeable change in the trunk position:
  - ✓Watch for a deviation from the neutral spine (i.e., the shoulders rounding forward) or an increase in the low-back arch.
  - ✓No part of the back should touch the back rest.
- Record the client's time on the record sheet presented as Figure 4 later in this section.

Figure 1
Trunk flexor endurance test

Trunk Lateral Endurance Test

The trunk lateral endurance test, also called the side-bridge test, assesses muscular endurance of the lateral core muscles (i.e., transverse abdominis, obliquus, quadratus lumborum, and erector spinae). Similar to the trunk flexor endurance test, this timed test involves static, isometric contractions of the lateral muscles on each side of the trunk that stabilize the spine.

Contraindications

This test may not be suitable for individuals:

- With shoulder pain or weakness
- Who suffer from low-back pain, have had recent back surgery, and/or are in the midst of an acute low-back flare-up

Equipment:

- Stopwatch
- Mat (optional)

Pre-test procedure:

- After explaining the purpose of this test, describe the proper body position.
  - ✓The starting position requires the client to be on his or her side with extended legs, aligning the feet on top of each other or in a tandem position (heel-to-toe).
  - ✓Have the client place the lower arm under the body and the upper arm on the side of the body.
  - ✓When the client is ready, instruct him or her to assume a full side-bridge position, keeping both legs extended and the sides of the feet on the floor. The elbow of the lower arm should be positioned directly under the shoulder with the forearm facing out (the forearm can be placed palm down for balance and support) and the upper arm should be resting along the side of the body or across the chest to the opposite shoulder.
  - ✓The hips should be elevated off the mat and the body should be in straight alignment (i.e., head, neck, torso, hips, and legs). The knee should be supported only by the client's foot/feet and the elbow/forearm of the lower arm (Figure 2).
- The goal of the test is to hold this position for as long as possible. Once the client breaks the position, the test is terminated.
- Encourage the client to practice this position prior to attempting the test.

Test protocol and administration:

- The CHES starts the stopwatch as the client moves into the side-bridge position.
- Terminate the test when there is a noticeable change in the trunk position
  - ✓A deviation from the neutral spine (i.e., the hips dropping downward)
  - ✓The hips shifting forward or backward in an effort to maintain balance and stability
- Record the client's time on the record sheet.
- Repeat the test on the opposite side and record this value on the record sheet presented as Figure 4 later in this section.

Figure 2
Trunk lateral endurance test

Trunk Extensor Endurance Test

The trunk extensor endurance test is generally used to assess muscular endurance of the torso extensor muscles (i.e., erector spinae, longissimus, iliocostalis, and multifidi). This is a timed test involving a static, isometric contraction of the trunk extensor muscles that stabilize the spine.

Contraindications
This test may not be suitable for:

- A client with major strength deficiencies, where the individual cannot even lift the torso from a forward flexed position to a neutral position
- A client with a high body mass, in which case it would be difficult for the CHES to support the client's suspended upper-body weight
- Individuals who suffer from low-back pain, have had recent back surgery, and/or are in the midst of an acute low-back flare-up

Equipment:

- Elevated, sturdy exam table
- Nylon strap
- Stopwatch

Pre-test procedure:

- After explaining the purpose of the test, explain the proper body position.
  - ✓The starting position requires the client to be prone, positioning the iliac crests at the table edge while supporting the upper extremity on the arms, which are placed on the floor or on a riser.
  - ✓While the client is supporting the weight of his or her upper body, anchor the client's lower legs to the table using a strap. If a strap is not used, the CHES will have to use his or her own body weight to stabilize the client's legs.
- The goal of the test is to hold a horizontal, prone position for as long as possible. Once the client falls below horizontal, the test is terminated.
- Encourage the client to practice this position prior to attempting the test.

Test protocol and administration:

- When ready, the client lifts/extends the torso until it is parallel to the floor with his or her arms crossed over the chest (Figure 3).
- Start the stopwatch as soon as the client assumes this position.
- Terminate the test when the client can no longer maintain the position.
- Record the client's time on the record sheet.

After completing all elements of McGill's torso muscular endurance test battery, the CHES can use Figure 4 to record the client's data.

Figure 4
Trunk extensor endurance test

Trunk flexor endurance test
Time to completion: _____

Trunk lateral endurance test
Right side time to completion: _____ Left side time to completion: _____

Trunk extensor endurance test
Time to completion: _____

Ratio of Comparison	Criteria for Good Relationship Between Muscles
Flexion:extension	Ratio less than 1.0
Right-side bridge:left-side bridge	Scores should be no greater than 0.05 from a balanced score of 1.0
Side bridge (each side):extension	Ratio less than 0.75

Flexion:extension ratio: _____ Rating: ❑ Good ❑ Poor

Right-side bridge:left-side bridge ratio: _____ Rating: ❑ Good ❑ Poor

Side-bridge (each side):extension ratio: _____ Rating: ❑ Good ❑ Poor

Figure 4
McGill's torso muscular endurance test battery—record sheet

1.32 Human Research Ethics Approval

The University of Waikato
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Hamilton, New Zealand

Human Research Ethics Committee
Roger Moltzen
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THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

24 April 2023

Adam Callaghan
Te Huataki Waiora School of Health
DHECS
By email: ajc72@students.waikato.ac.nz

Dear Adam

HREC(Health)2023# 06 Strengthening transverse abdominus/multifidus (TA) versus rectus abdominus/spinal erector (RA) muscles for non-specific chronic lower-back pain

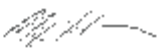
Thank you for your responses to the Committee feedback.

We are now pleased to provide formal approval for your project.

Please contact the Committee by email (humanethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,



Emeritus Professor Roger Moltzen MNZM
Chairperson
University of Waikato Human Research Ethics Committee

1.33 Low Back Pain Rating Scale

Low Back Pain Rating Scale of Manniche et al.

Overview:

Manniche et al developed rating scale to evaluate patients with low back pain. The scale covers the 4 manifest components of back pain and was designed for monitoring outcome following therapeutic interventions. The authors are from several hospitals in Denmark.

Measures in rating scale:

(1) back and leg pain (60 points)

(2) disability index (30 points)

(3) physical impairment (40 points)

Back and Leg Pain

Visual analogue scales (VAS) ranging from 0 (no pain) to 10 (worst imaginable pain):

(1) back pain at the time of the examination

(2) leg pain at the time of the examination

(3) the worst back pain within the last 2 weeks

(4) the worst leg pain within the last 2 weeks

(5) average level of back pain during the last 2 weeks

(6) average level of leg pain during the past 2 weeks

pain index =

= SUM(points for all 6 visual analogue scales)

Disability Index

Questions (Table 1 page 319)

(1) Can you sleep at night without low back pain interfereing?

(2) Can you do your daily work without low back pain reducing your activities?

(3) Can you do the easy chores at home such as watering flowers or cleaning the table?

(4) Can you put on shoes and stockings by yourself?

(5) Can you carry two full shopping bags (10 kilograms total)?

(6) Can you get up from a low armchair without difficulty?

(7) Can you bend over the wash basin to brush your teeth?

(8) Can you climb stairs from one floor to another without resting because of low back pain?

(9) Can you walk 400 meters without resting because of low back pain?

(10) Can you run 100 meters without resting because of low back pain?

(11) Can you ride a bike or drive a car without feeling any low back pain?

(12) Does low back pain influence your emotional relationship to your nearest family?

(13) Did you have to give up contact with other people within the last 2 weeks because of low back pain?

(14) If it was a present interest do you think that there are certain jobs which you would not be able to manage because of your back trouble?

(15) Do you think that the low back pain will influence your future?

Responses	Points	Forward	Reverse
not a problem	0	yes	no
can be a problem	1	can be	can be
is a problem	2	no	yes

Forward questions: 1 2 3 4 5 6 7 8 9 10 11

Reverse questions: 12 13 14 15

NOTE: In the paper scoring is given as yes = 0; can be problem = 1; no = 2. However these responses for the last 4 questions reverse the general trend of the first 11 questions. It makes more sense to me to reverse the scoring for the last 4 questions.

disability index = SUM(points for all 15 questions)

Physical Impairment

Measures:

(1) endurance of back muscles: length of time that the patient can lie horizontal above the floor with the legs strapped to a bench and the trunk unsupported from the level of the iliac crest

(2) back mobility: modified Schober's test (see Calin 1998 (a) draw a line between the posterior iliac spines then (b) identify a point 10 cm above the midpoint of the line then (c) with the person bending forward measure the distance from that point to the midpoint of the line connecting the posterior iliac spines and (d) determine the distraction = increase in measuremnt while bending forward.

(3) overall mobility: fastest time taken to go from (a) lying supine on a flat couch 80 cm above the floor to (b) standing beside the couch then (c) walking to the end of the couch where (d) a deep knee bend is done and then (e) return to the starting position.

(4) use of analgesics: based on the frequency of use for non-narcotic and narcotic analgesics

Measure	Finding	Points
back muscle endurance	>= 270 seconds	0
	240 – 269 seconds	1
	210 – 239 seconds	2
	180 – 209 seconds	3
	150 – 179 seconds	4
	120 – 149 seconds	5
	90 – 119 seconds	6
	80 – 89 seconds	7
	30 – 59 seconds	8
	1 – 29 seconds	9
	0 seconds	10
back mobility (modified Schober's test)	>= 60 mm	0
	50 – 59 mm	2
	40 – 49 mm	4
	30 – 39 mm	6
	20 – 29 mm	8
	0 – 19 mm	10
overall mobility test	< 10 seconds	0
	10 – 19 seconds	2
	20 – 29 seconds	4
	30 – 39 seconds	6
	40 – 49 seconds	8
	>= 50 seconds	10
analgesic use	none during past week	0
	use NSAID or non-narcotic analgesic 1-4 times a week	2
	use of NSAID or non-narcotic analgesic 5+ times a week	4

	use of morphine or analogues 1-4 times a week	8
	use of morphine or analogues 5+ times a week	10

impairment index = SUM(points for all 4 measures)

Interpretation:

- minimum score for subscores and total: 0
- maximum pain index: 60
- maximum disability index: 30
- maximum physical impairment: 40
- maximum total points: 130
- The higher the score the greater the level of disability and impairment.

Performance:

- The scale was found to be reliable based on comparisons with the Global Assessments reported by an experienced clinician and the patient.

- Inter-rater agreement is high.

References:

Calin A. Chapter 5.5.5: Ankylosing spondylitis pages 1058-1070 (page 1065). IN: Maddison PJ Isenberg DA et al (editors). Oxford Textbook of Rheumatology Second Edition. Oxford Medical Publications. 1998.

Manniche C Asmussen K et al. Low back pain rating scale: Validation of a tool for assessment of low back pain. Pain. 1994; 57: 317-326.

1.34 Physical Activity Readiness Questionnaire

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:**	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:**	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional and/or complete the ePARmed-X+ at www.eparmed.com before becoming more physically active.
- Your health changes – answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

2020 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a to 1c. If **NO** ☐ go to question 2.

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a–2b. If **NO** ☐ go to question 3.

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a–3d. If **NO** ☐ go to question 4.

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a–4b. If **NO** ☐ go to question 5.

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mm Hg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a–5e. If **NO** ☐ go to question 6.

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or lightheadedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6. **Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimers, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b | If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d | If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthma, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c | If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, lightheadedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c | If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c | If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: _____

_____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
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The PAR-Q+ was created using the evidence-based process led by the PAR-Q+ Collaboration and chaired by Dr. Darren E.R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie, CM. Production of this document was made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

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1.35 Consent Form

Lower Back Pain Research Study

University of Waikato
Participant Consent Form

I have read the **Participant Information Sheet** for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that participation is completely voluntary and I can decline to answer any particular questions or do any activity that I do not feel comfortable with. I can also withdraw at any time up until three weeks after my final session (last assessment and briefing). If I withdraw, I understand that any data I have contributed to the study will also be removed.

I agree to provide information to the researchers under the conditions of confidentiality set out on the **Participant Information Sheet**.

I agree to participate in this study under the conditions set out in the **Participant Information Sheet**.

Signed: _____

Name: _____

Date: _____

1.36 Participant Information Sheet

Lower Back Pain Research Study

University of Waikato

Participation Information Sheet

Thank you for showing interest in participating in my research! My name is Adam Callaghan, and I am currently undertaking a research study to complete my Master's degree in Health, Sport and Human Performance at the University of Waikato. My supervisor for this study is Dr Brett Langley.

What does my study hope to do?

The research study we are conducting is to evaluate how strengthening the different trunk/abdominal muscles impacts pain levels in people who suffer from chronic lower back pain. We are especially interested in how a stability-focused exercise intervention (core strength in the lumbar region) contrasts with a dynamic movement-focused intervention (movement in the lumbar region). The primary goals from this study are to assess which intervention provides a better outcome, and if one intervention acts as a better starting point for progressing to the other intervention. This research hopes to enhance best practices in managing lower back pain and could have important implications for rehabilitation strategies more broadly.

Who am I looking for?

You will need to have had chronic (for 12 weeks or longer) mild to moderate lower back pain, without a clear or diagnosed reason. You will need to be 18-59 years of age and not do more than one day of resistance training per week. For reasons of safety, you cannot have severe pain, disability-associated pain, or an injury or diagnosed pathology associated with the pain.

What would you be expected to do and how long will it take?

You would be involved in a study that is eight weeks of total duration. Over these eight weeks you will participate in two exercise interventions (four weeks per each intervention). Each intervention will require a total of 12 training sessions to be performed (three per week; one supervised and two by yourself). The expected time of each training is estimated to be 30-45 minutes depending on your self-selected rest time. Initial and follow-up assessments (three in total) are expected to take 90 minutes to complete.

Details of the intervention exercises and assessments

Each training will consist of four exercises to be completed. Each exercise has two warm-up sets (to minimize injury risk) and two working sets (until muscular or physiological fatigue). Each of the four exercises will have three variations to select from so your programme will be individualised based on your strength, movement capabilities, and your level of pain.

Three assessment and briefing sessions will take place during the course of the programme – one at the beginning, one midway through, and one at the end. During these sessions, you will be asked to complete a McGill's Torso Muscular Endurance Test Battery and the Low-Back Pain Rating Scale. The first measures trunk endurance and strength, while the second measures range of motion, trunk strength and levels of pain. During these sessions, I will also

work with you to master the required exercises for the next four weeks and provide you an illustrated exercise programme book on how to perform the different exercises and variations. The only other assessment is to complete the Low-Back Pain Rating Scale once per week during the supervised exercise session.

Your rights as a participant, should you choose to be a part of the study.

As a participant, you have the right to ask any question about the study - before, during, and after – that you want to ask. You are encouraged to have a support person join yourself during all assessment and briefing/ training sessions and any other meetings with the researchers. You also have the right to not answer any question or do any activity that you do not feel comfortable with. Your participation is completely voluntary and you can withdraw at any time up until three weeks after the final session we have. You can do this by telling, emailing, phoning, or texting me (or my supervisor) and you do not need a reason. Any data you have contributed to the study will also be removed.

Study risks

The primary risk is the worsening of the pain that you already suffer with, if your pain is caused by an undiagnosed pathology/injury to the spine that becomes aggravated by exercise, if you have not had prior medical imaging ruling out a clear pathology and/or injury, we ask if you could discuss this proposed study with their general practitioner for clearance, prior to initial assessment injury can also be a risk with any exercise program. If any type of injury occurs during your exercise programme, you are asked to immediately stop your exercise and let me know. Depending on the severity of the injury, you may need to seek medical care; I can help you with that.

Confidentiality and how it will be maintained

As a participant, you will be assigned a Participant Number. This is a code that will be used for all of your data so that your name and any identifying information that you give me can be kept safely locked away and separate from any research data. This means that all research data is recorded and analysed as de-identified data and your confidentiality as a participant can be preserved. None of the research outputs mentioned below will contain your name or any identifiable information about you.

What will happen to data?

All of the research data will be recorded and analysed as de-identified data on a password-protected computer and backed up on an encrypted USB drive that will be locked inside a drawer. Your paper Consent Form and Participant Number key will be kept separate in a locked cabinet in a secure University of Waikato office (Supervisor's office). After the study, your Consent Form and Participant Number key will be destroyed, but the research data will be kept for five years and stored on a secure University of Waikato data drive. The primary research output for this study is a Masters research thesis. Secondary outputs will include journal article or book chapter and rehabilitation educational material. Outputs may also include presentations regarding chronic back pain intervention at conferences material.

Who to contact for further information or in case of a study concern

Contact Adam Callaghan at:
Email: adam.callaghan.x@gmail.com

Phone: 0212200640

Contact Brett Langley at:
Email: blangley@waikato.ac.nz
Phone: 0224261292

This research project has been approved by the Human Research Ethics Committee of the University of Waikato under [number to be provided]. For any ethical questions or concerns please contact the Chair of the Committee, email humanethics@waikato.ac.nz, postal address, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240."

1.37 Recruitment Flyer