The effect of combining muscle energy technique with soft tissue massage on hamstring extensibility

Yashvant Masters

A research project submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy

Unitec Institute of Technology, 2014
Declaration

Name of candidate: Yashvant Masters
This Research Project entitled “The effect of combining muscle energy technique with soft tissue massage on hamstring extensibility” is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

Candidate’s declaration
I confirm that:

- This Research Project represents my own work;
- 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.

Research Ethics Committee Approval Number: 2010-1137

Candidate Signature:               Date:
Abstract

*Introduction:* The implications of reduced muscle extensibility are exemplified by the hamstrings and its effects of lower limb and lumbar mechanics. Reduced hamstring extensibility is often seen in conditions such as patellofemoral disorders, plantar fasciitis, and lower back pain. Osteopaths often use specific stretch techniques that essentially comprise of muscle energy and soft tissue massage to improve muscle extensibility and joint range of motion (ROM). Although commonly applied together, evidence to support the effectiveness of muscle energy technique (MET) combined with a specific cross-fibre soft tissue technique to increase knee joint ROM is scarce.

*Objective:* The aim of this study was to investigate the combined effects of an isometric contraction MET with a soft tissue cross-fibre technique on active knee extension (AKE) and passive knee extension (PKE).

*Design:* Repeated measures cross-over design.

*Methods:* 20 asymptomatic participants (aged 18-45) with a PKE angle of 20 degrees or more were pseudo-randomised to two counterbalanced groups. Group 1 (n=10) received MET and cross-fibre soft tissue and 7 days later received MET only. The same treatments in reverse order were performed on Group 2 (n=10). Measurements for AKE, PKE and passive elastic force were recorded pre and post-intervention.

*Results:* A three-way mixed-method multivariate analysis of variance (MANOVA) revealed a significant overall effect of time indicating that all measures improved following the interventions, regardless of the intervention. Greater improvements were seen in PKE ($p=0.041$) and passive force ($p=0.005$) with MET combined with soft tissue treatment, than with MET alone in both groups. No significant intervention effect for the AKE measure was observed ($p=0.55$).

*Conclusion:* This study demonstrated that adding cross-fibre soft tissue massage to MET improves passive knee ROM more than MET alone, due to an increase in stretch tolerance as measured by changes in passive force. However, both interventions failed to show any significant improvements in AKE.
**Key words:** Active knee extension, hamstring extensibility, muscle energy technique, passive knee extension, soft tissue massage.
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**Introduction to thesis structure**

This thesis is comprised of three main sections

1. **Review of Literature**
The review of relevant literature provides the theoretical basis and rationale for the study reported in the manuscript.

2. **Manuscript**
The manuscript is in the format specified for submission to the International Journal of Osteopathic Medicine.

3. **Appendices**
The appendices provide ethics documentation and other important documents.
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<tr>
<td>AKE</td>
<td>Active knee extension</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>CR</td>
<td>Contract-relax</td>
</tr>
<tr>
<td>(d)</td>
<td>Effect size (Cohen's d)</td>
</tr>
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<td>EMG</td>
<td>Electromyography</td>
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<tr>
<td>H-reflex</td>
<td>Hoffman reflex</td>
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<tr>
<td>MANOVA</td>
<td>Multivariate analysis of variance</td>
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<tr>
<td>MET</td>
<td>Muscle energy technique</td>
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<tr>
<td>MVIC</td>
<td>Maximal voluntary isometric contraction</td>
</tr>
<tr>
<td>(n)</td>
<td>Sample size</td>
</tr>
<tr>
<td>PNF</td>
<td>Proprioceptive neuromuscular facilitation</td>
</tr>
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<td>PKE</td>
<td>Passive knee extension</td>
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<tr>
<td>ROM</td>
<td>Range of motion</td>
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<tr>
<td>(s)</td>
<td>Seconds</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
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<tr>
<td>ST</td>
<td>Soft tissue</td>
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Section One: Literature Review
1. Introduction

Normal or ideal range of muscle extensibility is thought to promote optimal joint kinematics and have the potential to reduce the risk of injury (McCreary, Provance, Rodgers, & Romani, 2005; Weppler & Magnusson, 2010). When a muscle displays insufficient extensibility and is considered ‘short’ or ‘tight’ the motion between joint surfaces may be reduced, resulting in restricted joint range of motion (ROM) (McCreary et al., 2005). When a muscle shows excessive extensibility, the motion between joint surfaces may be disproportionately larger resulting in excessive joint ROM (McCreary et al., 2005). In both cases, an aberration from optimal extensibility is believed to precipitate abnormal wear patterns on the articular surfaces and capsular structures of the involved joints (Scott K Lynn & Costigan, 2009; McCreary et al., 2005; Weppler & Magnusson, 2010).

The hamstring muscle group is frequently observed to have reduced muscle extensibility (Nagarwal, A.K, Zutshi, K, Ram, C. S, & Zafar, R, 2009) with authors identifying consequent effects on lower limb and lumbar mechanics (Harty et al., 2005; Massoud et al., 2011; Nourbakhsh et al., 2006; White et al., 2009). This review defines muscle extensibility and describes the different components of extensibility. It then explores reduced muscle extensibility in the hamstring muscle group and the effect this has on the lower limb and spine. Finally, it considers the current evidence relating to the efficacy of treatments aimed at improved hamstring extensibility, and its effect on lower limb and spine mechanics and pain.
2. Muscle Extensibility

Muscle extensibility can be defined as the ability of a muscle to extend from a resting position to a predetermined endpoint, in which the joints maximal ROM reflects the muscle’s maximal length (Blackburn, Padua, Riemann, & Guskiewicz, 2004; Gajdosik, 2001; Weppler & Magnusson, 2010). Muscle extensibility is further defined as the ability of skeletal muscle to lengthen without muscle activation (Gajdosik, 2001; Weppler & Magnusson, 2010). It is also the distance that is achieved between an initial muscle length and the maximal muscle length (Gajdosik, 2001). When a muscle is passively stretched from a shortened position, the first point of resistance that is experienced is called initial passive resistance (Chaitow, 2006a; Gajdosik, Rieck, Sullivan, & Wightman, 1993).

Muscle extensibility is one aspect of muscle length, with muscle length said to be directly proportional to the number of sarcomeres in series found within the muscle (Hamill & Knutzen, 2003; Levangie & Norkin, 2005; Weppler & Magnusson, 2010). The muscle-tendon unit, which contains the sarcomeres, is the anatomical and physiological unit responsible for muscle contraction and thus voluntary joint movement (Hamill & Knutzen, 2003). The tendon itself is composed of dense regular connective tissue and is part of the series elastic component of the muscle-tendon unit which has minimal length extensibility properties (Gajdosik, 2001; Hamill & Knutzen, 2003). The muscle belly contributes largely to the overall passive length-tension relationship during muscle stretching (Blackburn et al., 2004; Gajdosik, 2001).

Muscle length is considered multi-dimensional as there are several elements that are important to understand when assessing changes in muscle extensibility (Weppler & Magnusson, 2010). Other measures such as tension, cross-sectional area, and time are used to assess important biomechanical elements of muscle extensibility such as stiffness, compliance, energy, hysteresis, stress, viscoelastic stress relaxation and creep, which are all relevant in understanding muscle length extensibility (Weppler & Magnusson, 2010).

Length tests are used by the clinician to assess excessive or limited muscle extensibility. In a clinical setting it is most common for length tests to demonstrate reduced muscle extensibility or what it synonymously known as muscle tightness or shortness. The latter terms are
subjective and are often used interchangeably within literature. Muscle tightness is considered an increase in tension from either active or passive mechanisms. Muscles can actively shorten through spasm or contraction; or passively through postural adaptation and scarring. Irrespective of the presence of active or passive mechanisms, muscle tightness causes a restriction in joint ROM which can create muscle imbalances (Myers, 2001; Phil Page, 2012; Phillip Page, Frank, & Lardner, 2010; Ward, 2003). It is important for muscles to achieve sufficient extensibility not only to allow for adequate joint ROM, but also to produce the necessary amount of active and passive tension that is required to stabilise a joint during movement (Weppler & Magnusson, 2010).

Muscle tissue is deformable with the change in its length at a particular moment in time being dependent on the tensile force that is applied (Weppler & Magnusson, 2010). The tension of a muscle is therefore defined as the passive resistance of a stretched muscle and equates to the applied tensile force (Weppler & Magnusson, 2010). Other terms such as flexibility and passive stiffness can sometimes be used to describe maximal passive joint ROM. Accurate understanding of these terms is necessary as flexibility and passive stiffness represent a physiological relationship of passive resistive forces and the passive length of the muscle as it is stretched (Gajdosik, 2001; Weppler & Magnusson, 2010). The term passive stiffness (or passive elastic stiffness) is the physiological change that occurs during the dynamic phase of stretching. It is defined as the change in ratio of passive resistance to the change in muscle length (Weppler & Magnusson, 2010). Other biomechanical properties of muscle length include viscoelastic stress relaxation and creep (Weppler & Magnusson, 2010). Viscoelastic stress relaxation is the decline in resistance to stretch shown as a percentage of the initial resistance (Gajdosik, 2001; Weppler & Magnusson, 2010).
3. Reduced Hamstring Extensibility

The effect of reduced muscle extensibility in the hamstring muscles has been extensively researched in literature. It has been reported that reduced hamstring extensibility has a wide range of effects on lower extremity and lumbo-pelvic mechanics. It is believed this is due to the complexity of the hamstring attachments, as it crosses both the hip and knee joints (Schuenke et al., 2006). The hamstring muscle group has its proximal insertion at the ischial tuberosity. Its distal insertions include the medial surface of the tibia at the pes anserine junction, the medial tibial condyle, and the fibular head. Authors believe this complex array of insertions allows decreased extensibility of the hamstrings to contribute to impaired function in the lower limb and lumbo-pelvic region (Gray, 1995; Hamill & Knutzen, 2009). Such impairments are caused when hamstring tension is increased and contribute to altered gait, patellofemoral joint dysfunction, plantar fasciitis and low back pain.

3.1. The influence of hamstring extensibility on gait

It has been proposed that an increase in tension of either medial or lateral hamstrings can alter the rotation patterns of the tibia on the femur and prevent adequate extension during normal gait (Stewart, Jonkers, & Roberts, 2004; Whitehead, Hillman, Richardson, Hazlewood, & Robb, 2007). Altered gait patterns can result in unusual wear patterns on the cartilaginous structures of the knee, and exacerbate anterior or medial knee pain (Elias et al., 2011; Scott K. Lynn, Kajaks, & Costigan, 2008). Substantial reductions in hamstring extensibility are, however, needed before significant changes in gait are apparent (Whitehead et al. (2007). Whitehead et al. (2007) investigated the effect on gait of simulated and isolated hamstring shortening in six healthy females. Imposed hamstring shortening at different lengths was conducted with the use of an adjustable brace to simulate three hamstring lengths: long (55° of knee flexion), medium (85°) and short (115°). Evaluation of the gait analysis showed that the imposition of fixed hamstring lengths with the knee extended to 85 degrees° and above produced significant adverse effects on gait which included: reduced speed, stride and step length; decreased hip flexion and increased knee flexion during stance; greater posterior pelvic tilt, lesser pelvic obliquity and rotation; and premature ankle dorsi- and plantar-flexion in stance. The results of this study are in concordance with other studies that have analysed reduced hamstring extensibility and gait (Arnold, Thelen, Schwartz, Anderson, & Delp, 2007; Cooney, Sanders, Concha, & Buczek, 2006). Whitehead et al. (2007) believe that adequate
hamstring length is essential for a normal gait. Although ‘adequate’ was individual, it was observed that some participants had evident hamstring shortening on physical examination yet minimal changes in gait.

3.2. The influence of hamstring extensibility on the patella-femoral joint

A possible cause for anterior patellar pain and antero-medial knee pain is reduced hamstring extensibility (Whyte, Moran, Shortt, & Marshall, 2010). Reduced hamstring extensibility causes posterior translation and external rotation of the tibia, changing the angle between the femur and tibia and thus placing a greater amount of stress on the pes anserine junction and patellar (Blackburn et al., 2004; Elias et al., 2011; Kwak et al., 2000). This biomechanical alteration in patella posture contributes to and exacerbates patella-femoral disorders (Hamill & Knutzen, 2009). In support of this premise, several authors have reported that individuals with patellar pain were more likely to have reduced hamstring extensibility than those without pain (Mousavi & Norasteh, 2011; White et al., 2009; Whyte et al., 2010). White et al. (2009) identified that passive hamstring extensibility was significantly reduced in those with patella-femoral pain (145.6° ± 8.7°) compared with asymptomatic individuals (153.7° ± 10.1°). These findings support the premise that hamstring extensibility is a contributing factor or possibly a predisposing factor to altered knee mechanics and patella-femoral pain. It is, however, unclear if reduced hamstring extensibility is the cause or an effect of patellofemoral pain as stated by White et al. (2009).

It has been hypothesised that reduced hamstring extensibility can shift the patellar laterally, transferring the pressure from the medial cartilage to the lateral cartilage of the patella. This shift can predispose to abnormal wear patterns. This phenomenon is supported by Elias et al. (2011) who found that as hamstring tension increased the patellar reciprocated by flexing and shifting laterally. Elias et al. (2011) concluded that this altered position is associated with an increase in patella-femoral pressure, which can further precipitate abnormal loading and subsequent wearing of the underlying patella cartilage. This finding reflects the deleterious effects of reduced hamstring extensibility on the function of the patellofemoral joint and indicate that any misalignment can cause pain (Elias et al., 2011).
3.3. The influence of hamstring extensibility on plantar fasciitis

Plantar fasciitis is a repetitive micro-trauma overload injury that occurs near the proximal attachment of the plantar fascia (Healey & Chen, 2010; Labovitz, Yu, & Kim, 2011). It has been indicated that reduced hamstring extensibility is a possible aetiological factor in the development of plantar fasciitis (Aranda Bolivar, Munuera, & Polo Padillo, 2013; Harty et al., 2005; Labovitz et al., 2011), and can increase the risk of developing plantar fasciitis by 8.7 times (Labovitz, Yu, & Kim, 2011). Harty et al. (2005) explored the possible reasons for the increased risk of plantar fasciitis due to reduced hamstring extensibility. The authors reported that reduced hamstring extensibility limited knee extension, which induced prolonged fore-foot loading pressure during gait, creating prolonged tension in the plantar fascia. The relationship between hamstring and plantar fascia tension was further discussed in a study by Aranda Bolivar et al. (2013) who used the straight leg raise test to measure hamstring muscle tightness in those with and without plantar fasciitis. The authors reported significant differences in straight leg raise ROM between those with plantar fasciitis (56.8°±9.8°) and those in a control group (85.9°±11.5°). It can be assumed that reduced hamstring extensibility creates a functional deficit on the plantar fascia through increased tension and mechanical stress.

3.4. The influence of hamstring extensibility on pelvic tilt and the lumbar spine

Pelvic tilt is defined as the degree to which the position of the pelvis rotates from the horizontal position when observed in the sagittal plane (Congdon, Bohannon, & Tiberio, 2005). A common reference line running from the anterior inferior iliac spine to the posterior superior iliac spine is used to determine the angle of pelvic tilt with a pelvic inclinometer (Rockey, 2008). Given that the hamstring muscles originate at the ischial tuberosity, it appears logical that hamstring tension can influence pelvic tilt during hip flexion (Congdon et al., 2005; Gajdosik, Albert, & Mitman, 1994; Gajdosik, Hatcher, & Whitsell, 1992; Kendall, McCreary, & Pro Vance, 2005; Li, McClure, & Pratt, 1996). Previous theories have suggested that poor hamstring extensibility results in a posterior pelvic posture, which reduces lumbar spine lordosis and consequently effects the mobility of the lumbo-pelvic region (Bridger, Orkin, & Henneberg, 1992; Hamill & Knutzen, 2003; Kendall et al., 2005; Kuchera, 2003; McCreary et al., 2005). Research to support this phenomenon is, however, varied. Contrary to the theory that reduced hamstring extensibility causes posterior pelvic tilt, Gajdosik et al. (1992) reported that individuals with reduced hamstring extensibility showed
no significant difference in pelvic tilt or altered lumbar spine lordosis compared to those with normal hamstring extensibility. Gajdosik et al. (1992) did, however, report that anterior pelvic tilt during forward bending was greatly limited in those with (52°±9°) compared to those without (72°±4°) reduced hamstring extensibility. Gajdosik et al. (1994) later found that those with reduced hamstring extensibility had increased thoracic mobility during forward bending compared to those without. The results from the latter study confirmed that tight hamstrings cause a greater compensatory influence of the thoracic region during forward flexion when a pelvic restriction is present. The importance of this phenomenon is reflected in manual workers performing lifting tasks, as discussed below.

It has been proposed that reduced hamstring extensibility plays a significant role in excessive loading of the spine during manual lifting tasks. In support of this, Carregaro and Gil Coury (2009) reported that individuals with reduced hamstring extensibility are at greater risk of injury as they adopt a more posterior tilted pelvis during manual lifting. The compensatory posterior pelvic tilt creates excessive flexion of the lumbar spine during lifting. The impact of this compensation thus increases the intra-discal pressure and anterior shear forces on the elastic structures of the spine (López-Miñarro & Alacid, 2010). Thus, increasing the risk of injury (Hamill & Knutzen, 2009).

3.5. The lower crossed syndrome
One of the most clinically significant findings in patients with non-specific low back pain is reduced hamstring extensibility (Marshall, Mannion, & Murphy, 2010; Massoud et al., 2011; Nourbakhsh et al., 2006; Nourbakhsh & Massoud, 2002; Tafazzoli & Lamontagne, 1996). While reduced hamstring extensibility is a common finding in patients with low back pain (Halbertsma, Göeken, Hof, Groothoff, & Eisma, 2001; Wong & Lee, 2004), authors have proposed that this phenomenon is a compensatory mechanism to control excessive lumbar spine lordosis, and is caused by specific patterns of muscle impairments known as ‘pelvic crossed syndrome’ or ‘lower crossed syndrome’(Chaitow, 2006b; Jull & Janda, 1987; Kendall et al., 2005; Massoud et al., 2011; Nourbakhsh et al., 2006). This theory proposes that a specific muscle imbalance exists in which tightness and over activity of the hip flexors and low back extensors (postural muscles) coexists with underactive lower abdominal and gluteal (phasic muscles) (Chaitow, 2006b; Nourbakhsh et al., 2006). The imbalance results in
anterior pelvic tilt, hyper-lordosis and restriction of the lumbar spine (Chaitow, 2006b; Phillip Page et al., 2010).

A recent study by Massoud et al. (2011) examined the relationship between hamstring extensibility and gluteal muscle strength in 159 participants (aged 20 - 65) with and without low back pain. The participants were categorised into one of three groups: low back pain with \((n=53)\) and without \((n=53)\) sacroiliac joint dysfunction and those with no back pain \((n=53)\).

The results from this study showed that hamstring extensibility was not significantly different \((p=0.31)\) in those with and without sacroiliac joint dysfunction. However, within the sacroiliac dysfunction group, those with gluteal weakness had significantly reduced hamstring extensibility \((158°±11°)\) compared to those without gluteal weakness \((165°±10°)\) \((p=0.02)\). This suggests a biomechanical correlation between hamstring and gluteal muscle function. In the other groups no statistically significant differences in hamstring extensibility were found in those with and without gluteal muscle weakness. They concluded that reduced hamstring extensibility seen in participants with sacroiliac joint dysfunction may be attributed to gluteal weakness (Massoud et al., 2011). As lumbar lordosis was not measured this study can only partially support the principles of the lower crossed syndrome. Furthermore, no studies were found that supported a relationship between reduced lumbar lordosis and lower back pain (Arab & Nourbakhsh, 2014; Nourbakhsh et al., 2006).

The mechanical link between impaired muscle patterns of the lower crossed syndrome is, however, explained by inhibited and weakened gluteal muscles, causing sacroiliac joint dysfunction. This aspect of the lower crossed syndrome is further supported in literature as the gluteus maximus and long head of the biceps femoris are both involved in the stability of the sacroiliac joint as they provide fibres to the sacrotuberous ligament and long dorsal ligaments at the ischial tuberosity (DeRosa & Porterfield, 2007; van Wingerden, Vleeming, Kleinrensink, & Stoeckart, 1997). If the gluteal muscles are weakened, the tension on the ligament is reduced. Consequently, the hamstrings are thought to compensate for this reduced ligament tension by tightening to improve sacroiliac joint stability (Massoud et al., 2011). It is important to note that most of the studies reviewed reported hamstring muscle tightness in individuals with low back pain, yet failed to differentiate between the sources of pain in the lumbar or sacral region. Further research is needed to identify the effects of both muscle impairments (muscle weakness and muscle shortness) collectively as it is difficult to ascertain
whether the cause was due to individual patterns of muscle impairments or both. Also, from a clinical perspective, further research is required to study the therapeutic value of strengthening gluteal muscles and lengthening hamstring muscles in patients with low back pain.
4. Stretching and Muscle Extensibility

The previous sections of this literature review have defined muscle extensibility and discussed the effect of reduced hamstring extensibility on mechanics of the lower extremities and the lumbo-pelvic region. The current literature suggests that reduced hamstring extensibility can cause altered gait patterns (Whitehead et al., 2007) and may precede the development of patella-femoral joint dysfunction (Elías et al., 2011; White et al., 2009), plantar fasciitis (Aranda Bolivar et al., 2013; Harty et al., 2005) and low back pain (Massoud et al., 2011; Nourbakhsh et al., 2006).

Manual therapists believe that maximum muscle extensibility is vital for maximum joint ROM (Folpp, Deall, Harvey, & Gwinn, 2006; Phil Page, 2012) and that reduced muscle extensibility can influence functional activities and athletic performance (Sexton & Chambers, 2006; Worrell, Smith, & Winegardner, 1994). There are many therapeutic interventions used by manual therapists that are designed to improve muscle extensibility and joint ROM. Such techniques include static stretching, massage therapy, proprioceptive neuromuscular facilitation (PNF) stretches and muscle energy technique (MET). These techniques are often employed as an important component of physical rehabilitation. For the purpose of this review both MET and PNF will be classified as contract-relax (CR) techniques due to their underlying similarities, unless clearly stated. Sections 4 through to 6 of this review will focus primarily on the role of static stretching, massage therapy and CR technique in the treatment of reduced muscle extensibility.

4.1. Stretching to improve muscle extensibility

Stretching exercises are frequently utilised and prescribed in manual therapy and are often the primary focus of rehabilitation (Phillip Page et al., 2010). The purpose of stretching is to prevent shortening and tightening of muscles. Stretching can also improve functional joint ROM by increasing the elasticity of not only muscles but tendons, fascia, ligaments and the joint capsule (Ylinen, 2008). Stretching to maintain adequate muscle extensibility has been largely advocated in physical rehabilitation as it is required to achieve physical movement and ideal joint postures (Levangie & Norkin, 2005). Individual lifestyles and professions may vary in their physical demands; an individual who is desk bound may not require normal joint ROM, whereas individuals involved in more physically demanding jobs may require greater
mobility of their extremities and spine (Carregaro & Gil Coury, 2009; Ylinen, 2008). Moreover, physical hobbies and sports involve greater demands on unilateral muscles due to specific movement patterns (Ylinen, 2008). With this in mind, increasing joint stiffness and reduced muscle extensibility is becoming more prevalent (Ylinen, 2008). It is, therefore, necessary for individuals to engage in stretching procedures to maintain adequate joint ROM that caters to the demands and physical requirements of their jobs. In a clinical setting, there are several factors which can limit muscle extensibility and joint ROM such as pain, muscle spasm, soft tissue adhesions, contractures and immobilisation, all of which can be improved through specific stretching procedures (Arab & Nourbakhsh, 2014; Ylinen, 2008).

4.2. Viscoelastic deformation during static stretching

Many studies have suggested that the immediate increase in joint ROM that is found after stretching is due to viscoelastic deformation (McHugh, Magnusson, Gleim, & Nicholas, 1992; Webright, Randolph, & Perrin, 1997). Mechanical elongation of muscle is thought to be ascribed to the viscoelastic properties of connective tissue. The term ‘viscoelastic’ is coined through the combined effect of viscous and elastic properties of muscle fibres, which undergo changes when a stretch is applied (Leveau, 1992). Muscle displays elasticity which implies that changes in muscle length are directly proportional to the applied force. These elastic properties allow the muscle to return to its original length after a stretch is applied and the tensile force is removed. The factors that influence these elastic behaviours are dependent on the load of the stretch that is applied (Leveau, 1992; Taylor, Dalton, Seaber, & Garrett, 1990), whereas the factors that influence the viscous behaviours of a muscle are dependent on the velocity of the applied stretch, which itself is dependent on rate and time (Gajdosik, Lentz, McFarley, Meyer, & Riggin, 2006; Weppler & Magnusson, 2010).

Viscoelastic deformation can be observed when a static stretch is applied to a muscle for a period of time and is expressed as the gradual decline in resistance of the muscle to the stretch. It is difficult to separate these two properties of muscle with regard to the cause of passive resistance to stretching, although it is known that immediately after a passive stretch is performed viscoelastic energy is lost causing a decrease in passive resistance. In contrast, a constant load stretch where the applied stretch uses a fixed torque can be used to assess creep, which is defined as the increase in muscle length in response to a constant stretch (Taylor et
al., 1990; Weppler & Magnusson, 2010). Creep is another viscoelastic property and is characterised by ‘continued deformation at a fixed load’ (Taylor et al., 1990).

4.3. Stretch tolerance change during static stretching
Viscoelastic deformation is evident when the torque required to reach a constant joint ROM is less following a static stretch, or when the torque remains constant yet the joint ROM increases (Ballantyne, Fryer, & McLaughlin, 2003). If the degree of torque is not standardised, the maximum joint ROM achieved may correspond to an individual’s change in perception of discomfort masking any evidence of ‘real’ changes to muscle extensibility (Huang et al., 2010). This mechanism is known as stretch tolerance. Following a static stretch, stretch tolerance occurs when a joint’s ROM increases with an increased torque measurement. This suggests that an individual is able to apply a greater tensile force to achieve greater extensibility. Similarly, joint ROM measurements can be influenced by individuals if they self-administer a greater stretch torque as their tolerance to stretch rises (Folpp et al., 2006; Magnusson, Simonsen, Aagaard, & Kjaer, 1996). It is, therefore, important to measure torque with joint ROM to discover whether the measured increase in ROM is from viscoelastic change or increased stretch tolerance.

4.4. The effect of stretching on reduced muscle extensibility
Static stretch is often used to improve muscle extensibility and joint ROM (Gajdosik, 1991). Several authors have found evidence to support this notion (Arabaci, 2008; Arazi, Asadi, & Hoseini, 2012; Gajdosik, 1991). Static stretching often consists of slow controlled movement of a joint towards its end range or until a stretch sensation is experienced and is held for up to 60 seconds (Gajdosik, 1991). A study by Arabaci (2008) investigated the effects of static stretch utilizing the sit-and-reach test to assess lower limb muscle extensibility. The study used a 15-minute static stretch protocol in which the flexors and extensors of the hip and knee, adductors, and plantar flexors were targeted. Each muscle was stretched for a period of 20-seconds followed by a 10-second rest period and repeated three times. The results from this study indicated that a 15-minute static stretch protocol was able to provide significant increases in sit-and-reach test scores. A more recent study by Arazi et al. (2012) investigated the same static stretch protocol on the lower limb as Arabaci (2008) and also found significant improvements in sit-and-reach test scores. However, the results from Arabaci (2008) and Arazi et al. (2012) should be interpreted with caution as they contain several
limitations. Both studies used male athletes who were involved in training programs at the time of the study. Both studies failed to control for the amount of training prior to testing, which may have altered test results as some athletes were from different sporting backgrounds and their level of activity may have varied. In addition, trained athletes may be less susceptible to stretching induced changes of muscle extensibility (Gajdosik, 1991). Therefore, the results from these studies cannot be generalised to females and those who are not actively involved in sport.

The effect of stretching on viscoelastic deformation is minimal, short-lived (Magnusson, Aagaard, & Nielson, 2000; Magnusson, Simonsen, Dyhre-Poulsen, et al., 1996) and has little to no wash-over effect on subsequent stretches performed in sequence (Magnusson et al., 2000). Although these studies measured only the immediate effects of static stretch, the temporal effects of static stretch and muscle extensibility have been found to last up to 2-hours (Gajdosik, 1991; Magnusson, 1998). However, this is debateable as some authors have found contradicting results. Magnusson et al. (2000) measured the short term effect of a 45-second static stretch to the hamstring muscle group. A total of three static stretches were performed, each followed by a 30-second interval. The authors reported no significant short term effect on subsequent stretches performed 30-seconds later. Each stretch showed a viscoelastic deformation response of 20% during the holding phase of the static stretch.

This was further demonstrated by Folpp et al. (2006) who reported that long term increases in muscle extensibility were due to increased tolerance to stretch rather than viscoelastic deformation. Folpp et al. (2006) investigated the effects of a static stretch administered five days a week over a 4-week period. Measurements were taken for ‘real’ hamstring muscle extensibility, which was defined as the angle of hip flexion corresponding with the greatest torque each participant could tolerate in the application of a standardised torque. The ‘apparent’ hamstring muscle extensibility (changes in stretch tolerance) was measured in a similar way with the exception of a non-standardised stretch torque in which the highest stretch torque that participants could tolerate was recorded. The authors reported that the overall treatment effect with the standardised torque was -1° (95% CI –4° to 3°), indicating that there were negligible changes in ‘real’ hamstring extensibility. Significant changes were, however, observed in the non-standardised treatment group showing a mean treatment effect
of 8° (95% CI 5° to 12°). This indicated that increased muscle extensibility in the hamstrings was due to increased stretch tolerance rather than any long term viscoelastic deformation.

4.5. Altered sarcomere numbers and muscle length

It has been theorised that stretch-induced increases in muscle length due to sustained stretch may be attributed to muscle length adaptations such as the addition of sarcomeres (Weppler & Magnusson, 2010). Several authors have found that a reduction in the number of sarcomeres due to muscle atrophy from immobilization in shortened positions has been associated with decreased tensile properties and a reduction in muscle length (Gossman, Sahrmann, & Rose, 1982; Tabary, Tabary, Tardieu, Tardieu, & Goldspink, 1972; Williams & Goldspink, 1973, 1978). Indeed, this phenomenon has been observed by Tabary et al. (1972) who examined the soleus muscles of cats and noted a 40% reduction in number of sarcomeres when placed in a plaster cast in a shortened position. Williams and Goldspink (1973) also found that immobilization of muscles prevented the adequate development of sarcomeres. In both studies, the muscle length and number of sarcomeres returned to normal shortly after the plaster casts were removed. The reverse was found for the soleus muscle placed in a lengthened position with a 19% increase in sarcomeres (Tabary et al., 1972). The findings from these studies show that muscle tissue is adaptable and that the number of sarcomeres and the length of sarcomeres, as well as the length of the muscle fibres can adjust to new functional lengths when placed in immobilized shortened or lengthened positions. The number of sarcomeres is either increased or decreased to allow for the minimum number of functional overlaps of the myosin-actin cross bridges with regard to its current length (Tabary et al., 1972). The majority of the research on altered sarcomere numbers is derived from animal studies, which therefore makes it difficult to generalise to humans.
5. **Massage Therapy and Muscle Extensibility**

Massage therapy aims to stimulate the proprioceptive receptors of the skin and underlying tissues through touch and pressure (Weerapong, Hume, & Kolt, 2005) and is believed to improve mechanical function of the musculoskeletal system leading to improved joint ROM (Arazi et al., 2012; Hopper et al., 2005; Huang et al., 2010; Rushton & Spencer, 2011; Wiktorsson-Möller, Oberg, Ekstrand, & Gillquist, 1983). It has been proposed to increase the extensibility of soft tissue including muscle, tendon, fascia, the joint capsule and ligaments, by preventing the formation of fibrosis and adhesions (Crosman, Chateauvert, & Weisberg, 1984). The effects of massage therapy are presumably produced by more than one mechanism and it is speculated that it has a wide influence on the body through biomechanical, neurological, and psychological mechanisms. This review will explore the proposed mechanisms, whereby massage improves joint ROM.

5.1. **Biomechanical mechanisms of massage therapy**

Massage therapy involves the use of biomechanical pressure exerted on deformable muscle tissue for the purpose of improving muscle extensibility and joint ROM. It is said to improve muscle-tendon unit compliance by reducing its active and passive stiffness (Weerapong et al., 2005). Increased muscle-tendon unit compliance is achieved by mobilising soft tissue and elongating shortened or adhered fibrous connective tissue (Hemmings, 2001; Weerapong et al., 2005). However, there is an absence of experimental research to support this.

There is limited literature regarding the effects of massage therapy on improving joint ROM. Crosman et al. (1984) studied the effects of a standardised 9-12 minute massage routine to the hamstring muscle group in 34 females aged 18-35. Participants were healthy, asymptomatic individuals and were randomised into a massage group or a control group. Clinical outcome measures were taken pre- and post-treatment and at a 7-day follow-up. Outcome measures of hamstring extensibility were the passive knee extension test and the straight leg raise test. The intervention comprised a combination of massage techniques including deep effleurage, stretching effleurage, petrissage, and friction. The results showed that those in the intervention group achieved a significant, immediate increase in the straight leg raise test of 10.6° (±8.63°), with a ‘very large’ effect size (Cohen’s d =1) and an increase in passive knee extension of 3.74° (±3.08°). This evidence suggests that massage therapy to the hamstring
muscle group can improve immediate muscle extensibility. All measurements did, however, show significant reductions in all outcome measures. As there was no control for time and speed during the straight leg raise test, and the number of repetitions used during testing was not stated, measurement bias was introduced. This may account for the control group demonstrating an improvement in straight leg raise of $2.4^\circ$ ($\pm6.31^\circ$), possibly due to the stretch induced effects of the testing procedures. The addition of torque as an outcome measure would aid in determining whether the observed increase in ROM was due to a change in viscoelastic properties or due to an increase in tolerance to stretch.

There is difficulty in determining the effect of massage therapy on muscle extensibility as studies have used a variety of different massage stroke types. For example, Rushton and Spencer (2011) investigated the effects of a dynamic passive knee extension stretch of 45-seconds followed by a 30-second application of a transverse medial glide soft tissue technique over the musculo-tendinous junction of the biceps femoris. The passive knee extension test was performed again following massage. The end-point measurements for pre- and post- intervention passive knee extension tests were taken at a point subjectively determined by the participant. ROM and passive torque were measured. The results from this study showed both an increase in passive knee extension and a decrease in passive resistance as measured by changes in passive torque. They concluded that the increase in ROM was partially explained by a reduction in passive resistance via a viscoelastic stress relaxation response of the musculo-tendinous junction (Rushton and Spencer, 2011). However, as in the study by Crosman et al. (1984), the methodological issue of measurement bias was introduced as no pre-determined torque or joint angle was used for the passive knee extension test as in other studies (Ballantyne, Fryer, & McLaughlin, 2003; Folpp et al., 2006; Hilbert, Sforzo, & Swensen, 2003). This makes it challenging to ascertain whether the changes observed were due to a viscoelastic response or increased stretch tolerance.

Similar results were found by Huang et al. (2010) who investigated the effectiveness of a short duration friction massage to the musculo-tendinous junction of the hamstrings muscle on 10 female participants. Each participant received three interventions over a 1-week period. The interventions were: no massage; a 10-second massage; and a 30-second massage. Results demonstrated that a single application of either a 10- or 30-second massage could improve passive straight leg raise ROM by 5.9% and 7.2%, respectively. However, unlike Rushton
and Spencer (2011), no change in passive tension was observed as measured by changes in torque. It could be concluded that as there was no change in torque, the underlying mechanism for increased joint ROM can be attributed to mechanical deformation.

Both of the above studies used only female participants, making it less generalisable to the population as gender differences in muscle extensibility have been previously demonstrated (Doriot & Wang, 2006; Feland, Myrer, & Merrill, 2001; Granata, Wilson, & Padua, 2002; Miller, MacDougall, Tarnopolsky, & Sale, 1993). Huang et al. (2010) and Rushton and Spencer (2011) focussed their massage interventions on the musculo-tendinous junction. Huang et al. (2010) used the passive straight leg raise test to assess changes in hip ROM compared to the passive knee extension test used by Rushton and Spencer (2011). The passive straight leg raise test is considered less effective than the passive knee extension test in detecting changes in ROM as it is commonly used as a sciatic nerve tension test, with possibility of neural tension interfering with accurate measures of hamstring extensibility (Gajdosik et al., 1993; Gill, Wilkinson, Edwards, & Grimmer, 2002). Furthermore, the studies used multiple types of massage strokes as used in Swedish style massage, or solely friction massage at the musculo-tendinous junction. To this author’s knowledge, no study has been identified that investigated the effect of a specific massage stroke, or a technique focussed on the entire muscle.

5.2. Neurological mechanisms of massage therapy

The neurological effects of massage are thought to be caused by stimulation of sensory receptors which can trigger an inhibitory effect on the motor neurons, thus decreasing neuromuscular excitability and reducing muscle tension (Weerapong et al., 2005). The Hoffman reflex (H-reflex) is used to measure neuromuscular excitability and is considered an electrical analogue of the stretch reflex (Weerapong et al., 2005). Few studies have shown the effect of massage on neuromuscular excitability as measured by the changes in the amplitude of the H-reflex. Sullivan, Williams, Seaborne, and Morelli (1991) found that a 4-minute petrissage massage to the triceps surae muscle produced a significant decrease in amplitude of the H-reflex by approximately 50% compared to a control receiving no massage. Current literature has failed to explain the relationship between massage induced reductions in electromyography (EMG) activity, passive muscle tension, and ROM. Huang et al. (2010) measured EMG activity alongside hip ROM and passive hamstring tension. Their results
showed that despite increased hip ROM after a single short duration massage, EMG activity was not altered nor was passive hamstring tension.

The degree of pressure applied during the massage procedure may influence the neuromuscular excitability. Goldberg, Sullivan, and Seaborne (1992) studied the effects of different massage pressures on EMG activity. It has been found that both light and deep massage pressures can produce significant reductions in EMG activity as observed by reduced amplitudes of the H-reflex. However, the deeper massage pressures were found to produce greater reductions in H-reflex amplitude. However, there are conflicting results within the literature on the effects of massage on EMG activity. Some authors have found that EMG activity decreases after massage is applied (Goldberg et al., 1992; S. J. Sullivan et al., 1991), while others have found no change (Huang et al., 2010). The differences in these studies may be due to small sample sizes used and the testing procedures employed. Therefore, further research is needed to determine whether massage therapy can induce a change in EMG activity and what relationship it has with passive muscle tension.
6. Muscle Energy Technique

Osteopaths frequently use specific stretching approaches to enhance muscle tissue extensibility through particular MET methods. MET is used by practitioners from different health professions and has been advocated in the use of stretching and increasing muscle extensibility, decreasing muscle hyper-tonicity and improving joint ROM (Chaitow, 2006a; Ehrenfeuchter & Sandhouse, 2003). Both PNF and MET stretching have been reported to be more effective than static stretching alone in improving joint ROM (Marek et al., 2005; Weppler & Magnusson, 2010; Yuktasir & Kaya, 2009). MET can be defined as “a form of osteopathic manipulative treatment in which the patient’s muscles are actively used on request, from a precisely controlled position, in a specific direction and against a distinctly executed counterforce” (Ehrenfeuchter & Sandhouse, 2003, pp. 881-907).

The systematic protocol for MET involves identifying a restrictive barrier within the normal range of joint motion, which is then followed by an isometric contraction of the agonist muscle. Subsequently, a passive stretch is applied to the muscle for a short period. This form of MET is also known as isometric CR or post-isometric relaxation (Chaitow, 2006a; Ward, 2003). Other forms of MET include contraction of the antagonist muscle at the first identifiable physiological barrier to motion, which is then followed by a passive stretch to the agonistic muscle. This form of MET is known as agonist CR and uses the principles of reciprocal inhibition (Chaitow, 2006a). For the purpose of this literature review only isometric CR techniques will be explored.

The physiological mechanisms that create changes in muscle extensibility produced by MET and passive stretching remain largely controversial (Chaitow, 2006a). Viscoelastic deformation has been previously tested in studies using static stretching (McHugh, Magnusson, Gleim, & Nicholas, 1992), CR (Magnusson et al., 1996) and massage (Rushton & Spencer, 2011). However, these studies have concluded that the underlying mechanism of increased muscle extensibility is likely due to altered reflex relaxation and altered tolerance to stretch. Most of the research that is pertinent to MET is derived from research related to PNF stretching due to the close similarities between the two techniques (Fryer, 2006).
6.1. Post-isometric relaxation

It has been proposed by several authors that MET creates muscle relaxation via a neurological reflex immediately after an isometric muscle contraction (Ehrenfeuchter & Sandhouse, 2003; Fryer, 2006; Greenman, 1996). The muscle relaxation that occurs after the isometric contraction has been theorised to cause activation of the Golgi tendon organs, which causes an inhibition of the alpha motor neuron pool (Kuchera & Kuchera, 1993; Ward, 2003). In support of this theory, two key studies have provided evidence that a brief neuromuscular inhibition occurs immediately after isometric muscle contraction. Moore and Kukulka (1991) studied the excitability of the alpha-motor neuron following a sub-maximal isometric contraction of the soleus muscle. The researchers found that myoelectric activity decreased for a period of ten seconds following the contraction and recognised this decrease as presynaptic inhibition causing muscle relaxation. Another study by Etnyre and Abraham (1986) measured the relaxation response and found that myoelectric activity reduced the activity of the H-reflex for a short period of two seconds after a single isometric contraction of the soleus muscle. Etnyre and Abraham (1986) also compared this to a static stretch and found that the H-reflex was not altered and therefore concluded that the changes were due to inhibition of the alpha motor neuron.

The studies mentioned above support the post-isometric contraction theory; however, further evidence showing a decrease in EMG activity after an isometric contraction is required before accepting inhibition of the neural reflex as a definite mechanism for an increase in muscle extensibility. In addition, it is debatable whether low level motor activity can limit the passive extensibility of a muscle (Fryer, 2006) as several studies have demonstrated that despite the presence of low level motor activity in a relaxed muscle, it appears to remain constantly unchanged during static stretch procedures (Magnusson, Simonsen, Aagaard, Dyhre-Poulsen, et al., 1996; Magnusson, Simonsen, Aagaard, Sørensen, & Kjaer, 1996; Magnusson, Simonsen, Dyhre-Poulsen, et al., 1996). Studies have found that considerable increases in passive ROM and EMG activity after MET techniques were performed (Ferber, Osternig, & Gravelle, 2002; Moore & Hutton, 1980; Osternig et al., 1987). Given the contrast within the literature, it is difficult to conclude whether or not myoelectric activity influences muscle extensibility. Further research is required to address the varying thoughts on this theory to enable a better understanding of myoelectric activity as a limiting factor of muscle extensibility.
6.2. Viscoelastic deformation and stretch tolerance during MET technique

MET protocols involve varying degrees of static stretching following a contract-relax technique. As discussed previously, static stretching causes a viscoelastic deformation in muscle tissue (McHugh et al., 1992) and an increased tolerance to stretch in participants (Magnusson et al., 1996). A number of studies exist that support the theory of increased stretch tolerance as a mechanism of increased joint ROM. In fact, Ballantyne et al. (2003) provided evidence that performing an isometric contraction of 75% of maximal voluntary force, for a total of four repetitions, significantly increased the passive knee extension and marginally increased torque, when the stretch was applied to a pain tolerance threshold. Ballantyne et al. (2003) found that passive knee extension increased by 2.7°±1.3°. An increase in torque was also demonstrated in the experimental group from pre-intervention measurements of 13.7 ± 3.2Nm to post-intervention measurements of 14.3 ± 3.4Nm (p=0.047). This increase in torque is marginally significant and supports the notion that stretch tolerance is a mechanism for increased muscle extensibility as greater force was required to achieve greater end range.

It has been hypothesised in two studies that increased stretch tolerance is a mechanism for increased muscle extensibility (Magnusson, Simonsen, Aagaard, Dyhre-Poulsen, et al., 1996; Magnusson, Simonsen, Aagaard, Sørensen, & Kjaer, 1996). These studies compared a CR stretch technique of 6 seconds followed by a ten second post isometric stretch phase with a 90-second static stretch. The results indicated an increase in both passive ROM and torque, indicating altered stretch tolerance. The underlying mechanisms for changes in stretch tolerance are not well understood. However, the concept of altered tolerance to stretching as a mechanism for an increase in muscle extensibility has now gained wider acceptance than the theory of reflex relaxation (Fryer, 2006). This has been observed in several studies that have found increased joint ROM and torque during testing procedures (Ballantyne et al., 2003; Folpp et al., 2006; Magnusson, Simonsen, Aagaard, Dyhre-Poulsen, et al., 1996).

6.3. Gate control theory

Previously, it has been proposed that the ‘gate control theory’ is one mechanism for altered stretch tolerance and pain perception. The gate control theory relates to a situation where two different types of stimuli such as pain and pressure trigger their respective receptors simultaneously (Fryer, 2006; Melzack & Wall, 1965; Sharman, Cresswell, & Riek, 2006).
During MET procedures a muscle is often stretched beyond its active ROM, which then stimulates the joint mechanoreceptors and proprioceptors, thereby creating an inhibition of the incoming signals of pain at the dorsal horn of the spinal cord. In addition, the force generated during contraction is detected and categorised as noxious stimuli, which immediately activates the Golgi tendon organs in order to inhibit the force and ensure the prevention of injury. As the MET protocol is repeated, both nociception and inhibition of the Golgi tendon organs are decreased, as the muscles and tendons become accustomed to their newly positioned lengths (Fryer, 2006; Magnusson, Simonsen, Aagaard, Dyhre-Poulsen, et al., 1996; Melzack & Wall, 1965; Sharman et al., 2006).

Evidence to support the mechanisms of altered stretch tolerance behind MET for increasing muscle extensibility is limited. However, it does seem plausible that MET can reduce the pain sensitivity and stretch tolerance of treated muscles during stretching, even though the effects may be psychological. There is currently no research on the psychological effects of MET on increasing muscle extensibility. Future studies are needed to help determine psychological effects of MET and increased muscle extensibility.
Chapter 7: Contract-Relax Technique on the Hamstring Muscle Group

The previous sections discussed the effect of stretching, massage therapy and MET on muscle extensibility. The next section will outline and discuss the effect of the CR technique applied specifically to the hamstring muscle group and its effect on hamstring extensibility.

7.1. The effect of contract-relax technique on hamstring extensibility

There are numerous studies that have investigated the effect of CR technique on hamstring extensibility that are related to CR MET (Ballantyne et al., 2003; Shadmehr, Hadian, Naiemi, & Jalaie, 2009; Smith & Fryer, 2008; Waseem, Nuhmani, & Ram, 2009) and CR PNF stretching (Feland & Marin, 2004; Feland et al., 2001; Ferber et al., 2002; Yuktasir & Kaya, 2009). These studies use similar protocols, however, subtle differences in each study can be found. These differences can mostly be attributed to variability in contraction durations, force, and the number of repetitions used.

The protocols used in the studies involving CR MET have varied from three to four sub-maximal muscle contract-relax repetitions, whilst the duration of contraction has ranged from 3 to 30 seconds (Ballantyne et al., 2003; Shadmehr et al., 2009; Smith & Fryer, 2008). In comparison, the CR PNF studies used two to five maximum muscle CR repetitions, with the duration ranging from three to ten seconds. Throughout the studies reviewed, contraction forces ranged from 20% to 100% of maximal voluntary isometric contraction (MVIC) force. Hamstring extensibility was measured using active and passive knee extension tests, straight leg raise, and torque.

7.2. The effect of contract-relax techniques on active knee extension

The results of two studies indicate that CR techniques can improve active knee extension ROM (Puente, Puentes et al., 2011; Puentes, Uhl, Arnold, & Gansneder, 2001). These studies both found comparable results in the mean increase of active knee extension ROM following CR PNF protocols using MVIC force during stretching procedures. Puentes, Puentes et al. (2001) investigated the lasting effects of a single CR stretch over a 32 minute period in males (aged 18.8±0.63 years) involved in military cadet training. The CR protocol consisted of firstly, a seven second passive stretch phase; secondly, a seven second contraction phase; and lastly, a five second relaxation phase that was followed by a seven second stretch. The results
indicated that hamstring extensibility significantly increased by 7.8° (SD not reported; $d=0.5$) following the intervention, with lasting effects maintained up to 6 minutes. The results from this study however, cannot be generalised to the normal population as this study used males involved in military cadet training, who were involved in high intensity training.

CR techniques have been hypothesised to be more effective than static stretching in improving muscle extensibility (Ferber, Osternig, & Gravelle, 2002). However, research to support this is limited as several studies have found that CR techniques produce comparable gains in joint ROM to static stretching (Feland, Myrer, & Merrill, 2001; Puentedura et al., 2011; Yuksasir & Kaya, 2009). Indeed, this was observed by Puentedura et al. (2011), who used a two intervention cross-over design to compare the immediate effects of a single application of a CR technique to a static stretch over a two week period on a mixed gendered group. The CR intervention consisted of a 10-second contraction phase repeated four times. The static stretch intervention consisted of a 30-second stretch, followed by a 10-second relaxation phase, repeated twice. The results from this study indicated significant mean increases of 8.9° following the CR technique and 9.1° following the static stretch, which is similar to that found by Spernoga et al. (2001). The results indicated that CR technique and static stretch produce comparable gains in muscle extensibility. A limitation of this study is that the participants’ opposite leg was used as a control allowing the participants to become familiarised with testing procedures. This could have influenced the testing results through motivation as the tests were active and therefore dependent on the participants. In addition, this study was found to be underpowered due to the small sample size leading to difficulty in detecting differences between intervention groups. Other studies have, however, found that CR techniques significantly improve active knee extension (Nagarwal. A.K, Zutshi. K, Ram. C. S, & Zafar. R, 2009; Smith & Fryer, 2008; Waseem et al., 2009). Another possible reason for the undetectable difference in interventions may have been due to a ceiling effect caused by the fact that participants were included in the study when exhibiting minimal restrictions in active knee extension.

The active knee extension test is reliable and arguably safe for assessing knee joint ROM because the end point of available joint ROM is dictated by the participant (Fryer, 2006; Norris & Matthews, 2005). The final position is, however, dependent on the tension developed by the participant’s quadriceps muscles and may be influenced by muscle fatigue.
and participant motivation (Norris & Matthews, 2005), which can cause variability within test results. To control for variable muscle fatigue in participants, both Sernoga et al. (2001) and Puentedura et al. (2011) used a standardised warm-up routine.

Recent studies have questioned the need for maximal contraction force during CR techniques. It has been proposed that submaximal contraction forces are as effective as maximal contraction force (Smith and Fryer, 2008; Waseem et al., 2009). Submaximal contraction force during the CR stretch procedure of 40% (Smith and Fryer, 2008) and 75% (Waseem et al., 2009) of MVIC, demonstrated similar increases in joint ROM. The studies did, however, use slightly different CR protocols. Smith and Fryer (2008) investigated the effects of a seven to ten second isometric contraction followed by a two to three second relaxation phase. The next phase consisted of either a three or 30-second post-isometric stretch depending on group allocation. Comparable results (8.48° and 7.89° respectively; SD not reported) were obtained between the two post-isometric stretch durations. In contrast, Waseem et al. (2009) investigated the effects of a CR MET over five consecutive days with a follow up measurement on the eighth day. The CR protocol used in this study involved a slightly shorter isometric contraction of five seconds followed by a three second relaxation phase, and was repeated for a total of four contractions. Unlike Smith and Fryer (2008) no post isometric stretch was used. Waseem et al. (2009) found only a 5.6° (SD not reported) increase in active knee extension. From these two studies it is apparent that submaximal contraction forces produce comparable increases in active knee extension ROM. In addition, both studies found significant lasting effects three days (Waseem et al., 2009) and one week (Smith & Fryer, 2008) after the final treatment session. It is important to note, however, that the underlying mechanisms of biomechanical change cannot be inferred from the outcome measures used in these studies as only active muscle testing was used and, with no passive measurements taken, the underlying mechanisms of altered extensibility cannot be inferred.

7.3. The effect of contract-relax techniques on passive knee extension
At present there is no ‘ideal’ contraction force for CR as the force used is varied within the literature. Submaximal contractions can produce similar improvements in passive joint ROM according to studies by Ballantyne et al. (2003) and Feland and Marin (2004). Both studies have shown that CR stretch techniques can produce immediate and short term increases in passive knee extension. Ballantyne et al. (2003) found that applying a CR MET using 75% of
MVIC force for five seconds followed by a three second rest period, repeated for a total of four cycles was able to produce a significant increase in passive knee extension of 2.7° ± 1.3. Similarly, Feland and Marin (2004) used a contraction duration of six seconds, followed by a longer rest period of ten seconds between contraction cycles, which was repeated three times each day for five consecutive days. However, in contrast to Ballantyne et al. (2003), Feland and Marin (2004) assessed the effectiveness of different contraction forces of 20%, 60% and 100% of MVIC. Their results showed that the use of submaximal contraction intensities of 20% and 60% (5° ± 4.83°; p=0.001 and 4.47° ± 6.58°; p=0.013, respectively) yield comparable gains in extensibility to 100% of MVIC 5.13° ± 5.11° (p=0.002). Therefore, not only are submaximal isometric contraction forces able to produce comparable gains in passive knee extension to maximal isometric contraction forces, they are also safer and more comfortable according to Ferber et al. (2002).

The duration of both contraction and post-isometric stretching phases are varied within literature. Many authors in the field of CR techniques have supported the use of contraction phases lasting between three and seven seconds (Chaitow, 2006b; Ehrenfeuchter & Sandhouse, 2003; Greenman, 1996), whereas authors of previous studies have used durations ranging from five to six seconds (Ballantyne et al., 2003; Feland et al., 2001), and seven to ten seconds (Shadmehr et al., 2009). There is limited research to support the value of longer contraction durations and conflicting results have been shown. It appears that longer contraction durations are more effective in increasing passive joint ROM. This is supported by Feland et al. (2001) who found that a CR technique to the hamstrings with a duration of six seconds, followed by a ten second relaxation period, demonstrated an immediate increase of 5° (SD not reported) in passive knee extension. In comparison, a more recent study by Shadmehr et al. (2009) examined the temporal effects of a slightly longer contraction duration of ten seconds followed by a ten second stretch repeated three times. Passive knee extension increased by 22.1° ± 4.4° over a 4 week period. It may be surmised from this that longer contraction duration provides greater increases in passive knee extension. There does not appear to be any research that has investigated contraction phases longer than 20 seconds on passive knee extension. Further research in this area may add to the knowledge base and find even greater benefits to passive knee ROM.
8. Massage Therapy and Stretching Techniques

Massage therapy, static stretching and CR stretching, when applied alone, have been found to be effective in the treatment of decreased muscle extensibility. Often massage precedes stretching in the clinical setting to firstly allow ‘loosening’ followed by ‘lengthening’ of the muscle. Only one study was found which compared massage therapy with contract-relax stretching (Wiktorsson-Möller, Oberg, Ekstrand, & Gillquist, 1983). Due to this limited evidence, this literature review will also evaluate articles comparing massage therapy with static stretching.

8.1. Massage therapy vs static stretching

It has been found that static stretching is as effective as Swiss massage on improving muscle extensibility. A recent study by Arazi et al. (2012) lends support to this as they compared the effects of a 10-minute Swiss massage technique to a 20-second static stretch repeated three times, each with a 10-second rest interval. The Swiss massage included varying strokes (including effleurage, friction, petrissage, vibration and tapotment) on the anterior and posterior thigh muscles and calf muscles. The static stretch was applied to the plantar flexor, hamstring, hip flexors, hip extensors, hip adductors and hip abductors. The results from this study indicate that Swiss massage is no more effective than static stretch when measured by the sit-and-reach test to assess muscle extensibility.

The effect of massage and static stretch on sit-and-reach test has also been compared by Arabaci (2008). This study used a counterbalanced crossover study design and compared the effects of massage therapy and static stretching against a control group on measures of physical performance and flexibility. The study involved 24 healthy males each receiving massage therapy, static stretching and no intervention over a 1-week period. The massage intervention was performed to the anterior thigh for five minutes and to the posterior leg (from the ankle to buttocks) for 10-minutes. The static stretch intervention was performed to the same muscles listed above for 20-seconds followed by a 10-second rest, repeated three times. The results showed that both massage and static stretching produced significant improvements in sit-and-reach test scores of 15.1% and 22.8%, respectively. However, the results indicate that stretching was only marginally better than massage in improving sit-and-reach scores. Both Arazi et al. (2012) and Arabaci (2008) used the sit-and-reach test as the
outcome measure, which is a non-specific indicator of hamstring extensibility. It has been suggested that 60% of the sit-and-reach test is achieved by hip flexion with the remaining 40% coming from the flexibility of the spine and shoulders (Barlow et al., 2004). It is, therefore, difficult to determine the contribution of massage and stretching to the hamstrings on the sit-and-reach test score.

8.2. Massage therapy combined with dynamic stretching
When massage and stretch techniques are combined, greater increases in muscle extensibility and joint ROM occur (Fritz, 2006). However, very few studies exist that have compared the effect of massage therapy and CR techniques. One study compared the effects of a dynamic soft tissue mobilisation technique with a classic massage (effleurage, petrissage and kneading) to the hamstrings muscle (Hopper et al., 2005). The dynamic soft tissue mobilisation technique consisted of an eight minute protocol utilising both active and passive components of muscle stretching. The therapist located areas of tightness within the muscle and used a fisted hand to apply a massage longitudinally and across the muscle, while the knee was passively extended. This was followed by an active stretch in conjunction with the strokes applied. Finally, an eccentric contraction of the hamstring muscles against the therapist’s resistance was performed. The results from this study showed that both techniques produced equally significant and comparable gains in passive knee extension, thus making it difficult to assess whether the improvement was from the active or passive elements of the dynamic soft tissue mobilisation. The participants recruited in this study were competitive athletes, which made it difficult to control the level of physical activity performed before testing procedures as some participants had completed aerobic or weights training. The authors recognised this as a major limitation of the study. The lack of control influenced the results as some participants may have been more or less flexible due to the differing levels of aerobic and weights training prior to measurements. The authors also recognised the small sample size as another major limitation as it produced insufficient power, preventing the detection of any significant differences.

8.3. Massage therapy vs contract-relax stretching
Adding a stretch technique to a specific massage technique is thought to provide added benefits to muscle extensibility. Previous studies have used varying massage methods yet have not examined the physiological benefits of massage. They have failed to evaluate the
different elements of massage such as pressure, time, and speed of the techniques (Hopper et al., 2005). In addition, very few studies have compared stretch to massage. One study by Wiktorsson-Möller et al. (1983) did, however, find that CR stretching was more effective than massage in increasing lower extremity ROM. This study investigated the effect of massage therapy and CR stretching in participants following a warm up session on ROM of the hip, knee and ankle. The massage procedure consisted of a 6-15 minute massage of the entire lower extremity. The stretching procedure used an isometric contraction at maximal joint extension for two seconds followed by an eight second passive stretch. This was repeated five to six times. Wiktorsson-Möller et al. (1983) found that massage significantly improved dorsi-flexion of the ankle by 12%, while other movements of the hip and knee were not significantly improved. Participants in the stretching group demonstrated a significant improvement in all six ranges of motion tested. Wiktorsson-Möller et al. (1983) did not use a CR stretching only group which therefore makes it difficult to assess if the increase in joint ROM came from stretching procedure or the warm up alone. Although this study measured the effects of warm-up, massage and a CR stretch, it did not compare the combined effects of CR stretching with massage, which is still an area of research that is very limited. A major limitation of this study is the small sample size, which consisted of eight participants, making it hard to generalise the findings. A larger sample size may have been able to detect greater changes in ROM following massage. A varied intervention dose in the massage therapy group may have also introduced intervention bias.
9. Conclusion

It is often perceived by manual therapists that decreased hamstring extensibility is a limiting factor in ROM of the hip and knee joints. In consequence, this restriction is said to lead to changes in pelvic and lumbar postures which predispose and/or exacerbate low back and lower extremity pain. Muscular tension can occur actively through contraction and muscle spasm and passively, through postural adaptation and scarring. Age and gender can also influence joint ROM.

Several authors have found that hamstring muscle extensibility can be improved through different methods of treatment including CR techniques, such as PNF and MET, and massage techniques. The majority of these studies have, however, used varying methods and treatment approaches in the application of both stretch and massage. The time, duration, and massage stroke types differed in each study and making it difficult to assess which technique is the most efficient. The MET studies have used similar protocols, yet the studies relating to massage therapy have used multiple stroke types as used in Swedish style massage, or solely friction massage at the musculo-tendinous junction. To the authors knowledge no study has been performed using a specific massage stroke (such as cross-fibre) to the entire hamstrings muscle group followed immediately by a MET.

Therefore, the aim of this experimental study reported in Section 2 of this thesis is to investigate the effects of an application of a soft tissue cross-fibre massage combined with MET on knee extension ROM, and compare it to MET used alone. The information gathered from this study will help guide osteopaths in using the most effective methods available to improve muscle extensibility.
10. References


Section Two: Manuscript
The effect of combining muscle energy technique with soft tissue massage on hamstring extensibility

This manuscript is written in the style described in the guide for authors for the International Journal of Osteopathic Medicine (see Appendix F). For the purposes of completion of this thesis some guidelines from have not been followed. Figures and Graphs have been placed throughout the body of the document (rather than on a separate document) for ease of examination. The International Journal Osteopathic Medicine requires a limit of 5000 words which has been exceeded here to allow full and evaluative discussion of the results in this thesis.

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The effect of combining muscle energy technique with soft tissue massage on hamstring extensibility
1. **ABSTRACT**

**Background:** The muscle energy technique (MET) and cross-fibre soft tissue massage have both been advocated for the treatment of restricted joint range of motion (ROM) in the lower extremity. Although commonly applied together, evidence to support the effectiveness of MET combined with a specific cross-fibre soft tissue technique to increase knee joint ROM is scarce.

**Objective:** The aim of this study was to investigate the combined effects of an isometric contraction MET with a soft tissue cross-fibre technique on active knee extension (AKE) and passive knee extension (PKE).

**Design:** Repeated measures cross-over design.

**Methods:** 20 asymptomatic participants (aged 18-45) with a PKE angle of 20 degrees or more were pseudo-randomised to two counterbalanced groups. Group 1 (n=10) received MET and cross-fibre soft tissue and 7 days later received MET only. The same treatments in reverse order were performed on Group 2 (n=10). Measurements for AKE, PKE and passive elastic force were recorded pre and post-intervention.

**Results:** A three-way mixed-method multivariate analysis of variance (MANOVA) revealed a significant overall effect of time indicating that all measures improved following the interventions, regardless of the intervention. Greater improvements were seen in PKE ($p=0.041$) and passive force ($p=0.005$) with MET combined with soft tissue treatment, than with MET alone in both groups. No significant intervention effect for the AKE measure was observed ($p=0.55$).

**Conclusion:** This study demonstrated that adding cross-fibre soft tissue massage to MET improves passive knee ROM more than MET alone, due to an increase in stretch tolerance as measured by changes in passive force. However, both interventions failed to show any significant improvements in AKE.

**Key words:** Active knee extension, hamstring extensibility, muscle energy technique, passive knee extension, soft tissue massage.
2. INTRODUCTION

Reduced muscle extensibility is an area that concerns every manual therapist due to the functional restrictions it places on joint range of movement.\textsuperscript{1} Muscle extensibility is defined as the ability of a muscle to lengthen from a resting state to a predetermined endpoint, in which the joint’s maximum range of motion reflects the muscles maximum length.\textsuperscript{2-4} The current literature supports the premise that optimal muscle extensibility is necessary to achieve maximum joint range of motion. It has been reported that an aberration in optimal extensibility can precipitate abnormal wear patterns on articular surfaces and capsular structures of the involved joints.\textsuperscript{1,4,5} The hamstring muscle group in particular has been frequently observed to have reduced muscle extensibility, and has been reported to contribute to altered lower limb and lumbo-pelvic mechanics.\textsuperscript{6} These changes include altered gait,\textsuperscript{7,8} patellofemoral joint dysfunction,\textsuperscript{9-12} plantar fasciitis\textsuperscript{13-15} and low back pain.\textsuperscript{16-19} It is, therefore, a common goal of manual therapists to improve muscle extensibility in the hamstrings to minimise the functional deficit it applies to joint range of motion.

Muscle extensibility is commonly treated through manual therapy techniques. Manual therapists, including osteopaths, use various techniques to improve muscle extensibility such as stretching,\textsuperscript{20,21} massage,\textsuperscript{22-24} and contract-relax (CR) stretching which includes both MET,\textsuperscript{25-28} and proprioceptive neuromuscular facilitation (PNF).\textsuperscript{29-32} These techniques, used individually, have been reported to increase muscle extensibility and successfully increase joint range of motion, decrease viscoelastic resistance, and improve tolerance to stretch.

CR techniques, such as muscle energy and PNF, actively engage an individual’s muscle upon request, from a position predetermined by the practitioner against a specific counterforce.\textsuperscript{33} CR technique has been advocated for the treatment of reduced muscle extensibility.\textsuperscript{34} It seems that CR technique is effective in improving muscle extensibility, however current literature contains varying protocols for the implementation of the intervention. The protocols include different contraction forces,\textsuperscript{25,27-29} contraction durations,\textsuperscript{25,30,33,35,36} and post-contraction stretch duration.\textsuperscript{25,26,29} There is clear evidence to suggest that sub-maximal contraction forces are as effective as maximal contraction forces in improving active,\textsuperscript{27,28} and passive range of motion.\textsuperscript{25,29} Authors have supported the use of contraction durations ranging from three to seven seconds,\textsuperscript{25,30,33,35,36} and there is some evidence to suggest greater improvements in
muscle extensibility are gained with longer contract durations of up to ten seconds. Although varying post-isometric stretch durations have been advocated, there seems to be no ‘ideal’ as durations ranging from 3 to 30 seconds have been reported to produce similar improvements in muscle extensibility.

It is well established that both massage therapy and stretch techniques are effective in improving muscle extensibility, with both demonstrating similar effectiveness when applied individually. There is evidence to suggest that adding a CR protocol to a static stretch intervention provides significantly greater increases in muscle extensibility over massage alone. The application of a single technique does not, however, reflect clinical practice as manual therapists often use soft tissue massage techniques followed by a stretch to enhance muscle extensibility. The combination of massage with CR stretch can achieve further increases in muscle extensibility over each technique used individually; however, there is no evidence to support this premise. Therefore, the purpose of this study is to investigate the immediate effect of a CR muscle energy technique used with and without a specific cross-fibre massage on clinical measures of hamstring muscle extensibility in asymptomatic individuals.
3. METHODS

3.1. Design

A repeated measures cross-over design was conducted to measure the combined effect of a soft tissue cross-fibre massage and a MET compared with the MET alone on hamstring extensibility (Figure 1.) The study was performed at the Unitec Osteopathic Clinic, Auckland, New Zealand. This study was approved by the Unitec Research Ethics Committee (Approval: 2010-1137).
**Figure 1.** Consort diagram of the study design. Abbreviations: MET = Muscle Energy Technique, ST= Soft Tissue.

Key: Group 1 ———
    Group 2 ———
3.2. Recruitment
Participants were recruited through the use of publically distributed posters and flyers, online social media (http://www.facebook.com) and by verbal invitation. Individuals that applied for the study were asked to attend an appointment at the osteopathic clinic to assess their eligibility. Each participant gave written and informed consent prior to eligibility screening and enrolment.

3.3. Eligibility
Assessment for eligibility followed a stringent inclusion and exclusion criteria. The inclusion criteria were healthy adult males aged 18-45 who exhibited a positive passive knee extension test (i.e. angle less than 20 degrees from full knee extension) (Figure 3a). Participants were excluded if they: a) had any current or recent injuries within the last 6 months to the lower extremities, hip or spine; b) were currently receiving manual therapy or treatment to the lower extremities; c) were involved in any form of regular stretching programme; or d) had a known musculoskeletal, neurological, vascular, lymphatic disorder.

Participants were asked to refrain from taking any over-the-counter medications that may affect the musculoskeletal system such as muscle relaxants or analgesics, avoid strenuous exercise, and minimise any heavy physical activity on the day of data collection. Participants who were considered eligible for the study were given an information sheet outlining the requirements of participation and were given the opportunity to discuss all protocols with the lead researcher.

3.4. Instrumentation
The room was arranged with one adjustable treatment plinth and a video camera (Sony digital model number DCR-HC40E) that was positioned two meters perpendicular to, and level with, the centre of the plinth. The positions of both table and tripod were measured and marked on the floor with tape to ensure consistency of the positions between the two sessions.

A plywood apparatus was built to fit over the plinth (Figure 2.) The wooden apparatus was designed to secure the participants limbs (one secured at 90 degrees hip flexion, the other secured in a neutral position) and prevent excessive movement during testing procedures. Straps were used to prevent further hip flexion during knee extension testing procedures. The
contralateral limb was securely strapped down to the table. To prevent excessive hip and pelvic rotations during testing procedures. For both tests, the participant’s head was kept in a neutral position to avoid any neural tension that may occur which can cause a limitation in knee ROM and extensibility of the hamstring muscle.

With the participants supine, bony landmarks were easily identified and marked with a circular adhesive label to provide reference points to measure the degree of knee extension. The landmarks used consisted of the greater trochanter of the femur, lateral femoral condyle and lateral malleolus.

3.5. Procedure
Once inducted into the study the participants were randomly assigned to one of two groups using a pseudo-random sequence generator (www.random.org). All participants underwent both intervention procedures: MET and MET combined with soft tissue massage (MET + ST) (Figure 1). Each participant received both intervention protocols separated by seven days at approximately the same time of day. Outcome measures were taken immediately prior to and following the intervention. Participants were instructed to refrain from strenuous exercise and stretching their hamstrings two days prior to the first testing session and during the 7-day interval between trial dates. The participants allocated to group 1 received MET alone in the first week follow by MET combined with soft tissue cross-fibre massage in the second week. Participants in group 2 received the interventions in the reverse order to group 1. The order of techniques followed normal clinical practice in which soft tissue cross-fibre technique was performed, followed by MET.

3.6. Outcome Measures
The extensibility of the hamstring muscles was assessed using the active knee extension (AKE) and passive knee extension (PKE) tests. A hand-held dynamometer was used during the PKE test to accurately record the force required to extend the participants knee.

active knee extension

The AKE test described by Magee (2002) was used for this study. The participant was instructed to slowly extend their knee while maintaining a relaxed foot position until no
further movement could be achieved. The end range of AKE was determined by the participant achieving maximal extension effort. The maximum angle of knee extension during this task was used for analysis. The average of 3 repetitions was used for analysis. The AKE has a high level of test-retest reliability for detecting changes in hamstring extensibility.\(^{43-45}\) The AKE has been used in several studies that have investigated reduced hamstring extensibility.\(^{27,46,47}\)

passive knee extension

The PKE test is another orthopaedic test that is often used to measure knee joint range of motion and hamstring extensibility.\(^{48}\) The operator firmly held the calcaneus and maintained the foot in a neutral foot position and then slowly (approx. 10°/s) extended the knee joint until the end range of knee extension was identified by the participant requesting to stop. The participants were all instructed to allow the knee to “extend to the point where they could go no further”. Additionally, a hand-held dynamometer (Chatillon Model MSE 100) was placed on the posterior calcaneus (Figure 2c) and used to determine the force used to reach end-range during the PKE test. Again, the average of three repetitions was used for analysis. Digital photography and computer analysis was used to determine the changes in ROM at the knee joint. All measurements of hamstring extensibility were reported as degrees from full knee extension (Figure 2).

The PKE has been reported to be a reliable test for detecting changes in passive hamstring tension,\(^{30,44,48}\) and has been commonly used in several studies investigating reduced hamstring extensibility.\(^{25,29-31}\) The use of a hand-held dynamometer to detect changes in passive resistance has also been found to have high reliability,\(^{49,50}\) and is used to aid with the understanding of biomechanical change and altered tolerance to stretch.\(^{23,25}\)
Figure 2: (A) resting position, (B) active knee extension measurement position, (C) and passive knee extension and force measurement position. Both active and passive tests were performed on the wooden apparatus pre- and post-intervention. The PKE test was conducted using the guidelines described by Gnat et al. (2010), where the participant lay supine on a plinth. The examiner flexed the participant’s right hip to 90 degrees and secured their thigh to a vertical board, while the opposite leg was secured to the table using straps.

1. Angle of knee extension
2. Force recorded using a dynamometer

3.7 Intervention
Participants remained fixed in the wooden apparatus for the duration of the measures and intervention, with the right lower limb being used for all participants. All techniques were performed by the lead researcher who is a final year osteopathic student.
The MET intervention used for this study was based on the method described by Chaitow (2006a), Greenman (1996) and Ehrenfeuchter and Sandhouse (2003) and was clearly explained to each participant immediately before each session. Participants were instructed to not extend their right hip while flexing their knee joint. The final instruction given to each participant was to indicate if at any point during the procedure they experienced pain or discomfort, which would be a sign for the procedure to be stopped immediately. The MET intervention proceeded as follows: a) the practitioner placed their left hand above the knee joint to provide stability, whilst the right hand was positioned above the posterior part of the calcaneus; b) slowly, the practitioner extended the knee joint until the first restriction barrier to stretch was perceived by the practitioner; c) the participant was asked to contract their hamstring muscle by “gently pushing their heel of their right foot down towards the table, using approximately 20% of their perceived strength”, the contraction phase was maintained for a period of seven seconds against the resistance provided by the practitioner as recommended by Greenman (1996); d) the participant was then instructed to “relax” the hamstring muscle. The post isometric relaxation phase was approximately 3-7 seconds to allow the participant to completely relax before the next step; g) the practitioner repeated from step b) for a total for three contraction phases.

The soft tissue cross-fibre intervention consisted of a five minute application of soft tissue massage to the hamstrings muscle group of the right followed by the MET as described above. The order in which technique was applied first follows normal clinical practice. The massage technique used in this study was a specific cross-fibre kneading technique, which consisted of only a rhythmic squeezing and massaging of the hamstring muscle in a transverse direction to the muscle fibres. This involved using the heel of the hand to create a push or a pull of the hamstring muscles in a cross-fibre direction on the biceps femoris part for a duration of 2.5 minutes followed by the semitendinosus and semimembranosus portions of the hamstrings for the remaining 2.5 minutes. Other techniques commonly used by massage therapists such as effleurage, tapotement, skin rolling or trigger point therapy were not used in this research.
The soft tissue cross-fibre intervention used in this study is as follows: a) the participant was placed in the prone position on the treatment table; b) After locating the biceps femoris part of the hamstrings muscle group, the practitioner used both hands with one hand directly on top of the other to apply the soft tissue cross-fibre massage. The practitioner used the entire palmer surface of their hand to perform the cross-fibre technique; c) the soft tissue cross-fibre technique described by Ehrenfeuchter et al. (2003) was used and consisted of a rhythmic, lateral stretching of the hamstring muscle, in which the origin and insertion were held stationary and the muscle belly was stretched like a bowstring; d) after 2.5 minutes, the practitioner then performed the soft tissue cross-fibre technique on the semimembranosus and semitendinosus portions of the hamstrings for the remaining 2.5 minutes. After the soft tissue cross-fibre technique was performed, the participant was asked to change to a supine position in order for the MET protocol described above to be performed. Finally, the participant was then asked to reposition themselves on the wooden apparatus and prepare for post-intervention measurements.

3.8. Data Extraction
The experimental trials were recorded by video using a digital camera (Sony digital model number DCR-HC40E) and were then transferred to a computer for analysis of the knee extension angles. The angles of AKE and PKE were measured using Image J software measurement tools while the participant was in the supine flexed hip and extended knee position immediately before and after the intervention. Once transferred to Image J computer software, three measurements were taken of each captured frame of maximal AKE and PKE angles and at each repeated measurement. The mean values of these measurements were calculated by the lead researcher and rounded to two decimal places and used for data analysis.

3.9. Statistical Analysis:
Statistical analysis of the experimental data was performed with a three-way mixed method multivariate analysis of variance (MANOVA) using the SPSS v20 programme for Windows®. The MANOVA was used to allow several dependant variables to be compared simultaneously with several independent variables and the possible interactions between independent variables. A between-group contrast was also performed to explore between-group differences. The MANOVA method was considered appropriate for this study as it
was a repeated measures design and allowed for the comparison of the effects between MET and MET combined with soft tissue cross-fibre interventions with the three outcome measures of AKE, PKE and force. In addition, to identify if changes in PKE were simply owing to increased force application or stretch tolerance, a Pearson’s product moment correlation coefficient was computed to explore the correlation between these variables. Throughout the text all data is reported as mean (SD), and significance is set at the $p<0.05$ level.
4. RESULTS:
The study sample consisted of 20 male participants randomly allocated to either group 1 (n=10) or group 2 (n=10). The mean age of participants was 27(±5.9), the mean weight of participants was 74.4kg (±11.5) and the mean height of participants was 177cm (±10.1). Paired t-tests indicated there was no significant difference between the groups for height (p=0.57) and weight (p=0.28), however, there was a significant difference in age (p=0.03).

A significant overall effect of time (pre intervention and immediately afterwards) was observed (Wilks λ = 0.296, F (3, 16) = 12.69, p<0.001, partial eta squared = 0.704, and power to detect effect = 0.997). Significant univariate main effects were obtained for AKE (F (1, 854.23) = 31.23, p <0.001, partial eta squared =0.634, and power to detect effect was 1), PKE (F (1, 183.7) = 28.65, p<0.001, partial eta squared = 0.614, and power to detect effect was .99) and Force (F (1, 265.84) = 12.09, p=0.003, partial eta squared = 0.402, and power to detect the effect was 0.908). Indicating that all measures improved following the interventions, regardless of the intervention.

A significant interaction was found between intervention and time (Wilks λ = 0.556, F (3, 16) = 4.26, p =0.02, partial eta squared = 0.444, and power to detect effect = 0.761). Univariate analysis failed to show a significant effect between MET and MET+ST for the AKE measure, F (1, 4.79) =0.365, p=0.554, partial eta squared = 0.020, and power to detect the effect was .088 (Figure 3). However, there was a significant effect for PKE (F (1, 28.195) = 4.87, p =0.041, partial eta squared = 0.213, power to detect the effect was 0.551) (Figure 4), and Force (F (1, 202.14) = 10.41, p = 0.005, partial eta squared = 0.367, power to detect the effect was 0.862) (Figure 5). Results indicate greater improvements in PKE and force with the MET combined with cross-fibre soft tissue group, compared with the MET alone group. A moderate negative correlation was found for PKE and force for MET alone, r = -0.488, n = 20, p=0.029, however a significant correlation of these variables was not observed for the MET combined with soft tissue cross-fibre group (r = 0.152, n =20, p =0.523).
Figure 3: AKE results for both interventions.

![Active knee extension results]  
Note: No significant effect when both interventions compared, \( p=0.554 \)

Figure 4: PKE results for both interventions

![Passive knee extension results]  
Note: * indicates significance at the \( p=0.05 \) level
4.1. Internal Validity

Multivariate analysis revealed a significant interaction between group (order allocation) and intervention (Wilks λ = 0.512, $F(3, 16) = 5.08$, $p = 0.012$, partial eta squared = 0.488. Power to detect the effect was 0.837). Univariate analysis indicated that this interaction was owing to a group by intervention effect for force only ($F(1, 2831) = 12.65$, $p = 0.002$, partial eta squared = 0.413, and power to detect the effect was 0.919). Significant interactions were not found for variables of AKE ($F(1, 92.07) = 2.79$, $p = 0.112$, partial eta squared = 0.134, and power to detect effect = 0.353) or PKE, ($F(1, 52.12) = 1$, $p = 0.330$, partial eta squared = 0.053, and power to detect effect = 0.158).
5. DISCUSSION

5.1. Overview
The aim of this study was to document the immediate effect of a CR MET combined with a specific cross-fibre massage on clinical measures of hamstring muscle extensibility in asymptomatic individuals. This study also sought to investigate the CR MET used in isolation. Whilst CR technique and massage therapy have been reported to independently improve muscle extensibility, as measured by active and passive knee ROM and force, there is no evidence that demonstrates the effectiveness of a specific massage technique combined with CR MET. The results of the current study indicate that CR MET combined with specific cross-fibre soft tissue massage to the hamstring group is associated with significant increases in PKE due to increased stretch tolerance. The combined techniques were not associated with any significant change in AKE. Significant increases in hamstring muscle extensibility were demonstrated in those receiving the MET alone and were attributed to mechanical deformation. This in itself is an important finding and implies that while soft tissue massage combined with contract-relax muscle energy is more effective than the muscle energy technique alone, the combination of techniques also creates viscoelastic deformation alongside altered stretch tolerance.

5.2. Contract-relax technique
The immediate increases in hamstring extensibility following CR technique observed in this study are consistent with the current evidence that CR stretching improves AKE, PKE in asymptomatic individuals. The current literature contains a wide range of CR protocols including different contraction forces, duration of contraction, and duration of post-isometric stretch. The CR stretch protocol of the current study was based on recommendations by Greenman (1996), yet there is little evidence to support these recommendations and it remains somewhat unclear which is the most beneficial protocol for CR stretching.

5.3. Muscle contraction force
Submaximal contraction forces are recommended for safety reasons to minimise risk of contraction induced injury. The findings of the current study supports the evidence that submaximal contraction forces are associated with increased muscle extensibility.
Feland and Marin (2004) concluded that submaximal contraction forces of 20% and 60% of maximum force were as effective as maximal contraction forces for increasing muscle extensibility.\textsuperscript{29} The current study did not compare the effectiveness of varied contraction forces on muscle extensibility yet the findings do suggest that a submaximal contraction force of 20% may be sufficient.

5.4. Muscle contraction duration

It appears that muscle contraction produces a brief depression of myoelectric activity possibly through the inhibition of the Golgi tendon organs, thereby allowing greater muscle extensibility.\textsuperscript{56,57} The findings of the current study suggest that a muscle contraction of seven seconds, as recommended by Greenman, 1996) is effective in increasing hamstring muscle extensibility.\textsuperscript{36} This is in concordance with authors who have used similar contraction durations ranging from three to seven seconds and with contraction duration of 10-seconds.\textsuperscript{6,25,30,46,53} Unlike evidence for muscle contraction force there is a lack of literature comparing the effectiveness of different contraction durations. It may be supposed that a longer contraction time allows for greater inhibition of Golgi tendon organs, allowing for further increases in muscle extensibility, however, further research is required to compare different contraction durations for the purpose of identifying the ‘ideal’ duration.

5.5. Post-isometric stretch duration

The present study used a short post-isometric stretch of between three and seven seconds as advocated by Greenman (1996), which is consistent with protocols used in currently published literature.\textsuperscript{6,25,31} It is unclear which duration is most effective. Smith and Fryer (2008) compared post-isometric contraction stretch durations of three and 30-seconds.\textsuperscript{27} The authors concluded that both stretch durations were equally effective in improving hamstring extensibility however only active hamstring extensibility was measured. Post-isometric contract stretch durations of 30-seconds or more may have a larger effect on passive hamstring extensibility through greater viscoelastic deformation and tolerance to stretch. There is no evidence to support this however. Further research comparing stretch duration on active and passive muscle extensibility is needed as it is difficult to determine which post-isometric stretch protocol is most effective, and which mechanism is being altered.
5.6. **Massage therapy and stretching techniques**

Increased muscle extensibility has been observed following CR stretching,\textsuperscript{25-27,29,30} and massage therapy,\textsuperscript{22,23,37,56} with a greater increase being observed following a CR stretch than massage therapy.\textsuperscript{38} Both CR and massage therapy share the similarity of viscoelastic deformation as an underlying mechanism for improving muscle extensibility.\textsuperscript{23,57}

The current study appears to be the only one measuring the effect of CR stretch combined with massage therapy and suggests that combining a CR stretch with massage therapy achieves greater increases in passive hamstring extensibility than CR stretch alone. The degree to which soft tissue massage contributed to the improved muscle extensibility is unclear. Several studies investigating massage alone have shown confounding results due to variations in massage stroke type, duration and location of applied massage.\textsuperscript{22-24,37,38,56} To date, the author recognises that no previous studies have investigated the effects of a soft tissue cross-fibre combined with a MET. The present study suggests that the combined effects of soft tissue cross-fibre and CR technique produce both viscoelastic deformations alongside altered stretch tolerance. However, inferences of the cumulative effects of soft tissue cross-fibre and CR techniques can be made, as the results indicated that viscoelastic deformation was further enhanced with the addition of soft tissue cross-fibre as displayed by greater hamstring extensibility.

The present study used a five minute cross-fibre soft tissue massage technique on the hamstrings for improving passive extensibility but found similar results to studies that used varying durations from 10 to 30 seconds,\textsuperscript{23,24} and 9 to 12 minutes.\textsuperscript{22,38} Although these studies found significant improvements in muscle extensibility, the stroke types and location in which the massage was applied varied between studies. Many used all stroke types involved in Swiss massage over the entire muscle,\textsuperscript{22,37,56} or a specific element of Swiss massage such as petrissage\textsuperscript{38} Other studies used a friction type massage over the musculotendinous junction only.\textsuperscript{23,24} While the present study used a cross-fibre stroke, it still remains unclear which duration, stroke type and location massage produces the greatest improvements in muscle extensibility.
5.7. Physiological mechanisms of muscle extensibility

active knee extension
The findings of the current study are in accord with the literature which demonstrates significant improvement in active knee extension following massage therapy combined with CR technique.\textsuperscript{27,46} Interestingly, the current study did not find any significant difference in AKE between those receiving the combined intervention and those receiving the CR technique alone, a finding also reported by Puentedura et al. (2011).\textsuperscript{46} It may be reasoned that the inability to detect any significant difference between the two intervention groups may be due to a ceiling effect, as participants with minimal restriction in active knee extension were included.\textsuperscript{46} Other theories for this lack of significant difference include participant motivation; reduced quadriceps contraction strength and quadriceps fatigue.\textsuperscript{45} A standardised warm-up protocol prior to testing is one method proposed to minimise varied muscle fatigue and has been implemented in previous studies.\textsuperscript{46,47} The present study could have benefited from a warm-up protocol prior to the intervention to rule out fatigue as a preventative mechanism of active knee extension.

Another possible reason for this could be that massage therapy does not add further reductions in myoelectric activity over contract-relax technique alone. Decreased myoelectric activity occurs following normal muscle contraction.\textsuperscript{54} However, there is conflicting evidence regarding myoelectric activity following massage therapy. Some authors have reported decreased myoelectric activity (measured by the Hoffman reflex) following massage therapy.\textsuperscript{58,59} However, Huang et al. (2010) reported no significant change in myoelectric activity following their massage intervention.\textsuperscript{23} It remains unclear how altered myoelectric activity provides resistance to AKE, although it has been suggested that it increases at the end point of a passive stretch and may be attributed to involuntary stretch-induced muscle activations.\textsuperscript{57,60} Further research is needed to establish the role of altered myoelectric activity as a limiting factor of active muscle extensibility.

passive knee extension:
The findings of the present study demonstrate increased PKE following CR technique with and without massage therapy. The underlying mechanisms for each technique appear to be different. This study supports the current evidence for increased tolerance to stretch as a
mechanism of increased muscle extensibility as PKE increased with the presence of increased passive torque.\textsuperscript{25,61} Interestingly, this was only found in the combined intervention group. When MET was used alone an increase in PKE was found without significant changes in force, indicating a biomechanical viscoelastic deformation. Although some studies have found viscoelastic deformation as a mechanism for increased muscle extensibility, it was not expected in the present study as altered stretch tolerance has recently become more accepted than viscoelastic change.\textsuperscript{4,61} A possible reason for these conflicting results may be due to non-standardised torque measurements during PKE tests. The present study would have benefited from a standardised measurement of torque comparing pre- and post-test measurements and having controlled for joint angle as used by Ballantyne et al. (2003).\textsuperscript{25} This study ensured that the same pre-test measurement for torque and joint angle were measured following the intervention to evaluate viscoelastic change in its first post-test measurement or altered stretch tolerance in successive test trials.

The increase in passive ROM could be explained by increased compliance or reduced muscle stiffness due to the massage technique employed. The increase in muscle extensibility following soft tissue combined with MET can be attributed to elongation and mobilisation of shortened and adhered connective tissue as stated by Huang et al. (2010).\textsuperscript{23} Huang et al. (2010) measured the effect of a short duration massage at the musculotendinous junction and found that passive straight leg raise test results were improved significantly due to increased stretch tolerance.\textsuperscript{23} However, compared to our study the soft tissue cross-fibre was applied to the entire muscle belly as it contributes largely to the overall passive length-tension relationship during muscle stretching.\textsuperscript{2,3} Furthermore, the passive tension of muscle is dependent on structural properties of muscle such as the surrounding fascia, tendons, ligaments and joint capsules.\textsuperscript{62,63} The degree to which these can elements can be altered by stretch and massage is unknown.

5.8. \textit{Internal validity}
A limitation of this study was that the lead researcher carried out eligibility assessment, the administration of the intervention, and collected relevant date. Although the use of single researching practitioner introduces bias the design of the study is representative of clinical practice, in which osteopaths assess active and passive range of motion and then implement a
treatment strategy. The use of a blinded assessor independent from the lead researcher would strengthen the internal validity of the study.

The present study used active and passive knee extension tests alongside measurements of force to assess hamstring extensibility. Despite having excellent reliability for both AKE, and PKE, limitations exist for these tests of hamstring extensibility. The end range that is achieved during the AKE is dependent on subject motivation, and quadriceps muscle strength and fatigue as found by Norris and Matthews (2005) who also recognised these as potential limitations.

Furthermore, other studies have found that the end range achieved with PKE is reliant on the tester and depends on the amount of force used to achieve maximal joint ROM. The use of a hand held dynamometer proved difficult to control the speed during passive knee extension. If incorrectly used, excessive speed can induced a stretch-reflex which can limit further passive knee extension and create altered measures of force as found by Gnat et al. (2010).

5.9. External validity
The technique protocol used in this study was analogous to how soft tissue cross-fibre and muscle-energy technique are applied in a clinical setting. However, the present study used only asymptomatic males that were aged 18 to 45 years who exhibited a restriction in hamstring extensibility. It is therefore not representative of patients presenting to an osteopathic clinic. The findings of this study may be generalised only to those patients who have a similar clinical presentation.

5.10. Future Research
This study supports the current evidence for massage therapy combined with CR MET technique on short term increases in muscle extensibility. There is, however, limited evidence for the long term effect of soft tissue cross-fibre or CR technique on joint range of motion. Future research investigating the long term effects and the underlying mechanisms of change would add to the base knowledge on improving muscle extensibility and its effect on viscoelastic deformation, stretch tolerance and increases in muscle length through increased numbers of sarcomeres.
The present study has shown the immediate effectiveness of soft tissue cross-fibre combined with MET in improving muscle extensibility in asymptomatic populations. Future research may look to investigate the long term benefits of such techniques on hamstring extensibility in those who suffer from low back pain, patellofemoral joint dysfunction and plantar fasciitis.
6. **CONCLUSION**

The present study documented the immediate effect of a specific soft tissue cross-fibre technique combined with a contract-relax muscle energy technique on reduced hamstring extensibility. It found that a single application of soft tissue cross-fibre massage combined with muscle energy technique produced significant immediate effects in passive knee extension through both mechanical and stretch tolerance change. No significant change in active knee extension was observed. While the effects of these techniques were documented in asymptomatic individuals, such techniques may be beneficial to those who display reduced muscle extensibility in conditions such as low back pain, patellofemoral disorders, and plantar fasciitis.
7. REFERENCES


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Section Three: Appendices
Appendix A: Recruitment Poster and Flyer
Do you have tight hamstrings?

If you are between the ages of 18-45 years and think you have tight hamstrings you may be eligible to participate in this study.

I am currently completing a Master’s of Osteopathy degree at Unitec New Zealand, part of which involves a research project. The study will investigate the combined effects of a muscle energy technique and soft tissue massage on hamstring extensibility.

If you are interested or require more information please contact Yashvant Masters.

Can you help in this study?

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If you are interested or require more information please contact Yashvant Masters.

Can you help in this study?
Appendix B: Participant Information Sheet
RESEARCH INFORMATION FOR PARTICIPANTS

The combined effects of a muscle energy technique and soft tissue massage on hamstring extensibility

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

Principle Researcher

Hello, my name is Yashvant Masters. I am a fifth year osteopathic student at Unitec, undertaking my research dissertation as part of my Master of Osteopathy. Along with my supervisors, Rob Moran and Jamie Mannion, I would like to invite you to participate in a study investigating “The combined effects of a muscle energy technique and soft tissue massage on hamstring extensibility”.

Our Purpose

This study will look to measure the effects of two osteopathic techniques when combined together in people with reduced hamstring extensibility. The two techniques to be used are cross-fibre soft tissue massage and a muscle energy technique. Reduced hamstring extensibility is characterised by the sensation of tightness behind the thigh when attempting to extend the knee.

The primary aim of this study is to find out if combining a cross-fibre soft tissue massage technique with a muscle energy technique has a greater effect on hamstring extensibility, compared with each technique applied in isolation. By taking part in this study you are helping us discover the most effective way of applying these techniques in order to improve hamstring extensibility. You are also helping to provide initial data for future osteopathic research in this area.

Your voluntary participation

If you agree to participate, you will be asked to sign a consent form. This does not stop you from changing your mind if you wish to withdraw from the project. However, any withdrawals must be done within two weeks after you have completed your final assessment.

Who may participate?

We are looking for adults between the ages of 18-45 who have reduced hamstring extensibility. Reduced hamstring extensibility is characterised by the sensation of tightness or inability to fully extend the knee due to tightness within the hamstring muscle. Participants may be included in the
study if physical tests show reduced hamstring extensibility. Unfortunately you will not be included in the study if you are:

- Involved in any form of stretching programme
- Currently receiving treatment on the lower back, hip, knee, ankle or foot
- Currently suffering from lower back, hip, knee or foot pain or have had an injury to the spine or lower limb within the last 6 months
- Experiencing any neurological symptoms into the legs such as sciatic nerve impingement
- Aware of any orthopaedic condition that you may such as osteoarthritis, knee or patella dislocations, congenital anomalies, disc herniation’s or other problems affecting the spine and lower limbs
- Known to have lymphatic problems, suffer from varicose veins or have a history of deep vein thrombosis
- Taking any medication that affect the musculoskeletal system (such as muscle relaxants or pain relief medication)

Please feel free to contact the lead researcher if you are unsure about your eligibility.

**What will happen in the study?**

Should you agree to participate in the study, you will be required to attend 2 sessions, which will include measuring the degree of hamstring extensibility and the 2 interventions described below. The study will commence from the initial encounter and will last for a period of 2 consecutive weeks. The order in which you receive each intervention is randomised and determined by the design of the study. You will receive one intervention in the first week and another in the second week. Each participant will receive all of the following interventions.

The interventions are:

1. **Muscle Energy Technique (MET)**
   - This intervention involves three applications of a post isometric stretch technique to the participant’s hamstrings of the dominant leg. This intervention is based on an osteopathic technique that is supported by scientific literature and has been found to be beneficial in improving hamstring extensibility.

2. **Soft tissue massage combined with MET**
   - This intervention involves one five minute application of soft tissue massage to the hamstrings muscle group of the dominant leg. The massage technique used in this study will be a cross fibre - kneading technique, which will involve using the base of the hand and consist of a rhythmic squeezing and massaging of the muscle in a cross fibre direction to the muscle fibres.
   - After the massage technique has been completed a MET will be performed on the same limb. In all cases, the soft tissue massage will be performed first and then followed by the MET.

The initial session will take 40 minutes, with subsequent sessions lasting 30 minutes. For effective diagnosis of reduced hamstring extensibility you will be required to undress to your underwear.
(shorts are acceptable). The osteopathic techniques used in this study are those that are regularly used in the Student Osteopathic Clinic. The techniques will be carried out by a student osteopath currently completing their Masters of Osteopathy program at Unitec New Zealand.

**Assessments:**

Two assessments are conducted throughout the course of the study, and will consist of active and passive knee extension tests. Each test will take no more than 2-3 minutes each to complete.

The passive knee extension test will initially be used to determine eligibility for the study. The active knee extension and passive knee extension tests will both be used throughout the two week period of the study. A digital camera will be used alongside Image J (computer programme) to determine the angle of knee extension. A hand-held dynamometer will also be used to measure the torque at end of knee extension.

**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 included in the study, your name will be recorded on a case history form as per usual clinical policy. 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 room in the Unitec Student Osteopathic Clinic and will be stored for a minimum of 5 years. Access to this data will be limited to the principle researcher (Yashvant Masters), the research supervisor, the osteopathic tutors at the Student Osteopathic Clinic, and yourself.

**Discomforts/risks and benefits**

The techniques to be used in this study have been shown to reduce perceived hamstring muscle tightness, and improve function of the lower extremity.

There are minimal potential risks involved in this study. Mild discomfort may be experienced after the techniques are performed but is not considered as an adverse reaction. The potential risk of a blood clot being released following the cross fibre soft tissue massage technique has been described in the literature to occur in the elderly, morbidly obese, oral contraceptive users, tobacco smokers, and those who have been immobilised for extended periods. This will be taken into consideration when assessing the participant for eligibility and the benefit to risk ratio. All osteopathic techniques to be used will be discussed prior to being conducted and your consent will be sought. Should your symptoms worsen, you will be referred to an appropriate healthcare professional.

*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](http://www.acc.co.nz)

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

**Contact Details**
Yashvant Masters  
Phone: 0211414022  
Email: yashvantmasters@gmail.com

Mr Jamie Mannion  
Phone: 021 0629007  
Email: jaymannion@gmail.com

**UREC REGISTRATION NUMBER: 2010-1137**  
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.
Appendix C: Participant Consent Form
Participant consent form

The combined effects of a muscle energy technique and soft tissue massage on hamstring extensibility

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 then please sign at the bottom of the page. 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 don't have to take part in this study if I don't want to and I may withdraw at any time up to two weeks after completing the final assessment.
- 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: ……………………………

Principle Researcher: ………………………….. Date: ……………………………

UREC REGISTRATION NUMBER: 2010-1137

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Appendix D: Cultural Supervision
Tena koe Yashvant,

Listed herewith are the relevant cultural sensitivities of our discussion today, in regards to your proposed research topic.

- The feet are extremely sacred in regard to waewae tapu, or sacred footprints, as explained, the basis of our whole Powhiri process and formal welcome.

- Also in regard to sacred imprint, a process of memory imprint upon our mother, Papatuanuku and sustainability, an integral part of the powhiri process.

- In regard to holistic acknowledgment of geneology or whakapapa through sacred DNA or origins for every culture and people of earth also through the powhiri process.

- All information that can be extracted through the feet, even just the heel, as you unintentionally may leave your imprint on someone else via your index finger and thumb.

- Should someone come to you whose footprints are out of balance, you may contribute to assisting them to find balance of tread, as the feet are almost as tapu within Te Ao Maori, as the head, and every other part of this amazing data base known as "Tinana".

Our powhiri process is the highest honour Maori can bestow on anyone, teachings handed down through generations over thousands of years that are still very relevant today and I would like to acknowledge the research you have chosen.

Good luck with your application, and should you require further assistance, please do not hesitate to contact me.

Mauri ora,
Whaea Lynda
Kaiawhina Te Noho Kotahitanga Marae
Unitec Institute of Technology
Appendix E: Ethical Approval
Dear Yashvant,

Your file number for this application: 2010-1137
Title: The combined effects of a muscle energy technique and soft tissue massage on hamstring extensibility in a normal asymptomatic population

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: 12.7.2011
Finish date: 11.7.2012

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: Andy Stewart
Cynthia Almeida