The efficacy of a ‘novel mobilisation technique’ on thoracic, lumbar, hip and knee range of motion

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A research project submitted in partial fulfillment of the requirements for the degree of Master of Osteopathy, Unitec New Zealand, 2014
Declaration

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This thesis entitled: The efficacy of a ‘novel mobilisation technique’ on thoracic, lumbar, hip and knee range of motion is submitted in partial fulfillment for the requirements for the Unitec degree of Master of Osteopathy.

Candidate’s declaration

I confirm that:
This thesis represents my own work;
The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

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List of Abbreviations

CI  Confidence Interval (95% unless stated otherwise)
°  Degrees
ES  Effect size
ICC  Intraclass correlation coefficient
KE  Knee extension
LBP  Low Back Pain
LSP  Lumbar spine
MWM  Mobilisation with movement
n  Sample size
ROM  Range of motion
SLR  Straight leg raise
±  Standard deviation
TSP  Thoracic spine
t  T-test
y  Years
Introduction to thesis

Low back pain (LBP) is one of the most common complaints addressed by manual therapists (Slater, Davies, Parsons, Quitner, & Schug, 2012), and there is an extensive literature regarding aetiology, classification, methods of diagnosis and effective treatments for LBP. Low back pain has a substantial financial cost to the healthcare system and employers due to decreased productivity and lost days from work (Wynne-Jones et al., 2014).

A wide range of different forms of manual and manipulative therapy have been investigated for the treatment of LBP (Hidalgo, Detrembleur, Hall, Mahaudens, & Nielsens, 2014; Tsertsvadze et al., 2014). One form of therapy popular amongst manual therapy practitioners is the ‘Mulligan concept’ (Hing, Bigelow, & Bremner, 2008). Mulligan’s mobilisation with movement, sometimes referred to as ‘MWMs’ have been investigated for their effect on dorsiflexion and pain in sub-acute ankle sprains (Collins, Teys, & Vicenzino, 2004), lateral epicondylalgia (Paungmali, Vicenzino, & Smith, 2003), range of motion and pressure pain threshold in pain-limited shoulders (Teys, Bisset, & Vicenzino, 2008), lumbar spine mobilisation and the sympathetic response (Moutzouri, Perry, & Billis, 2012), cervical spine mobilisation and the sympathetic response (Moulson & Watson, 2006) and trunk stabilization exercises combined with Mulligan’s mobilisation with movement on degenerative osteoarthritis of the knee (Nam, Park, Yong, & Kim, 2013). The Mulligan’s ‘MWM’s’ using the traction straight SLR, has also been investigated in asymptomatic subjects (T Hall, Cacho, McNee, Riches, & Walsh, 2001) and subjects with LBP (T Hall, Beyerlein, et al., 2006; T Hall, Hardt, Schafer, & Wallin, 2006) demonstrating increases in range of motion during the straight leg raise test (SLR). The SLR is a commonly utilised clinical test to evaluate ‘hamstring length’ (Boland & Adams, 2000; Majlesi, Togay, Unalan, & Toprak, 2008) as well as assessment of neurodynamic function in people with lower extremity, and lower back pain and dysfunction (Butler, 2000).

The Mulligan traction SLR is a technique, designed for a single application, and is applied within a pain free range. The purpose of the technique is to improve hamstring extensibility, SLR range and improve mobility of subjects presenting with leg or lumbar spine pain (T Hall, Beyerlein, et al., 2006; T Hall et al., 2001; T Hall, Hardt, et al., 2006). The technique employs longitudinal traction of the entire lower limb, at the point of limitation, remaining in a pain free range (T Hall, Beyerlein, et al., 2006; T Hall et al., 2001).

Post-isometric relaxation is a common technique used by manual therapists for muscle tension and myofascial pain (Emary, 2012; Gupta, Jaiswal, & Chhabra, 2008). The technique mechanism uses neuromuscular inhibition (Gupta et al., 2008) by isometric contractual phase followed by gentle stretching of the same muscle (Wright & Drysdale, 2008). Similar techniques include muscle energy techniques (MET) and proprioceptive neuromuscular facilitation (PNF), increase ROM, flexibility (Hindle, Whitcomb, Briggs, & Hong, 2012b), muscle strength and gait function (Huo et al., 2013).
Given the common use of the Mulligan traction SLR and post-isometric relaxation techniques individually and their given effects, it was hypothesised that combining the two techniques may have a larger effect. The aim of this study was to investigate the effects of combining the Mulligan’s traction SLR and a post-isometric relaxation technique on thoracic, lumbar spine, hip range of motion.

Traditionally, SLR technique attributed to changes in hip flexion, ‘hamstring’ and calf extensibility, however, concepts including regional interdependence (McCormack, 2012), osteopathic principle of ‘body is a unit’ (Parsons & Marcer, 2006) and fascial congruity of the hamstrings, gluteus maximus, thoracolumbar fascia and latissimus dorsi (Antonio, Wolfgang, Robert, Fullerton, & Carla, 2013) suggest that treatment effects could be affected by the combined technique, also affecting the thoracic spine.

This thesis is arranged into three sections. Section 1 contains a literature review regarding low back pain, regional interdependence, osteopathic manipulative therapy and Mulligan’s traction SLR techniques. Section 2 is a report of an experimental investigation into the combination of Mulligan’s traction SLR and a post-isometric relaxation technique. The report is formatted in a ‘manuscript style’. Section 3 is an Appendix containing study related material including ethics documentation.
Section 1

‘Literature Review’
Introduction to Literature Review

This literature review begins with an overview of lower back pain and its impact. An overview of anatomy of the thoracic and lumbar spine, fascia and tendons and how they influence lower back pain through their kinematic effects as a posterior fascial chain is included. Then the literature review gives an overview of current classifications of low back pain including: McKenzie, treatment based, pathoanatomical based, neuro-physiological model, psychosocial model and O’Sullivan’s classification of chronic low back pain. Next is an overview of thoracic and lumbar spine and hip range of motion and measurement of the range of motion. Then hamstring flexibility is described and its influence on spinal range of motion. The treatment of lower back is described including the various treatment options available. Then the literature review introduces the concept of regional interdependence and critically analyses articles using the regional interdependence concept. An overview of osteopathy is provided and how it relates to regional interdependence, with examples of research exploring treatment of low back pain. To conclude the literature review, the Mulligan ‘mobilisation with movement’ concept is described and three key papers that investigated the Mulligan technique using the SLR technique are critically analysed.

The literature reviewed was searched using the keywords: low back pain, Mulligan’s technique, osteopathy, physical therapy, physiotherapy, thoracic spine, lumbar spine, fascia, tendon, McKenzie classification, O’Sullivan classification, regional interdependence and hamstrings. Online databases included: PubMed (Medline), EBSCO host, Google Scholar and ScienceDirect.
1. Literature Review

1.1 Low back pain overview
Low back pain (LBP) is one of the most common complaints addressed by manual therapists (O'Sullivan, 2005; Slater, Davies, Parsons, Quitner, et al., 2012). Non-specific LBP is the most commonly diagnosed complaint for people with LBP, estimated at between 85-95% of all cases (Hoy et al., 2010), of unknown aetiology (Furlan et al., 2011). An episode of LBP is normally self-limiting and resolves within 10 weeks, most cases run a chronic-episodic course over the person’s lifetime (Hoy, Brooks, Byth, & Buchbinder, 2010). Chronic low back pain is a huge financial burden to the healthcare system (Furlan et al., 2011), with absence from work and decreased productivity (Furlan et al., 2011; Van Middelkoop et al., 2010; Widanarko et al., 2012; Wynne-Jones et al., 2014). Hoy et al (2012) estimated that the global mean prevalence of activity-restricting LBP lasting for longer than 1 day was 11.9 (2.0%), and the overall prevalence was 31.0 (0.6%). The mean onset of age for low back is 30, with peak occurrences between 45-60 years old (Makris, Fraenkel, Han, Leo-Summers, & Gill, 2011). Risk factors associated with low back pain include; sedentary lifestyle, extremely active lifestyles, low general health and occupational repetitive lifting and loading (Brennan, Shafat, Donncha, & Vekins, 2007). Rehabilitation and recovery duration can be influenced by psychosocial factors, financial compensation, low activity levels and lack of knowledge and understanding (Makris et al., 2011).

1.2 Anatomy and biomechanics of the thoracic and lumbar spine, pelvis and hip
Low back pain commonly refers to dysfunction occurring in the lumbar spine and pelvic regions (Hebert, Stomski, French, & Rubinstein, 2013). When treating (LBP), areas of close anatomical location need considering, when considering the emerging concepts of regional interdependence (Sueki, Cleland, & Wainner, 2013; Welsh, Hanney, Podschun, & Kolber, 2010), the osteopathic principle of ‘body is a unit’ (Parsons & Marcer, 2006) and muscular train inter-connectedness via fascial connections. These include the thoracic spine and hips.

1.2.1 Lumbar spine, pelvis and hip
The lumbar spine (LSP) consists of L1-5, is 16cm in length and is 18% of the sitting height (Canavese & Dimeglio, 2013; Dimeglio & Canavese, 2012). It articulates with the sacrum and the innominates, which articulate with the hips. The pelvis (Ilia, Ilium and pubic bones) and the sacrum join the trunk and posterior limbs, creating the spinal base support and transfers the load of the thoracolumbar region to the lower limbs (Huec, Aunoble, Philippe, & Nicolas, 2011). The femoral heads are highly mobile and also allow force transmission to the lower limb (Huec et al., 2011).

1.2.2 Thoracic spine
The thoracic spine (TSP) is from T1 to T12, measuring 27cm long and constituting 30% of sitting height (Canavese & Dimeglio, 2013; Dimeglio & Canavese, 2012). The TSP incorporates the ribs 1 to 12, with articulations with the proceeding vertebra via costovertebral and costotransverse joints (Canavese & Dimeglio, 2013). The TSP has relatively thinner discs and is much stiffer than the lumbar spine to incorporate the rib cage (Marre et al., 2011). The TSP, cervical spine and LSP house the spinal
cord (Marre et al., 2011). The thoracolumbar fascia is a complex, connective tissue structure, playing an important role in force transmission of the spine and trunk muscles (Langevin et al., 2011). Muscle interactions include; latissimus dorsi, serratus posterior, erector spinae, internal and external obliques, gluteal maximus (Langevin et al., 2011). The thoracolumbar joint is a common cause for lower lumbar and lumbosacral area pain due to its function of a transitional junction, with facets joints changing orientation abruptly and being a joint of transitional spinal stress (Proctor, Dupuis, & Cassidy, 1985).

1.2.3 Fascia

Fascia is a 3-dimensional collagen matrix, that surrounds and penetrates all structures of the body (Kumka & Bonar, 2012). It is comprised of superficial and deep layers (Benjamin, 2009; H. Wang, Wei, Wu, & Luo, 2009). There are four types of fascia including; ‘linking’, ‘fascicular’, ‘compression’ and ‘separating’. Linking fascia is subdivided into dynamic and passive fascial structures. Dynamic linking for major fascial groups related to movement and joint stability. Passive linking fascia is acted on by other extramuscular tissues to maintain continuity throughout the body or form tunnels and sheaths (Kumka & Bonar, 2012). Fascicular fascia forms adapted tunnels and is important in organization, transport, strength and locomotion (Kumka & Bonar, 2012). Compression fascia is important for locomotion and venous return, as it influences compartment pressure. Separating fascia is used to absorb forces and decrease friction, to allow for better sliding of tissues (Kumka & Bonar, 2012).

1.2.4 Tendons

Tendons exhibit viscoelastic properties. The elasticity refers to the ability to return to its original state before deformation. Viscosity refers to the tendons resistance to flow. High viscosity exhibits high resistance to deformation (Levangie & Norkin, 2005). When a tendon is under strain there are 4 stages of stress-strain. The initial phase is the ‘stretching-out’ toe region, occurring in the first 2% of the tendon stretching, due to mechanical unloading the crimped tendon fibrils. The second phase is the linear stage of the stress-strain curve, where the physiological upper limit is reached, with the collagen fibrils orientated in the direction of the tensile mechanical load and the tendon is stretched by up to 4%. The next stage is micro followed by macro-tearing of the tendon structure, with eventual tendon rupture (Levangie & Norkin, 2005; Lorenzo & Caffarena, 2005; J. Wang, 2006; J. Wang, Guo, & Li, 2012).

1.3 Target tissues during ‘novel mobilisation’ technique

The posterior muscle chain includes the thoracic, lumbar and hip extensor muscles, which can be involved with LBP (Ridder, Oosterwijk, Vleeming, Vanderstraeten, & Danneels, 2013), due to their fascial connections (Schleip, Findley, Chaitow, & Huijing, 2012). When the novel mobilisation technique is applied at 70-90° of limb flexion, the targeted structures include the hamstrings, gluteus maximus, thoracolumbar fascia and latissimus dorsi (Antonio et al., 2013; Carvalhais et al., 2013), therefore, potentially creating changes at the hip, thoracic and lumbar spine. The post-isometric relaxation technique is targeted at hypertonic muscles, where the muscle is stretched to of increased resistance, then the subject isometrically contracts the muscle for 5-10 seconds, then the muscle is
further stretched (Blanco et al., 2006). The post-isometric relaxation technique is an effective method of increasing hamstring flexibility (Czaprowski et al., 2013a).

1.4 Pathophysiology related to low back pain
The cause of LBP is complex and multi-factorial, with interactions of psychological, biological and social factors (Forster et al., 2013). There are a variety of biological causes of LBP including; bones, intervertebral discs, joints, ligaments, muscles, neural structures and blood vessels (Hancock, Maher, Laslett, Hay, & Koes, 2011; Hoy et al., 2010). Most cases of back pain do not have an identifiable cause, with the remaining 5-15% having a specific cause including; infection, neoplasm or osteoporotic fracture (Hoy et al., 2010; Jones, Pandit, & Lavy, 2014). Some common conditions causing LBP include; Osteoarthritis and Ankylosing Spondylitis. Low back pain can also be affected by co-morbidities including; depression, anxiety and disease, impinging on the patient’s quality of life (Forster et al., 2013). A consequence of low back pain can be the change in movement patterns, with altered muscle activation and antalgic postures (Hodges & Moseley, 2003; Langevin & Sherman, 2007). The changes in movement patterns can be particularly evident in chronic LBP patients. Pain mechanisms involve; primary afferent neurons, spinal cord, brain stem, thalamus, limbic system and cortex (Hodges & Moseley, 2003; Langevin & Sherman, 2007). Most LBP injuries are due to repetitive and cumulative trauma, at the end of range, causing progressive tissue failure, rather than a singular event (Liebenson, 2000).

1.5 Thoracic and lumbar spine range of motion
The lumbar spine typically exhibits 30° of extension and 40° of flexion in the sagittal plane (Kapandji, 1974; Schuenke, Schulte, & Schumacher, 2006). The LSP also has between 20°-30° of lateral flexion (Side bending) in the coronal plane and 10° of total rotation in the transverse plane (Kapandji, 1974; Schuenke et al., 2006). In comparison to the TSP, the LSP has significantly less freedom of movement. This is to allow for the lumbar spine’s function of force transference to the pelvis and lower extremity. The forces that the LSP dissipates include; ground reaction forces, gravity and body weight. The TSP has a total of 70° rotation, 40° total lateral flexion, 25° extension and 35° flexion (Schuenke et al., 2006).

1.5.1 Measuring spinal range of motion
The lumbar spine range of motion can be measured by the Schober’s test. The original Schober’s test places a mark on the posterior superior iliac spine which overlies the lumbosacral junction, whilst the patient stands upright. A second mark is placed 10cm above the first mark. The modified version of this test places a third maker 5cm bellow the lumbosacral junction. The patient then bends forward to touch their toes. The average increase between the second and third marker is 5.5cm for women and 7.1cm for men. If the increase between the markers is 2 standard deviation less than the normal range there is hypomobility of the lumbar spine (Macrae & Wright, 1969). This test is reliant on the skin stretching or distracting over the lumbar segments to show lumbar flexion. There is currently no Schober’s test for the thoracic spine but the Schober’s test could be modified to incorporate the thoracic spine. Placing a fourth marker at the first thoracic vertebra and observing the increase between the markers, could be a method of measuring the range of flexion of the thoracic spine.
1.6 Hip range of motion and clinical implication

Normal range is 70-90° of hip flexion, creating a sense of ‘tightness’ in the posterior thigh. With neural involvement shooting pain may be described at a lower angle of hip flexion (Majlesi et al., 2008). Hip range of motion is required as part of everyday activities including but not limited to walking, running, bending and jumping. The task of sitting to standing requires trunk and hip flexion, followed by limb and trunk extension, thus demonstrating the biomechanical range of motion required to achieve the movement adequately (Tully, Fotoohabadi, & Galea, 2005). Hip flexion is achieved through femur movement on the pelvis, posterior tilting of the pelvis and lumbar spine flattening (Congdon, Bohannon, & Tiberio, 2005; Dewberry, Bohannon, Tiberio, Murray, & Zannotti, 2003; Kuo, Tully, & Galea, 2010). Hip flexion is also related to hamstring flexibility (Dewberry et al., 2003).

1.6.1 Measuring hip range of motion

The SLR test has a biomechanical effect on the lumbosacral neural structures, pelvic mobility and hamstrings (Hsieh, Walker, & Gillis, 1983). The test is used to reproduce back and leg pain which can be caused by hamstring tightness, pathologies or sciatic nerve dysfunction (Boland & Adams, 2000; Hoppenfeld, 1976; Hsieh et al., 1983; Majlesi et al., 2008). Neural components include; sciatic nerve and its surrounding tissues (Muscle, bone, fibrous tissue), connective tissue within the nerve, connective tissue within the spinal canal, conducting elements of the nervous system and intrinsic blood supply (Butler & Gifford, 1989). The SLR test identifies dysfunction within the lumbosacral nerve in relation to their intervertebral foramen but is not limited to this area to create dysfunction (Boland & Adams, 2000). The sciatic nerve has many regions of ‘tension points’ throughout its pathway through the lower extremity including the tibial nerve posterior to the knee (Dilley, Summerhayes, & Lynn, 2007).

The test requires the subject to lie supine with the knee extension and passive hip flexion (Boyd, Wanek, Gray, & Topp, 2009; Majlesi et al., 2008). Normal range is 70-90° of hip flexion, creating a sense of ‘tightness’ in the posterior thigh. With neural involvement shooting pain may be described at a lower angle of hip flexion (Majlesi et al., 2008). Sciatic nerve involvement occurring after 70° of hip flexion is reported to not involve the nerve at its spinal roots but compression of the nerve outside the spinal canal (Majlesi et al., 2008). The end point of the test varies, it may include; first onset of pain, first onset of tension felt by the practitioner or end of range (Boyd et al., 2009). Positive findings for the test include; reproduction of familiar pain, asymmetry between limbs and increased or decreased range of motion (Boyd et al., 2009). Pain felt in the posterior thigh the pain is most likely to be caused by hamstring tightness. To differentiate between hamstring tightness and sciatic nerve dysfunction the foot is dorsiflexed, creating neural tension and the pain increases (Boland & Adams, 2000). This alters the sciatic nerve length without affecting the hamstring muscles. Neural tension is more commonly referred to as neurodynamics, which is interplay between of biomechanical, physiological and morphological function (Ellis & Hing, 2008). Once the neurodynamics is compromised the nervous system is vulnerable to ischemia, neural oedema and hypoxia, altering the neurodynamics (Ellis & Hing, 2008).
1.7 Hamstring flexibility and spinal range of motion
Reduced hamstring flexibility is reportedly a risk factor for non-specific LBP, changes in lumbopelvic rhythm and injury when hip range of motion is reduced (Lopez-Minarro, Muyor, Belmonte, & Alacid, 2012). There is an increased risk of lumbar disc herniation, reduced lumbar lordosis, decreased range of lumbar spine range of motion, increased range of thoracic spine range of motion and increased thoracic curvature with reduced flexibility of the hamstrings (Czaprowski et al., 2013a).

Reported changes relating to increased hamstring extensibility demonstrate increased hip flexion and increased both active and passive ranges of knee extension (Lopez-Minarro et al., 2012). This change was correlated to the attachments of the hamstrings proximally at the ischial tuberosity, except for biceps femoris short head, attaching to linea aspera on the posterior proximal femur (Dalley & Moore, 2006). Tension of the hamstrings therefore influences hip range of motion and the mechanics of the pelvis via its attachment to the ischial tuberosity on the posterior pelvis (Congdon et al., 2005). The pelvic mechanics change by changing the pelvic posture and sagittal spinal curvature, increasing intervertebral stress and intradiscal pressure of the thoracic and lumbar spine (Muyor, Alacid, & Lopez-Minarro, 2011).

One study investigated the effect of hamstring stretching on pelvic tilt and spinal curvature. It demonstrated an increase in anterior pelvic tilt and lumbar and thoracic flexion (Lopez-Minarro et al., 2012). Stretching is commonly described as static, dynamic or pre-contracted techniques. The most common is static stretching in which a specific position is held where the muscle is in tension (Page, 2012). Dynamic stretching is active stretching moving through the full range of motion to its end of range and repeating (Page, 2012). Pre-contraction stretching involves contraction of the muscle being stretched or its agonist before stretching (Page, 2012).

1.8 Treatment of low back pain
There are a variety of forms of treatments available for LBP. Treatment can include; medication, pain management therapy, cognitive behavioral therapy and self management (Slater, Davies, Parsons, Quintner, & Schug, 2012). Self management can include; heat, ice, rest, joint supportive bandages and stretching (Furlan et al., 2012). It is demonstrated the most effective form of care is inter-professional, with several healthcare providers collaborating to provide evidence based care (Slater, Davies, Parsons, Quintner, et al., 2012). Some types of manual therapy treatment include; physiotherapy, osteopathy, acupuncture, chiropractic, massage therapy and musculoskeletal therapists (Clar et al., 2014; Furlan et al., 2012; Kent, Mjosund, & Petersen, 2010). Some manual therapy techniques can included; joint mobilisation, soft tissue mobilisation, stretching, prescribing specific exercises and strengthening (Clar et al., 2014). Manual therapy is demonstrated to be effective for physical function and disability, mental health and pain (Balthazard et al., 2012). The literature currently recommends active exercises to reduce functional disability of chronic non-specific LBP but can be negatively impacted upon by poor pain tolerance, negative anticipation and low level of exercise (Balthazard et al., 2012). Studies have combined manual therapy with active exercises as an effective form of treatment for lower back pain (Balthazard et al., 2012; Geisser, Wiggert, Haig, & Colwell, 2005). Active exercise is
incorporating muscle strengthening and conditioning to maintain treatment effects and keep the patient involved in their recovery.

1.8.1 Overview of a study using post-isometric relaxation on the hamstrings

One study compared subject applied hamstring post-isometric relaxation or muscle energy technique and gluteus maximus strengthening exercises combined with hamstring static stretches, over a 6-week period. The participants in this study were children with a mean age of 11.4 years old ± 0.6, with no current pain and regular levels of physical activity. They were required to attend one guided physiotherapy session a week and 6 self-directed sessions at home, following a handout given to them. The study demonstrated statistically significant improvements in both groups in the straight leg raise by 9.3° (SD 11.0) and 11.1° (SD 11.6) respectively. The popliteal angle with active knee extension increased in both group by 5.2° (SD 11.4) and 7.7° (SD 11.9). The modified standing finger to floor tests by 3.5cm (SD 5.3) and 3 cm (SD 5.3) respectively (Czaprowski et al., 2013b). The most significant improvement was seen in the group combining stretching with the muscle strengthening. This supports the idea of manual therapy techniques combined with active exercises for improved results.

1.9 Classification of low back pain

1.9.1 McKenzie Classification

The McKenzie classification system is used to classify patients with LBP into four groups given the patients clinical presentation (Clare, Adams, & Maher, 2005; May & Donelson, 2008). The 3 main classifications are derangement, dysfunction, and postural, with other used for known pathologies (Clare, Adams, & Maher, 2007; Machado, Maher, Herbert, Clare, & McAuley, 2010).

1.9.1.1 McKenzie classification ‘derangement’

Derangement is caused by mechanical deformation of soft tissues due to internal derangement (Hefford, 2006; McKenzie, 1981). The pain is commonly centralised and duration of greater than 7 weeks (Clare et al., 2005; May, 2006; May & Donelson, 2008). The patient commonly presents with a limitation in their extension range of motion (Clare et al., 2005). This is demonstrated to improve with treatment when a reduction, abolition or centralisation of pain is addressed (May, 2006). The pain is commonly resolved by repetitive movements into the direction of pain and avoidance of the opposite direction (Clare et al., 2005; Hefford, 2006).

1.9.1.2 McKenzie classification ‘dysfunction’

The dysfunction classification is mechanical deformation of soft tissues due to adaptive shortening leading to loss of movement (Hefford, 2006; McKenzie, 1981). The pain is intermittent and reproduced in a single direction of movement at the end of range (Clare et al., 2005; May, 2006; May & Donelson, 2008). The symptoms remain the same with repeated movements. Treatment is aimed at end of range in pain reproducing direction, allowing stretching and lengthening of the adaptive shortened tissue to occur (May & Donelson, 2008).
1.9.1.3 McKenzie classification ‘postural’

The ‘postural’ McKenzie classification is based on postural stresses from maintained and prolonged positions, eventually causing intermittent pain (Clare et al., 2005; Hefford, 2006; May, 2006; McKenzie, 1981). The symptoms are generally felt symmetrical and with loading on the midline, a change in position will relieve the symptoms (May & Donelson, 2008). This is different from end of range static, extrinsic loads. Treatment is aimed at educating the patient on corrective postures to reduce strain on tissues (Clare et al., 2005; May & Donelson, 2008).

1.9.2 Treatment based classification

The purpose of the treatment-based classification is to guide practitioners using the initial consultation to determine which treatment strategy would be the most appropriate of different treatment options (Karayannis, Jull, & Hodges, 2012). The first part of the assessment is to determine whether the patient requires multidisciplinary management or can be treated solely by the physical therapist (Karayannis et al., 2012). Then the severity of the symptoms and level of disability is assessed and categorised into stages. Stage 1 is the acute phase, with treatment based on symptom relief. Stage 2 is sub-acute phase, with treatment aimed at symptom relief and a quick return to normal function. Stage 3 is based on patients who must return to high physical demands but demonstrate low physical conditioning (Karayannis et al., 2012). The third part of the assessment is categorising the patient to the most appropriate form of treatment. The treatment categories are; manipulation, stabilisation, specific exercise or traction (Apeldoorn, Bosmans, Ostelo, De Vet, & Van Tulder, 2012; Apeldoorn et al., 2010; Karayannis et al., 2012). Manipulation is a high velocity thrust in the lumbo-pelvic region, stabilisation is exercises promoting co-contraction of spinal stabilising muscles, specific exercises is repeated, end of range spinal movements in the direction of the pain and traction is static mechanical, prone traction with exercises to centralise symptoms (Apeldoorn et al., 2012; Karayannis et al., 2012).

1.9.3 Pathoanatomic based classification

The aim of the pathoanatomic based classification is to direct treatment based on linking orthopedic tests findings with an assumed pathologic structure (Karayannis et al., 2012). The pathoanatomical model refers to intervertebral discs, facet joint degeneration, annular tears, disc prolapse, spondylolisthesis, foraminal and spinal stenosis in relation to back pain. However these structures are commonly found with ‘abnormal findings’ in asymptomatic subjects, decreasing the correlation of pain and disability with pathoanatomical findings (O'Sullivan, 2005).

1.9.4 Neuro-physiological model

The neuro-physiological model identifies that pain can be generated at the periphery, spinal cord and cortical levels. This is evident in central sensitisation and pain memory (Prakash & Golwala, 2011; Woolf, 2011). Pain memory is also hypothesised to relate to the psychosocial model (Prakash & Golwala, 2011).
1.9.5 Psychosocial model
The psychosocial model identifies the influence of negative thinking, fear, abnormal anxiety, avoidance behaviour, catastrophising with muscle guarding, high pain levels and disability (O'Sullivan, 2005). There is a potential correlation between pain, memory and emotion, with one pain memory or emotion triggering the other (Prakash & Golwala, 2011).

1.9.6 O'Sullivan classification
O’Sullivan’s classification of chronic lower back pain includes 3 subgroups. The first small subgroup is classified based pain derived psychosocial and/or social factors. All chronic pain has elements of psychosocial and social factors but this subgroup is driven by these factors. These factors include; high levels of disability, altered pain processing, amplified non-remitting pain and resultant motor control and movement disorders. Some psychosocial features include; fear, anger, depression, negative beliefs, unresolved emotional issues, poor coping strategies and inter-personal circumstances. The pain is not provoked by clear and consistent mechanical factors and when pain is produced the response is disproportional and abnormal to what would be expected. This classification should be administered by a clinical psychologist or psychiatrist (O'Sullivan, 2005).

1.9.6.1 O’Sullivan classification second subgroup
The second subgroup is based on a pathological underlying process with secondary high levels of pain and disability associated with movement and control impairments (O'Sullivan, 2005). This classification can also include red flag conditions and present with antalgic movement patterns and altered movement patterns. To treat this type of chronic lower back pain, the underlying pathological process must first be treated.

1.9.6.2 O’Sullivan classification third subgroup
The third subgroup is mal-adaptive movement or control impairments and faulty coping strategies causing abnormal tissue loading, pain, distress and disability (Dankaerts & O'Sullivan, 2011; O'Sullivan, 2005). Due to involvement of movement and control impairments, treatment needs to address muscle guarding and retraining of impaired movement. Also, treatment needs to include addressing movement related fear and anxiety (Karayannis et al., 2012). Movement impairment is based on pain avoidance behaviour and control impairments are based on pain provocation behaviour (Dankaerts & O'Sullivan, 2011; Karayannis et al., 2012; O'Sullivan, 2005).
1.10 Regional interdependence

Regional interdependence is the concept that unrelated musculoskeletal impairments, in remote anatomical regions, may contribute to the patient's primary presenting complaint (McCormack, 2012; Strunce, Walker, Boyles, & Young, 2009; Sueki et al., 2013; Welsh et al., 2010). Musculoskeletal dysfunction may respond more favourably to a global treatment approach that, in addition to localised treatment, considers distant structures and treats dysfunctions that may influence the patient's symptoms. The 'founder' of osteopathy, A.T. Still, described treating the body as a whole (Parsons & Marcer, 2006). Regional interdependence relates to A.T Still’s concept of regarding the body is a unit, not just treating the symptomatic area.

There is some evidence of the concept of the body as a unit in manual therapy including; treating the cervical and thoracic spine and ribs in relation to shoulder pain (Strunce et al., 2009), thoracic spine manipulation and adhesive capsulitis (McCormack, 2012), patellofemoral syndrome and lumbopelvic manipulation (Crowell & Wofford, 2012) and treating the hip and ankle in relation to patellofemoral syndrome of the knee (Welsh et al., 2010).

1.10.1 Regional interdependence in relation to shoulder pain treatment

The aim of Strunce et al. (2009) was to investigate the immediate effect of manipulation of the thoracic spine and/or the upper ribs in relation to shoulder pain. They recruited 21 subjects that met strict inclusion and exclusion criteria, which decreased the influence of external factors on their findings. Exclusion criteria included; pain from an active disease and/or pathology, rotator cuff tear, adhesive capsulitis and cervical nerve root pathology. The mean age of the participants was 47 years (SD 12.6 years), with a pain duration mean of 4.2 months (SD 4.8 months), with the duration of pain ranging from 1-18 months, which could have influenced the results. Acute pain (duration of less than 3 months) significantly decreases in pain and disability in the first 6 weeks, after 6 weeks there are only small reductions in pain and disability (Costa et al., 2012). Chronic pain (lasting longer than 3 months) can be influenced by fear avoidance behaviour (Asmundson, Noel, Petter, & Parkerson, 2012), psychosocial factors, movement pattern abnormalities, central sensitisation, connective tissue remodeling (Langevin & Sherman, 2007) durations should not be directly compared. There was no reported control and/or sham groups.

All the subjects received high-velocity thrust manipulations to the upper thoracic spine and/or ribs from one practitioner, who was an orthopaedic manual therapist (Strunce et al., 2009). Subjects also received a seated cervicothoracic junction distraction manipulation if necessary, therefore the treatment procedure was not standardised. The type and number of manipulative techniques performed during the treatment session were based on the presence or absence of specific thoracic and/or upper rib impairments. The techniques were well described and included images to support.
The results of Strunce et al’s (2009) study demonstrated a mean increase of 38° in shoulder flexion, 38° in shoulder abduction and 30° in total rotation. These results show the correlation between the cervical and thoracic spine and the upper ribs. They also show how by examining the entire shoulder region and its surrounding influences, the shoulder can be treated indirectly.

1.10.2 Regional interdependence in patellofemoral syndrome and lumbopelvic manipulation

Crowell and Wofford (2012) investigated the effects of a single session of a lumbopelvic manipulation on subjects with patellofemoral pain syndrome. The outcome measures for this study included; 3 functional tasks (squat, step-up, step-down) using the numerical pain rating scale during the tasks, hip internal active range of motion, muscle strength (hip abductors, external rotators, extensors and knee extensors) using a handheld dynamometer and functional single and triple hop tests. All measurements were taken at baseline and immediately post the lumbopelvic manipulation, by the same researcher and performed in the same order. The global rating of change questionnaire was completed by the subjects immediately and 1 week post-intervention. It is not reported if the researchers involved were blinded for this study.

There were 44 subjects included in Crowell and Wofford’s (2012) study, which was a mixture of men (n=16) and women (n=28). It was not reported if the subjects were blinded to the aims of the study. A mixture of male and female subjects could have influenced the results due to gender differences in pain characteristics. Differences between genders include; pain prevalence higher in women, women more likely to seek treatment for pain, women more likely to have comorbidities, women more likely than men to experience disability from the same pain condition, gender role expectation and beliefs about pain and potential hormonal influences (Fillingim, King, Riberio-Dasilva, Rahim-Williams, & Riley, 2009; Greenspan et al., 2007; Vigil, Rowell, & Lutz, 2014).

The inclusion criteria included; 18-50 years old and signs and symptoms consistent with patellofemoral syndrome (atraumatic anterior knee pain, aggravated by at least two of the following: stair ascent, stair descent, squating, prolonged sitting, kneeling or isometric quadriceps contraction). Exclusion criteria included: prior knee or spinal surgery, severe lumbosacral nerve root compression signs, tenderness to palpation at the tibiofemoral joint lines or patellar tendon, ligamentous instability, suspected meniscal injury, systemic disease, connective tissue disorders, pregnancy, osteoporosis with documented compression fracture or subjects currently receiving treatment for knee pain. The subjects were screened by a researcher for ligament instability and meniscal injury. All the outcome measures were performed by a second researcher. It was not reported if the researchers were blinded to the aims of the study, which subjects the study to bias, limiting the study’s internal and external validity.

The procedure included the patient lying supine and the first examiner performed the lumbopelvic manipulation on the same side as the symptomatic knee. If no cavitation was perceived by the subject or examiner, the examiner repositioned the subject and the lumbopelvic manipulation was performed again. There was a maximum of two manipulations per symptomatic side, with both sides manipulated if both knees were symptomatic.
The results of Crowell and Wofford (2012) study, demonstrated 57% of subjects had a positive outcome immediately following the lumbopelvic manipulation on the numerical pain rating scale or the GRC (Crowell & Wofford, 2012). A positive outcome was defined as a 50% or greater improvement on the NPRS or +4 on the GRC (Crowell & Wofford, 2012). The average improvement for the 3 functional tasks was 35% on the NPRS. Statistically significant improvement were reported in hip internal rotation ROM, hip extension strength, and hip abduction strength. Results of the other outcome measures were not reported. The effect of the manipulation was only analyzed in subjects who had a successful response to manipulation.

1.11 Osteopathic Manipulative Therapy

A form of manual therapy includes osteopathic manipulative therapy (OMT). Techniques used in OMT include: high-velocity-low amplitude thrusts (HVLA’s), soft tissue stretching, articulation, pressure, myofascial stretching and release, myofascial positional tender points and post-isometric release (Cruser et al., 2012; Parsons & Marcer, 2006). One of the principles of osteopathy is ‘the body is a unit’ (Parsons & Marcer, 2006). When treating patients, the osteopathic practitioner treats the area of pain and examines and treats all influencing areas. Some evidence of the osteopathic principle that ‘the body is a unit’ and treating a wider area than the symptomatic region include; OMT and acute LBP (Cruser et al., 2012) and OMT compared to ultrasound therapy in chronic LBP (Licciardone, Minotti, Gatchel, Kearns, & Singh, 2013).

1.11.1 Osteopathic Manipulative Therapy and acute low back pain

Cruser et al., (2012) conducted a randomised controlled trial on 60 military personnel, presenting with acute low back pain, with (n=30) receiving OMT and (n=30) receiving their usual care only (UCO). Exclusion criteria included; Serious neurological, rheumatological or othropedic conditions, pregnant, over 35 years old, 13+ mm leg length discrepancy, leg pain worse than their back pain including radioculopathy or currently receiving manual therapy for their current episode of back pain.

The OMT intervention applied once a week for 4 weeks, by non-blinded study treatment physicians. The study treatment physicians received 4 training sessions before the start of the study and 2 sessions during the 4 week intervention. Due to only receiving 4 sessions of training and not being blinded the internal and external validity of the study is compromised. OMT techniques used included; soft tissue, myofascial release, counter strain, muscle energy, sacro-iliac articulation and high-velocity, low amplitude manipulation.

The outcome measures on Cruser et al., (2012) study included the Quadruple Visual Analogue scale for pain intensity, Roland Morris Disability questionnaire for back-specific functioning and the Short Form health survey (SF-36) for quality of life. The SF-36 was only taken at baseline, therefore the results of this questionnaire are limited. Also a patient expectation questionnaire developed for the study was used to determine perceived improvement and satisfaction with treatment. Outcome measures were taken one week after sessions 1-3 and 4 weeks after the 4th intervention.
The subjects in the study were allowed to continue medication use (naproxen, ibuprofen, acetaminophen, cyclobenzaprine and acetaminophen with codeine). This could have influenced the results due to the medication analgesic effect (Hinson, Roberts, & James, 2010) and the subjects were not asked to maintain a medication log.

Not all subjects were able to attend all the treatment sessions (Cruser et al., 2012). The OMT group consisted of 14 females and 16 males, with the UCO group consisting of 13 females and 17 males.

1.11.2 Osteopathic manipulative therapy and ultrasound therapy in chronic low back pain
Licciardone et al., (2013) conducted a randomised, double-blinded, sham-controlled trial that compared OMT with ultrasound therapy (UST). There were (n=455) subjects recruited, aged between 21 and 69 years (mean 41 years) and women (n=284). Gender considerations need to be taken into account due to differences in pain tolerance, attitudes, beliefs and hormonal influences (Fillingim et al., 2009; Vigil et al., 2014).

Subjects were randomised into 4 groups; OMT + UST, OMT + sham UST, sham OMT + UST and sham OMT + sham UST. Patients were allocated to 15 practitioners who delivered treatments at weeks 0, 1, 2, 4, 6, and 8. Subjects were allowed to receive other forms of treatment and non-prescription medication, which was recorded and monitored, with the exception of OMT and other manual therapies. The OMT techniques were applied to the lumbosacral, iliac and pubic regions and included; high-velocity-low amplitude thrusts (HVLA’s), moderate-velocity and moderate-amplitude thrusts, soft tissue stretching, kneading, pressure, myofascial stretching and release, myofascial positional tender points and post-isometric release (Licciardone et al., 2013). The technique duration was controlled (15 minutes) but the sequence of techniques and number of techniques used was not controlled. This is similar to a normal osteopathic clinical setting. The sham OMT involved hand contact, active and passive ROM, light touch and improper patient positioning. For the sham OMT and UST to have been effective, the subjects must be adequately blinded to which intervention they received and therefore not provoke expectations of treatment effects (Bialosky et al., 2009). The treatment sessions were standardised to 15 minutes and the UST sessions to 10 minutes.

Outcome measures included; visual analogue scale (VAS), initiative on methods, measurement and pain assessment in clinical trials, Roland-Morris Disability questionnaire, medical outcomes study short form-36 health survey (SF-36 GH), number of lost work days and satisfaction with back care on a 5-point Likert scale. Placebo may have been an underlying factor with expectations from previous manual therapy effects, practitioner’s attitude and desire to be relieved of symptoms (Bialosky, Bishop, George, & Robinson, 2011). The effects of manual therapy are physiological and psychological. The psychological effects include; a sense of care, compassion and comfort (Singh & Leder, 2012), relaxation, well-being, relief, fear of pain, irritation and anxiety (Aghabati, Mohammadi, & Esmaiel, 2010).
The results of the Licciardone et al., (2013) study demonstrated reductions in VAS pain scores in the OMT group compared to the sham OMT group \( (p= 0.002) \) but not with the UST group compared to the sham UST group (Licciardone et al., 2013). The results show the co-treatments included: exercise programs, lumbar supports, non-prescriptions drugs, complementary alternative medicine therapies and physical therapy (Licciardone et al., 2013). The co-treatments are not described in detail and could have influenced the results due to their direct effects on pain, therefore making the results validity compromised and hard to interpret. Exercise therapy is shown to decrease pain and disability (Middlekoop et al., 2011) and non-prescription drugs including ibuprofen, acetaminophen, are shown to have an analgesic effect (Hinson et al., 2010). It was not stated which non-prescription drugs were taken and therefore it is not possible to determine their effects on the results. Lumbar supports have been used to prevent and manage low back pain (Roelofs, Poppel, Bierma-Zeinstra, & Mechelen, 2010). Complementary alternative therapies can include a wide variety of alternative treatments, these can include; mind-body modalities, natural products, manual therapy, and energy healing therapies (Anderson & Taylor, 2012a), massage and acupuncture (Anderson & Taylor, 2012b; Bertisch, Wee, & McCarthy, 2008). Physical therapy is a broad term that can include; exercise, electrotherapeutic modalities, soft tissue therapies, braces and splints (Sussmilch-Leitch, Collins, Bialocerkowski, Warden, & Crossley, 2012).

1.12 Mulligan Concept

The Mulligan concept was first described by Brian Mulligan, a New Zealand physiotherapist in 1991 (Reid, Rivett, Katekar, & Callister, 2012). The concept is based on mobilisation with movement combining a sustained passive accessory force to a joint with active movement generated by the patient (Kachingwe, Phillips, Sletten, & Plunkett, 2008; Paungmali, O'Leary, Souvlis, & Vicenzino, 2003; Vicenzino, Cleland, & Bisset, 2007; Vicenzino, Hing, Rivett, & Hall, 2011). Mobilisation with movement is used by manual therapists in the treatment of musculoskeletal pain (Hing et al., 2008; Teyes et al., 2008). The purpose of this form of technique is to increase function and decrease pain, addressing positional faults creating subtle biomechanical changes including stiffness and joint restriction (Kachingwe et al., 2008; Moutzouri, Billis, Strimpakos, Kottika, & Oldham, 2008). The technique is applied with no pain experienced by the patient (Hing et al., 2008; Kachingwe et al., 2008; Moutzouri et al., 2008). Some research investigating the Mulligan’s mobilisation with movement effect includes; dorsiflexion and pain in subacute ankle sprains (Collins et al., 2004), lateral epicondylalgia (Paungmali, Vicenzino, et al., 2003), range of motion and pressure pain threshold in pain-limited shoulders (Teyes et al., 2008), lumbar spine mobilisation and the sympathetic response (Moutzouri et al., 2012), cervical spine mobilisation and the sympathetic response (Moulson & Watson, 2006) and trunk stabilisation exercises combined with Mulligan’s mobilisation with movement on degenerative osteoarthritis of the knee (Nam et al., 2013).

1.12.1 Overview of Mulligan traction SLR on healthy subjects

Hall et al., (2001) study investigated the effect of the Mulligan traction SLR on 26, healthy subjects (mean age 25.9 years, SD 6.8), with an equal number of males and females. The inclusion criteria
included; 18 years old or older and first onset of stretch of less than 90° in the SLR. It was not stated if the first onset of stretch in the SLR was an active (performed by the subject) or passive (performed by the practitioner) range of motion. Exclusion criteria included; significant history of back or leg pain limiting the hip, knee or ankle ROM. To be included in the study, subjects were required to have at least 100° of hip flexion (with the knee flexed) and full knee extension.

The outcome measures of Hall et al., (2001) study included SLR, pelvic rotation and hip flexion, measured using a bubble inclinometer. The measurements were taken before and immediately after the single application of the technique. The SLR was measured at the first onset of stretch and was repeated 4 times before the measurements were taken. The repetitions could have also influenced the results by the visco-elastic properties of tendons and could have worked on the ‘toe region’ of the involved tendon. Therefore when measuring the SLR range, a greater range may have been achieved due to changes in stretch tolerance (Marshall & Siegler, 2014) and stretching during the second phase of the stress-strain curve of tendons (J. Wang et al., 2012). The authors chose to do the repetitions to minimise increases in the SLR range due to tendon stretching (T Hall et al., 2001). After the 3 applications of the traction SLR technique, a further 3 repetitions of the SLR before any measurements were taken. It is unclear why 4 SLR repetitions were used before the traction SLR technique was applied but only 3 repetitions were used after the technique.

One researcher carried out all the outcome measurements and a second researcher performed the traction SLR technique on every subject. Using the same researcher for all measurements and a second researcher to perform all the traction SLR’s increased the intra-reliability of the results. This was done to ensure blinding of the researchers to minimise bias and increase the validity of the results. The authors stated the technique was described to the subjects but it was not reported if the subjects were blinded to aims of the study, this could have also influenced the results. There was no control or placebo group reported in this study and the contralateral leg was not reportedly measured.

The results of this study demonstrated a mean increase in the SLR from 49.9° (SD 12.8°) to 63.2° (SD 15.9°). Pelvic rotation increased by 11.7° (SD 6°) to 14.4° (SD 6.5°). The authors determined hip flexion as the SLR value minus the measured pelvic rotation value. Due to the small sample size the results are less likely to be representative of the target population.
1.12.2 Overview of Mulligan bent leg raise using post-isometric relaxation

Hall, Hardt, Schafer and Wallin (2006) investigated the effects of the Mulligan technique SLR using a bent leg. This double-blinded, randomised placebo-controlled trial used 24 subjects. The inclusion criteria included lower back pain and/or thigh pain and unilateral limitation of SLR of 15° compared to the opposite leg. Exclusion criteria included neurological compromise in the lower quarter. The exclusion criteria did not reportedly exclude subjects that were currently receiving manual therapy, which could have influenced the results.

The outcome measures for this study included; SLR, pelvic rotation and hip flexion, measured according the first onset of pain and the average pain intensity over a 24 hour period. The measurements were taken before, immediately and 24 hours post technique. Two blinded practitioners performed the measurements. It is not clear if the same examiner did the same subjects and/or the same measurements pre and post. Intra and inter-rater reliability could have been compromised with the use of two examiners.

A third examiner performed the bent leg SLR combined with post-isometric relaxation of the hamstrings. The treatment group consisted of 7 females and 5 males (n=12), mean age 41 years (SD 16 years). The placebo group consisted of 8 females and 4 males (n=12) and mean age was 48 years (SD 13 years). The treatment consisted of a bent leg to 90° and 3 times, 5second duration post-isometric contractions of the hamstrings. The placebo group consisted of soft tissue to the foot with the leg bent to 90°.

Due to differences at baseline measurement between the placebo and treatment group, the authors chose to adjust the means and therefore limiting the validity of the results. The adjusted means demonstrated no immediate changes in the SLR range after the bent leg technique but a mean 7° ± 3° increase 24 hours post intervention. The scores for pain intensity were described to have significantly decreased in both groups but the before, immediate and 24 hours post intervention values were not reported. This also decreases the validity of the results. Pelvic rotation in the SLR was reported as 30% of the SLR range and the remaining 70% was achieved by hip flexion (T Hall, Hardt, et al., 2006).

1.12.3 Overview of Mulligan traction SLR on subjects with low back pain

Hall et al., (2006) investigated the effect of the traction SLR on subjects with low back pain. The study recruited 19 subjects with a mean age of 37 years (SD 12 years). The average duration of the LBP was 2 years and 9 months; the range of pain duration was from 3 weeks to 10 years. This wide range of duration of pain makes this study non-specific to a target population. It is unfair to compare acute pain (lasting less than 3 months) with chronic pain that has been present for 10 years. Acute pain is reported to significantly decrease in pain and disability in the first 6 weeks, after 6 weeks there are only small reductions in pain and disability (Costa et al., 2012). Therefore the significant range of duration of pain could have influenced the results.
Inclusion criteria included; lower back pain, a limitation in SLR due to pain greater than the non-involved side (T Hall, Beyerlein, et al., 2006). Exclusion criteria included; knee and/or ankle pathology limiting movement, neurological symptoms and a history of spinal surgery in the past 6 months. It was reported that the majority of the subjects in this study were currently receiving physiotherapy. The type of physiotherapy treatment and body region being treated was not stated. This could have significantly influenced the results as physiotherapy is commonly used as form of manual therapy in subjects with LBP (Harman, Fenety, & Padfield, 2009; Hurley et al., 2010). All subjects were divided into presence (n=6) or absence of neural sensitive tissue described by Hall and Elvey (T. Hall & Elvey, 1999). The subjects received a single session, of the 3 repetitions of the traction SLR. Measures used in this study included; VAS, SLR and pelvic rotation, using two bubble goniometers, with time points before and immediately after. There was no reported warm up session before the measures were taken. The subjects were blinded to technique. There were 3 researchers involved with the procedure, one performed the straight leg raises, one took the measurements and one performed the traction SLR technique. The results of this study demonstrated significant increases in the SLR; $10^\circ$ increase in the mechano-sensitive group and $11^\circ$ in the non-mechano-sensitive group (T. Hall & Elvey, 1999). The ES $\approx 0.9$ for the SLR. The study also concluded pelvic rotation did not influence the range of SLR rather the SLR range was due to hip flexion. The study clearly demonstrated the effect of the traction SLR technique but the non-specific group of subjects, with varied durations of pain made the results hard to apply to a target population. There was no randomisation of subjects as there was no control or placebo group. It was not reported whether the opposite leg was used as a control.

1.14 Rational for investigation

Assertions have been identified between the spine, pelvis and length of the hamstring muscles with the development of lower back pain. Lower back pain risk factors have been identified to include occupational lifting and twisting, spinal abnormalities and psychological risk factors including; low mood and fear-avoidance beliefs (Shambrook et al., 2011). Stretching the hamstring muscles has been investigated in relation to trunk flexion. It has been identified to increase forward bending by increasing the range of motion of the hips and thoracic spine, not effect standing lumbar and pelvic postures and could influence pattern of lumbar and hip movement during forward bending (Gajdosik, Albert, & Mitmen, 1994; Kuo et al., 2010; Li, McClure, & Pratt, 1996; Lopez-Minarro et al., 2012; Muyor et al., 2011). These studies have only used stretching as a technique to address hamstring tension. A gap in the current research is combining stretching with muscle energy technique and Mulligan’s traction SLR technique to the hip to identify changes in hamstring length and trunk flexion. This is important as combining the two techniques could create a larger effect on hip range of motion and as with previous studies findings, the combined technique could influence trunk flexion as well.

The research question is to determine the efficacy of a novel mobilisation technique on thoracic and lumbar spine, hip and knee range of motion. This will be addressed in a report of an experiment in section 2.
References


points in the masseter muscle involving post-isometric relaxation or strain/counterstrain. *Journal of Bodywork and Movement therapy, 10*(3), 197-205.


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Section 2

‘Manuscript’
Abstract

The efficacy of a ‘novel mobilisation technique’ on thoracic, lumbar, hip and knee range of motion

Background  Low back pain is a common problem affecting most people at some stage in their lives. Manual therapy is commonly used as a form of treatment in the presence of lower back pain.

Aim  The aim of the study was to investigate the concepts of regional interdependence with Mulligan’s mobilisation with movement and the effect of a novel mobilisation technique (Mulligan’s traction SLR combined with a post-isometric relaxation).

Study Design  The present study was a controlled pre-post experimental research design.

Method  Twelve, healthy and physically active male participants (mean age 28.1 ± 3.5 years), with perceived ‘tight hamstrings’ were recruited for the study. Participants were randomised to receive the novel mobilisation technique to the left (n=6) or right (n=6) leg, using the contralateral limb as the control. Outcome measures included; SLR, KE, modified Schober’s (Tsp, Lsp) and sit and reach tests, which were taken before, immediately and 1 hour post intervention.

Results  The main statistically significant and clinically meaningful result included immediate changes in the modified Schober’s Tsp (mean difference = -0.40 ± SD 0.48, 95% CI -0.70 to -0.10, t = -2.9, p = 0.014, d = 0.435) and changes in the sit and reach test immediately post (mean difference = -2.20cm ± 1.56, 95% CI -3.30 to -1.20cm, t = -4.869, p<0.001, d = 0.325, “small”) and at 1-hour post (mean difference = -2.62 ± 2.89, 95% CI -4.5 to -0.78cm, t = -3.1, p = 0.009, d = 0.39 “small”). There were no significant changes in the SLR, KE active or passive and modified Schober’s Lsp tests, immediately or 1-hour post intervention.

Conclusion  The novel mobilisation technique applied to the hip demonstrated statistically significant changes in the modified Schober’s Tsp and sit and reach tests. The main limitations to the present study included a potential ‘ceiling’ effect with the baseline SLR values, short technique duration (‘time under tension’) and no warm up.
**Introduction**

The concept of ‘myofascial anatomy trains’ was first described by Thomas Myers in 1990 (Myers, 2009). Myers describes 12 “myofascial trains” which are individual muscles linked via fascia to form functional fascial planes (Myers, 2009). One of the myofascial trains is the ‘superficial backline’ (SBL). The primary function of the SBL has been described “as to act as one continuous line of integrated myofascia to support the body in full upright extension, preventing the tendency to curl over into flexion (Myers, 2009).

Related to the concept of ‘anatomy trains’ is ‘regional interdependence’, which is a recently described concept in physical and manual therapy, which involves considering the biomechanical influence of one region on another closely associated area (Clark, Walkowski, Conatser, Eland, & Howell, 2009; Crowell & Wofford, 2012; Geisser et al., 2005; Wainner, Whitman, Cleland, & Flynn, 2007). For example, Crowell and Wofford (2012) investigated the effects of a single session of a lumbopelvic manipulation on subjects with patellofemoral pain syndrome. There has been some research using regional interdependence on different regions of the body but none using the anatomical muscular train.

One of the principles of osteopathy is “the body as a single unit” (Ward, 2003). This principle refers to the body anatomically being linked by fascia, but also how the different body systems (neurological, endocrine, musculoskeletal) have to work as a “team” to function in harmony (Parsons & Marcer, 2006). The confluence of three concepts (anatomy trains, regional interdependence and osteopathic principle ‘body is a unit’) all have the similar underlying construct of the importance of body regions being related and not addressed in isolation.

If there is decreased range of motion in the lumbar and/or the thoracic spine, osteopathy practitioners could potentially draw on the concepts of AT, RI, osteo principle to restore the normal range of motion through the treatment of regions distant to the lumbar and thoracic spine. Given the prominence of the Mulligan’s and PIR concepts in manual therapy, and no previous work combining these approaches together, the aim of this study was to investigate combining the two techniques and their effect on thoracic, lumbar spine, hip and knee range of motion.
2. Methods

2.1 Design
A controlled pre-post experimental research design was used to determine the amount of change (Berg & Latin, 2007) in the straight leg raise, knee extension, modified Schober’s tests (thoracic, lumbar), and sit and reach tests, following a novel mobilisation technique combining Mulligan’s traction straight leg raise, with the a post-isometric relaxation technique to the hip.

2.2 Participants
Participants were recruited by advertisements placed around the Unitec campus and the local area. All participants were provided with an information sheet that clearly described the research project, which was sent to them either by post or email. The participants were then contacted to identify any concerns, screen for eligibility, and confirm they were available in the given intervention time period. Participants that met the inclusion criteria reviewed the information sheet and had the opportunity to have their questions answered. Before proceeding with the study, all participants were required to sign a consent form. Participants were eligible to participate if they were: (1) aged between 18 to 45 years, (2) perceived they had “tight hamstrings”. The term ‘tight hamstrings’ was defined as the sensation of discomfort in the back of the thighs when attempting to touch their toes; (3) ability to speak English and (4) restricted range of motion during the straight leg raise tests, using the Functional Movement Screen (Cook, Burton, & Hoogenboom, 2006) of a ‘grade 1’ or ‘2’. Exclusion criteria were: (1) a pathological aetiology of restricted range of motion; (2) reported receiving treatment for lower back, pelvic or lower extremity pain in the past 6-months. All participants gave written informed consent prior to participating and the Unitec Research Ethics approved all study procedures (UREC Approval no.: 2011-1241).

2.3 Sample Size Determination
Based on a priori power analysis drawing from the observed effect size from Hall et al (2006) (d=0.86; alpha = 0.05; minimum power = 0.8; paired samples t-test for pre-post change), a targeted minimum of 13 participants was planned.

2.4 Measures
2.4.1 Descriptive characteristics
Participants selected for the study had their height, weight, leg dominance, were recorded for descriptive purposes.

2.4.2 Independent variable
2.4.2.1 Technique
The novel mobilisation technique combined Mulligan’s traction SLR technique with a post-isometric relaxation technique applied to the hip, which required the participant to be lying supine, with one
pillow under their head (see Figure 1 for illustration of technique). The research assistant started the technique by holding the participants ankle in a neutral position and flexed the participant’s entire lower extremity. The knee was kept extended at all times during the technique. The limb was flexed until the research assistant felt the first onset of resistance to passive movement of the limb in flexion. At this point the research assistant applied traction to the entire limb by applying a longitudinal force down the long axis of the limb using a grip of the ankle. Once the traction was applied the participant was instructed to “gently push your limb back down towards the plinth, using 10% of your total strength”. This position was maintained for approximately 8 s, then the participant was asked to relax. This procedure was repeated twice, each time moving into further limb flexion, stopping at the next point of tension felt by the research assistant.

![Image](image_url)

**Figure 1** Mulligan traction SLR combined with a post-isometric relaxation technique

### 2.4.3 Dependent Variables

Dependent variables were: modified Schober’s test of the thoracic, and lumbar spine, straight leg raise, sit and reach and knee extension. Three repetitions of all outcome measures were performed and the mean used in all subsequent analysis. Each participant was evaluated bilaterally to identify baseline measures and one leg was randomly allocated to receive the treatment technique and the other leg as a control (no treatment).

#### 2.4.3.1 Modified Schober’s Test

The modified Schober’s test was developed as a clinical procedure to assess lumbar spine flexion, using skin markers to evaluate range of motion (Robinson & Mengshoel, 2014). Three stickers were placed on the participants back on the spinous process of T1, T12 and S2 as markers to measure the
change in range of motion achieved. The participant was asked to “bend forward to touch your toes, keeping your knees extended and chin on your chest”. Once the participants maximal spinal flexion was achieved, they were required to maintain the position for 3 seconds while the measurements were taken. The range of motion was determined by using a flexible plastic tape measure, measuring the distance between the markers before and at maximal spinal flexion. The range was calculated as the difference between the end of range and start distance between the markers.

2.4.3.2 Straight Leg Raise Test
The SLR test is a neurodynamic test, commonly used clinically (Boyd & Villa, 2012). The test requires the subject to lie supine with their knee extended and flex the hip. This test was performed both actively (by the participant) and passively (by the principal researcher) to be able to compare range of motion differences. Passive range of motion was defined as the maximal range of motion achieved in the anatomical range. Active range of motion was defined as the maximal range of motion the participant could achieve within their physiological range.

2.4.3.3 Sit and Reach Test
The sit and reach test has been used to assess hamstring and lower back flexibility (Lemmink, Kemper, De Greef, Rispens, & Stevens, 2003; Lopez-Minarro, Sainz de Baranda Andjujar, & Rodriguez-Garcia, 2009). The test involved the participant sit with their back against a wall with their legs straight and the sit and reach measurement box placed in front of their feet. The participant flexed forward keeping their arms straight and the distance from their finger tips to the box was measured. If the participant was unable to reach the box the measurement was recorded as a negative number.

2.4.3.4 Knee Extension Test
A knee extension test was used to evaluate the length of the hamstrings (Guex, Fourchet, Loepelt, & Millet, 2012). The knee extension test accurately measured the hamstring length by external influences of the lumbar spine, pelvis and hip/s being removed (Rakos et al., 2001). The participant was required to lie supine with their knee and hip bent to 90°, whilst the opposite leg remained straight and on the plinth. The lumbar spine remained flat on the plinth, whilst the pelvis and hips stabilized to avoid influencing the measurements. The test was first performed actively (by the participant), and then passively (by the principal researcher).

2.5 Procedures
Participants were blinded to specific aims of the study but briefed about all procedures they would experience during the study. The baseline measurements were: modified Schober’s test, straight leg raise, knee extension and sit and reach test. The research was carried out in a laboratory setting. A plinth, used at a standard height, was positioned in front of a plain white wall. A digital camera was set on a tripod, at a distance of 2 m in front of the plinth. A video was taken of the SLR and KE outcome measures, of which still digital images were analysed using ImageJ (Rasband, 2014), to calculate the range of motion achieved. The participants then received a single intervention of the novel mobilisation technique, which was a combination of the Mulligan’s traction straight leg raise with a post-isometric relaxation technique applied to the hip, using the contralateral hip as the control. The research assistant
applying the technique was a postgraduate student, with 2 years of clinical experience. The research assistant carried out the novel mobilisation technique and was blinded to the aim of the study to minimise bias. The research assistant performing the technique randomized which leg was treated by selecting 1 of 12 pre randomised cards, marked ‘left’ or ‘right’ (6 of each). The principal researcher was not informed of the treated leg until after all the measurements were collected to minimise bias. To make the research more representative of typical clinical practice, there was no warm up exercise prescribed to participants. Immediately post technique all outcome measures were repeated. Then the participants were asked to relax in a comfortable seated position, for 1 h before the measures were repeated. During the 1 h interval the participants were not permitted to walk, except for going wees.

2.6 Data analysis

2.6.1 Data extraction
Digital image analysis software (Image J), was used to calculate the range of motion, in degrees, of the active and passive SLR and KE tests. Self-adhesive markers were placed on the left and right femoral greater trochanters, lateral femoral condyles and lateral malleoli and used as measurement points to determine range of motion.

2.6.2 Establishing reliability of measures and measurement error
A sample of 10 participants was recruited to establish the standard error measurement (SEM) for each variable. The mean of 3 repetitions of each outcome measurement (active and passive SLR, sit and reach, active and passive KE and modified Schober’s Tsp and Lsp) were recorded and an intraclass correlation coefficient (ICC model 3,1) was calculated. The SEM was calculated using the formula SEM = SD * SQRT(1-ICC), where SD was the pooled SD from all repetitions. The minimum detectable change (MDC) based on a 95% confidence interval was calculated using the formulae MDC = 1.96 * SQRT2 * SEM.

2.6.3 Statistical analysis
All analysis was performed using SPSS (v20, IBM SPSS Inc). Raw data was tabulated in spreadsheets, and imported into SPSS. Assumptions of normality were explored using skewness, kurtosis, and a formal test of normality calculated using the Shapiro-Wilk statistic. Visual inspection of P-P and Q-Q plots, together with the Shapiro-Wilk test indicated that the data was, for most contrasts, normally distributed and therefore a parametric approach to analysis was used. Pair-wise contrasts were undertaken using paired t-tests and 95% confidence intervals determined for the mean differences. Alpha = 0.05 was used as the threshold for statistical significance. To assist in interpretation the findings Cohen’s effect statistic ‘d’ was also calculated and interpreted using the guidelines suggested by Hopkins (REF). Data are presented as mean ± standard deviation (SD) throughout the text.
3. Results

3.1 Participant characteristics
Twelve male participants responded to the advertising for the study, met the inclusion and exclusion criteria, were available and were enrolled in the study. All participants reported they were physically active. The mean age was 28.1 ± 3.5y, height was 178.7 ± 7.8cm, and weight 81.7 ± 9.8kg. All 12 participants reported they were right leg dominant.

3.2 Measurement error
Table 1 shows measurement error calculations for each variable.

3.3 Results for pre vs post and post60 for each variable

3.3.1 Active and Passive SLR
For active straight leg raise, no significant difference, across any time points (Pre vs Post, Post vs Post60 and Pre vs Post60) was observed. This was also the same for the passive straight leg raise test, across the same time points. See table 2

3.3.2 Active and Passive KE Test
For active and passive knee extension, no significant difference, at across any time points (Pre vs Post, Post vs Post60, and Pre vs Post60). See table 2.

3.3.3 Sit and Reach Test
There was a significant improvement in range between pre and post measurements in the sit and reach test (mean difference = -2.20cm ± 1.56, 95% CI -3.30 to -1.20cm, t=-4.869, p<0.001, d= 0.325, “small”). The difference was of a similar magnitude at the post60 time point (p=0.531). There was also a significant improvement in range between the pre and post60 measurement in the sit and reach test (mean difference = -2.62 ± 2.89, 95% CI -4.5 to -0.78cm, t=-3.1, p = 0.009, d = 0.39). The improvement in range between pre and post60 was greater than the SEM of 2.46cm. See table 2 and figure 2.

3.3.4 Modified Schober’s Test – Thoracic Spine
There was a significant difference between pre and post measures in the modified Schober’s test of the thoracic spine (mean difference = -0.40 ± SD 0.48, 95% CI -0.70 to -0.10, t=-2.9, p = 0.014, d = 0.435). The observed increase was slightly less than the SEM of 0.42cm. This change was not maintained at the post60 time point. See table 2 and figure 2.

3.3.5 Modified Schober’s Test – Lumbar Spine
For modified Schober’s test of the thoracic spine, there was no significant difference, across any time points (Pre vs Post, Post vs Post60, Post vs Post60). See table 2.
### Table 1. Measurement error for all variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>SD Pooled</th>
<th>ICC (3,1)</th>
<th>95% Confidence Interval</th>
<th>SEM</th>
<th>MDC95</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>Active Straight Leg Raise (deg)</td>
<td>14.41</td>
<td>0.81</td>
<td>0.64</td>
<td>0.91</td>
<td>6.36</td>
</tr>
<tr>
<td>Passive Straight Leg Raise (deg)</td>
<td>8.04</td>
<td>0.87</td>
<td>0.75</td>
<td>0.94</td>
<td>2.88</td>
</tr>
<tr>
<td>Active Knee Extension (deg)</td>
<td>12.51</td>
<td>0.97</td>
<td>0.94</td>
<td>0.99</td>
<td>2.09</td>
</tr>
<tr>
<td>Passive Knee Extension (deg)</td>
<td>8.86</td>
<td>0.91</td>
<td>0.81</td>
<td>0.96</td>
<td>2.73</td>
</tr>
<tr>
<td>Sit and Reach (cm)</td>
<td>10.98</td>
<td>0.95</td>
<td>0.87</td>
<td>0.99</td>
<td>2.46</td>
</tr>
<tr>
<td>Modified Schober’s Tsp (cm)</td>
<td>1.54</td>
<td>0.93</td>
<td>0.80</td>
<td>0.98</td>
<td>0.42</td>
</tr>
<tr>
<td>Modified Schober’s Lsp (cm)</td>
<td>1.24</td>
<td>0.93</td>
<td>0.80</td>
<td>0.98</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Notes: SD = Standard deviation. ICC = Intraclass correlation coefficient. SEM = Standard error measurement. MDC95 = Minimal detectable change
### Table 2. Results for all variables

<table>
<thead>
<tr>
<th>Measure</th>
<th>Post (SD)</th>
<th>Post60 (SD)</th>
<th>Contrast</th>
<th>Mean Difference (SD)</th>
<th>95% Confidence Interval</th>
<th>t-value</th>
<th>p-value</th>
<th>Effect Size</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE Passive Control (deg)</td>
<td>61.2 (7.6)</td>
<td>61.2 (8.0)</td>
<td>Pre v Post60</td>
<td>-0.4 (2.3)</td>
<td>-1.9</td>
<td>-0.6</td>
<td>0.009</td>
<td>0.40</td>
<td>'trivial'</td>
</tr>
<tr>
<td>KE Active Treatment (deg)</td>
<td>59.7 (11.4)</td>
<td>60.0 (11.0)</td>
<td>Pre v Post60</td>
<td>0.2 (0.5)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.14</td>
<td>0.02</td>
<td>'small'</td>
</tr>
<tr>
<td>Modified Schober’s Tsp (cm)</td>
<td>68.6 (6.1)</td>
<td>68.7 (6.2)</td>
<td>Pre v Post60</td>
<td>0.1 (0.8)</td>
<td>0.6</td>
<td>-0.4</td>
<td>0.4</td>
<td>0.10</td>
<td>'trivial'</td>
</tr>
<tr>
<td>Modified Schober’s Lsp (cm)</td>
<td>6.1 (1.0)</td>
<td>6.1 (1.2)</td>
<td>Post v Post60</td>
<td>-0.01 (0.5)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.02</td>
<td>0.20</td>
<td>'small'</td>
</tr>
<tr>
<td>SLR Passive Treatment (deg)</td>
<td>62.6 (6.6)</td>
<td>62.4 (6.7)</td>
<td>Pre v Post60</td>
<td>0.2 (3.7)</td>
<td>2.6</td>
<td>0.2</td>
<td>0.02</td>
<td>0.02</td>
<td>'trivial'</td>
</tr>
<tr>
<td>SLR Active Control (deg)</td>
<td>68.7 (9.9)</td>
<td>67.1 (10.5)</td>
<td>Pre v Post60</td>
<td>-1.6 (3.3)</td>
<td>3.7</td>
<td>-0.6</td>
<td>0.1</td>
<td>0.20</td>
<td>'small'</td>
</tr>
<tr>
<td>SLR Active Treatment (deg)</td>
<td>68.5 (8.9)</td>
<td>67.0 (8.2)</td>
<td>Pre v Post60</td>
<td>1.5 (4.1)</td>
<td>4.1</td>
<td>1.3</td>
<td>0.2</td>
<td>0.20</td>
<td>'small'</td>
</tr>
<tr>
<td>SLR Passive Control (deg)</td>
<td>68.6 (6.1)</td>
<td>68.8 (5.2)</td>
<td>Pre v Post60</td>
<td>-0.1 (3.2)</td>
<td>0.8</td>
<td>-3.3</td>
<td>0.2</td>
<td>0.20</td>
<td>'small'</td>
</tr>
<tr>
<td>KE Active Treatment (deg)</td>
<td>60.0 (11.7)</td>
<td>61.4 (10.3)</td>
<td>Pre v Post60</td>
<td>-1.4 (2.6)</td>
<td>0.2</td>
<td>-3.1</td>
<td>0.1</td>
<td>0.10</td>
<td>'trivial'</td>
</tr>
<tr>
<td>KE Active Control (deg)</td>
<td>59.7 (11.4)</td>
<td>60.0 (11.0)</td>
<td>Pre v Post60</td>
<td>-0.01 (5.1)</td>
<td>3.2</td>
<td>-3.2</td>
<td>1.0</td>
<td>0.03</td>
<td>'large'</td>
</tr>
<tr>
<td>KE Passive Treatment (deg)</td>
<td>61.2 (8.0)</td>
<td>62.0 (7.6)</td>
<td>Pre v Post60</td>
<td>-0.9 (5.1)</td>
<td>2.4</td>
<td>-4.1</td>
<td>0.6</td>
<td>0.10</td>
<td>'trivial'</td>
</tr>
<tr>
<td>KE Passive Control (deg)</td>
<td>61.2 (7.6)</td>
<td>62.6 (6.6)</td>
<td>Pre v Post60</td>
<td>-1.4 (4.3)</td>
<td>1.3</td>
<td>-4.2</td>
<td>0.3</td>
<td>0.20</td>
<td>'small'</td>
</tr>
</tbody>
</table>

Figure 2. Upper panel shows Sit and Reach Test results at time points pre, post and post60. Lower panel shows Modified Schober’s Test Thoracic spine results at time points pre, post and post60.
4. Discussion

4.1 Overview

The aim of the present study was to determine the immediate effects of a novel mobilisation technique (combined elements of both the Mulligan traction with SLR, with a post-isometric contract-relax technique), applied to a hip, on changes in range of motion at the knee, hip, thoracic and lumbar spine. The expected outcomes were increases in range of motion in the SLR and knee extension tests, with some improvement in the sit and reach and modified Schober’s tests. Contrary to expectations, the main findings of the present study were statistically significant improvements in thoracic spine flexion both immediately, and 60 minutes after the technique was applied, but no changes in SLR or knee extension range. The outcome of the sit and reach test was a significant increase in range of motion both immediately, and 60 minutes post technique administration.

4.2 Rationale for combining techniques

Both Mulligan traction with SLR, and post-isometric contract-relax techniques, have been demonstrated in previous studies to improve hip range of motion. The Mulligan traction with SLR technique has been demonstrated to improve SLR range (Hall et al., 2006; Hall, Cacho, McNeel, Riches, & Walsh, 2001; Hall, Hardt, Schafer, & Wallin, 2006), and lower back pain and referred thigh pain (T Hall, Beyerlein, et al., 2006). Post-isometric relaxation techniques applied to the hamstrings have been associated with increased range of hip flexion, reduced stiffness and tension at the hamstring muscle-tendon junctions and improvements in muscle elasticity (Hindle, Whitcomb, Briggs, & Hong, 2012a; Lopez-Minarro et al., 2012; Selkow et al., 2009). Based on the fascial continuity of the hamstrings, gluteus maximus and thoracolumbar fascia (Antonio et al., 2013; Carvalhais et al., 2013) and the concept of ‘anatomy trains’ (Myers, 2009), the rationale for combining techniques was to determine whether a greater effect could be achieved in the hip and knee and if effects could be observed in the thoracic and lumbar spine.

4.3 Rationale for investigation

Hamstring flexibility is clinically important as thigh muscle imbalances and hamstring muscle weakness are intrinsic risk factors for hamstring muscle strain-type injuries (Freckleton & Pizzari, 2013). There are studies to suggest an association between lower extremity asymmetry of movement as a risk factor for lower back pain, due to altered patterns of movement, and increased spinal strain (Al-Eisa, Egan, Deluzio, & Wassersug, 2006; Lederman, 2011). Some of the biomechanical risk factors related to asymmetry include: leg length discrepancies (Harvey et al., 2010; Sabharwal & Kumar, 2008), inflexibility of the lower limb (Feldman, Shrier, Rossignol, & Abenhaim, 2001), pelvic and sacral asymmetry (Al-Eisa et al., 2006), variations in lumbar lordosis and thoracic kyphosis and low muscle strength. Therefore, one of the goals of therapeutic intervention, including manual therapy techniques, should be aimed at reducing asymmetries, thus improving biomechanics (Cook et al., 2006; Witt & Venter, 2009).
4.4 Wider literature- Similarities and differences

There are some notable differences between the present study and previous studies investigating the effect of Mulligan traction SLR, including: Differences in findings (T Hall, Beyerlein, et al., 2006; T Hall et al., 2001; T Hall, Hardt, et al., 2006), SLR end points (T Hall et al., 2001), participants (T Hall, Beyerlein, et al., 2006), and measurement time points (T Hall, Beyerlein, et al., 2006; T Hall et al., 2001).

4.4.1 Differences in findings

The absence of change in SLR and knee extension ROM following the technique conflicts with previous studies investigating the effect of the Mulligan traction SLR in healthy asymptomatic subjects (T Hall et al., 2001), subjects presenting with lower back pain (T Hall, Beyerlein, et al., 2006), and the effect of the Mulligan technique using a bent leg (T Hall, Hardt, et al., 2006). All three studies report statistically significant increases in SLR test ranging from 7° to 13° immediately post-technique. The magnitude of effect size (ES) for pre and post SLR range in these studies lies in the ‘moderate’ range (Hopkins, 1997) with effect sizes estimated from published data being of the order ES ≈ 0.9 (T Hall et al., 2001), ES ≈ 0.9 (T Hall, Beyerlein, et al., 2006) and ES ≈ 0.6 for the treatment group and a small effect size for the placebo group (ES ≈ 0.4) (T Hall, Beyerlein, et al., 2006).

4.4.2 Difference in SLR endpoints

Hall et al.’s 2001 study on healthy subjects reported a mean (SD) pre-intervention SLR range of 49.90° (12.80°), and the range of post-intervention SLR was defined as the point where “the participant first felt the onset of stretch in the posterior thigh”. The present study defined the endpoint for SLR range using the maximal range the participant could actively achieve, and the passive end of range by the examiner encountering an end feel characteristic of physiological end of range. Passive range of motion determines the amount of movement possible at the joint, and allows the practitioner to identify the quality of the range of movement, end feel and noting the onset of pain (Clarkson, 2000). The decision to define passive end of range less conservatively than Hall et al.’s (2001) study was based on the perception that this definition was more representative of typical clinical practice. These differences in study design limit the extent to which direct comparisons can be made.

4.4.3 Difference of participants

The study by Hall, et al., (2006), on participants with lower back pain, examined the Mulligan traction SLR technique on two treatment groups, with lower back pain. It contrasts with the present study as their participants were symptomatic, therefore their range of SLR was influenced by pain and could have responded favourably to treatment, compared to the present studies asymptomatic participants. The two groups of participants, were defined as with and without the presence of mechanosensitive neural tissue, through a list of clinical criteria (T. Hall & Elvev, 1999). The Hall et al., (2006) study demonstrated a 10° increase, with a ‘moderate’ effect (ES ≈ 0.7), for SLR immediately post technique in the mechanosensitive group and an 11° increase, (ES ≈ 0.9), in the non-mechanosensitive group. The SLR range was measured when the participant first reported the onset of pain. This measurement point for SLR is different from the present study but was appropriate due to the presence of lower back
pain, because in clinical practice it is appropriate to use the first onset of pain as the end of range in the SLR measurement.

4.4.4 Difference in measurement time points
Both Hall et al., (2001) and Hall et al., (2006) took their SLR measurements immediately after the technique was performed. This is different from the present study in which measurements were taken immediately after and 1 hour post technique to identify the duration of the effect, therefore the results of this study do not address the duration of the change in SLR test. The implication is that inferences about the duration of the observed effects cannot be made. If not applied repetitively, the treatment effect of a post-isometric relaxation technique tends to last seconds to minutes, (Roberts, 1997). Other studies have identified improvements in knee extension following hamstring stretching but the effect duration was limited to 3 to 6-minutes post technique (Lopez-Minarro et al., 2012; Spernoga, Uhl, Arnold, & Gansneder, 2001). The results of the present study are limited to immediate and short-term changes. To further identify long term changes post technique, a third time point of 24-hours may be appropriate, although controlling for participant activity between sessions may be challenging.

4.4.5 Explanation for changes in the Modified Schober’s Test and Sit and Reach measurements
A potential explanation for changes in the sit and reach and the thoracic spine measurements during the modified Schober’s tests, is the anatomical link between the gluteus maximus, latissimus dorsi and the thoracolumbar fascia (Antonio et al., 2013; Barker, Briggs, & Bogeski, 2004). The link between gluteus maximus insertions into the iliotibial tract and intermuscular septum, create a passage for force transfer and mechanical coordination of the lower limb, pelvic region and lumbar spine (Antonio et al., 2013; Carvalhais et al., 2013). The force is transmitted intramuscularly, intermuscularly or extramuscularly via connective tissue and non-connective tissues including fascia, neurovascular tracts (Carvalhais et al., 2013). The novel mobilisation technique employed in the present study could have been stretching not only the hamstrings and gluteus maximus muscles, but the stretching force could have been transmitted to the thoracolumbar fascia, thus creating changes in the thoracic spine range of motion.

4.5 Limitations
It is not clear why the current findings fail to identify improvements in the knee extension and SLR tests, but there are four potential explanations to consider. These include: ceiling effect, technique duration, no warm-up, and no pelvic rotation measured.

4.5.1 Ceiling effect
An important limitation inherent in the design, was the potential ‘ceiling effect’ related to the baseline SLR scores in which participants with higher baseline range are less likely to respond to interventions. The ceiling effect can be described as a score limitation at the top of the scale, which can lead to artifactual parameter estimates in data analysis (Na, Ha, & Lee, 2012; L. Wang, Zhang, McArdle, & Salthouse, 2009). In the present study the inclusion criterion for range of SLR was a grade 1 or 2 on the Functional Movement Screening test (FMS). The active SLR on the FMS tested for functional hamstring flexibility, hip mobility and abdominal stability (Cook et al., 2006). The FMS active SLR
test was used due to its defined classification of hip dysfunction, with grade 1 described as relative hip mobility limitation and grade 2 described as minor hip mobility limitations or moderate isolated, unilateral muscle tightness (Cook et al., 2006). However, subjects included in the present study were the upper range of the grade 2 scale, therefore a ceiling effect could have been created in this situation. The average active and passive SLR range value of 68.5° in the present study is just below the normal, expected physiological range of 70°, with a further 16° on average achievable with spinal flexion and rotation (Elson & Aspinall, 2008), but, in this sample was still classified as a grade 2 on the FMS score. In the wider literature, the mean range of the SLR test varies widely, probably due to the different end points used in different studies. These end points include: first onset of stretch in the posterior thigh, firm resistance, physiological end range and the first onset of pain. Other SLR reported averages include; between 50-120° (Troup, 1986), 35° measured from the first onset of a ‘pulling’ sensation (Tanigawa, 1972) and at firm resistance a mean of 85° (Gajdosik, LeVea, & Bohannon, 1985). The normal range of the SLR is also reported as 70-90° of hip flexion, where a sense of ‘tightness’ in the posterior thigh can be felt by the participant (Boland & Adams, 2000; Boyd et al., 2009; Kumar et al., 2012; Wilkinson, Edwards, & Grimmer, 2002). In retrospect, to avoid a ‘ceiling effect’ the FMS categorization would have been most useful as a preliminary screen (e.g. score of 1 or 2), to qualify for SLR measure and satisfying a defined ROM, such as less than 50° active SLR.

4.5.2 Technique duration
A second possible explanation is the short duration of technique administration (‘time under tension’) leading to minimal effect. Due to the viscoelastic properties of tendons, if the technique was only applied in the elastic, first two phases of the stress-strain curve (Levangie & Norkin, 2005), once the load on the tendon was removed the tendon potentially returned to its original structure, with deformation and lengthening not remaining. Further, the rate at which the technique was applied may have been a contributing factor. If the technique was applied too quickly there can be a higher level of muscle stiffness due to the muscle tensile resistance and viscoelastic properties (Knudson, 2006). The duration of the technique and the speed of which the technique was not highly controlled in this study. The absence of control was purposeful in the design, and was intended to be similar to conditions in clinical practice.

4.5.3 No warm-up
Thirdly, a potential explanation for no changes observed in the knee extension and SLR tests, is no warm up was performed during our study. In the absence of a warm up, the mobilisation technique may have only been working on the muscle tendon unit stretch, in its ‘stretching out’ or ‘toe region’ (Levangie & Norkin, 2005; Lorenzo & Caffarena, 2005; J. Wang et al., 2012). In Hall et al.’s., (2001) study Mulligan’s traction SLR on normal subjects, the pre measurements consisted of four SLR repetitions before data was collected. This was done to minimise any SLR changes due to stretch of the muscle tendon unit (T Hall et al., 2001). This could have influenced Hall et al., (2001) results by stretch being eliminated during the warm up and the technique directly working in the plastic phase of the stress-strain curve thus potentially demonstrating deformation of the tendon and creating longer lasting effects in length and viscoelastic properties. The present study did not employ a warm up.
because in normal clinical practice, warm ups are not commonly performed before examination or treatment in typical clinical practice.

4.5.4 Missing pelvic rotation measurement

A fourth limitation of this study is the absence of pelvic rotation measurement, to explain changes identified in the modified Schober’s test of the thoracic spine and the sit and reach test. It has been identified that changes with the sit and reach test could be due contributions of pelvic rotation, hip flexion, and lumbar spine flexion (Czaprowski et al., 2013a; Lopez-Minarro et al., 2012). Czaprowski et al., (2013) study demonstrated a statistically significant improvement in the SLR, popliteal angle with active knee extension and modified standing finger to floor tests. A possible explanation for these changes is improved stretch tolerance (Halbertsma & Goeken, 1994; Knudson, 2006; Spernoga et al., 2001) and changes in pelvic anterior rotation (Czaprowski et al., 2013a; Lopez-Minarro et al., 2012). Along with SLR and the sit and reach test, it would have been beneficial to have measured changes in pelvic rotation pre and post technique application, to identify if changes in SLR are associated with altered pelvic rotation rather than pure hip flexion.

4.6 Further Work

There are limitations to this study that could be addressed in future studies undertaking similar investigations. Firstly, revision of the inclusion criteria, with a SLR value below 50° to avoid a ceiling effect and consideration of including participants with lumbopelvic dysfunction. Secondly, future studies should extend the duration of the technique – increasing time under tension, allowing adequate time for a treatment effect to occur. Also performing a warm up before the technique to avoid treating in the viscoelastic ‘toe region’. Lastly, measuring pelvic rotation to permit identification of pelvic influence on changes in the sit and reach and modified Schober’s tests.
Conclusion
The aim of the present study was to investigate the concepts of regional interdependence with Mulligan’s mobilisation with movement and the effect of a novel mobilisation technique (Mulligan’s traction SLR combined with a post-isometric relaxation). The novel mobilisation technique applied to the hip demonstrated statistically significant changes in the modified Schober’s Tsp and sit and reach tests. The main limitations to the present study included a potential ‘ceiling’ effect with the baseline SLR values, short technique duration (‘time under tension’) and no warm up.
References


Section 2

Appendices
Appendix

Participant Information Sheet

RESEARCH INFORMATION FOR PARTICIPANTS
The efficacy of a modified straight leg raise technique (Mulligan’s traction technique) on lumbar, thoracic, hip and knee range of motion

You are invited to participate in our research investigation. Please read carefully through this information sheet before you make a decision about volunteering.

Principal Researcher
Sarah Woolley (Bachelor of Applied Science (Human Biology)) – Sarah is currently in her first year of the Masters of Osteopathy programme at Unitec New Zealand.

Our Purpose
This study will look to measure the effect of an osteopathic technique on flexibility of the back and legs, in people with perceived hamstring tightness. Hamstring tightness is characterised by not being able to touch your toes.

The primary aim of this study is to investigate the effect of a simple stretching technique, to determine how flexibility of the thigh, hip and lower back may contribute to changes in movement. By taking part in this study you are helping us discover if osteopathic techniques could help people with hamstring tightness. You are also helping us provide initial data for future osteopathic research.

Your voluntary participation
Your participation in this study is entirely voluntary and you may withdraw at any time during the study. Data collected from your involvement in the study may be withdrawn up until one week following your final assessment.

Who may participate?
We are looking for male adults between the ages of 18-40 who perceive they have ‘tight hamstrings’. “Hamstring tightness” is characterised by not being able to touch your toes and ‘tightness’ in the back of your leg. Participants may be included in the study if you have perceived hamstring tightness and restricted range of motion in the spine and hip.
Unfortunately you won’t be eligible to participate in the study if:
- you have a known medical cause for restricted back range of motion or tight hamstrings (such as a recent muscle injury)
- you are currently receiving medical treatment (including physiotherapy, exercise therapy, osteopathy etc)

Please feel free to contact the Sarah if you are unsure about your eligibility.
**What will happen in the study?**

Should you agree to participate in the study, you'll need to attend an initial session which will include a review of your health history and completing some flexibility measures of your back and hip. The study will start one week after the initial session and will include two sessions. These sessions will include one technique session and one follow up session. Both sessions will include the range of motion tests.

**Osteopathic treatment**

The osteopathic treatment will include a single technique which is based on “Mulligan’s traction technique”. The practitioner will apply traction to your leg as you lie on your back and very slowly over the course of 1-2 minutes lift your leg towards the ceiling. You will experience mild to moderate "stretching" sensation in the back of your thigh, however this should not be painful and you are able to cease the technique at any point.

The initial session will take 90-minutes. The second session will involve the osteopathic technique and measurements, which will take 90-minutes. The range of motion measurements will be taken before the technique, immediately after the technique, and one hour after the treatment.

So we can properly assess your flexibility you’ll be required to wear loose shorts. The osteopathic technique to be used has been routinely used in treating muscle and joint problems for many years. The osteopathic treatment will be carried out by a student osteopath currently completing their Masters of Osteopathy program at Unitec New Zealand, and will be supervised by a registered Osteopath.

**Assessments**

The flexibility tests we’re using are all commonly performed in practice and include: a straight leg raise test, forward bending of the back, sit and reach test and knee flexibility. Each test will be performed by the principal researcher.

**What we do with the data and results, and how we protect your privacy.**

Personal information is collected and stored under the guidelines provided by the Privacy Act 1993 and the Health Information Privacy Code 1994. Should you be selected to participate, your name will be recorded on a case history form. However, in all other instances of information collection your identity will remain anonymous and you will simply have an identification number. If the information you provide is reported or published, this will be done in a way that does not identify you as its source. All the data recorded will be stored in a password-locked computer and archived in a locked file cabinet in the office of the supervisor and will be stored for a minimum of 5 years. Access to this data will be limited to the principal researcher (Sarah Woolley), the research supervisor. You’re welcome to have a copy of your information taken during this study.

**Possible risks**

The osteopathic technique used in this study has been used in a clinical context to increase hip and pelvis range of motion in patients with lower back pain.

After the technique is applied, there is a low chance that you may experience mild muscle soreness in the back your thigh. This is rare, and if it occurs is temporary and will only last 24-48 hours without any ongoing complication.

The osteopathic technique used will be discussed prior to application and your further verbal consent will be sought.
Compensation may be available in the unlikely event of injury of negligence
Should you incur a physical injury as a result of your participation in this study, you may be covered by ACC under the Injury Prevention, Rehabilitation and Compensation Act 2002. You may or may not be entitled to ACC compensation, depending on several factors such as whether or not you are an earner. ACC will usually cover a proportion of income lost due to a physical injury, this does not cover mental injury unless as a direct result from a physical injury. ACC cover may affect your right to sue. Please contact your nearest ACC office for further information (0800 735 566) or visit their website: www.acc.co.nz

Please contact us if you need further information about the study.

Contact Details

Sarah Woolley
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UREC REGISTRATION NUMBER: (2010-1099)
This study has been approved by the UNITEC Research Ethics Committee from (date) to (date). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Consent Form

Participant consent form

The efficacy of a modified straight leg raise technique ("Mulligan's traction technique") on lumbar, thoracic, hip and knee range of motion

This form is to ensure that you understand the requirements of your participation and that you are aware of your rights. Please read carefully through the points below. If you are happy and agree with the points the please sign at the bottom. If you have any questions at all please ask the researcher before signing this form.

- I have had the research project explained to me and I have read and understood the information sheet given to me.
- I understand that I may withdraw at any time prior to the completion of the research project.
- I understand that everything I say and the information I provide will be collected in accordance with the Health Information Privacy Code 1994 and kept confidential and in accordance with the Privacy Act 1993. I understand that the only persons who will have access to my information will be the researchers and relevant clinical staff.
- I understand that all the information I give will be stored securely on a computer at Unitec for a period of 5-years.
- I understand that my discussion with the researcher will be recorded on a case history form as per usual clinical policy.
- I understand that I can see the finished research document.
- I have had time to consider the information provided, to ask questions, and to seek any guidance.
- I give my consent to be a part of this project.

Participant Signature: ………………………... Date: ………………………...

Principal Researcher: ………………………... Date: ………………………...

UREC REGISTRATION NUMBER: (2011.XXX)
This study has been approved by the UNITEC Research Ethics Committee from (10 December 2011) to (31 December 2012). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Ethics Approval

Sarah Woolley  
962a Beach Road  
Torbay  
Auckland  

24.5.12

Dear Sarah,

Your file number for this application: 2011-1241  
Title: The efficacy of a modified straight leg raise technique (“Mulligan’s traction technique”) on lumbar, thoracic, hip and knee range of motion.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 25.5.12  
Finish date: 24.5.13

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.

2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely,

Scott Wilson  
Deputy Chair, UREC

CC: Rob Moran  
Cynthia Almeida