

# **An investigation into the effects of manual technique targeted towards psoas major muscle on lumbar range of motion**

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A research project submitted in partial fulfillment for the requirements for the degree  
of Master of Osteopathy at Unitec 2008

# Declaration

**Name of candidate:** Marshall Gabin

This Research Project is submitted in partial fulfillment for the requirements for the Unitec degree of Master of Osteopathy.

The regulations for the degree are set out in the Master of Osteopathy Programme Schedule and are elaborated in the course handbook.

## **Candidate's declaration**

I confirm that:

- This Research Project represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Northern Y Regional Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by said Committee.

Approval Reference Number: NTY/07/09/097

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## DISSERTATION ABSTRACT

**Background and objective:** The relationship between the psoas muscle and lumbar range of motion has been little investigated. Limited literature exists that has investigated its role in lumbar range of movement. The aim of this study was to determine changes in lumbar range of motion following an osteopathic treatment of the psoas muscle versus a sham intervention.

**Design:** Randomized, assessor blinded, placebo controlled trial.

**Methods:** Twenty-five subjects (16 males, 9 females; mean age=38.3yrs, SD=10.8) met the inclusion/exclusion criteria and were enrolled in the study. Subjects were screened for clinical evidence of slight-to-moderate psoas dysfunction (low-to-moderate back pain, groin pain, or limitation in hip extension). Subjects were randomly assigned to receive either a psoas treatment intervention or a sham intervention. The primary outcome measure was change in lumbar range of motion (in flexion, extension, right- and left-side-bending) using the double-inclinometer method.

**Results:** There was little change post-intervention in lumbar flexion, extension, right- and left-side-bending. The effect size for post-intervention measures was 'trivial to small' ( $d=0.06$  to  $0.35$ ) for the treatment group in all movements, and trivial to small ( $d=0.08$  to  $0.35$ ) for the sham group. The percentage of subjects with changes less than the smallest detectable difference (SDD) was less than 10% for the treatment group, and approximately eight to 15% for the sham group in all ranges. The percentage of subjects with changes greater than the SDD was less than 10% for the treatment group, and less than 8% for the sham group in all ranges. Due to the difference noted between pre-conditioning and pre-intervention measures, a secondary analysis was undertaken based on a revised pre-intervention measure made up of an average of pre-conditioning means and pre-intervention means. The percentage of subjects measuring less than, within, or greater than the SDD were comparable to original measures. The effect size for these post-intervention measures for the treatment group was 'trivial to small' ( $d = 0.14$  to  $0.36$ ), and for the sham group was 'trivial to medium' ( $d=0.06$  to  $0.53$ ).

**Conclusions:** The results indicate that treatment of the psoas, as performed in this study, does not influence lumbar range of motion in flexion, extension, and right- and left-side-bending in subjects with mild dysfunction of the psoas muscle.

**Key words:** Osteopathy; psoas; iliopsoas; lumbar range of motion; double-inclinometer

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## **Acknowledgements**

I wish to thank the following people for their support throughout the process of completing this research project:

To all the participants who so generously gave up their time to be part of my research.

To my supervisors: Dr Andy Stewart for his support and feedback, and Rob Moran for his assistance during research proposal stage, data analysis, and his tireless support and feedback. To Simon Yardley and Kerry Castell-Spence, who generously gave of their spare time to provide the assessment for this project. To my wife for her support, encouragement and the sacrifices she has made.

## Abbreviations and Terminology

ROM	range of motion
LBP	low back pain
VAS	Visual Analog Scale
SEM	Standard Error of Measurement
SDD	Smallest Detectable Difference
SD	Standard Deviation
<i>d</i>	Effect Size (Cohen's <i>d</i> )
RCT	Randomized Controlled Trial
ICC	Intra-class Correlation Coefficient
SFMPQ	Short Form McGill Pain Questionnaire
CSA	cross sectional area

*Psoas*: in this document, “psoas” will be used to describe only the psoas major muscle.

*ASIS*: anterior superior iliac spine; an anatomic location on the anterior portion of the pelvic innominate.

*Iliopsoas*: used when describing the combination of the psoas major and iliacus muscles together, which combine into a single common tendon that inserts onto the lesser trochanter of the femur.

## **SECTION I – LITERATURE REVIEW**

## ***Introduction to the Dissertation***

The psoas muscle is a major muscle in the human body, attaching to all lumbar vertebrae and discs and also to the lesser trochanter of the femur. It is made up of the psoas major and psoas minor, however, the psoas minor is present in only 60% of the population (Salmons, 1995).

The functions of the psoas major, as described in most anatomical texts, includes flexion of the lumbar spine, flexion and slight external rotation of the femur, and flexion of the lumbar spine and pelvis when the femurs are fixed. Anatomically, the psoas<sup>1</sup> has significant fascial relations with the diaphragm, as well as continuity with the pelvis floor, through fascial linkages with the transverse abdominus and the internal oblique muscles. Psoas provides a structural connection between the diaphragm, lumbar spine, pelvic floor, and lower extremity (Gibbons, Comerford, & Emerson, 2002). The psoas may also play a role in low back pain.(Ingber, 1989; Kappler, 1973; McGill, 2004).

Research indicates that psoas may have a local stability role in the lumbar spine. Deep muscles, such as the psoas, act as joint stabilizers and maintain posture due to being closest to the axis of joint rotation (Ingber, 1989). Evidence from magnetic resonance imaging of living humans suggests the potential function of psoas major as a lateral stabilizer of the lumbar spine via axial compressive loading. The psoas major may also function as a lumbar and hip stabilizer through axial compression and vertical shortening, respectively (Bogduk, Percy, & Hadfield, 1992).

Ida Rolf<sup>2</sup>, the developer of Rolfing, is one of the pioneers of modern structural bodywork. Rolf considered the psoas one of the most significant muscles in the body, a bridge between the upper body and the legs, counter balancing the rectus abdominus muscle in an agonist/antagonist relationship, and basic in the mechanics of walking and standing (Rolf, 1989). Rolf's opinion was that initiation of leg movement in

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<sup>1</sup> 'Psoas' as defined here (and afterwards, unless specifically defined differently) indicates the psoas major muscle. The psoas minor muscle lies anteriorly to the psoas major muscle. It arises from the 12<sup>th</sup> thoracic and first lumbar vertebral bodies and the disc between. It ends in a long, flat tendon, attaching to the iliopectineal eminence and iliac fascia. It is variable and absent in approximately 40% of subjects (Salmons, 1995).

<sup>2</sup> <sup>2</sup> Ida Rolf (1986-1979), was a physiotherapist and Ph.D. in chemistry, and the developer of Structural Integration, or Rolfing, and the founder of the Rolf Institute of Structural Integration. She was one of the pioneers of structural bodywork, emphasizing structural alignment of the body with gravity.

walking was initiated in the trunk first and transmitted to the legs (together with the gluteal muscles) through the psoas. Nachemson (1966) and Andersson, Grundstrim, Oddsson & Torstensson (1992) have both hypothesized that the vertebral portion of the psoas major muscle takes part in maintaining upright postures and also increases the load on the intervertebral discs in these positions. The psoas is important in postural adaptation. Hip flexion caused by a shortening of the psoas, permits the pelvis to posteriorly rotate and decrease lumbar spinal lordosis, associated with disc loading (Bridger, Orkin, & Henneberg, 1992).

A review of the literature reveals that the psoas major has not been extensively investigated, and there exists only limited knowledge about its mechanical function with respect to the lumbar spine. Several electromyographic studies have shown psoas electrical activity for various postures and movements, (Andersson, Grundstrom, & Thorstensson, 1995; Andersson, Oddsson, Grundstram, Nitsson, & Thorstensson, 1996) and overall lumbar range of motion (ROM) has been investigated, however, no studies have been identified investigating the efficacy of any manual technique that is intended to target the psoas major muscle and alter lumbar spinal biomechanics or range of motion.

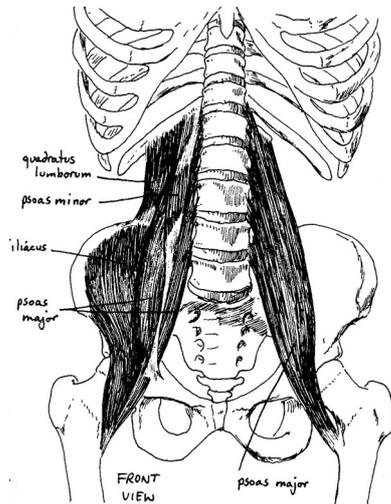
Section one of this dissertation is the Literature Review with four parts. Part one of the literature review will discuss the normal and abnormal anatomy of the psoas muscle and its functionality as presently researched, as well as clinical aspects of manual treatment of the psoas. Part two will discuss experimental methods and objective measurements for investigating psoas function and lumbar spinal range of motion (ROM). Part three will discuss issues in the performance of technique and manual therapy experiments. The final part will review literature pertinent to data analysis in experimental investigations such as that reported in Section two of the dissertation.

Section two of the dissertation investigates the following research question:

To what extent does osteopathic treatment targeted at the psoas muscle influence lumbar range of motion, in flexion, extension, right- and left-sidebending.

## ***Psoas major; normal anatomy***

The psoas major muscle is most widely known as a flexor of the hip. According to Grey's Anatomy (Salmons, 1995), it is a long muscle lying on either side of the lumbar spine, arising from the anterior surfaces and lower borders of the transverse processes of all lumbar vertebrae. The highest slip arises from the lower margin of the



12<sup>th</sup> thoracic vertebrae, the lowest from the margins of the bodies of L4 and L5 vertebrae and disc. The muscle descends along the pelvic brim, continues posteriorly to the inguinal ligament and anteriorly to the capsule of the hip joint, and converges with the tendon of the iliacus muscle, attaching to the lesser trochanter of the femur (Salmons, 1995).

The psoas major muscle is the largest muscle in cross section at the lower levels of the lumbar spine, and has fibrous attachments to the anterior aspect of all lumbar transverse processes and to the antero-medial aspect of all lumbar discs and adjoining bodies except L5-S1 (Bogduk,

Figure 1: Illustration of the psoas  
(Reproduced with permission)  
(Gorman, 1981)

Pearcy, & Hadfield, 1992). Maximum cross-sectional areas for the psoas were observed at the L4-5 level (Reid, Livingston, & Pearsall, 1994).

Overlapping segmental fascicles (group of muscle fibers sharing a common site of attachment on the vertebral column) run infero-laterally to reach a central tendon where they descend over the pelvic brim and share a common insertion with iliacus to the lesser trochanter (Gibbons, Pelley, & Molgard, 2001). The psoas major is sometimes considered together with the iliacus muscle (hence the name “iliopsoas”). Psoas major has significant fascial relations; the superior psoas fascia is continuous with the medial arcuate ligament. The right and left crus of the diaphragm and their fascia overlap psoas. The psoas’ infero-medial fascia is continuous with the pelvis floor fascia, forming a link with the conjoint tendon, transverse abdominus, and the internal oblique muscles.

Separate nerves supply the anterior and posterior psoas fascicles. The posterior are supplied by the ventral rami of spinal nerves T12-L4 and the anterior are supplied by branches of the femoral nerve from L2 to 4. The lumbar plexus is situated within the psoas major muscle in the majority of cases found in cadaver studies (Kirchmair, Lirk, Colvin, Mitterschiffthaler, & Moriggl, 2008), with minor variants found posterior to the muscle.

Blunt dissection of psoas major reveals several distinct fascicles with each fascicle having two distinct components, a vertebral head and a discal head (Bogduk et al. 1992). The most superficial fibers of the vertebral head attach along an arch spanning adjacent superior and inferior vertebral margins. Fibers of the vertebral head attach along the superior half of the vertebral body as far posteriorly as the pedicle. Fibers of the discal head form a broad attachment along the lateral aspect of the intervertebral disc. The deepest attachment of the discal head fill the intertransverse interval. Distally, each of the fascicles of psoas terminates in a common tendon within the psoas muscle proximal to the point at which psoas merges with iliacus. In contrast to Bogduk et al (1992), Jemmett, MacDonald, & Agur, (2004) found no axial attachment of the psoas to the L5 vertebral body or transverse process. Since both studies employed few specimens, the contradictory findings may be indicative of variations within the 'normal' anatomy of the psoas muscle.

### ***Normal functions of the psoas muscle***

A review of the literature by Santaguida & McGill (1995) reveals that the psoas major has been little investigated, with limited knowledge documented concerning its mechanical capacity with respect to the lumbar spine. This lack of investigation is possibly due to the psoas' location deep within the body which does not allow ease of access for electromyographic studies (using myographic electrodes); its common tendon with the iliacus muscle, and its complex anatomy.

The functions of the psoas major, as described by most standard anatomical texts, includes flexion of the lumbar spine, flexion and slight external rotation of the femur, and flexion of the lumbar spine and pelvis when the femurs are fixed. However, according to the research literature, there is much disparity as to the primary function of the psoas muscle. A search of the literature found evidence that the psoas' main

role may be either as a stabilizer of the lumbar spine, a hip flexor, or as a stabilizer of the hip joint.

### **Lumbar stability function of the psoas**

Several authors have concluded that muscles such as the psoas, having segmental patterns of attachment, are architecturally suited to generating the intersegmental stiffness required to maintain stability in the lumbar spine (Bogduk, Pearcy, & Hadfield, 1992; Jemmett, MacDonald, & Agur, 2004). Deep muscles, such as the iliopsoas, act as joint stabilizers and maintain posture due to being closest to the axis of joint rotation (Ingber, 1989). As such, the psoas may act to maintain posture and stabilize the trunk for antigravity activity.

Bogduk et al. (1992), performing cadaver dissections, found all fascicles of the psoas to be almost identical in length. Their biomechanical model concluded the psoas was not designed to execute or control flexion of the lumbar spine, as the upper lumbar segments would require longer fascicles in order to perform this function. Their theoretical concept was that the lower fascicles tend to flex the lower lumbar spine, while the upper fascicles tend to extend the upper portion, pulling the lumbar spine into more lordosis. Maximum contraction of the psoas would create very large compressive forces and large shearing forces on the lumbar motion segments, while severely shearing the L5/S1 segment. Upon extension of the lumbar spine without hip movement, the upper segments' extension forces increase relative to the erect posture. Lumbar segments L4 and L5 remain in flexion, but decrease relative to the erect posture. Total compression force on each segment is similar to erect posture, however, upper segmental shear forces increase. Only the L4-5 level is subject to flexion by all fascicles in all positions. Bogduk et al. (1992) state that the primary role of the psoas on the lumbar spine is generating force along a longitudinal moment to enhance spinal stability via axial compression. Penning (2000) came to the same conclusions using a different modeling technique.

Santaguida et al. (1995), using anatomical data from cadavers and geometrical scaling data from MRI scans of living participants, suggests the dominant function of the psoas major muscle at all lumbar levels is a potential lateral stabilizing function on the lumbar spine with compressive loading, especially during activities such as lifting.

Johnson & Reid (1991) used a 2-dimensional computer model to determine lumbar compressive and shear forces during various curl-up exercises.<sup>3</sup> It was found that contraction of the iliopsoas (and therefore maximum compressive and shear forces on the lumbar spine) was greatest at 0 degrees of hip flexion, and minimized as hip flexion increased. That lumbar and shear forces were minimized as the degree of hip flexion was maximized could suggest the importance of the lumbar spine stabilizing function. Using biomechanical modeling, Quint et al. (1998) identified that coactivation of psoas and multifidus muscles decreased range of motion at L4-5 by 20% during lateral bending and axial movements, thereby biomechanically increasing stability.

Gibbons (2001) hypothesized that psoas major, with its anatomical attachments to the diaphragm and the pelvic floor allows the muscle to act as a link between these two areas to help maintain stability of the “lumbar cylinder mechanism” (the ‘cylinder’ being formed by the diaphragm, the pelvic floor, and abdominal and posterior spinal musculature). His model proposed the posterior fascicles play a local (intersegmental) stability role while the anterior fascicles play a global (overall lumbar spinal) stability role. Gibbons, Peley, & Molgard (2001) states the psoas contracts eccentrically in spinal stability, such as leaning backwards from a sitting position, as well as from a seated position to standing.

Electromyographic studies of the psoas have been problematic due to its depth in the abdominal cavity. Use of surface electrodes has recorded little to no activity in this muscle, or more likely, activity from other more superficial muscles. Use of thin-wire electrodes placed directly into the substance of the psoas muscle have produced useful data. In several studies, psoas activity was found to be the greatest in upright sitting (with erect trunk), in supine with maximum kyphotic spine (“shoulder lift” sit up), and in contralateral straight leg lift (i.e. hip flexion) in standing and supine (Andersson et al.,1995; Andersson et al.,1996). High levels of psoas activity in upright sitting positions without support adds evidence to the hypothesis that the vertebral portion of the psoas major muscle takes part in maintaining upright postures and also helps to

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<sup>3</sup> Curl-up exercises’ refers to various exercises similar to sit-ups traditionally performed to strengthen abdominal muscles, including curl-ups with zero degrees of hip and knee flexion, hips flexed 45 degrees/knees flexed 90 degrees, and hip and knees flexed 90 degrees.

take the load off the intervertebral discs in this position (Andersson, Grundström, Oddsson, & Thorstensson, 1992; Andersson, Oddsson, Grundström, Nitsson, & Thorstensson, 1996; Nachemson, 1966). Schafer (1999) claims that Nachemson's early electromyographic studies show that the iliopsoas is just as important a lumbar stabilizer against gravitational forces in standing as it is a hip flexor during gait.

### **Other functions of the psoas muscle**

Other studies have found evidence for psoas function other than spinal stability. Using intramuscular thin-wire electromyography, Jucker, McGill, Kropf, & Steffen (1998), found psoas activation uniformly low during several lifting activities (eg lifting a barbell of 20Kg or upright standing with symmetric loads in both hands), with increase in weight, suggesting that psoas plays virtually no role in modulating spine stability. Their research found the quadratus lumborum muscle to be the primary spinal stabilizer in these activities. Based on this earlier work, McGill argues that the psoas is primarily a hip flexor and provides hip stiffness, dispersing the stress of this activity over the length of the lumbar region (McGill, 2004).

Yoshio, Murakami, & Sato (2002) concluded that the psoas major contributed very little to hip flexion. They theorized that the primary role for psoas major is hip stability, achieved through maintaining the femoral head in the acetabulum. Bridger et al. (1992) found the iliopsoas to be important in postural adaptation, functioning as a lumbar and hip stabilizer through axial compression and vertical shortening of the lumbar spine, respectively. Schafer (1999) stated that in normal erect posture, only about 12% of the weight of the abdominal organs is borne by the suspensory ligaments, the majority being supported by the inclined psoas and held there by the abdominal wall. According to clinical evidence from Jean-Pierre Barral<sup>4</sup> (Barral, 2005) the left psoas is often in spasm in gastro esophageal problems due to its attachments to the crura of the diaphragm. Barral has found clinically the left kidney, due to its position sitting on top of the psoas, slides along the psoas as a 'rail' during renal ptosis (Barral pg. 141).

According to Gluck & Liebenson's (1997) clinical opinion, an overactive iliopsoas can

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<sup>4</sup> Jean-Pierre Barral, D.O., prominent French osteopath and physiotherapist, is the developer of Visceral Manipulation therapy. He has published 7 books on visceral manipulation, and lectures worldwide.

substitute for the abdominals and cause impaired movement patterns during trunk flexion. When this occurs, as the patient flexes the trunk forward, the lumbar spine will be prevented from kyphosing because of the over activity of the shortened iliopsoas. In lifting activities, the psoas counteracts the extension movement produced by the thoracolumbar fascia. Lewit (1984) found evidence of psoas spasm in thoracolumbar lesions.

It was Ida Rolf's opinion that the psoas is basic in the mechanics of walking and standing, counterbalancing the rectus abdominus. She believed that psoas dysfunction was reflected into the diaphragm and rib cage. Her contention was that movement in walking is initiated in the trunk and transmitted to the legs through the psoas (Rolf, 1989).<sup>5</sup> The psoas muscle has also been found to be a good predictor of postural adaptation (Bridger et al., 1992).

### ***Psoas dysfunction, body structure adaptation, and possible links to low back pain***

Bachrach, Micelotta, & Winuk (1991) proposed a possible biomechanical explanation for the causation of "most low back pain". In their opinion (not demonstrated in any formal investigation), the following changes in body structure due to a chronically shortened psoas include: An increase in lumbar lordosis, stretching and weakness of the abdominal muscles, shortening of thoraco-lumbar paravertebral muscles and fascia, compensatory increase in thoracic kyphosis, a flattened cervical lordosis, and forward head posture.

In their opinion, nociceptors in the paraspinal and accessory spinal muscles become facilitated, with concomitant facet impingement and apophyseal joint capsule restriction that may cause pain. Mechanical compression of discs may generate somatic referred pain. Psoas dysfunction may also cause the pelvis to extend on the lumbar spine, anteriorly rotating ileums, causing wedging of the sacrum and pain to be generated from stretching of the anterior sacro-iliac ligaments, uni-laterally or bi-laterally. They conclude that chronic psoas dysfunction, through the generation of

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<sup>5</sup> As most texts and studies on the psoas have focused on the regional functionality of the psoas in hip flexion and lumbar spinal compression, Rolf's ideas on the psoas function expand the possible body-wide ramifications of psoas function and dysfunction.

chronic lumbar hyperlordosis, may be a significant source of lumbar disc disease through the increase in torsional/shearing forces in the discs.

Kappler (1973), found clinically that chronic contracture of the psoas (most commonly caused by flexion stress of the lumbar spine) results in loss of normal lumbar lordosis, and flexion fixation of the upper lumbar vertebral segments. This restriction of mobility causes the lumbosacral joint to go into extension relative to the sacrum putting increased compressive force into the lumbosacral and sacroiliac joints. Kappler claimed, (anecdotally) chronic or recurrent psoas restriction could be a source of low-back pain. Ingber (1989) found anecdotal evidence of psoas myofascial dysfunction (manifested in tenderness of the psoas muscle via deep abdominal palpation of the psoas muscle) as a cause of low back pain, with concomitant loss of spinal and hip extension range of motion. Dry needling of iliopsoas trigger points<sup>6</sup> (clinically) reduced pain and restored function. Based on their clinical experience, Simons & Travell (1983, 1992) found myofascial trigger points formation in the psoas muscle. These trigger points were found to refer pain along the spine ipsilaterally from the thoracic region to the sacroiliac area, and also to the anterior thigh and groin, and (in their opinion) may be a component of low back pain.

Dangeria and Naesh (1998) found evidence that the cross sectional area (CSA) of psoas decreases with increasing age for men and women, as well as psoas atrophy in participants with chronic low back pain, and reduction in psoas CSA at the level and the site of disc herniation on the ipsilateral side. Nachemson (1966) considered that a contracted psoas might increase intradiscal pressure. As the lumbar plexus is situated within the psoas major muscle in a majority of cases (Kirchmair et al., 2008), structural weakness or dysfunction of the psoas could possibly compress nerves of the lumbar plexus and thereby affect their function (Crotti, Carai, Carai, Sgaramella, & Sias, 2005).

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<sup>6</sup> According to Simons (2004), the clinical definition of a myofascial trigger point is “a hyperirritable nodule of spot tenderness in a palpable taut band of skeletal muscle, from which a local twitch response can be elicited when appropriately stimulated, that refers pain to a distance, and that can cause distant motor and autonomic effects”.

## **Pain syndromes and the psoas**

In a search of the literature (keywords 'psoas', iliopsoas'), the majority of psoas studies concerned patho-physiological issues of the psoas: spinal- or bacterial-associated psoas abscesses (Maron, Levine, Dobbs , & Geisler, 2006; Mückley et al., 2003; Swanson, Lau, Kornman, Wallace, & Polyakov, 2008), snapping hip syndrome (Byrd, 2004; Ilizaliturri, Villalobos, Chaidez, Valero, & Aguilera, 2005; O'Kane, 1999; Tatu, Paratte, Diop, & Monnier, 2001), iliopsoas tendon dysfunction (Della Valle, Rafii, & Jaffe, 2001), impingement of the psoas tendon after total hip replacement (Trousdale, Cabanela, & Berry, 1995; Yang & Bronson, 1993), iliopsoas bursitis (Morelli & Smith, 2001; Toohey, LaSalle, Martinez, & Polisson, 1990), and malignancy of the psoas (Ampil, Lall, & Datta, 2001; Behranwala & Thomas, 2002) .

### ***Anterior hip, groin or thigh pain caused by psoas dysfunction***

A cause of anterior hip pain may be due to dysfunction of the psoas muscle. Internal 'snapping hip syndrome' is caused by slippage of the iliopsoas tendon over the iliopectineal eminence or the femoral head. A "snap" or deep "clunk" may be heard over the tendon at the hip flexor crease as the hip moves from flexion to extension (Byrd, 2004; O'Kane, 1999). It may be painful or painless. Anterior hip pain may also be caused by psoas tendonitis or bursitis (O'Kane, 1999)

Iliopsoas Syndrome is the name given to a condition in which a person has bursitis, tendonitis, strain, spasm, or flexion contracture of the iliopsoas. The condition occurs primarily in gymnasts, dancers and track athletes and is associated with repetitive hip flexion. It is characterized by deep groin pain in the hip and thigh region, sometimes radiating to the anterior hip or thigh, hip stiffness, increased pain in walking or standing, flexion deformity of the leg on the affected side, and a pelvic shift to the contralateral side. It may sometimes be accompanied by a 'snapping' sensation felt around the hip with movement (called 'snapping hip' syndrome) (Morelli & Smith, 2001; Ward, 2003).

### ***Manual Techniques for treatment of the psoas***

There are several techniques described by various authors for treatment of the psoas muscle. They fall into the following categories; manipulative techniques, stretching

techniques, and palpation techniques. A search of the literature found no studies investigating the reliability or validity of these techniques. All descriptive information on the following techniques is based on clinical and anecdotal evidence.

### **Manipulation technique for treatment of the psoas**

Kappler (1973) describes psoas muscle involvement as being a factor “in significant percentage of low back complaints”. His theory, based on clinical and anecdotal evidence, is that prolonged flexion of the lumbar spine causes the psoas muscle to spasm, which causes the upper lumbar spinal segments to be fixed in flexion (which he calls ‘flexion stress’). Increased stress at the lumbosacral area produces pain in the midline of the lumbosacral area. Kappler’s recommended treatment for this condition is specific manipulative treatment to bring the upper lumbar vertebral segments back into extension.

### **Stretching technique for treatment of the psoas**

Graber (1997) describes a post-isometric relaxation technique (PIR) to stretch the psoas muscle. This technique involves passive lengthening of the muscle to its painless limit, followed by low intensity muscle contractions, then voluntary relaxation and gentle lengthening of the muscle, thereby decreasing muscle hypertonicity. The theoretical basis for the effects of PIR are that the isometric contraction of muscle places a load on the Golgi tendon organs, which results in a period of relative hypotonicity, during which time the muscle can be more easily stretched (Chaitow & DeLany, 2002).

Muscle Energy Technique (MET) is a technique clinically used to lengthen a shortened, contracted muscle or to mobilize a bony joint with limited mobility, and is defined as “a manual therapy procedure which involves the voluntary contraction of patient muscle in a precisely controlled direction, at varying levels of intensity, against a distinctly executed counterforce applied by the operator” (Greenman, 1996). The theoretical basis for MET’s effects are explained by postisometric relaxation (see above) and reciprocal inhibition (isometric contraction of a muscle resulting in a relaxation in the antagonist muscle, thereby allowing the agonist to be more easily stretched). Muscle energy technique for the psoas involves the patient supine on a table with the thigh of the involved leg off the table. The operator resists the patient’s

contraction of hip flexion for 5-7 seconds, for multiple repetitions, with the operator increasing hip extension (stretching) between repetitions.

### **Palpation techniques for treatment of the psoas**

The osteopathic modality called ‘inhibition’ is described as “the application of steady pressure to soften tissues to effect relaxation and normalize reflex activity” (Ward, 2003). Inhibition usually involves the use of fingers or other body parts to exert constant mild to moderate pressure on regions of muscle in spasm, with the intent to decrease tonicity of the muscles and symptoms due to that tonicity.

According to Travel et al. (1992), digital pressure (or ‘ischemic compression’) applied to a tissue will result in temporary tissue ischemia, which is reversed when pressure is released. It has been theorized, that once pressure is removed, existing metabolic waste products are flushed away by the resulting hyperemia (Dowling, 2000).

Constantly applied pressure of a mild to moderate intensity to a neural pain pathway may decrease output from that pathway. This process is called ‘habituation’ (Groves & Thompson, 1970). Constant digital pressure may also mechanically stretch the tissues as the elastic barrier of the tissues is reached and the viscous or plastic component of the tissue commences (Cantu & Grodin, 1992). Moderate mechanical stresses brought about by digital pressure is thought to be essential for connective tissue health and repair (Lederman, 2005). Pain reduction may occur as a result of a process called sensory gating, in which the processing and perception of one sensory modality (such as pain) may be reduced by a concomitant stimulation of another (digital pressure) (Lederman, 2005).

Iliopsoas hypertonicity can be confirmed by the presence of tension and pain during deep palpation of the abdomen below the umbilicus, lateral to the linea alba, medial to and slightly inferior to the ASIS. This hypertonicity will feel as a taut longitudinal bundle. The muscle is also palpable in the upper sulcus of the pubic arch (Schafer, 1999).

### ***Myofascial Trigger Points (MTPs) and the psoas muscle***

According to Simons (2004), the clinical definition of a myofascial trigger point is

“a hyperirritable nodule of spot tenderness in a palpable taut band of skeletal muscle, from which a local twitch response can be elicited when appropriately stimulated, that refers pain to a distance, and that can cause distant motor and autonomic effects” (p. 97).

Travell et al. (1983) described MTP examination of the iliopsoas at three locations (indirect palpation of the psoas major muscle via deep palpation through the abdominal wall):

- a) deep pressure at the lateral border of the femoral triangle over the lesser trochanter (the psoas musculotendinous junction). Pain from MTPs in this part of the muscle usually refer (in their clinical experience) to the low back and anteromedial aspect of the thigh and to the groin.
- b) palpation over the inner border of the ileum behind the ASIS (the proximal fibers of the iliacus). Pain from MTPs in the area usually refer to (in their clinical experience) the low back and sacroiliac area.
- c) pressure through the abdominal wall, lateral to the rectus abdominus, at the level of the umbilicus and lower, compressing the psoas against the lumbar spine. Pain from MTPs in this area refer mainly to the lower back.

Simons (2004) describes a manual therapy for inactivating MTPs called Trigger point pressure release, “a painless but uncomfortable barrier-release technique”, involving ischemic compression applied along the length of the involved muscle fibers.

### ***Deep palpation techniques to influence the psoas muscle***

Paul St. John, developer of the St. John method of neuromuscular therapy, describes treatment of the psoas in the form of deep palpation (through the abdominal wall) just lateral to the lateral border of the rectus abdominus at the level of the umbilicus. The patient is supine, with the leg of the side being treated flexed 90 degrees at the knee, with the knee resting on the operator’s abdomen. By resisting active flexion of the hip (the patient tries to bring his knee toward his head while the operator resists the action), while keeping the palpating hand at this area, the position of the psoas may be clarified by feeling for the muscle tightening under the palpating hand. To treat the lower portion of

the psoas, the area directly medial to the sartorius muscle and directly below the inguinal ligament is palpated deeply. (St. John, 1992). As in the description above by Travell et al. (1983) in examination of psoas MTPs, this technique is thought to compress the belly of the psoas against the lumbar spine, and addresses active sites of tenderness and referred pain.

Holmich et al. (2004) describes a technique to palpate the psoas muscle: The subject lies supine. The examiner places his/her hands over the lower lateral abdomen at the level of the anterior iliac spine. Palpation is performed with both hands; the fingers should be used to make the palpation as gentle as possible. The lateral edge of the rectus abdominus muscle is located, and palpation is performed on the lateral side of this. The fingers are gently pressed posteriorly while pushing the abdominal structures away to reach the psoas muscle. The subject must be relaxed. When the hands are as “deep into the tissues” as possible, the subject is told to elevate the foot 10 cm on the side being tested to clarify hand placement. The psoas muscle is now palpated firmly over as large an area as possible without lifting the fingers from the skin. This palpation technique can be used as a treatment technique for the psoas. Holmich et. al. (2004) found good intra-observer agreement for the above technique (mean percentage of agreement=93.8, mean interobserver kappa value=.84). The techniques of St. John and Holmich are very similar, except that in St. John, the patients leg being treated is flexed at the knee while in Holmich’s technique, the patient’s leg being treated is straight. In both techniques, resistance to hip flexion will cause psoas muscle contraction and help the operator localize treatment area.

## ***Review of experimental and objective methods for investigation of the psoas muscle:***

### **Review of experimental measures for investigation of the psoas**

#### ***The Thomas Test for psoas hypertonicity***

Hip extension results in a “close pack” configuration for the hip joint (i.e. the increased compressive force on the femoral head into the acetabulum as the capsule and capsular ligaments gain tension and increased tension of the psoas major tendon insertion onto the lesser trochanter of the femur). The Thomas test is the standard for assessment of iliopsoas length via measurement of the angle of hip extension (with the pelvis stabilized) from horizontal of subjects lying supine on a plinth. The method described by Bridger et al. (1992) is as follows: The subject reclines with both legs hanging over the edge of the plinth. The subject then raises both knees to the chest to rotate the pelvis posteriorly and flatten the lumbar curve. The subject then holds one knee to their chest to stabilize the lumbar spine and pelvis while the experimenter lowers the opposite leg, keeping the knee extended. A goniometer placed along the line of the subject’s femur by the experimenter is used to position the thigh horizontally. It is then adjusted to read zero. The measured leg is then lowered passively by the experimenter. A reading is taken when resistance prevented further hip extension. Thus, the angle to the horizontal of the arc described by movement of the thigh is obtained and used as the index of iliopsoas muscle length. (Bridger, van Houweninge, & Wilkinson, 1989)

#### ***The Modified Thomas Test***

One of the most common errors when using the Thomas test is a failure to keep the lumbar spine flat against the table (Tyler, Zook, Brittis, & Gleim, 1996). Godges, Macrae, Longdon, & Tinberg & McRae (1989) developed a modified Thomas test in which the contralateral leg is held in hip flexion and the lumbar spine is palpated for movement to eliminate pelvic tilt. Inter-rater reliability of the Modified Thomas test as reported by Gabbe, Bennell, Wajswelner, & Finch (2004) was found to be very good to excellent (ICC = 0.92, p=.67). Harvey (1998) reported very good to excellent test-retest reliability (ICC=.91-.94 for 2 trials) Holmich, Holmich, & Bjerg. (2004) found

good intra-observer agreement of a test for evaluation of pain and tightness of the psoas muscle via the Thomas test (mean percentage of agreement=92.4, mean interobserver k value=.74). Holm et al. (2000) found high intra-tester reliability (ICC =0.94 for hip extension) of goniometric measurement of hip ROM.

### ***The Iliacus Test***

According to Eland et al. (2002) the Thomas test cannot differentiate between contracture of the psoas major, iliacus and rectus femoris. Their hypothesis is that the Thomas test is a 'regional test' (i.e. does not isolate the tissues crossing only the hip joint (e.g. the iliacus muscle)). Several joints (sacroiliac, lumbar, pubic) are involved in the performance and assessment of the Thomas test, and therefore the Thomas test cannot assess the contribution of these individual joints in hip extension. The test also cannot differentiate contractures of the iliacus muscle from the psoas muscle. They devised a variation of the Thomas test, called the Iliacus test, which differentiated the contribution of the iliacus and psoas major muscles in hip extension. The key difference in performing the Thomas test and the iliacus test is that, in performing the iliacus test, the operator stabilizes the ipsilateral innominate at the anterior superior iliac spine (ASIS) to maintain position of the ASIS during extension of the lower extremity, preventing anterior rotation of the innominate bone. A significant measurable difference in ROM was found for the two tests, with the means of the iliacus test exhibiting significantly less range of motion (in hip extension) than the means of the Thomas test for both right and left lower extremity.<sup>7</sup>

## **Review of objective measures for investigation of the psoas**

### ***Visual Analogue Scale (VAS)***

The visual analogue scale (VAS) evaluates a subject's perception of pain intensity on a 100 point scale. The VAS is a 100mm unmarked horizontal line with a pain descriptor at each end; "No Pain" at one end to "Unbearable Pain" at the other (Yeomans & Liebenson, 1996). The subject reports pain intensity by marking the line

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<sup>7</sup> Mean preangle (gravity dependent end point for hip extension ROM) for Thomas test was 6.4(9.9) (in degrees (SD)) for left extremity and 10.3(8.8) for right extremity. Mean preangle for iliacus test for left extremity was 4.4(10.3) and for right extremity was 6.8(9.9). Mean postangle (examiner-induced knee pressure end point for hip extension ROM) for Thomas test was 18.2(8.2) for left extremity and 18.6(8.3) for right extremity. Mean postangle for iliacus test was 17.0(9.2) for left extremity and 16.5(7.7) for right extremity.

and the distance from the left anchor ('No Pain') to the mark is measured in millimetres. The validity of the VAS as an outcome measure is well established (Crossley, Bennell, Cowan, & Green, 2004; Merskey, 1973; Ostelo, 2005; D. D. Price, Bush, Long, & Harkins, 1994; D. P. Price, McGrath, Rafii, & Buckingham, 1983; Vicenzino, 1998; Yeomans & Liebenson, 1996). The VAS has a high level of responsiveness, reliability, and validity permitting detection of clinically relevant changes (Reading, 1980).

### ***Short Form McGill Pain Questionnaire (SF-MPQ)***

The McGill Pain Questionnaire (MPQ) was developed as a pain assessment tool for clinical and research purposes. It includes a list of descriptors for sensory, affective and evaluative aspects of pain. The SF-MPQ is a shortened form of the MPQ, consisting of 15 descriptors of pain, 11 from the sensory, and 4 from the affective categories of the MPQ. The SF-MPQ has shown good test-retest reliability (ICC (1,1)=0.75 for total scores, 0.76 for sensory scores, and 0.62 for affective scores) (Strand, Ljunggren, Bogen, Ask, & Johnsen, 2008) and validity (internal consistency based on Melzack factor structure for sensory dimensions = 0.78 and for affective dimensions = 0.76)(Wright, Asmundson, & McCreary, 2001).

### ***Literature review pertaining to assessment and measurement of lumbar spinal ROM (outcome measures)***

#### **Inclinometer method of assessing spinal range of motion:**

An inclinometer is a hand-held device, either analogue (i.e. circular, fluid-filled device with a weighted gravity pendulum indicator that remains oriented in the vertical direction) or digital (with output to a computer software program that captures and displays the data). According to the American Medical Association's Guides to the Evaluation of Permanent Impairment (AMA, 2001), the use of inclinometers is the preferred method for obtaining accurate and reproducible measurements for the spine. To measure lumbar range of motion using the double inclinometer method, one inclinometer is placed either on the sacrum, or at the L5/S1 intervertebral space and the other is placed on the first lumbar vertebrae, or at the T12/L1 intervertebral space. For flexion, the subject is asked to bend forward maximally while both inclinometers

are in position. Lumbar flexion ROM can be estimated as the difference between the two measurements. Extension, and right- and left-sidebending can be measured using the same method.

### ***Sources of error in use of inclinometers***

The major sources of error in the use of inclinometers to measure spinal range of motion are (Keeley et al., 1986; Mannion & Troke, 1999; Mayer, Kondraske, Brady Beals, & Gatchel, 1997; Rondinelli, Murphy, Esler, Marciano, & Cholmakjian, 1992)

- a) device error (the true accuracy/precision of the device).
- b) assessor/device interface error (assessors use of the device, and procedural errors)
- c) subject performance error (individual differences among subjects)
- d) overall error (a combination of all of the above sources of error)

According to Mayer et al. (1997) the most insignificant error in the use of inclinometers to measure spinal range of motion is device measurement error. This includes the accuracy/precision of the device itself.

The largest contributor to test accuracy is assessor/device interface error (the assessor's use of the device, and procedural errors). Common errors may include:

- Ability to identify bony landmarks for inclinometer placement, such as the spinous processes of thoracic, lumbar, or sacral vertebral segments, causing misplacement of the inclinometer
- Variations in movement of the skin and adipose tissue over the underlying bony structures in persons of different age (due to skin elasticity) and obesity (distance from the inclinometer to the bony structure) as the subject flexes or extends, which may compromise inclinometer placement reliability. The skin mark, and therefore the inclinometer, may move caudally relative to the bony structures during flexion, or cephalad during extension, causing the inclinometer to be at a vertebral level different than intended (Mayer, Kondraske, Brady Beals, & Gatchel, 1997; Samo et al., 1997).
- Tendency of the inclinometer to 'wobble' on the sacrum, which may give false readings (Keeley et al., 1986; Mayer et al., 1997)

- Misplacement of the inclinometer back to the original landmarks after subject movement
- Not maintaining constant pressure of the inclinometer and therefore changing its angle on the skin or misreading the scales
- Use of adhesive straps to attach sensors which may cause improper sensor placement as the subject moves (Mayer et al., 1997).

Therefore, the most significant factor in eliminating measurement error is in the training of and practice with the device by the assessors (Rondinelli et al., 1992).

Other sources of error, such as the use of external fixation devices (Ng, Kippers, Richardson, & Parnianpour, 2001; Samo et al., 1997; Saur, Ensink, Frese, Seeger, & Hildebrandt, 1996) introduce measurement error, as their effect on measurement accuracy is unknown. Samo et al. (1997) suggested the double inclinometer method might lack clinical utility because the assessor manually holding inclinometers stationary while the subject moves, could possibly compromise inclinometer position and therefore accuracy. Error may also be minimized when measurements are obtained by the same assessor than by multiple assessors (i.e. minimization of inter-operator error (Lea & Gerhardt, 1995).

### ***Inclinometer reliability and validity***

With regards to inclinometry, reliability is the consistency with which a range of motion can be measured using the device (Knutson, Soderberg, & Ballantyne, 1994). Validity is defined as the extent to which this particular device actually measures the true range of motion (Dillard, Trafimow, Andersson, & Cronin, 1991; Mayer, Tencer, Kristoferson, & Mooney, 1984). To establish validity, an inclinometer used to measure lumbar range of motion must be compared to a recognized 'gold standard'. Various researchers have defined radiography as the 'gold standard' for spinal movement measurement (Dillard, Trafimow, Andersson, & Cronin, 1991; Littlewood & May, 2007). However "the use of radiographic methods for long-term, rehabilitative evaluation is unjustifiable in terms of cost and patient risk" (Mayer, Tencer, Kristoferson, & Mooney, 1984).

Most of the studies found regarding inclinometer use to study lumbar ROM concern reliability of measurement (Adams, Dolan, Marx, & Hutton, 1986; Bo, Hilde, & Storheim, 1997; Keeley et al., 1986; Roussel et al., 2006; Saur, Ensink, Frese, Seeger, & Hildebrandt, 1996), reliability and/or validity of various types of equipment or the technique (Chen et al., 1997; Madson, Youdas, & Suman, 1999; Ng, Kippers, Richardson, & Parnianpour, 2001; Paquet, Malouin, Richards, Dionne, & Comeu, 1991; Williams, Binkley, Bloch, Goldsmith, & Minuk, 1993), validity of measurement (Adams, Dolan, Marx, & Hutton, 1986; Mayer, Tencer, Kristoferson, & Mooney, 1984; Saur, Ensink, Frese, Seeger, & Hildebrandt, 1996; Williams, Goldsmith, & Minuk, 1998) or comparison of measurement methods (Dillard, Trafimow, Andersson, & Cronin, 1991; Rondinelli, Murphy, Esler, Marciano, & Cholmakjian, 1992).

### ***Intra-rater reliability in using inclinometers to measure lumbar spinal motion***

As the present study will be using a single-assessor model, only intra-rater reliability information has been included. Comparisons between studies is difficult because investigators use a variety of statistical measures to interpret their data, including the CV (coefficient of variation), intraclass correlation coefficients (ICC) and other correlation coefficients (such as Pearson's  $r$ ).

Several studies show good intra-rater reliability of inclinometer use on the lumbar spine, and several studies showing moderate to poor reliability (see tables below). Overall, studies of flexion showed better reliability than studies of extension. See Tables 1 and 2.

**Table 1:** Studies examining intra-rater reliability using inclinometers to measure *lumbar spine flexion*:

Author	Pearson's r	Coefficient of variation (CV)*	ICC	Reliability **
Mellin (Mellin, 1986)	0.86	6.4%		Very good
Portek, Percy, Reader & Mowat (1983)		16.4%		moderate
Merritt, McLean, Erickson & Offord (1986)		13.4%		moderate
Gill Krag Johnson, Haugh & Pope(1988)		9.3-33.9%		moderate
Dillard et al. (1991)	0.79			Very good
Klein, Snyder-Mackler,Roy & DeLuca (1991)			0.89	moderate
Rondinelli et al. (1992)			0.70 – 0.86	moderate
Ng et al. (2001)	0.87	5.5%	0.87	Good-very good
Williams et al., (1993)	0.13 – 0.87			Poor-very good
Keeley et al. (1986)	0.90 – 0.96			Very good
Dopf, Mandel, Geiger & Mayer (1994)		5.1%		good
Nitschke,Nattrass,Disler, Chou& Ooi (1999)	0.90		0.90	Very good
Bo et al., (1997)	0.84-0.92	4.3 – 6.8%		Very good
Chen et al., (1997)			0.50-0.90	Poor - good
Paquet et al. (1991)	0.97			Very good -excellent

Notes

\* based on Hopkins (2000) (CV 1 -5% is considered acceptable for reliability)

\*\*based on r value scale in Hopkins (2000) (0.1=small effect, 0.3=moderate effect, 0.5=large effect, 0.7=very large effect, and 0.9=nearly perfect effect) and ICC value of >=0.90 for correlation

**Table 2:** Studies examining intra-rater reliability using inclinometers to measure *lumbar spine extension*:

Study	Pearson's r	Coefficient of variation (CV)	ICC	Reliability*
Portek et al. (1983)		15.7%		moderate
Klein et al. (1991)			0.82	moderate
Williams et al. (1993)	0.28-0.66			Poor - moderate
Nitschke et al. (1999)	0.71		0.70	good
Keeley et al. (1986)	0.90-0.96			Very good
Mellin G (1986)	0.93-	3%		Very good
Ng et al.(2001)	0.92	14.2%	0.92	Very good
Gill et al. (1988)		3.6-4.7%		good
Dopf et al. (1994)	0.94	18.1%		Very good
Dillard et al. (1991)	0.27			Poor-moderate
Merritt et al. (1986)		50.7%		poor
Bo et al. (1997)	0.85-0.86	18.8 -21.4%		Very good
Chen et al. (1997)			0.16-0.77	Poor-moderate

Notes

\* based on Hopkins (2000) (CV 1 -5% is considered good)

\*\*based on r value scale in Hopkins (2000) (0.1=small effect, 0.3=moderate effect, 0.5=large effect, 0.7=very large effect, and 0.9=nearly perfect effect) and ICC value of >=0.90 for correlation

In interpreting table 2, it has been observed in a few studies that high ICC values may not equal low CV values (Mannion & Dolan, 1994; Ng, Kippers, Richardson, & Parnianpour, 2001). Also, It has been suggested that CV is more a measure of precision than of reliability (Knutson, Soderberg, & Ballantyne, 1994). ICC measures may be a more appropriate test of reliability due to the fact it measures the extent of agreement in addition to the association between the two variables (Knutson et al., (1994)). The disparity of results from Tables one and two may be a result of the lack of uniformity of measurement precision due to differences in observer technique and training, choice of reference landmark for inclinometer placement, observer variations in technique, and potential interactive effects of all the above (Rondinelli et al., 1992).

### ***Inclinometer Validity***

According to Dillard et al., (1991), the validity of an inclinometer is the extent to which its measurements represent the true motion of the vertebrae. Several studies have investigated the validity of using inclinometers compared to the gold standard (i.e. radiography). Samo et al. (1997) found validity of use of inclinometers in lumbar extension lower than for flexion. Overall, they concluded validity for lumbar inclinometry as being 'poor'. Mean lumbar spinal flexion was at least 19.6 deg less than mean flexion as measured by radiographs (the 'gold standard'). Validity for extension was rated 'very poor', with absolute differences as high as 2700%. Samo et al.'s findings supported the findings of Portek et al. (1983), who found 'moderate' to 'poor' correlation between radiography and inclinometer use in flexion ( $r=0.52$ ) and extension ( $r=0.38$ ).

In contrast, Saur et al. (1996) found high correlation ( $r=0.97$ ;  $P\leq 0.001$ ) between radiography and inclinometry in measuring overall lumbar ROM (LROM). Mayer et al. (1994) found that total lumbar ROM was essentially identical for inclinometer and radiographic measurements, and estimated the difference could be within 10% (mean lumbar motion as measured by inclinometry = 60.5 deg. (SD=16.7 deg); as measured by X-rays = 58.5 deg.). Adams et al. (1986), measuring lumbar curvature using double electronic inclinometers, found no significant difference between flexion angles obtained by X-rays and inclinometers. Williams et al., (1998) used double inclinometry to measure lumbar flexion, measuring 46.7 deg (SD=13.1) compared to radiography 57.1 deg (SD 18.7), with Pearson's  $r=0.67$  ( $P<0.001$ ). Paquet et al.

(1991), using an electrogoniometer to measure gross trunk flexion, found high correlation ( $r = 0.97$ ) compared with values obtained by Mayer et al. (1984).

Littlewood & May (2007), performed a systematic review to examine whether “low-tech” procedures (such as inclinometry, observation, tape measurement, etc.) used to determine lumbar range of movement are of acceptable validity compared the ‘gold standard’ of measurement. Only four studies were found relevant for study (others were not considered due to low methodological quality). Three of those studies used double inclinometers (Samo et al., 1997; Saur, Ensink, Frese, Seeger, & Hildebrandt, 1996; Williams, Goldsmith, & Minuk, 1998). According to the standards set by the authors for acceptable levels of agreement (i.e. potential validity requiring correlation coefficient values  $> 0.85$ ), Samo et al. (1997) and Williams et al. (1998) both had unacceptable levels of agreement. All studies reviewed had problems with examiner blinding, and therefore had defects in methodological design. None of the studies reviewed were regarded as high quality. The conclusion reached by the authors was that double inclinometry may be valid for determining total lumbar ROM. There was conflicting evidence regarding the validity of the double inclinometry technique for determining lumbar flexion ROM, and limited evidence that the double inclinometry technique may not be valid to measure lumbar extension ROM in comparison to radiographic analysis. The authors therefore concluded the double inclinometry method may be valid for measuring total lumbar ROM, but not for flexion or extension ROM.

Portek et al. (1983) considered validity to be enhanced if measurements were made by the same observer (i.e. single assessor model). In Samo et al. (1997), using multiple examiners produced wide ranging results (ICC=0.81 to 0.99), with lower validity.

In conclusion, there is little consistency among the studies found, with some studies supporting validity (Adams, Dolan, Marx, & Hutton, 1986; Keeley et al., 1986; Mayer, Tencer, Kristoferson, & Mooney, 1984), and some critical of spinal inclinometry (Bo, Hilde, & Storheim, 1997; Dillard, Trafimow, Andersson, & Cronin, 1991). Overall, results for inclinometer reliability and validity are mixed. Operator training with the devices, procedural errors, ability to identify body landmarks for device placement, and variations in subject morphology as it relates to assessor device

use seems to be an important factor in mitigating reliability inconsistencies. Inability to more fully utilize radiography in validity studies may limit its usefulness to validate techniques or devices.

## ***Review of issues in the performance of technique and manual therapy experiments***

### **Use of pre-conditioning**

The goal of pre-conditioning in studies measuring lumbar range of motion is to bring muscular and ligamentous tissues involved in lumbar ROM to a 'steady state', so as to decrease variability in the measurements. A further goal is to reduce injuries. It is common practice to carry out preconditioning efforts prior to any measurement of tendon properties (Pearson et al. (2007)). Previous studies have utilised preconditioning trials prior to measurement of tendon properties to ensure reproducibility (Kubo, Kanehisa, & Fukunaga, 2002; Onambele-Pearson & Pearson, 2007; Pearson, Burgess, & Onambele, 2007; Reeves, Maganaris, & Narici, 2003; Rigby, 1964; Wood, Cooke, & Goodship, 1988). Pre-conditioning, or 'warm-ups' performed prior to the measurement of ranges of movement are often used by physiotherapists to improve flexibility and decrease variability due to creep deformation in the tissues (Keeley et al., 1986; Waddell, Somerville, Henderson, & Newton, 1992). Keely et al (1986) demonstrated that such warm-ups gave more stable and reliable measurements.

With repeated stretching or cyclic loading of viscoelastic tissues (such as tendons) incremental elongation takes place. This elongation of tissue decreases with each cycle of stretching until a steady state is reached, at which point the tissue will not elongate any more. At this point, the tissue is said to be preconditioned (Lederman, 2000). In Wood, Cooke & Goodship (1988) cyclical loading on a tendon resulted in an increase in elasticity. Taylor, Dalton, Seaber, & Garrett (1990) found that 80% of the elongation of a muscle-tendon unit by cyclical stretching will occur in the first four cycles of stretching. Schatzmann, Brunner & Staubli (1998) also found the most significant effect is suggested to occur during the first few cycles. 'Tendon creep' is another term for the elongation of a tendon when load is applied over time (Pearson, Burgess, & Onambele, 2007). Ault and Hoffman (1992), in a microscopic description of the tendon structure and its changes in the course of deformation, found tissue deformation tends to become constant after sufficient preconditioning.

In Schatzmann et al. (1998), cyclic preconditioning before testing was found to allow uniform measurements. Safran, Garrett, Seaber, Glisson & Ribbeck (1988). found evidence that warm-up (i.e. preconditioning) stretches the musculotendinous unit and results in an increased length at a given load, putting less tension on the musculotendinous junction and resulting in a reduced incidence of injury to the muscle-tendon junction. Their results found that that a greater force and increase in length are needed to tear isometrically preconditioned muscle.

## **Use of Sham in Manual Therapy Investigations**

The sham intervention used in a manual therapy study must closely resemble the active treatment if blinding of participants is to be successful (Bockenbauer, Julliard, Lo, Huang, & Sheth, 2002; Noll, Degenhardt, Stuart, McGovern, & Matteson, 2004). Licciardone, Stoll & Fulda (2003) in their study of OMT for chronic low back pain, defined these “sham treatments included range of motion activities, light touch, and simulated OMT techniques. The latter consisted of manually applied forces of diminished magnitude aimed purposely to avoid treatable areas of somatic dysfunction and to provide minimal likelihood of therapeutic effect.” Noll et al. (2004) have found that blinding to the treatment protocol is best achieved if the sham treatment closely mimics the treatment protocol in application to the same body areas, duration and similar sequence.

All forms of therapeutic touch have potentially beneficial physiological effects (McPartland et al., 2005; Noll, Degenhardt, Stuart, McGovern, & Matteson, 2004). From a review of placebo effects in pain related studies, Licciardone (2004) found small but consistent effects attributable to placebos. In a systematic review, Hrobjartsson & Gotzsche (2001), found evidence that placebos had a possible small beneficial effect, as compared with no treatment, in trials that used self-reported continuous outcomes.

A drawback to the use of sham interventions in manual therapy studies is that blinding practitioners who deliver OMT (osteopathic manipulative technique) and the sham manipulative treatment protocols not possible (McPartland et al., 2005). Also, all forms of therapeutic touch can elicit beneficial physiological effects, therefore

reducing the magnitude of the effect size (Noll et al., 2004). A potential pitfall in using sham techniques is that the sham could be considered as simply another form of generic manipulation, thus diluting any treatment effect that may occur with the active intervention.

Several authors recommend that researchers use subjects unfamiliar with osteopathic manipulative techniques (OMT), as people with previous experience of osteopathy are likely to be more difficult to blind using a sham treatment protocol due to the greater likelihood of being able to distinguish sham from treatment (Bockenbauer, Julliard, Lo, Huang, & Sheth, 2002; Hondras, Linde, & Jones, 2005; Licciardone, 2004; Noll, Degenhardt, Stuart, McGovern, & Matteson, 2004). However, a subject's familiarity with some types of manual therapy will not necessarily make them more difficult to blind if other types of manual therapy are used (Noll, Degenhardt, Stuart, McGovern, & Matteson, 2004). In other words, a subject familiar with OMT techniques such as HVLA (high velocity, low amplitude), *may* not be familiar with 'light touch' techniques, such as craniosacral or myofascial work. Using forms of manual therapy less familiar to the subjects in the treatment group may make blinding successful. Sham 'light touch' treatment protocols may also be easier to blind than other osteopathic treatment techniques, as both sham and treatment techniques both use very light pressure, with very little movement in the practitioner felt by the subject for either technique (McPartland et al., 2005). Hondras et al. (2005), suggest that a reason for the success in blinding in their study was that gentle 'light touch' techniques (such as myofascial, soft tissue, and lymphatic pumping techniques) used as the treatment techniques closely resembled the "light touch" used in the sham treatment protocol. Lack of familiarity with the protocol treatment may account for the success of the sham protocol in subject blinding (Noll, Degenhardt, Johnson, & Burt, 2008).

Subject blinding using sham treatment methods has had varied results. McPartland et al. (2005) found reasonable success, with 75% of the participants in the OMT treatment group believing they had received the active treatment, and 60% of the participants in the control group believed they had received the control (sham) treatment. In Noll et al. (2004), using a post study survey to assess effectiveness of the sham for blinding participants, found the same percentage of participants (43%) in both treatment and sham groups thought they had received the treatment. No

participant thought he or she received the sham, and most thought they had benefited from the 'treatment'. These results led the authors to conclude the sham treatment protocol was successful for blinding most of the participants to group assignment. In a study of chiropractic manipulation for childhood asthma, using a sham treatment for the control group, it was reported that 63% of the subjects were uncertain about group assignment (Balon et al., 1998). In Noll et al (2008), 43% of the subjects (nursing home residents) in the experimental group correctly guessed they had received OMT. The same percentage of the sham group incorrectly guessed they had received OMT. No statistical testing that may indicate the success in blinding was done for any of these studies, but it would seem logical that 10% or more difference (from 50:50) of subjects incorrectly guessing what group they belonged to would indicate a level of success. In a search of the literature, no sham interventions for the psoas were found, so therefore no direct comparisons can be made as to success of blinding of participants to group assignment in the following investigation.

## ***Literature review pertaining to data analysis***

### **Reliability - Intraclass correlation of coefficient (ICC), Statistical Detectable Difference (SDD), and Standard Error of Measurement (SEM)**

Intra-class correlation coefficients (ICC) are used to assess inter-rater and intra-rater reliability of quantitative measurements, and as a measure of reproducibility.

According to Shrout & Fleiss (1979), the ICC is the correlation between one measurement (single rating or mean of ratings) on a target and another measurement obtained on that target. In the investigation found in Section two,, ICCs were used to examine the reliability of inclinometer measurement for the single blinded assessor, and as a measure of reproducibility. Reliability refers to “the reproducibility of values of a test, assay or other measurement in repeated trials on the same individuals” (Hopkins, 2000).

Correlation coefficient values of greater than 0.80 - 0.85 are generally required to infer reliability (Littlewood & May, 2007). Portney & Watkins (1993) suggest that values about 0.75 are indicative of good reliability and that for clinical measurements reliability should exceed 0.90 to ensure reasonable validity. According to the criteria of Hopkins (2000), ICCs from 0.0 to 0.1 may be considered ‘trivial’; from 0.1 to 0.3 are considered ‘small’, from 0.3 to 0.5 are considered ‘moderate’, from 0.5 to 0.7 are considered ‘large’, from 0.7 to 0.9 are considered ‘very large’, and ICCs from 0.9 to 1.0 ‘almost perfect’.

Calculations of ICCs are required for the calculation of the standard error of measurement (SEM) and the smallest detectable difference (SDD). The SEM reflects the variability of measurements due to repetition and random error, and gives an indication of the absolute reliability of the measures used (Kropmans, Dijkstral, Stegengal, Stewart, & de Bontl, 1999). The SEM is calculated as the square root of the absolute error variance ( $SEM = SD \cdot \sqrt{1 - ICC}$ ), where SD is the standard deviation of the grand mean (Kroopmans et al., 1999). The SDD for the measurements reflects the smallest valid change between the two independent measurements that can be

detected in a subject. If the variances between the two observations are approximately the same, the SDD is calculated using the formula ( $SDD = 1.96 \cdot \sqrt{2} \cdot SEM$ ). If the variances between the two observations is different, the SDD is calculated using the formula  $SDD = 1.96 \cdot \sqrt{SEM_{p(first)} + SEM_{p(second)}}$  (Kropmans et al., 1999) The SDD is a clinically relevant measure that represents the change that might be expected because of an intervention rather than sampling error at the 0.05 level of statistical significance.

## ***Previous studies of psoas treatment and Lumbar Range of Motion***

A search of the literature reveals only one study on treatment of the psoas muscle and its effect on lumbar range of motion (Kapadia, 2000). Kapadia's study is an unpublished undergraduate project report in which treatment of the psoas using muscle energy technique produced "statistically significant" increases in lumbar spinal range of motion in all directions except flexion.<sup>8</sup> No other studies were found to have investigated lumbar ROM changes associated with the treatment of the psoas muscle. Biomechanical models of the relationship between psoas and lumbar movement have been posited by Bogduk et al (1992), Penning (2000), and others, however, these studies did not investigate treatment of the muscle and its effects on lumbar ROM.

## ***Conclusion***

The anatomy of the psoas has been extensively investigated. There are several views as to the primary function of the psoas muscle. The traditional explanation of psoas function is that of a hip flexor, however modeling studies (Bogduk, Percy, & Hadfield, 1992; Penning, 2000) indicate a role as a stabilizer of the lumbar spine. Electromyographic studies (McGill, 2004) indicate psoas has only a limited role in spinal stabilization, but rather functions as a hip flexor dispersing stress over the length of the lumbar spine. Psoas has also been proposed to play a role in hip stiffness and stabilization. Its exact role in lumbar spinal kinematics is inconclusive. Although biomechanical models seem to indicate the psoas has more of a compression/stability function of the lumbar spine than a motion function, little investigation has been done so far to confirm this. The psoas muscle's role in low back pain has never been quantified, but anecdotal evidence is quite abundant (Ingber, 1989; Kappler, 1973). Only one study was found directly applicable to the objectives of the present study, and it was neither published nor peer-reviewed.

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<sup>8</sup> the author was not able to obtain full text, only the abstract

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## **SECTION II - MANUSCRIPT**

### ***Note regarding format***

There are several points in the manuscript where the author has, for the convenience of the reader, made reference to Section III of the dissertation. These references are not part of the journal manuscript as such, and are indicated by square brackets eg [see Appendix 1]

# **An investigation into the effects of manual technique targeted towards psoas major muscle on lumbar range of motion**

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## ABSTRACT

**Background and objective:** The relationship between the psoas muscle and lumbar range of motion has been investigated little. Limited literature exists to support its role in lumbar range of movement. The aim of this study was to determine changes in lumbar range of motion following an osteopathic treatment of the psoas muscle versus a sham intervention.

**Design:** Randomized, assessor blinded, placebo controlled trial.

**Methods:** Twenty-five subjects (16 males, 9 females; mean age=38.3yrs, SD=10.8) met the inclusion/exclusion criteria and were enrolled in the study. Subjects were screened for clinical evidence of slight-to-moderate psoas dysfunction (low-to-moderate back pain, groin pain, or limitation in hip extension). Subjects were randomly assigned to receive either a psoas treatment intervention or a sham intervention. The primary outcome measure was change in lumbar range of motion (in flexion, extension, right- and left-side-bending) using the double-inclinometer method.

**Results:** There was little change post-intervention in lumbar flexion, extension, right- and left-side-bending. The effect size for post-intervention measures was 'trivial' to 'small' ( $d=0.06$  to  $0.35$ ) for the treatment group in all ranges of movement and 'trivial' to 'small' ( $d=0.08$  to  $0.35$ ) for the sham group. The percentage of subjects with changes less than the smallest detectable difference (SDD) was less than 10% for the treatment group, and approximately eight to 15% for the sham group in all ranges of movement. The percentage of subjects with changes greater than the SDD was less than 10% for the treatment group, and less than 8% for the sham group in all ranges. Due to differences noted between pre-conditioning and pre-intervention measures, a secondary analysis was undertaken based on a revised pre-intervention measure composed of an average of pre-conditioning means and pre-intervention means. The percentage of subjects measuring less than, within, or greater than the SDD were comparable to the initial analysis. Effect sizes for these post-intervention measures for the treatment group was 'trivial' or 'small' ( $d = 0.14$  to  $0.36$ ), and for the sham group was 'trivial' to 'medium' ( $d=0.06$  to  $0.53$ ).

**Conclusions:** The results indicate that treatment of the psoas, as performed in this study, does not influence lumbar range of motion in flexion, extension, and right- and left-side-bending in subjects with mild dysfunction of the psoas muscle.

**Key words:** Osteopathy; psoas; iliopsoas; lumbar range of motion; double-inclinometer

## INTRODUCTION

The psoas muscle is a major muscle in the human body, attaching to all lumbar vertebrae and discs and also to the lesser trochanter of the femur. It is made up of the psoas major and psoas minor, however, the psoas minor is present in only 60% of the population.<sup>1</sup>

The functions of the psoas major, as described by anatomical texts, includes flexion of the lumbar spine, flexion and slight external rotation of the femur, and flexion of the lumbar spine and pelvis when the femurs are fixed. Anatomically, the psoas has significant fascial relations with the diaphragm, as well as continuity with the pelvic floor, and with the transverse abdominus and the internal oblique muscles. The psoas muscle provides a structural connection between the diaphragm, lumbar spine, pelvic floor, and lower extremity,<sup>2</sup> and may play a role in low back pathology.<sup>3,4</sup>

Research indicates that psoas may have a local stability role in the lumbar spine. Deep muscles, such as the psoas, act as joint stabilizers and maintain posture due to being closest to the axis of joint rotation.<sup>3</sup> Evidence from magnetic resonance imaging of living humans highlights the function of psoas major as a potential lateral stabilizing function on the lumbar spine through compressive axial loading of the lumbar spine. Evidence was found that the psoas major acts as a prime flexor of the hip and hip stabilizer through axial compression of the lumbar spine.<sup>5</sup>

Ida Rolf<sup>a</sup>, the developer of 'Rolfing' (a form of deep tissue massage) considered the psoas "one of the most significant muscles in the body, a bridge between the upper body and the legs",<sup>6</sup> counterbalancing the rectus abdominus muscle in an agonist/antagonist relationship, fundamental in the mechanics of walking and standing. According to Rolf, leg movement in walking is first initiated in the trunk and transmitted to the legs. Nachemson<sup>7</sup> and Andersson et al.<sup>8</sup> hypothesized that the vertebral portion of the psoas major muscle takes part in maintaining upright postures and also increases the load on the intervertebral discs in these positions. The psoas is also likely to be important in postural adaptation. Hip flexion shortens the psoas, permitting the pelvis to posteriorly rotate and decrease lumbar spinal lordosis, (associated with disc loading).<sup>9</sup>

A review of the literature reveals that the psoas major has been little investigated, with limited knowledge about its mechanical capacity with respect to the lumbar spine.<sup>10</sup> Several electromyographic studies have shown psoas electrical activity for various postures and movements,<sup>11,12</sup> and overall lumbar ROM has been investigated, however, no studies have

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<sup>a</sup> Ida Rolf (1986-1979), was a physiotherapist and Ph.D. in chemistry, and the developer of Structural Integration, or Rolfing, and the founder of the Rolf Institute of Structural Integration. She was one of the pioneers of structural bodywork, emphasizing structural alignment of the body with gravity.

been identified investigating the efficacy of any manual technique that is intended to target the psoas major muscle and effects on lumbar spinal biomechanics or range of motion. The aim of this study was to investigate osteopathic treatment targeted towards the psoas muscle, and any subsequent changes in lumbar range of motion (flexion, extension, right- and left-side-bending) post intervention.

## METHODS

### Design

A randomized, single-blinded, controlled trial was used to investigate differences in lumbar range of motion following an osteopathic treatment of the psoas muscle versus a sham intervention for subjects with either non-specific low back pain (LBP) or limitation in hip extension. See figure 1 for a schematic of the study design.

[Insert Figure 1]

### ***Eligibility Criteria Assessment***

Twenty-seven people (male=17, female=10) were recruited from the staff of a poultry processing center in West Auckland, NZ. All subjects volunteered to take part in this study. To be eligible for inclusion in the study, subjects were required to have a history of either mild low back pain (not greater than 30/100 on a visual analogue scale) for the three month period prior to the study, or had current groin pain, or demonstrated a clinical limitation of hip extension (as measured by the Thomas Test<sup>13</sup>). Before enrolment all volunteers completed a general medical questionnaire [see Appendix A]. Volunteers were excluded if they exhibited any of the following:

1. signs or symptoms of degenerative joint disease or inflammation of the hip or spine, or any back pain with nerve root pain, neurological symptoms or signs, serious spinal pathology (such as tumor or infection), previous spinal surgery, spinal fracture or any structural spinal deformity such as scoliosis or spondylolisthesis;
2. another medical condition that could interfere with the therapy (i.e. cardio-vascular disease, osteoporosis, systemic inflammatory, metabolic or lymphatic disorders, severe arthritis, or recent surgery);
3. a history of long term steroid usage;
4. had received treatment of the spine or hips within the last week;
5. could not read or write in English;
6. had used analgesics in the previous 24 hours
7. had a total hip replacement

After explanation of the study procedures, all subjects gave written informed consent. The study protocol and all procedures were approved by the Northern Y Regional Ethics Committee [see Appendix B].

If the subject responded positively to the LBP question on the medical questionnaire, he/she also completed a body chart to record the topographical distribution of their symptoms,) as well as completing a VAS scale for pain intensity (see figure 2), and the Short Form McGill Pain Questionnaire.<sup>14</sup> [see Appendix A].

### ***Visual Analogue Scale***

The visual analogue scale (VAS) used was a 90mm horizontal line marked on the left with 'no pain' and on the far right with 'worst pain possible'. Subjects were asked to indicate the intensity of their pain on the line. A body chart was also provided for the subjects to record the distribution of their pain by drawing on the chart. Previous studies have demonstrated the reliability and construct validity of the VAS by demonstrating strong correlations with other self-reported measures of pain intensity.<sup>15, 16</sup> The distance from the 'no pain' end to the mark made by the patient was measured to the nearest millimeter, converted to a score out of 100 and recorded as their VAS score of pain intensity.

### ***Short Form McGill Pain Questionnaire***

All subjects who had positively responded to the low back pain item in the medical screening questionnaire also completed the Short Form McGill Pain Questionnaire (SFMPQ), which assessed the description and intensity of pain they had, out of a series of 15 different pain descriptors. The first 11 pain descriptors are physical or sensory, and the remaining 4 are affective or emotional descriptors [see appendix A].

### ***Iliopsoas length measurement via the Modified Thomas Test***

All subjects were examined by two research assistants in a separate room to screen for limitation of hip extension using the modified Thomas Test<sup>17</sup> (see figure 3). Iliopsoas length was indirectly measured using the procedure described by Bridger,<sup>18</sup> Subjects reclined in a supine position with both legs hanging over the edge of the table, before raising both knees to the chest to rotate the pelvis posteriorly and flatten the lumbar curve (see Fig 2a and 2b). The subjects then held one knee to the chest to stabilise the lumbar spine and pelvis while one assistant lowered the opposite leg, keeping the knee extended. A standard 2-arm goniometer was centered over the greater trochanter of the femur. The measured leg was then lowered passively by the assistant. The angle of hip extension was recorded at the point when resistance did not invoke further hip extension. If a 'bony end-feel' was palpated during the procedure the subject was excluded because of the possibility of osteoarthritis. A measurement of 5 degrees or less below horizontal was considered to meet the criteria for inclusion. The assistants marked on the questionnaire their findings for each subject (degrees above or below horizontal for both left and right leg). Written instruction and practical training in the correct performance of the procedure was undertaken by the

assistants prior to the experiment to ensure appropriate measurement techniques. [see Appendix C]

[Insert Figure 2a]

[Insert Figure 2b]

### ***Measurement of Lumbar Range of Motion***

All measurements of lumbar range of motion were performed using two solid state 3-axis (roll, pitch, and yaw) orientation sensors (3DM, Microstrain Inc., VT, USA). The sensors were connected via serial-to-USB ports to a Macintosh MacPro laptop computer (Apple Computer Inc) running Windows XP (Microsoft Corporation). Custom written software supplied by Microstrain (Microstrain Inc., VT, USA) was used to capture raw data from both sensors simultaneously and saved to hard disc for later analysis. Raw data were extracted and processed in Microsoft Excel [see Appendix E and F]. The orientation sensors were factory calibrated and manufacturer data sheets indicate accuracy within 0.93 degrees in pitch, within 0.33 degrees in roll, and within 1.0 degrees for yaw angles. [see appendix D]

With the subject standing in an upright position, an ink mark was made at the L5-S1 and T12-L1 interspinous levels. The T12 spinous process was located by identifying the inferior margins of rib 12 bilaterally and simultaneously palpating these margins supero-medially with the tips of the assistant's thumbs. The S1 landmark was found by a palpatory technique described by Hoppenfeld<sup>19</sup>. A single inclinometer was placed in the center of each of these lines (over the L5-S1 and T12-L1 interspaces) for each subject. The inclinometers were held in place by one assistant as the subject performed the range of motion movements, while the other assistant operated the computer software (Figure 3).

An angular measure of lumbar curvature was calculated from the inclination of the lumbar spine at the L5-S1 and T12-L1 landmarks. For flexion, subjects were asked to "reach down with the finger tips of both hands as far as possible towards your toes, checking that you keep your knees straight, and then come up to a straight position". Subject foot position was standardized using adhesive tape markers on the floor. For extension, the subject was then asked to "arch backwards as far as possible looking up to the ceiling as far as comfortable, coming back to an upright position each time" (see Figures 3a and 3b). For side-bending, the subject was then instructed to "side-bend to the right, (coming back to an upright position each time), with as little rotation as possible, keeping your feet on the floor and knees straight". Sidebending to the opposite side (left) was then undertaken. The order of side-bending (right than left) was applied consistently.

[Insert Figure 3a]

[Insert Figure 3b]

The double inclinometer method of measuring spinal range of motion has been demonstrated to have 'excellent' reliability.<sup>20 21</sup>

## **Sample Size**

Using G\*Power software (v3.0.1)<sup>26</sup> the *a priori* sample size for a two tailed t-test for the difference between two dependent means was calculated. Based on an alpha error probability of 0.05 and a power (1- $\beta$  error probability) of 0.80, and effect size of 0.5, the minimum sample size required was 26 subjects.

## **Randomization**

Subjects who met all inclusion criteria were randomly assigned using a computer generated randomization list<sup>22</sup> and opaque envelopes to either 1) the 'treatment intervention' group or 2) the 'sham intervention' group. The study utilized assessor-blinded outcomes measurement,<sup>27</sup> with the two assistants blinded to intervention group assignment for the duration of data collection.

## **Pre-Intervention Assessment and Measurement**

All subjects who met the eligibility criteria were included in the study. During the pre-intervention assessment process the practitioner and assistants were blinded to group allocation. All pre- and post-intervention assessment of subjects was performed by two assistants. The practitioner, who performed the intervention/sham treatments was also the principal investigator, and was blinded to all pre-intervention and post-intervention assessments. Pre-intervention assessment consisted of two parts: pre-conditioning and pre-intervention.

### ***Pre-conditioning***

In order to validate the mean number of pre-conditioning repetitions necessary to reach a stable measure of lumbar range of motion, a pilot study was undertaken prior to the main study. Subjects (n=10) performed 20 flexion/extensions and side-bending movements with each movement recorded using the double inclinometer method as described above. Subjects were then instructed to rest five minutes, before repeating the process a second time. Raw data were plotted and visual inspection used to identify of the number of repetitions necessary to achieve a stable measure where subsequent repetitions resulted in no further increases in range of movement. After inspection of the data plots of 10 subjects, it was concluded that for the field study each subject should perform five flexion/extensions and

10 side-bending movements for the pre-conditioning phase. During the study, pre-conditioning flexion/extension (n=5) and right- and left-side-bending (n=10) movements were recorded by the assistants for each subject.

### ***Pre-intervention measurement***

After pre-conditioning measurements were recorded, and a 5 minute rest, subjects then repeated the above flexion/extension and side-bending movements five times, measured and recorded by the same double inclinometer method as described previously. After the pre-intervention measurement was completed, the group allocation was revealed to the practitioner/principal investigator.

## **Intervention Protocol**

Following pre-intervention measurements, the practitioner/principal investigator applied the allocated intervention (either sham or treatment) to the subject. The practitioner was a trained manual therapist with over 10 years experience in a clinical environment, and was in the process of completing a postgraduate pre-registration qualification in osteopathy. All intervention and sham protocols were performed for a total of five minutes and timed with an electronic timer.

### ***Treatment Intervention***

The intervention technique (with minor modifications) was based on the work of Holmich<sup>23</sup> and is described below:

- 1) The subject lay supine and was reminded that they could stop the intervention at any time. The practitioner placed his hands over the lower lateral abdomen at the level of the anterior iliac spine. Palpation was performed with both hands; palpation was as gentle as possible. The subject's ipsilateral leg was flexed to relax the abdominal tissues.
- 2) The lateral edge of the rectus abdominus muscle was located and palpated. The fingers pressed posteriorly while gently pushing the abdominal structures away in order to apply pressure towards the belly of the iliopsoas muscle. The subject was reminded to stay relaxed.
- 3) Pressure was exerted with a gradually increasing pressure until the subject reported the first moment they experienced pain they would score as 7/10 on a verbal rating scale (1 being low and 10 being high).
- 4) When the practitioner's hands were as "deep" as possible, the subject was told to bring their bent knee to their chest against resistance. The psoas muscle was then palpated firmly over as large an area as possible without lifting the fingers from the

skin.

- 5) Direct inhibition technique of the muscle was then performed. Several areas of the psoas were treated in this way. Pressure was sustained for several seconds in each area until the pain level as perceived by the subject lessened (see Figure 4).
- 6) The above procedure was performed on both left and right sides of all subjects.

[Insert Figure 4]

After the intervention the subject returned to the assessment room (to the adjoining room) for post-intervention outcomes measurement.

### ***Sham Intervention***

The subject was supine on the treatment table in the same position as the treatment intervention subjects (Figure 5). Moderate pressure was applied by the practitioner over the lower abdominal wall with the thenar eminence of one hand. The other hand was positioned under the subject's back directly opposite the top hand. To replicate the same duration as the treatment intervention, pressure was held for two and half minutes on each side. In order to enhance the inert nature of the sham treatment, the practitioner made no attempt to palpate or engage any perceived tissue barriers of the abdomen or psoas muscle. The sham was developed to closely mimic the treatment protocol in application to the same body area, duration, and similar sequence of manipulation.<sup>24</sup> Subjects were informed that they were being treated with an osteopathic myofascial release technique, that the technique involved moderate pressure on the skin and underlying tissues, and that they should feel no pain. There was a maximum time interval of five minutes between the intervention phase (treatment or sham) and post-intervention outcomes assessment.

[Insert Figure 5]

### **Outcome Measures**

The immediate effects of manual treatment targetting the psoas through deep palpatory pressure through the abdominal wall were investigated using the primary outcome measures of lumbar range of motion in flexion, extension, and left- and right-side-bending via the double inclinometer method as described above.

## DATA ANALYSIS

### ***Data Management***

Raw data from the inferior inclinometer (placed at L5-S1) were subtracted from data obtained from the superior inclinometer (placed at T12-L1) to get relative data representing lumbar spine range of motion, in flexion, extension, right and left side-bending, in preconditioning, pre-intervention, and post-intervention for each subject. All raw data were plotted for inspection using Microsoft Excel®. A total of six charts were produced for each subject. See Figure 6 for an example of the raw chart data. [See appendix F for an example of raw data].

[Insert Figure 6]

The first five peaks indicate flexion, followed by extension data. Troughs of each incident were subtracted from each peak to get relative values. Five data points were obtained for each subject in flexion, extension, right and left side-bending. Means and standard deviations (SD) were calculated for each set of data points for each subject in each condition (preconditioning, pre-intervention, and post-intervention for flexion, extension, right side-bending, and left side-bending). The mean of the individual subject means (and standard deviation) was then calculated for all 25 subjects.

### ***Statistical analysis***

Raw data were initially plotted to determine normality of distribution. It was evident from these plots that the data were not normally distributed. It was therefore decided to use non-parametric analysis (Mann-Whitney test) for this study to obtain p values for lumbar movement for pre-conditioning, pre-intervention, and post-intervention. Effect sizes were calculated using Cohen's *d*.<sup>25</sup>

Intra-class correlation coefficients (ICC) were used to examine the reliability of inclinometer measurement for the single blinded assessor, and as a measure of reproducibility.<sup>26</sup> Intra-class correlation coefficients (ICCs) were required for the calculation of the standard error of measurement (SEM) and the smallest detectable difference (SDD). The SEM reflects the variability of measurements due to repetition and random error, and gives an indication of the absolute reliability of the measures used.<sup>27</sup> The SEM was calculated as the square root of the absolute error variance ( $SEM = SD \cdot \sqrt{(1 - ICC)}$ ), where SD was the standard deviation of the grand mean.<sup>27</sup> The SDD for the measurements reflects the smallest valid change between the two measurements that can be detected in a subject. If the variances between the two observations are approximately the same, the SDD was calculated using the formula ( $SDD = 1.96 \cdot \sqrt{2} \cdot SEM$ ). If the variances between the 2 observations were different, the SDD was calculated using the formula  $SDD = 1.96 \cdot \sqrt{SEM_{p(first)}^2 + SEM_{p(second)}^2}$ .<sup>27</sup> The SDD is a clinically

relevant measure that represents the change that might be expected because of an intervention rather than sampling error at the 0.05 level of statistical significance. The ICCs were interpreted according to the criteria of Hopkins,<sup>34</sup> in which ICCs from 0.0 to 0.1 were considered 'trivial'; from 0.1 to 0.3 were considered 'small', from 0.3 to 0.5 were considered 'moderate', from 0.5 to 0.7 was considered 'large', from 0.7 to 0.9 was considered 'very large', and ICCs from 0.9 to 1.0 'almost perfect'. Effect size were interpreted according to Hopkins, in which an effect size less than 0.2 is considered 'trivial'; from 0.2 to 0.6 is considered 'small'; from 0.6 to 1.2 is considered 'moderate'; from 1.2 to 2.0 is considered 'large'; from 2.0 to 4.0 is considered 'very large'; from 4.0 – infinite is considered 'nearly perfect'.

Microsoft Office Excel 2008 for Macintosh (Microsoft Corp., Seattle WA USA) was used to tabulate raw data, calculate means, SD, effect size, SEM and SDD. ICCs and P values were calculated using SPSS v16.0 for Macintosh statistical software (SPSS Inc. Chicago,IL, USA).

# RESULTS

## Subjects

Two volunteers were withdrawn from the study before data collection, because one had no pain while the other had radicular-like pain in one leg. There were 12 subjects in the treatment intervention group and 13 subjects in the sham intervention group (refer to Table 1 for subject demographics).

[Insert Table 1]

## Pre-intervention measures

No significant differences were found between the groups for the pre-intervention measures. Values for flexion, extension, right and left side-bending for preconditioning and pre-intervention are reported in Table 2:

[Insert Table 2]

## Reliability measures

Values for the smallest detectable difference (SDD) are presented in Table 3. The percentage of subjects falling within, less than, and greater than the SDD are found in Table 4.

[Insert Table 3]

[Insert Table 4]

### ***Intra-assessor reliability measures:***

The range of ICCs for the different trials in various ranges of motion for pre-conditioning, pre-intervention and post-intervention are presented in Table 5: Values for flexion ranged from 0.92 to 0.99. Values for Extension ranged from 0.73 to 0.94. Values for right side-bending ranged from 0.21 to 0.94. Values for left side-bending ranged from 0.13 to 0.98.

[Insert Table 5]

## Post-intervention measures

P- values and effect sizes for post-intervention measures in all lumbar spinal ROMs are shown in Table 6. For flexion, the p value was .84, with effect size 'small' (sham group=0.30, treatment group=0.35). For extension, the p value was 0.18, with effect size 'trivial' (sham group=0.06, treatment group=0.08). For right side-bending, the p value was 0.54, with an effect size from 'trivial' (treatment group=0.08) to 'small' (sham group=0.30). For left side-bending, the p value was 0.64, with an effect size from 'trivial' (treatment group=0.06) to small (sham group=0.35).

[Insert Table 6]

## Secondary analysis based on average of pre-conditioning and pre-intervention means

Due to the difference noted between pre-conditioning and pre-intervention measures, a secondary analysis was undertaken based on a revised pre-intervention measure made up of an average of pre-conditioning means and pre-intervention means (called "pre1"). All previous calculations were performed using these new values.

Reliability measures (ICCs) and values for the smallest detectable difference (SDD) obtained using pre1 values are presented in Table 7.

[Insert Table 7]

The number of subjects less than, within, or greater than SDDs calculated for all ROMs (pre1 values) are seen in Table 8.

[Insert Table 8]

P values and effect sizes for post-intervention measures (pre1 values) in all lumbar spinal ROMs are shown in Table 9. For flexion, the p value was .37, with effect size 'small' (sham group=0.40, treatment group=0.21). For extension, the p value was 0.46, with effect size 'trivial' (sham group=0.10, treatment group=0.06). For right side-bending, the p value was 0.76, with an effect size 'trivial' (treatment group=-0.14, sham group=0.06). For left side-bending, the p value was 0.95, with an effect size from 'small' (treatment group=0.36) to medium (sham group=0.53).

[Insert Table 9]

Means values for treatment and sham groups comparing the pre-conditioning phase, pre-intervention phase and the post-intervention phase are shown in Table 10. Mean changes in all ranges of motion for both treatment and sham groups except for left side-bending/treatment group decreased in value from the pre-conditioning phase to the pre-intervention phase to the post-intervention phase.

[Insert Table 10]

## DISCUSSION

The present study was designed to investigate the extent to which deep palpatory pressure over the abdomen directed towards treatment of the psoas muscle would produce a change in lumbar range of movement. There was no substantial difference in range of motion of the lumbar spine, in flexion, extension, right- and left-sidebending for pre-intervention versus post intervention for both treatment and sham groups. The effect size for post-intervention measures for both the treatment and sham groups ranged from 'small' to 'trivial'. The percentage of subjects demonstrating changes in ROM (pre- versus post-intervention) measuring less than the smallest detectable difference (SDD) was 10% or less for the treatment group (ranging from 0% in extension to 9-10% in all other ranges of motion), and approximately 8 to 15% for the sham group (ranging from 7.7% in flexion, extension and left side-bending to 15% in right side-bending). For the treatment group, the percentage of subjects demonstrating changes in ROM (pre- versus post-intervention) as measuring greater than the SDD was 0% (in flexion, right- and left side-bending) to 9% (in extension). For the sham group, the percentage of subjects measuring greater than the SDD was 0% (in left side-bending) to 7.7% (in flexion, right- and left side-bending). For the treatment group, the percentage of subjects falling within the SDD was 90-91%, and for the sham group, the percentage of subjects falling within the SDD was between 77% (in right side-bending) and 92.3% (left side-bending).

Test-retest reliability measures for range of motion varied from 'good' (for right- and left-side bending) to 'poor' (for extension). Correlation coefficients should be greater than  $r=0.8$  to fulfill criterion for acceptable reliability.<sup>28, 29</sup> Chin<sup>30</sup> recommends that coefficients greater than 0.6 have clinical utility. Intra-assessor reliability was good to excellent in all ranges of movement, except for right side-bending/ post-intervention and left side-bending /pre-conditioning. The lower intra-assessor reliability measures in side bending may be due to the increased difficulty for the assistant in accurately holding the inclinometers in place during side-bending maneuvers.

When the pre-conditioning means and pre-intervention means were averaged to give a new pre-intervention measure ("pre1"), the percentage of subjects demonstrating changes in ROM measuring less than the SDD were less than 18% for the treatment group and less than 8% for the sham group in all movements. Subjects demonstrating changes in ROM measuring greater than the SDD were less than 10% for the treatment group and less than 8% for the sham group. Reliability measures for flexion and extension improved on measures of the original analysis. while reliability for right side-bending decreased from 'good' to 'poor'. The effect size for these post-intervention measures was 'trivial' or 'small', except for the sham group in left-side-bending, which was 'medium'.

Results indicate that there were no substantial effects of the intervention in the treatment group, the ROM measures of the majority of subjects in this group falling within the SDD. Results for the sham group were similar, with the majority of subjects' ROM measures falling within the SDD. The sham group had a greater percentage of subjects with ROM measures less than the SDD.

Based on actual study sample ( $n=25$ ) and effect sizes ( $d=0.35$ ) and an alpha error probability of 0.05, the observed power was calculated at 0.43. In order to adequately power the study (power=0.80), assuming effect size=0.35, a total sample size of 67 is required. Recruitment at this level was unachievable due to funding and logistics.

As there are no published studies that have investigated lumbar ROM changes associated with treatment procedures similar to that employed in the current study, it is not possible to make direct comparisons. However, the results of this study provide evidence that gross lumbar range of motion is not a major role of the psoas muscle. Bogduk<sup>5</sup> and Gibbons et al.<sup>2</sup> suggest that psoas has minimal capacity to produce any significant range of motion at the lumbar spine, its primary role being to generate force along a longitudinal moment to enhance spinal stability via axial compression. If psoas is indeed a stabilizer of the lumbar spine, then the minimal changes observed in gross lumbar ROM in this study would be expected.

Another explanation for the minimal changes observed in gross lumbar ROM is the possibility that the treatment provided did not substantially influence the psoas. Either the treatments did not palpate deep enough, or did not have a direct influence on the muscle. Assuming Bogduk<sup>5</sup> and Gibbons et al.<sup>2</sup> are incorrect about psoas function, (i.e. psoas did influence lumbar ROM), no substantial changes would be expected as a result of this technique. In order to influence the psoas with the technique used in this study (i.e. deep palpation through the abdominal wall), the practitioner would have had to palpate through the transverse abdominus and external oblique muscles. Evidence has been found that transverse abdominus contraction increases lumbar stiffness and decreases intervertebral displacement.<sup>31</sup> Therefore, the technique used in this study may also have influenced the transverse abdominus muscle, whose concomitant influence on the spine is an unknown factor.

Another possible explanation for the minimal changes observed is that the lumbar spine does not possess prime agonistic muscle groups for movement in any of the cardinal planes (flexion, extension, side-bending, torsion). Spinal movement is composed of a series of complex patterns,<sup>32</sup> an intricate system of many functional units involved in most gross movements allowing for normal function even with the impairment of one or more of these units.<sup>33</sup> Dissection studies have shown that the psoas is part of a group of muscles arranged

in a continuous fashion around the spinal column, and therefore may work together for spinal movement.<sup>34</sup> Therefore, because of the complex arrangement of muscles that are determinants of lumbar ROM, small changes from intervention in one muscle may not be apparent when measuring gross lumbar ROM.

## **Psychosocial considerations**

As the subjects in the study all had either back or groin pain (albeit moderate), or movement limitations, and had jobs requiring demanding physical work, it might be possible that their performance in this study could be related to, or influenced by, their attitudes and beliefs about pain and disability.<sup>35</sup> The mean affective scores reported by subjects for the SFMPQ was low. The subjects' pain level had a low association with these affective descriptors. However, there could be other psychological issues operating that were not measured, such as fear avoidance and coping. Waddell<sup>36</sup> notes that correlations between pain, physical impairment, and disability are low. Psychosocial factors and psychological aspects of pain and their possible influence on outcomes of treatment were not explored in this study. Future work should consider this, given the important role of these factors in addressing musculoskeletal impairments.<sup>37</sup>

## **Sources of error**

The major sources of error in this type of study are:

- a) Device error. This relates to measurement error of the device.
- b) Assessor/device interface error. This may include assessors use of the device, error in finding reference landmarks for inclinometer placement, intra-assessor variations in technique, adequate finger pressure maintained on the skin/fat pad for consistent positioning of the inclinometer, and procedural errors.<sup>28, 38</sup>
- c) Subject performance error. This includes differences in body mass, hamstring tightness, and psychosocial/pain behavior between subjects which can influence performance, and thereby introduce error into the study. See explanation in subsequent section "Subject performance error:
- d) Overall error. The potential interactive effects among the above.

## ***Inclinometer reliability and validity***

According to Mayer et al,<sup>39</sup> the most insignificant error is device measurement error. The American Medical Association's Guides to the Evaluation of Permanent Impairment,<sup>40</sup> consider use of inclinometers to be the preferred method for obtaining accurate and reproducible measurements for the spine. The device used in this study was not directly investigated for reliability or validity. An assumption of the study was to accept the

manufacturer claims as to the accuracy of the devices. The manufacturer reports accuracy in flexion and extension = 0.33 degrees; and for side bending = 0.93 degrees. Measurement error attributable to the device is therefore small. No studies on spinal range of motion using the same inclinometers used in the study were found by the author. Since the objective of the study was to test for a change in lumbar range of motion, the validity of the device compared to a 'gold standard' or other measurement devices was not relevant. The importance was that the device be consistent between measurements. This is an assumption of this study.

### ***Assessor- device interface considerations***

According to Rondinelli et al.<sup>28</sup> training and practice with the device by the assessors is the most substantial factor in eliminating measurement error. Assessor-device interface characteristics include accurate identification of bony landmarks, accurate device placement and holding during subject movement, and careful instructions to subjects are vital criteria for standardizing the inclinometric protocol. According to Mayer<sup>39</sup>, the largest contributor to test accuracy is the assessor's use of the device. In this study, the assistants were trained by the principal investigator in anatomic placement of the inclinometers, holding the inclinometers in place during subject movement, and instructing subjects in movements. The assistant who held the inclinometers on all subjects practiced the measurement techniques on approximately 10 persons before data were collected, and the principal investigator was satisfied the assistant was proficient in performing the techniques.

Even with training, sources of assessor error that might compromise measurement accuracy include the following:

- a) Having to hold the inclinometers stationary while the subject moves.<sup>41</sup> Movement between the skin and the inclinometers could return erroneous values for ROM. Studies that have looked at assessor/device interface issues<sup>39</sup> have concluded this source of error to be small compared to taping the inclinometer to the skin, or holding the sensor in place with a strap.
- b) Misidentification of body landmarks for inclinometer placement, either due to lack of training or due to obesity of the subject. After reviewing the assistant's work with practice subjects prior to data collection, the principal investigator was satisfied the assistant consistently placed the inclinometers at the same level between trials. Marks were made on the skin to ensure correct placement.
- c) Either not instructing subjects about correct movements, or not correcting faulty movements by subjects. If subjects move too quickly, there is the possibility of erroneous inclinometer data. Assistants were trained in these measurement procedures prior to data collection.

The same assistant undertook all ROM measures using the inclinometers on each subject while the second assistant controlled the software. Therefore, the potential for error arising

from inter-assessor reliability was avoided. Intra-assessor reliability was found to be 'good' to 'excellent' (Table 5).

### ***Subject performance error***

Differences in body mass (causing variability of inclinometer placement) can influence performance and thereby introduce error into the study. In this study, subjects were not weighed, however many appeared to be overweight. Overweight and obese subjects' anatomical landmarks can be more difficult to find due to a greater distance between the skin and the underlying spinous processes of the lumbar vertebrae.<sup>42, 43</sup> In subjects who were obviously overweight or obese, it might also have been more difficult for the assistant to maintain a constant contact of the inclinometer at the correct anatomical landmark during subject movements.<sup>39</sup>

Differences in hamstring tightness between subjects might influence subject performance, and thereby introduce error into the study. According to Mayer<sup>43</sup>, standing pelvic flexion with extended knees is restrained by hamstring tightness on the most limited side. Gross compound sagittal motion (i.e. flexion) is composed of a 60:40 ratio of lumbar movement to pelvic movement through the initial 90 degrees. After this initial phase, 'terminal flexion' is achieved almost exclusively through pelvic motion, ultimately depending on the degree of hamstring tightness. As hamstring tightness could restrict pelvic movement, this could influence the subjects' level of effort<sup>43</sup>, and therefore possibly influence lumbar range of movement. Van Wingerden et al<sup>44</sup>, states that increased hamstring tension prevents anterior rotation of the pelvis, which reduces the forward-bent position of the spine. This reduction of spinal position could influence spinal ROM measurements. As hamstring tightness was not measured, it cannot be known if factor would cause differences in subjects' gross flexion, subjects' level of effort to achieve flexion, and therefore possible influence in subjects' lumbar range of motion, and therefore influence the results of the study.

Another possible source of error involves subjects returning to a neutral upright position between flexion or extension movements..<sup>45</sup> In this study (Portek, Pearcy, Reader & Mowat.), it was found that coefficients of variation for flexion and extension separately (16.4 deg and 15.7 deg, respectively) were greater than for flexion plus extension (at the same time) (9.6 deg), demonstrating the problem of establishing a neutral upright position.

Differences in psychosocial/pain behavior between subjects<sup>43, 46</sup> can influence performance and thereby introduce error into the study. There is evidence from several studies that repeated flexion causes fatigue in the erector spinae muscles<sup>47</sup>, and has been hypothesized to increase the risk of injury to intervertebral discs.<sup>47-49</sup> Fatigue may have caused subjects to restrict full range of motion, or be interpreted as pain, also causing the same behavior. It is also possible that fear avoidance behavior (referring to the avoidance of movements or

activities based on fear<sup>46</sup>) may cause subjects to restrict full range of motion. As pain behavior or fatigue was not an outcome measure, it cannot be known if these factors influenced the results of the study.

Table 10 shows a possible trend in the data. The average of means decreased from pre-conditioning to pre-intervention to post-intervention in both groups, in all lumbar ROMs except for the sham group in left side-bending. However the magnitude of the changes were less than the SD or SDD, making them insubstantial.

## Limitations of the study

This study measured gross lumbar motion only, and did not take into account the complex movement characteristics of the intervertebral joints. The results of our study have found evidence that psoas has minimal influence on gross lumbar spinal movement. Bogduk's biomechanical model<sup>5</sup> of the psoas suggests psoas has minimal ability to produce any significant range of motion at the lumbar spine. The moment arms of psoas' fascicles are small, suggesting psoas influence on the lumbar spine might be of inter-segmental compression and shear forces in nature. Dangaria et al<sup>50</sup> found psoas cross-sectional areas (CSA) significantly decreased at the site of disc herniation on the symptomatic side. Barker<sup>51</sup> found psoas showed a marked ipsilateral decrease in CSA at the clinically symptomatic level between L1 and L5 in subjects with unilateral low back pain. This evidence points to the need for further research on psoas' influence on lumbar segmental motion.

No sub-analysis by age was undertaken. Subjects of different ages may respond differently to the technique used in the study. Older subjects could have less lumbar joint mobility due to facet and disc degenerative changes or capsular/ ligamentous contractures,<sup>52, 53</sup> and therefore may be less responsive to the treatment. However, as the results of the study showed no substantial change in lumbar ROM, the author does not believe this would influence the conclusions of the study.

Many of the subjects appeared to be overweight, possibly diminishing the ability of the practitioner to penetrate deep enough into the abdomen of those subjects to adequately influence the psoas. Most subjects in the sample were of Pacific Island ethnicity. Body type/morphology from a larger diversity of ethnicities could possibly make the study more generalizable to a larger population, however the author believes that ethnicity-influenced physiological response to the technique would be negligible.

The sample was recruited from a poultry processing manufacturer, where repeated bending, lifting, and turning are routinely performed. Due to the physical nature of their jobs, this group of subjects might react differently to prolonged lumbar range of motion than other groups, such as sedentary office workers. There is evidence that repetitive lifting tasks induce

measurable fatigue in the erector spinae muscles and increases the bending stress acting on the lumbar spine, and diminished protective muscular reflexes.<sup>47, 48, 54</sup> Sitting as an occupational activity has a low association with low back pain.<sup>55</sup> Therefore, it is plausible that study results utilizing sedentary workers would differ from subjects utilized in the present study.

The technique used in this study, although well known clinically, has never been validated. Although it was thought the technique would target the psoas muscle, and our intention was to influence the muscle, it is unknown to what extent the technique influenced the psoas versus other tissues.

According to Patterson<sup>56</sup> osteopathic manipulative studies fall into two categories, either technique studies (utilizing one or more specific techniques), or studies of osteopathic treatment (utilizing a regimen of techniques to treat a problem). The present study is a technique study. Only one treatment technique, targeted to produce a response to the psoas muscle, was employed in this study. Other osteopathic techniques, as well as osteopathic treatment regimens to influence lumbar ROM, may produce results different from the present study.

## **Suggestions for future research**

As the psoas muscle has been little investigated, there are several areas of research that would need to be addressed in order to obtain a more complete view of the role of the psoas in lumbar spinal kinematics and low back pain.

### ***Foundation research***

A definition of what qualifies as psoas dysfunction needs to be clarified and validated. Many authors talk about 'psoas insufficiency'<sup>57</sup>, 'psoas hypertonicity, or 'psoas dysfunction'. However, the author has found no criteria that adequately define these conditions.

The most common test for psoas hyperonicity is the Thomas Test (or modified Thomas test). The author has not found any validation studies for the Thomas test as it relates to psoas. There are few reliability studies for this test.<sup>23, 58, 59</sup> It is inconclusive that the test itself can differentiate the psoas from other hip flexor muscles. There is currently no gold standard to evaluate psoas dysfunction.

Diagnostic studies defining psoas dysfunction need to be undertaken, along with reliability studies of relevant criteria. Establishment of the minimally clinically important difference (MCID)<sup>60</sup> for various outcome measures in relation to psoas would establish the significance of differences observed for study baseline information, and make interpretation of data

meaningful.

### ***Studies investigating the role of psoas in back pain***

Studies that address the relevance of psoas dysfunction (once 'psoas dysfunction' has been defined and validated) in people with low back pain need to be undertaken to understand psoas' role in low back pain. Anecdotal and case studies have implied low back pain is reduced with osteopathic treatment of the psoas.<sup>4, 57, 61</sup> but there is little published data. Several authors have stated a connection between psoas hypertonicity and low back pain,<sup>4, 62, 63</sup> but little study has been done on quantifying any relationship. Further research in this area should include outcome measures that include psychosocial considerations as they relate to low-back pain and spinal movement. This information would be valuable in quantifying how subjects' performance is limited by psychosocial/behavioral issues in addition to physical factors.

### ***Studies investigating psoas' influence on lumbar biomechanics***

Technique and treatment studies can be undertaken to validate technique and treatment regimens targeted at the psoas muscle and its role in lumbar spinal with quantifiable criteria. Such studies also provide valuable clinical data, as well as leading to improved clinical decision making. As explained above, further studies into the psoas' influence on intersegmental ranges of motion in the lumbar spine would help to quantify psoas' role in axial compression, as theorized by recent biomechanical models, and possibly adding evidence of psoas' role in lumbar spinal axial compression Research on the psoas' function showing changes in IARs (instantaneous axis of rotation; the centre of rotation of an intervertebral joint)<sup>64</sup> or FCRs (finite centres of rotation; the centre of rotation of a joint, defined as the point at which is unchanged by translation and rotational forces),<sup>65</sup> of lumbar segments would shed light on the psoas' role in compression of lumbar intervertebral joints during lumbar spinal movement. Studies of lumbar kinematics have been undertaken using videofluoroscopic methods.<sup>66, 67</sup> This technique may be useful in establishing whether lumbar segmental IARs would be influenced by treatment of the psoas.

## **Conclusion**

From the results of this study, use of an osteopathic technique targeted at treatment of the psoas did not substantially influence gross lumbar range of motion in flexion, extension, or right- or left-side-bending in subjects with moderate back pain, groin pain, or limitation of hip extension. Further research should consider investigating psoas' role in lumbar inter-segmental movement.

## **ACKNOWLEDGEMENTS**

The author thanks Simon Yardley (senior osteopathic student, Department of Health Science, Unitec New Zealand) and Kerry Castell-Spence for their time and help with data collection.

## List of Figures

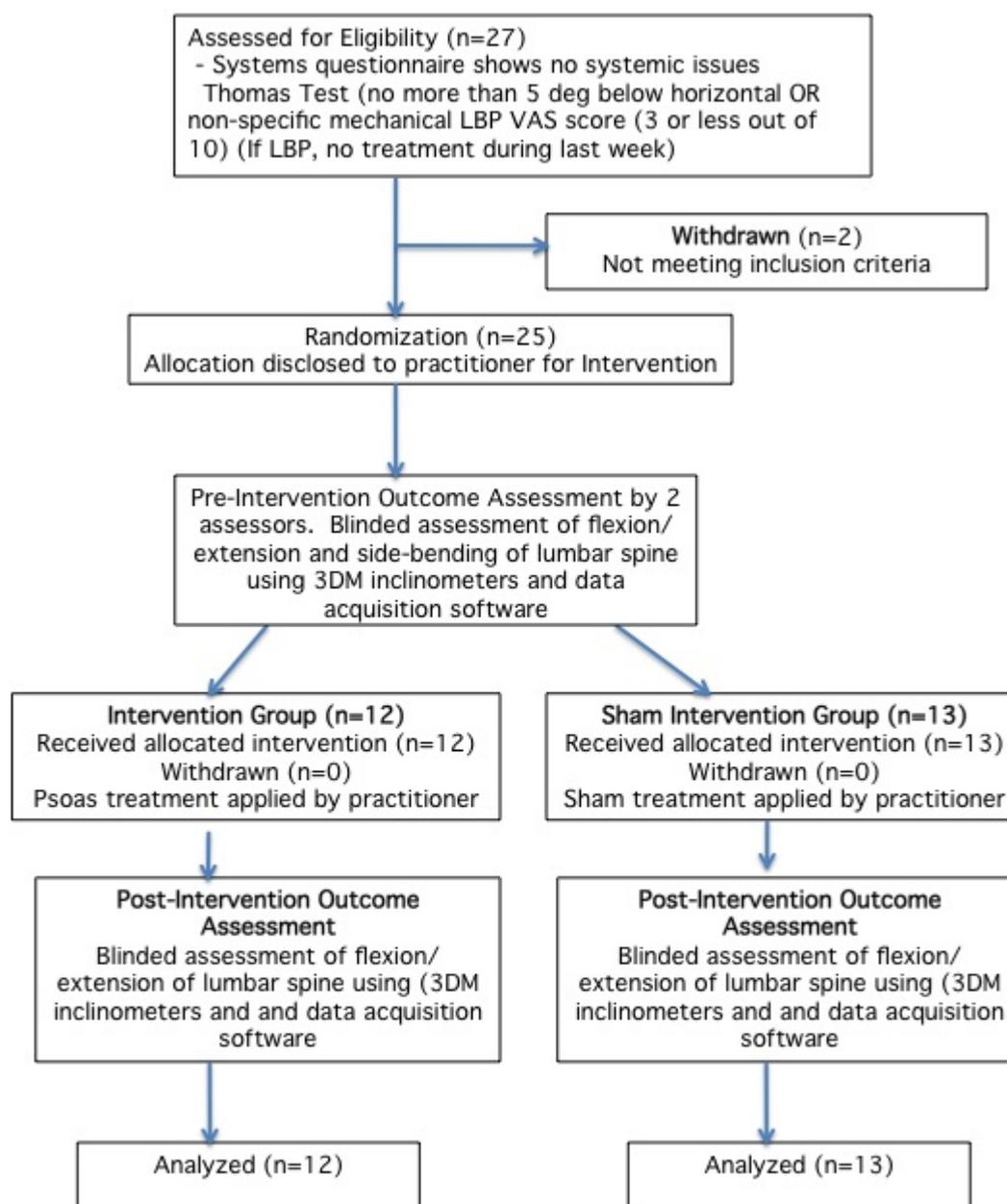


Figure 1: Schematic of Study Design



Figure 2a: Position for the measurement of psoas ROM using the Modified Thomas Test. On instruction from an investigator, the subject reclines on the plinth with both legs hanging over the edge. The subject then raises both knees to their chest to rotate the pelvis posteriorly and flatten the lumbar curve. The subject then holds one knee to the chest to stabilize the lumbar spine and pelvis while the investigator lowers the opposite leg, keeping the knee extended.



Figure 2b: Measurement of psoas ROM via use of goniometer. After positioning of the subject, a goniometer is placed along the line of the femur. The angle is recorded. A measurement of  $\leq 5$  degrees below horizontal is positive for inclusion.



Figure 3a: Inclinometer placement at T12/L1 and L5/S1 interspineous segments. Investigator holds inclinometers in place during flexion by subject. Subjects were instructed to reach down with the finger tips of both hands as far as possible towards their toes, keeping their knees straight, and then come up to a straight position.



Figure 3b: Inclinometer placement at T12/L1 and L5/S1 interspineous segments. Investigator holds inclinometers in place during extension by subject. Subjects were instructed to arch backwards as far as possible looking up to the ceiling as far as comfortable, then coming back to an upright position.



Figure 4: Psoas treatment intervention; subject position (supine) and practitioner position, with fingers positioned over the tissues of the psoas. With subject's ipsilateral leg bent to soften the abdominal tissues, practitioner gently palpates tissues just lateral to rectus abdominus just below the level of the umbilicus to engage the psoas. In order to make sure practitioner's fingers were directly over the psoas, the subject was asked to bring their bent knee to their chest against resistance. The practitioner could then feel the psoas 'tense' under their palpating fingers. Direct inhibition of the muscle was then undertaken.



Figure 5: Sham intervention; subject position (supine) and practitioner's hands in position with thenar eminence over the area of the psoas. Light to moderate pressure was applied over the lower abdominal wall, with the thenar eminence of one hand of the practitioner over the subject's ipsilateral psoas, the other hand under the subject's back directly opposite the top hand. The sham was developed to closely mimic the treatment protocol, however no attempt was made to palpate or engage any perceived tissue barriers of the abdomen or psoas. Subjects were informed that they were being treated with an osteopathic myofascial release technique, that the technique involved moderate pressure on the skin and underlying tissues, and that they should feel no pain.

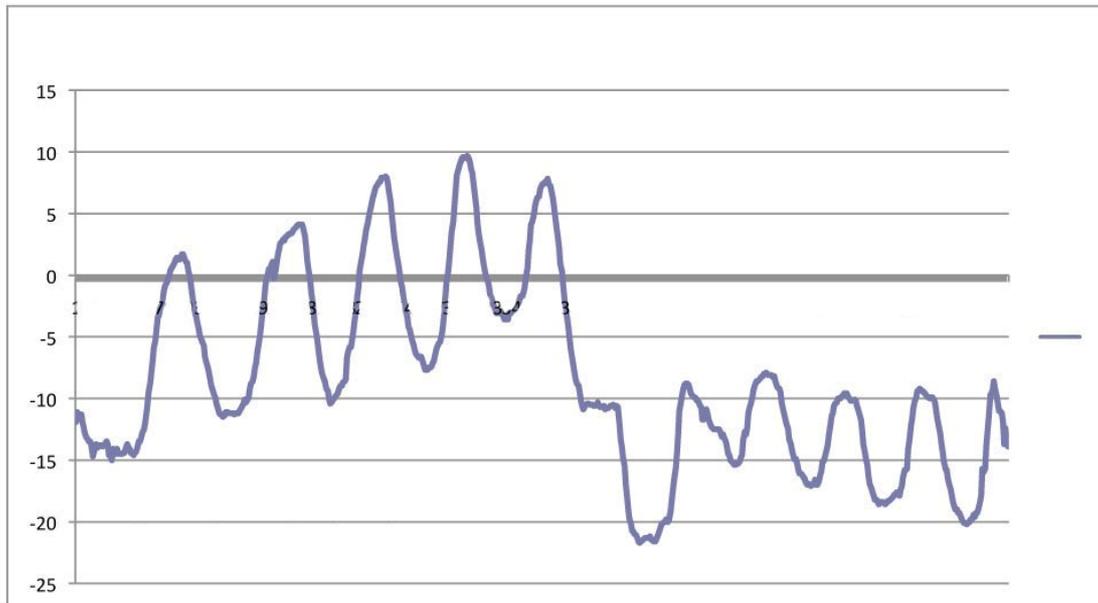


Figure 6: Sample of raw chart data (as derived from raw data in Microsoft Excel®). (X axis=time; Y axis=degrees) This example is flexion (5 'peaks' on the left) and extension (5 'peaks' on the right). Troughs of each incident were subtracted from each peak to get relative values. Five data points were thereby obtained for each subject in flexion, extension, right and left side-bending, for pre-conditioning, pre-intervention, and post-intervention.

## Tables

Table 1: subject demographics

	Treatment group	Sham Group
No. subjects	12	13
No. males	7	9
No. Females	5	4
Mean age (SD)	38.5 (9.2)	38.5 (11.8)
Mean VAS score (SD)	1.4 (1.4)	1.9 (1.1)
Mean SFMPQ sensory score	1.9	1.6
Mean SFMPQ affective score	0.25	0.15

Notes: VAS = visual analogue score for pain intensity; SFMPQ = Short Form McGill Pain Questionnaire; SD = standard deviation

Table 2: Pre-intervention measures

	Treatment group		Sham group		P value
	Means*	SD	Means*	SD	
Flexion					
preconditioning	49.7	8.7	46.5	11.7	0.66
preintervention	49.1	26.8	43.9	10.9	0.50
Extension					
preconditioning	17.0	5.8	20.0	6.7	0.46
pre-intervention	17.0	7.3	19.0	5.6	0.24
Right sidebending					
preconditioning	17.9	5.2	19.7	4.8	0.32
preintervention	16.3	5.2	18.2	5.6	0.56
Left sidebending					
preconditioning	15.8	4.8	17.9	4.6	0.26
preintervention	16.4	5.8	16.5	5.0	1.0

Notes: \* Data are the mean of each data point for all subjects

Table 3: Reliability Measures and the smallest detectable difference (SDD) pre-conditioning/ pre-intervention

	ICC	Smallest Detectable Difference (degrees)
Flexion		
pre-conditioning/ pre-intervention	0.64	26
Extension		
pre-conditioning/ pre-intervention	0.47	12.7
Right sidebending		
pre-conditioning/ pre-intervention	0.88	3.7
Left sidebending		
pre-conditioning/ pre-intervention	0.88	3.6

Notes: ICC = intra-class correlation coefficient

Table 4: Subjects less than, within, and greater than the Smallest Detectable Difference

	No. subjects	subjects < SDD (% of total)	subjects within SDD (% of total)	No. subjects > SDD (% of total)
Flexion				
treatment group	11*	1 (9)	10 (91)	0
sham group	13	1 (7.7)	11 (85)	1 (7.7)
Extension				
treatment group	11*	0	10 (91)	1 (9)
sham group	13	1 (7.7)	11 (85)	1 (7.7)
Right side-bending				
treatment group	11**	1 (9)	10 (91)	0
sham group	13	2 (15.3)	10 (77)	1 (7.7)
Left side-bending				
treatment group	10**	1 (10)	9 (90)	0
sham group	13	1 (7.7)	12	0

Notes

\*Flexion and extension data from one treatment group subject was unusable

\*\*Left side-bending data from 2 treatment group subjects, and right side-bending data from 1 treatment group subject was unusable.

SDD= smallest detectable difference

Table 5: Intra-assessor reliability measures

	ICC range (low to high)	Confidence intervals (90%)
Flexion		
Pre-conditioning	0.93 to 0.96	0.85 to 0.98
Pre-intervention	0.97 to 0.98	0.93 to 0.99
Post-intervention	0.92 to 0.99	0.82 to 0.99
Extension		
Pre-conditioning	0.84 to 0.93	0.66 to 0.97
pre-intervention	0.73 to 0.94	0.46 to 0.97
Post-intervention	0.82 to 0.94	0.62 to 0.98
Right side-bending		
Pre-conditioning	0.64 to 0.94	0.39 to 0.97
Pre-intervention	0.87 to 0.96	0.73 to 0.98
Post-intervention	0.21 to 0.93	-0.19 to 0.97
Left side-bending		
Pre-conditioning	0.13 to 0.95	-0.29 to 0.98
Pre-intervention	0.87 to 0.93	0.71 to 0.97
Post-intervention	0.90 to 0.98	0.79 to 0.99

Table 6: Post-intervention measures

	P value	Effect size* (d)	Effect size descriptor*
Flexion			
treatment group		0.35	Small
sham group	.84	0.30	Small
Extension			
treatment group		0.06	Trivial
sham group	.18	0.08	Trivial
Right side-bending			
treatment group		0.08	Trivial
sham group	.54	0.30	Small
Left side-bending			
treatment group		0.06	Trivial
sham group	.64	0.35	Small

Notes: \* Effect size and effect size descriptors from Hopkins WG (2002). A scale of magnitudes for effect statistics. In: A New View of Statistics. <http://www.sportsci.org/resource/stats/index.html>

Table 7: Reliability measures for pre1 values

	ICC	Smallest Detectable Difference (degrees)
Flexion	0.86	14.3
Extension	0.69	10.6
Right side-bending	0.71	9.2
Left side-bending	0.88	4.8

Notes: ICC= intra-class correlation coefficient

Table 8: Subjects less than, within, and greater than the Smallest Detectable Difference for pre1 values

	No. subjects	subjects < SDD (% of total)	subjects within SDD (% of total)	subjects > SDD (% of total)
Flexion				
treatment group	11*	2 (18)	9 (82)	0
sham group	13	2 (15.4)	11 (84.6)	0
Extension				
treatment group	11*	0	10 (91)	1 (9)
sham group	13	2 (15.3)	10 (77)	1 (7.7)
Right side-bending				
treatment group	11**	0	11 (100)	0
sham group	13	1 (7.7)	12 (92.3)	0
Left side-bending				
treatment group	10**	0	10 (100)	0
sham group	13	1 (7.7)	12 (92.3)	0

Notes:

\*Flexion and extension data from one treatment group subject was unusable

\*\*Left side-bending data from 2 treatment group subjects, and right side-bending data from 1 treatment group subject was unusable.

SDD= smallest detectable difference

Table 9: Post-intervention measures for pre1 values

	P value	Effect size* (d)	Effect size descriptor*
Flexion			
treatment group		0.21	Small
sham group	.37	0.40	Small
Extension			
treatment group		0.06	Trivial
sham group	.46	0.10	Trivial
Right side-bending			
treatment group		-0.14	Trivial
sham group	.76	0.06	Trivial
Left side-bending			
treatment group		0.36	Small
sham group	.95	0.53	Medium

Notes: \* Effect size and effect size descriptors from Hopkins WG (2002). A scale of magnitudes for effect statistics.  
 In: A New View of Statistics. <http://www.sportsci.org/resource/stats/index.html>

Table 10: Mean changes in ranges of motion for subject groups in different directions of movement over the course of the study

	Preconditioning	Pre-intervention	Post-intervention
Flexion			
Treatment group	49.7 (8.7)	49.1 (26.8)	41.2 (17.7)
Sham group	46.5 (11.7)	43.9 (10.9)	40.1 (14.8)
Extension			
Treatment group	17.5 (5.8)	16.78 (7.3)	16.2 (9.9)
Sham group	20.0 (6.7)	18.8 (5.6)	18.4 (6.0)
Right side-bending			
Treatment group	17.9 (5.2)	16.3 (5.2)	15.9 (6.2)
Sham group	19.7 (4.8)	18.7 (5.6)	17.4 (3.4)
Left side-bending			
Treatment group	15.8 (4.8)	16.4 (5.8)	16.0 (6.4)
Sham group	17.9 (4.6)	16.5 (5.0)	15.0 (3.7)

Note: Data are the average of means (SD) of all subject's mean results for each range of motion

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# Appendices

# Appendix A

## Screening Questionnaire for General Health and Musculoskeletal Injury History

### Questionnaire on General Health and Musculoskeletal Injuries

Participant number: _____	My age is: _____
My gender is: <input type="checkbox"/> Male <input type="checkbox"/> Female	My ethnicity is: _____

1. Have you recently received, or am presently receiving treatment for any musculoskeletal disorder? If yes, please explain.
2. Do you experience any low back pain now, or have experienced low back pain in the last year?
3. Have you received any treatment for low back pain in the last week?
4. Do you experience any hip pain or stiffness when you extend your hip, or have experienced such in the last year?
5. Do you experience any groin pain, or have experienced groin pain in the last year?

**If you experience pain in ANY of the above situations, please fill out the body map /pain scale and the short form McGill pain questionnaire on the following page.**

6. Are you currently taking any prescription pain medication? Do you regularly use any prescription or over-the-counter medication? If so, please explain.
7. Have you been diagnosed, treated and/or medicated for any circulatory, blood or heart conditions in the last 10 years (including any of the following)?
 

<input type="checkbox"/> Arteriosclerosis/Artherosclerosis	<input type="checkbox"/> Rheumatic fever
<input type="checkbox"/> Coronary Artery Disease / Angina	<input type="checkbox"/> Pericarditis
<input type="checkbox"/> High Blood Pressure (Hypertension), (if controlled by diet leave blank)	<input type="checkbox"/> Blood Clots / Deep Vein Thrombosis (exclude single attack)
<input type="checkbox"/> Aneurysm	<input type="checkbox"/> Other (please explain)
8. Have you been diagnosed, treated and/or medicated for any serious digestive conditions in the last 10 years? If so, please explain:
9. Have you been diagnosed, treated and/or medicated for endocrine, lymphatic or metabolic conditions in the last 10 years (including the long term use of steroids)?
10. Are you currently receiving treatment or have received treatment within the last month for any muscle, skeletal or skin conditions, including any of the following?
 

Arthritis (chronic or severe osteo- or rheumatoid arthritis includes Ankylosing Spondylitis, Degenerative Disk Disease, and Psoriatic Arthritis; includes conditions that are controlled by aspirin or over-the-counter non-steroidal anti-inflammatory agents)

Bone Disorders (includes Osteoporosis, hip dysplasia, fractures, or bone spurs)

Cartilage/Ligament/Tendon Conditions (includes Chondritis, or Dupuytren's Contracture (in hands)

Synovitis (a joint lining inflammation, including Tendonitis or Tendinitis)

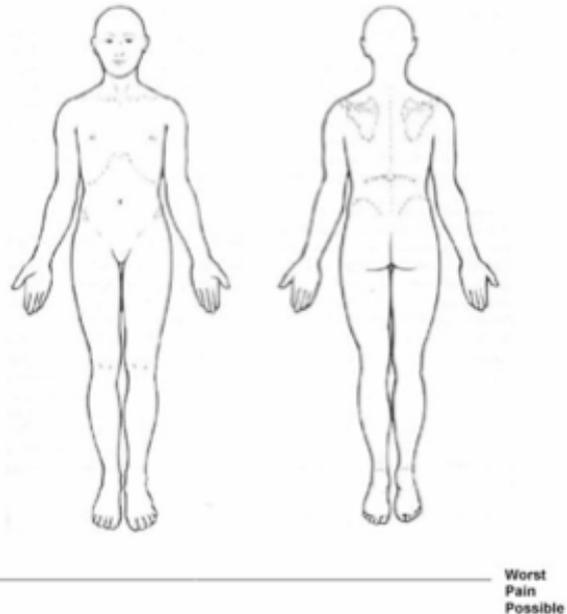
Tendonitis of Thumb (De Quervain's Disease)
11. Have you been diagnosed, treated and/or medicated for osteoporosis?
12. Have you been diagnosed, treated, and/or medicated for degenerative joint disease, either on the spine, hip, or anywhere else?

## Body Map/ Visual Analogue Scale for pain & Short Form McGill Pain Questionnaire

### Body Map/ pain scale

Indicate on this line how bad your pain is—at the left end of line means no pain at all, at right end means worst pain possible.

Also, please draw on the body map where you feel the pain.



### SHORT FORM MCGILL PAIN QUESTIONNAIRE and PAIN DIAGRAM

*(Reproduced with permission of author © Dr. Ron Melzack, for publication and distribution)*

Check the column to indicate the level of your pain for each word, or leave blank if it does not apply to you.

		Mild	Moderate	Severe
1	Throbbing			
2	Shooting			
3	Stabbing			
4	Sharp			
5	Cramping			
6	Gnawing			
7	Hot-burning			
8	Aching			
9	Heavy			
10	Tender			
11	Splitting			
12	Tiring-Exhausting			
13	Sickening			
14	Fearful			
15	Cruel-Punishing			

### Modified Thomas Test: TO BE FILLED IN BY ASSESSOR ONLY

Degree above horizontal

Degree below horizontal

Right:

Left:

# Appendix B – Ethics Resources

## Consent Form



### An Investigation into the Effects of Manual Technique of the Psoas Major Muscle on Lumbar Range of Motion

#### Consent Form (February 2008, version 2.0)

This research project is to investigate the change in lumbar range of motion outcome measures by manual treatment of the psoas muscle. The research is being undertaken by Marshall Gabin from Unitec New Zealand, and will be supervised by Dr Andy Stewart and Derek Nash.

Name of Participant:.....

I have seen the Information Sheet dated November 2007 for people wishing to participate in the project investigating the change in lumbar ROM outcome measures by manual treatment of the psoas muscle.

I have had the opportunity to read the contents of the information sheet and to discuss the project with the researchers and I am satisfied with the explanations I have been given.

I understand that taking part in this project is voluntary (my choice) and that I may withdraw up until the point at which data analysis is started and this will in no way affect my access to the services provided by Unitec New Zealand or any other support service.

I understand I will need to remove any superficial clothing covering the upper body (shirts/blouses etc), from the waist up [NOT underwear].

I understand all data will be kept indefinitely and may be used for further research purposes.

I understand that I can withdraw from the study if, for any reason, I want this.

I understand that my participation in this project is confidential and that no material that could identify me will be used in any reports on this project.

I have had enough time to consider whether I want to take part.

I know whom to contact if I have any questions or concerns about the project

The principal researcher and first contact for this project is:

Marshall Gabin  
021 780 885  
mailto:mgabin@bodyworkasia.com

Signature.....participant ..... (Date)

Project explained by.....

Signature..... (Date)

The participant should retain a copy of this consent form.

This study has been approved by the Northern Y Regional Ethics Committee from Feb. 2008 to December 2008. If you have concerns about the way in which the research is being conducted you can contact the following: Health Advocates: Advocates Network Services Trust, Phone (09) 623 5799, 0800 205 555, Fax (09) 623 5798, PO Box 9983, Newmarket, Auckland. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome

# Information Form



## **A Proposed Investigation into the Effects of Manual Technique of the Psoas Major Muscle on Lumbar Range of Motion**

### **Information Sheet** (February 2008, Version 2.0)

#### **About the research**

You are invited to take part in a research project being undertaken as part of the Masters of Osteopathy Degree. This information sheet is designed to inform you as to the nature of the research and what will happen should you choose to take part.

The purpose of this research is to investigate the change in lumbar spine range of motion and mobility when the psoas muscle (a major flexor muscle of the hip) is treated. We are recruiting individuals who may or may not have back pain or groin pain, or limitation of hip extension. It is hoped that the information gained from this research will help osteopaths when making treatment decisions in the management of patients.

The intervention treatment requires the application of pressure into the subject's lower abdomen in order to treat the psoas major muscle. This process will be carried out by a trained operator in a controlled environment, with minimal pressure applied on a gradually increasing scale until the subject experiences pain that they would classify as '7-out-of-10' on a '1-out-of-10' scale (one being the lowest). During this technique the participant is only required to relax. The subject will be instructed that they can stop the treatment at any time.

**You have the right not to participate, or withdraw from this research project at any time up until the point of data analysis (2 weeks after the last session). Contact Marshall Gabin or Andy Stewart that you no longer wish to participate by telephone or email, or by telling us when we contact you.**

**An executive summary of the results of the study will be made available to all participants who request it. A copy of the final report will be available at the Unitec New Zealand library. All participants are welcome to view this. Summaries and recommendations may be published in research journals.**

#### **The researchers**

The researcher is Marshall Gabin. Dr Andy Stewart and Derek Nash are supervising the research project.

#### **What will participation involve?**

- To currently have a limitation in hip extension, back pain, or groin pain.
- Read and complete a screening questionnaire on General Health and Musculoskeletal Injuries that may prevent you from participating in the project.
- Be available for one data collection session lasting up to 1 ½ hours.
- The research will require you to undergo a treatment consisting of pressure to the lower abdomen in order to treat the psoas major muscle. You may experience discomfort from the pressure. This will be carried out by a trained operator in a controlled environment, with the pressure applied gradually until pain is experienced.
- Another trained assessor will collect data via measuring the range of motion of your lower (lumbar) spine, both in forward/backward bending, as well as sidebending via the use of inclinometers. This testing process will be repeated before and after treatment in order to assess the treatment's effectiveness.
- As this is an experimental design research you may be randomly assigned to either a treatment group to receive the psoas muscle treatment or another group receiving another osteopathic technique. You will not be informed of the type of technique you receive until the end of data collection, as the experimental method requires that this information is concealed from you until after treatment and data collection has finished.

- All participants will receive one complementary follow-up treatment session with the principal researcher, one week after data collection or at a later date that suits.
- In order to participate all subjects are required to sign a consent form.
- The research requires a participant to remove any superficial clothing covering the upper body (shirts/blouses etc), from the waist up [NOT underwear].
- For the purpose of data collection three to five anatomical landmarks on your spine will be identified via markers attached with double-sided tape.
- There will be no sudden movements and your comfort will be monitored. You will be allowed rest breaks, as you require them. You are free to withdraw from the sessions at any point and do not need to state a reason for doing so.
- Consent to the research team's use of the research data in preparing both a research project dissertation and an article for publication (all data will be anonymous).
- Consent to the storage of your anonymous research data indefinitely for future research.

#### **Getting help**

Please contact either one of us should you require help with this research project.

Marshall Gabin	Email: <a href="mailto:mgabin@bodyworkasia.com">mgabin@bodyworkasia.com</a>	Phone: 021 780 885
Dr Andy Stewart	E-mail: <a href="mailto:astewart@unitec.ac.nz">astewart@unitec.ac.nz</a>	Phone: (09) 815 4321 ext. 8384
Derek Nash	Email: <a href="mailto:dnash@unitec.ac.nz">dnash@unitec.ac.nz</a>	Phone: (09) 815 4321 ext 5085

#### **Potential risks to research participants**

There is no known published data indicating any risks associated with this research. However, the researcher accepts that it is possible there may be some undetermined risks involved in the research process. In the case that any potential risk of harm should arise for any research participant, it will be treated on an individual basis. In any such case the research process will be halted immediately.

#### **Confidentiality**

Confidentiality and your anonymity will be protected in the following ways:

- Only the researchers will see completed questionnaires and consent forms.
- All forms will be stored in a locked file. Only the researchers will have access to this file.
- Any data derived from the research will be anonymous and your identity will be kept confidential.

#### **Information and concerns**

If you want further information about the project, you can call or email the above addresses.

At anytime if you are concerned or confused about the research project you may contact Marshall Gabin, the primary researcher at the details above.

**If you have concerns about the way in which the research is being conducted you can contact the following:**

Health Advocates: Advocates Network Services Trust, Phone (09) 623 5799, 0800 205 555, Fax (09) 623 5798, PO Box 9983, Newmarket, Auckland. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

**Finally, we would like to thank you for your valuable contribution to this research.**

This study has been approved by the Northern Y Regional Ethics Committee from Feb. 2008 to December 2008.

## Appendix C

Written instructions on performing the modified Thomas Test given to the assessors

### Thomas test instructions:

Subjects recline with both legs hanging over the edge of the table.

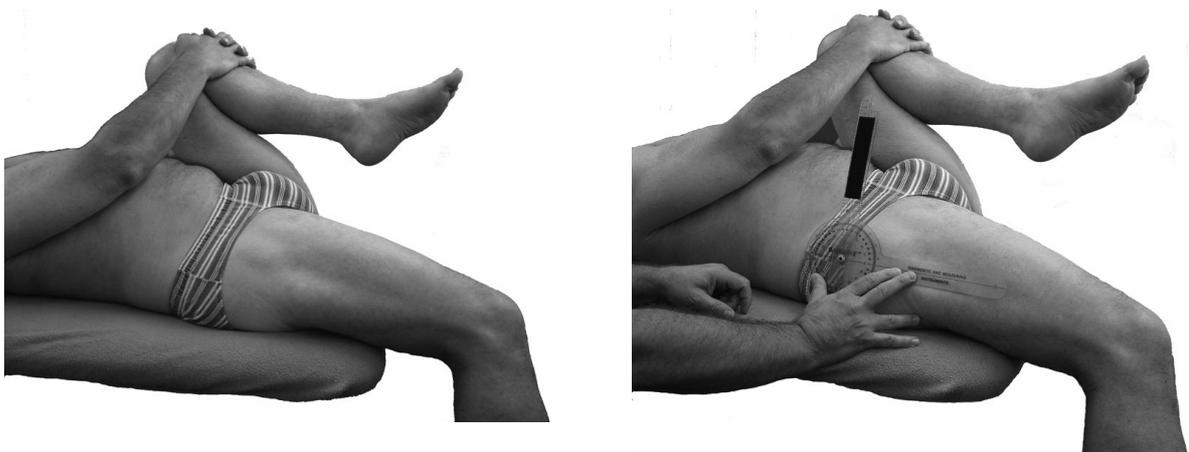
They then raise both knees to the chest to rotate the pelvis posteriorly and flatten the lumbar curve.

The subject then holds one knee to the chest to stabilise the lumbar spine and pelvis while the investigator lowered the opposite leg, keeping the knee extended.

An inclinometer was placed along the line of the femur. The measured leg was then lowered passively by the experimenter. A reading was taken when resistance prevented further hip extension.

A measurement of 5 deg. below horizontal or less is positive for inclusion.

If a bony end feel was felt prior to end ROM (which may indicated severe Osteoarthritis), the subject is excluded.



# Appendix D

Microstrain® 3DM orientation sensor technical information

## 3DM®



[Download Inclinometer Overview](#)



*Solid State 3-axis Pitch, Roll, and Yaw Sensor*



### OVERVIEW

### SPECIFICATIONS

### DOCUMENTATION

### CONTACT

### BUY

#### Description

3DM® is a 3-axis orientation sensor capable of measuring: 180° of yaw heading, 180° of pitch, and 70° of roll. Orthogonal arrays of magnetometers and accelerometers are used to compute the pitch, roll and yaw (also referred to as heading or azimuth) over a wide angular range.

The 3DM® is sold as a starter kit for the first unit purchased, after which, just the board can be purchased. The starter kit includes the standard board, enclosure (shown), software, requisite serial communications and power cable, and a manual.

The Windows® software provided communicates with 3DM® over a serial port. The software gives the user complete control over how data is processed, presented, and logged. The output may be programmed to provide raw magnetic field and accelerometer outputs, or processed pitch, roll, and yaw outputs. User programmed digital filters are used to process sensor data either statically or dynamically, depending on the change in 3DM® movement over time.

3DM® runs off of a single supply positive voltage ranging from 5.3 to 12 volts DC. 3DM's can be used alone or combined in networked arrays.

#### Applications

**Marine, Automotive**  
navigation, compassing

**Military**  
laser direction finding, sonobuoy position, direction finding, UUV's, UAV's

**Heavy Equipment**  
leveling, inclination and angulation control

**Virtual Reality**  
head and body tracking

**Communications**  
antenna positioning

**Biomechanics**  
joint position feedback, controllers for neuro-muscular stimulators

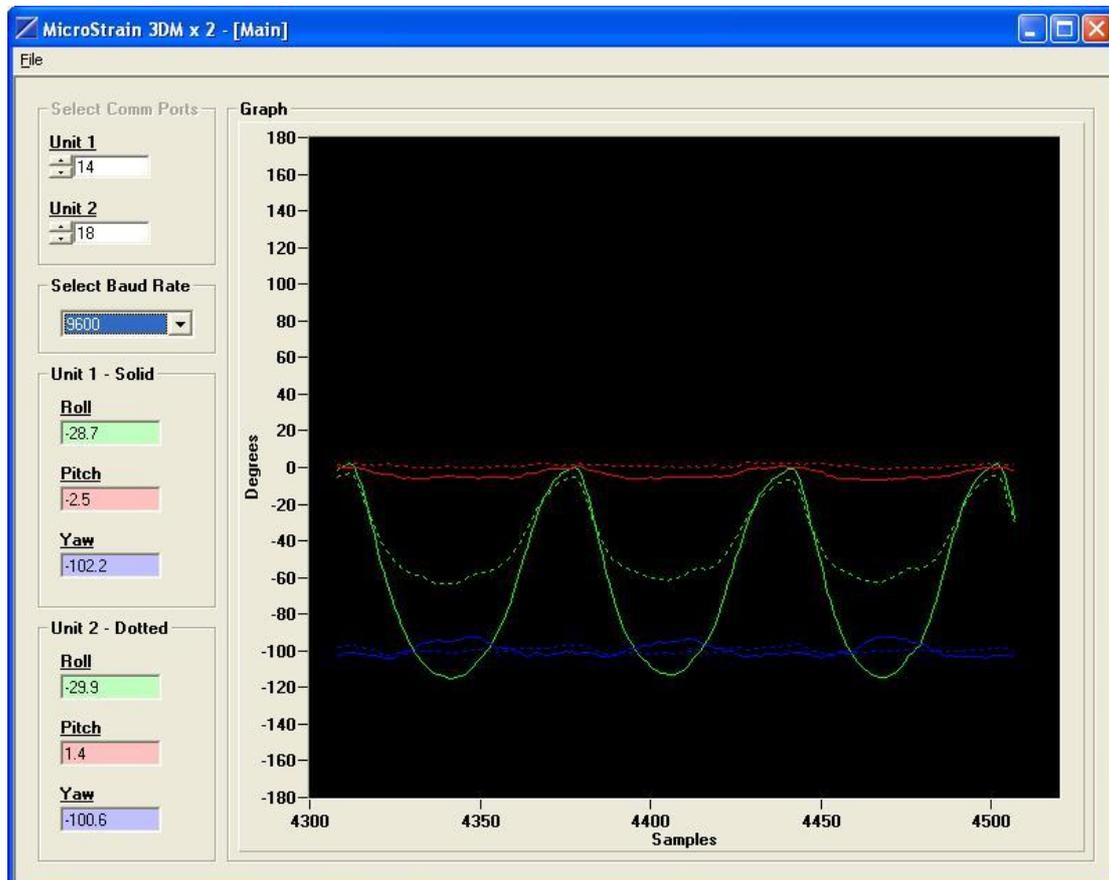
**Geomechanics, Oil Exploration**  
well drilling navigation

## Technical specification of the 3DM inclinometer (cont.):

OVERVIEW	SPECIFICATIONS	DOCUMENTATION	CONTACT	BUY
Range	Yaw: 180° Pitch: 90° Roll: 180°			
A/D Resolution	12 bits			
Digital Filter	Infinite Impulse Response (IIR) User programmable weighted moving average			
Angle Resolution (no digital filtering)	Pitch: 0.30° (typical) Roll: 0.25° (typical) Yaw: 0.50° (typical)			
Angle Resolution (most aggressive digital filtering)	Pitch: < 0.1° Roll: < 0.1° Yaw: < 0.1°			
<i>Resolution specs. taken during static motions</i>				
Accuracy	Pitch: 0.93° typical (yaw from 0 - 360° and roll=0°) Roll: 0.33° typical (yaw from 0 - 360° and pitch =0°) Yaw: 1.0° typical (pitch and roll=0°)			
<i>Accuracy is defined as the square root of the sum of the errors squared (non-repeatability, temperature coefficients and nonlinearity).</i>				
Angle measurement nonlinearity (pitch and roll)	0.23% F.S.			
Angle measurement repeatability	Pitch: 0.07° (typical) Roll: 0.07° (typical) Yaw: 0.26° (typical)			
Update rate (angle mode)	45 Hz/3 channels (maximum) 30 Hz/3 channels (typical)			
<i>Update rate is specified with a maximum and typical value since it depends on how many points the A/D converter averages.</i>				
Update rate (raw mode)	70 Hz/ 6 channels			
Output modes	Raw: ax,ay,az accelerometer Raw: bx,by,bz magnetic field Units: pitch, roll, and yaw in degrees			
Output format	RS-232 serial			
Transmission Rate	9600 bits/sec			
Supply voltage	+5.2 VDC min., +12 VDC max.			
Supply current	50 milliamps/node @ standard speed			
Connectors	Sensor: RJ11 type power: min. coaxial jack			
Operating Temperature	- 25°C to 70°C			
Temperature Drift (%/° C) (mean, std.dev.)	Pitch: 0.009 0.008 Roll: 0.033 0.025 Yaw: 0.019 0.019			
Module size	1.7" wide, 2.5" long, 0.7" thick			
Weight	75.0 gr. with enclosure, 26.9 gr. without enclosure			
<a href="#">3DM@ enclosure (.pdf file)</a>	3.5" wide x 2.5" long x 1.0" thick			

## Appendix E

Screen shot of customized program written by Microstrain Inc. used to capture data from 2 Microstrain® 3DM inclinometers simultaneously.



## Appendix F

Screen shot of Microsoft Excel® of sample of raw data. Data is sampled every 0.05 seconds, in 3 planes of movement; flexion/extension (=‘roll’), side-bending (=‘pitch’), and rotation (=‘yaw’).

	A	B	C	D	E	F	G	H	I
	Host Time	Unit 1 Roll	Unit 1 Pitch	Unit 1 Yaw	Unit 1 Timer Ticks	Unit 2 Roll	Unit 2 Pitch	Unit 2 Yaw	Unit 2 Timer Ticks
2	0.05	-91.1	-0.2	125.1	60035	-74.2	1.7	127.1	63429
3	0.11	-91.5	-0.8	124.9	60042	-74.3	1.6	126.8	63436
4	0.16	-91.4	0.3	126.1	60049	-74.5	2	126.9	63443
5	0.21	-92.8	0.6	126.6	60056	-74.4	1.8	126.8	63448
6	0.27	-94.3	0.9	127	60063	-74.3	2.2	126.8	63455
7	0.33	-94	1.1	127.6	60070	-74.6	2.2	126.3	63462
8	0.38	-94.7	1.4	127.8	60077	-74.4	2.5	126	63469
9	0.43	-93.5	2.3	128.8	60082	-74.4	2.9	125.5	63476
10	0.48	-92.3	4.7	129.7	60089	-74.3	3	125.1	63481
11	0.54	-92.9	5.3	127.8	60096	-74.7	3	124.3	63488
12	0.59	-90.9	4.6	126.9	60103	-74.9	3.2	123.7	63495
13	0.65	-89.8	6.2	128.2	60110	-75.2	3.7	123.7	63502
14	0.71	-89	7.2	130.2	60117	-75.6	4.1	123.8	63509
15	0.77	-87.9	7.3	131.4	60124	-76.1	3.2	123.3	63516
16	0.83	-87	7.6	131	60131	-76.4	2.9	123.2	63523
17	0.89	-83.9	7	130.4	60138	-76.9	2.8	122.8	63532
18	0.95	-83.3	9	129	60147	-77.2	4	123.2	63539
19	1	-82.9	10.9	129.2	60152	-77.3	5	123.7	63546
20	1.06	-84.1	8.7	126.9	60159	-77.6	5.9	124.1	63551
21	1.12	-84.3	10.6	130.3	60166	-78	6.2	124	63558
22	1.17	-87.4	10.7	130.7	60173	-78.8	6.4	123.8	63567
23	1.23	-90.8	11.5	130.4	60180	-79.3	6.3	123.6	63572
24	1.29	-93	10.9	129.6	60187	-79.7	5.9	123.3	63579
25	1.35	-94.7	10.4	129.2	60194	-79.7	5	123.1	63588
26	1.41	-95.6	9.5	129	60201	-79.8	4.1	122.7	63595
27	1.47	-95.9	8.2	128.7	60208	-79.6	3.6	122.7	63602
28	1.53	-96.6	7.5	128.3	60217	-78.8	2.8	122.9	63609
29	1.58	-96.2	6.3	128.2	60224	-78.2	2	123.2	63616
30	1.64	-96	5.3	127.9	60229	-77.7	1.1	123.2	63623
31	1.69	-95.1	4	128	60236	-77.5	0.5	123.2	63630
32	1.75	-95.7	3.9	128.1	60243	-77.2	0.4	123.6	63637
33	1.81	-96	2.7	127.9	60250	-77.2	0.6	123.9	63642
34	1.87	-96.5	1.8	127.8	60257	-77	0.8	124.6	63651
35	1.93	-96	0.4	127.5	60266	-77.1	1	125	63658
36	1.99	-96.5	0	127.3	60273	-76.9	0.9	125.3	63667
37	2.04	-94.9	0.4	128.4	60280	-76.8	0.8	125.4	63672
38	2.1	-95.1	-0.2	127.8	60285	-76.7	1.2	125.8	63679
39	2.16	-95.7	-0.2	127.5	60294	-76.5	1.2	126.1	63686
40	2.22	-95.2	1.4	127.5	60301	-76.5	1.2	126.3	63693
41	2.28	-95.2	0.1	125.2	60308	-76.8	1.2	126.7	63700
42	2.34	-95	-0.8	124	60315	-77.1	0.9	127.3	63709
43	2.4	-94.9	-0.4	124.3	60322	-77.4	0.5	127.4	63716
44	2.46	-95.7	0.3	124.7	60329	-77.6	0.4	127.6	63723
45	2.52	-95.9	-0.1	125.2	60338	-77.8	0.3	127.7	63730
46	2.58	-97.6	-0.6	125.1	60345	-77.8	0	127.7	63737
47	2.64	-97.4	-1.2	125.5	60352	-77.7	0	127.7	63744
48	2.69	-97.7	-0.4	126.4	60359	-77.6	-0.3	127.8	63751
49	2.74	-97.5	-0.3	126.9	60364	-77.7	-0.5	127.9	63758

## Appendix G

### Instructions for authors for manuscript submission

## INTERNATIONAL JOURNAL OF OSTEOPATHIC MEDICINE

Former title: Journal of Osteopathic Medicine

### Guide for Authors

The journal Editors welcome contributions for publication from the following categories: Letters to the Editor, Reviews and Original Articles, Commentaries and Clinical Practice case studies with educational value.

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The above represents a very brief outline of this form of submission. It can be advantageous to print this "Guide for Authors" section from the site for reference in the subsequent stages of article preparation.

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### Types of contributions

*Letters to the Editor* As is common in biomedical journals the editorial board welcomes critical response to any aspect of the journal. In particular, letters that point out deficiencies and that add to, or further clarify points made in a recently published work, are welcomed. The Editorial Board reserves the right to offer authors of papers the right of rebuttal, which may be published alongside the letter.

*Reviews and Original Articles* These should be either i) reports of new findings related to osteopathic medicine that are supported by research evidence. These should be original, previously unpublished works. The report will normally be divided into the following sections: abstract, introduction, materials and methods, results, discussion, conclusion, references. Or ii) critical or systematic review that seeks to summarise or draw conclusions from the established literature on a topic relevant to osteopathic medicine.

*Short review* The drawing together of present knowledge in a subject area, in order to provide a background for the reader not currently versed in the literature of a particular topic. Shorter in length than and not intended to be as comprehensive as that of the literature review paper. With more emphasis on outlining areas of deficit in the current literature that warrant further investigation.

*Research Note* Findings of interest arising from a larger study but not the primary aim of the research endeavour, for example short experiments aimed at establishing the reliability of new equipment used in the primary experiment or other incidental findings of interest, arising from, but not the topic of the primary research. Including further clarification of an

experimental protocol after addition of further controls, or statistical reassessment of raw data.

*Preliminary Findings* Presentation of results from pilot studies which may establish a solid basis for further investigations. Format similar to original research report but with more emphasis in discussion of future studies and hypotheses arising from pilot study.

*Commentaries* Include articles that do not fit into the above criteria as original research. Includes commentary and essays especially in regards to history, philosophy, professional, educational, clinical, ethical, political and legal aspects of osteopathic medicine.

*Clinical Practice* Authors are encouraged to submit papers in one of the following formats: Case Report, Case Problem, and Evidence in Practice.

*Case Reports* usually document the management of one patient, with an emphasis on presentations that are unusual, rare or where there was an unexpected response to treatment eg. an unexpected side effect or adverse reaction. Authors may also wish to present a case series where multiple occurrences of a similar phenomenon are documented. Preference will be given to reports that are prospective in their planning and utilise Single System Designs, including objective measures.

The aim of the Case Problem is to provide a more thorough discussion of the differential diagnosis of a clinical problem. The emphasis is on the clinical reasoning and logic employed in the diagnostic process.

The purpose of the Evidence in Practice report is to provide an account of the application of the recognised Evidence Based Medicine process to a real clinical problem. The paper should be written with reference to each of the following five steps: 1. Developing an answerable clinical question. 2. The processes employed in searching the literature for evidence. 3. The appraisal of evidence for usefulness and applicability. 4. Integrating the critical appraisal with existing clinical expertise and with the patient's unique biology, values, and circumstances. 5. Reflect on the process (steps 1-4), evaluating effectiveness, and identifying deficiencies.

### **Presentation of Typescripts**

Your article should be typed on A4 paper, double-spaced with margins of at least 3cm. Number all pages consecutively beginning with the title page.

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Both qualitative and quantitative research approaches should be accompanied by a

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#### References

Responsibility for the accuracy of bibliographic citations lies entirely with the Authors.

Citations in the text: Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Avoid using references in the abstract. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either "Unpublished results" or "Personal communication" Citation of a reference as "in press" implies that the item has been accepted for publication.

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2. Strunk Jr W, White EB. *The elements of style*. 3rd ed. New York: Macmillan; 1979.

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