The immediate effects of manual therapy on dorsiflexion and joint position sense at the talocrural joint in participants with a history of lateral ankle sprain

Nathan Alanson

A research project submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy at Unitec Institute of Technology 2012
DECLARATION

Name of candidate: Nathan Alanson

This Thesis/Dissertation/Research Project entitled: The immediate effects of manual therapy on dorsiflexion and joint position sense at the talocrural joint in participants with a history of lateral ankle sprain. Is submitted in partial fulfilment for the requirements for the Unitec degree of Masters of Osteopathy.

Candidate’s declaration

I confirm that:

- This Thesis/Dissertation/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 Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.
- Research Ethics Committee Approval Number: 2009-998

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ACKNOWLEDGEMENTS

Thanks to the participants who volunteered to take part in this study

Thanks to my supervisor Rob Moran without his expertise and guidance this could project could not have been done.

Thanks to Arnika, Megan and Scotty who helped in the editing and proofreading.

Finally thanks to my wife Chiharu and my daughters Kiana and Aika, and my parents for their patience and support. This was a long time coming with a few setbacks along the way but I finally have finished! Now time to get a real job!

継続は力なり

Perseverance is power

Osu!
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<tr>
<td>DF</td>
<td>Dorsiflexion</td>
</tr>
<tr>
<td>ROM</td>
<td>Range of motion</td>
</tr>
<tr>
<td>JPS</td>
<td>Joint position sense</td>
</tr>
<tr>
<td>HVLA</td>
<td>High velocity low amplitude</td>
</tr>
<tr>
<td>MWM</td>
<td>Mobilisations with movement</td>
</tr>
<tr>
<td>CNS</td>
<td>Central nervous system</td>
</tr>
<tr>
<td>ATFL</td>
<td>Anterior talofibular ligament</td>
</tr>
<tr>
<td>CFL</td>
<td>Calcaneofibular ligament</td>
</tr>
<tr>
<td>PTFL</td>
<td>Posterior talofibular ligament</td>
</tr>
<tr>
<td>MAI</td>
<td>Mechanical ankle instability</td>
</tr>
<tr>
<td>FAI</td>
<td>Functional ankle instability</td>
</tr>
<tr>
<td>RICE</td>
<td>Rest ice compression elevation</td>
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Structure of the literature review
The purpose of this literature review is to explore the literature pertaining to normal ankle function, ankle dysfunction and lateral ankle sprains to provide a theoretical background for further study. Firstly the literature review introduces manual therapy; gives a brief overview of normal ankle anatomy and function, and then describes proprioception and joint position sense (JPS). The following section addresses the topics of ankle injury, ankle dysfunction and lateral ankle sprains. The review then evaluates the methodological approaches used to assess both dorsiflexion (DF) range of motion (ROM) and joint position sense (JPS) at the ankle. The final section includes a critical appraisal of studies concerning the effects of manual therapy on DF and JPS on participants with a history of lateral ankle sprain.

Background to understanding use of manual therapy techniques

A brief overview of manual therapy
The practice of manual therapy originates back in Europe to 400BC and has historically been a part of many cultures in other regions of the world (Pettman, 2007). The 19th century saw the establishment of defined manual therapy based professions such as osteopathy, chiropractic and later manipulative physiotherapy and with them the development of manipulative therapy (Pettman, 2007). Modern day manual therapy has evolved to encompass a wide variety of techniques, and is a popular mode of therapy for musculoskeletal disorders perhaps due to being non-invasive and relatively inexpensive (Bokarius & Bokarius, 2010).

Defining mobilisation and manipulation
The terms ‘manipulation’ and ‘mobilisation’ are often used interchangeably in the manual therapy literature. This interchanging of terms is due to the differing classification of techniques and definitions used within the different groups of manual therapy and eponymously named techniques and concepts developed by clinicians such as Kaltenborn (1989), Paris (1988), Maitland (1991) and Mulligan (1995). For example, the term ‘manipulation’ is often used as an umbrella term to encompass a wide variety of techniques including: soft tissue massage techniques, mobilisation techniques applied to joints, and manipulation or high velocity thrust techniques (Keir & Goats, 1991). Manipulation within osteopathy literature outside North America typically refers to a technique involving a high velocity low amplitude (HVLA) thrust, however, alternatively HVLA manipulation has also been referred to as “mobilisation with impulse” (Greenman, 2003) and “grade V mobilisation” (Maitland, 1991). In a recent commentary on the matter of the terminology within
the manual therapy field, Evans and Lucas (2010) highlight the “variation and discordance” within
the literature in regards to defining manipulation, stating “the interchanging of terms is problematic
due to the differences in application of the techniques and ignores the potential for differences in efficac,
safety and appropriateness” (Evans & Lucas, 2010). Furthermore an important problem
with inconsistent use arises when systematic reviewers choose to pool mobilisation and
manipulation studies together leading to difficulties in interpreting treatment effects and the
potential for misunderstandings and misrepresentation between techniques (Ernst & Canter, 2006;
Lucas & Moran, 2007). Therefore there is a need for the differing groups of manual therapy to use
both standardised and accurate terminology when describing techniques (Evans & Lucas, 2010; Koes

Adding to the confusion is the different terminology used within the differing groups of manual
therapy when referring to the same type of manual techniques. For example osteopaths use the
term ‘articulation’ which is similar to ‘mobilisation’ within the field of physiotherapy. Both terms
are used to refer to techniques characterised passive repetitive oscillatory movements applied
within a ROM or against a barrier (Fryer, Carub, & McIver, 2004; Keir & Goats, 1991; Maitland, 1991).
Mobilisation techniques may vary by amplitude of application with some therapists applying a
grading system incorporating a range of amplitudes or oscillation and application forces within
various degrees of tissue resistance (Greenman, 2003; Maitland, 1991). The use of grading systems
does not ensure consistent application of the same grade by different practitioners. Previous studies
have demonstrated differing mobilisation forces between practitioners within the same grade of
mobilisation (Harms & Bader, 1997; Snodgrass, Rivett, & Robertson, 2006; Snodgrass, Rivett,
Robertson, & Stojanovski, 2009).

Maitland (1991) and Keir and Goats (1991) distinguish the difference between mobilisation and
manipulation by defining mobilisation as those techniques that can be resisted by the patient if they
choose to do so in contrast to HVLA manipulation which cannot be controlled by the patient due to
the speed of the application, definitions which arguably generalises the confusion between
techniques. For the purpose of this literature review, the term ‘manipulation’ will refer to a single
technique involving a HVLA thrust technique, differentiated from mobilisation techniques
characterised by 1) passive; 2) rhythmic; and 3) repetitive movements.

The therapeutic effects of mobilisation
The following two subsections concerning the therapeutic effects of mobilisation are brief overviews
of the theories concerning the effects of mobilisation on connective tissue and pain mediation. The
purpose is to give a brief outline of the current theories associated with the therapeutic mechanisms associated with mobilisation before the rest of the literature explores the role of mobilisation and the effects on ROM and JPS at the ankle.

The effects of mobilisation on connective tissue

A number of therapeutic goals following the application of mobilisation techniques have been described including improvements in joint ROM (Glasgow, Tooth, & Fleming, 2010; Threlkeld, 1992), promotion of soft tissue repair (Getgood, Bhullar, & Rushton, 2009a; Glasgow et al., 2010; Hunter, 1998; Lederman, 2005; Threlkeld, 1992), improved pain levels (Cassidy, Lopes, & Yong-Hing, 1992; Malisza et al., 2003; McLean, Naish, Reed, Urry, & Vicenzino, 2002; Sluka & Wright, 2001), and restoration of the ability to return to normal activity (Green, Refshauge, Crosbie, & Adams, 2001).

Several authors have reviewed the theories concerning the pathology of soft-tissue and joint injury, and the effects of manual therapy on tissue repair. According to Glasgow et al (2010) injury to a joint results in adhesions which is the formation of abnormal cross-links and the deposition of shortened, disorganised collagen tissue fibre. Glasgow et al (2010) indicates that it is essential to restore normal ROM of the injured joint because normal ROM ensures the appropriate formation and organisation of collagen fibres within the soft tissue structures of the joint. Therefore both Glasgow et al (2010) and Threlkeld (1992) theorise that mobilisation is thought to re-establish joint ROM by breaking down the adhesions and restoring the viscous and elastic properties of the extracellular matrix within the connective tissue structures of the injured joint. Threlkeld (1992) claims that mobilisation techniques aid the healing process through promoting growth and reorganisation of collagen fibres, plus remodelling of previously damaged soft tissue structures, however, more recent studies are needed to support Threlkeld theories considering the paper is now 20 years old.

According to Getgood et al (2009b) preclinical studies show mechanical stress stimulates both the metabolism and flow of synovial fluid which Getgood et al (2009b) surmises, improves the nutrient supply to the articular cartilage within the joint. Lederman(2005) hypothesises that the mechanical stress from mobilisation stimulates the mechanisms of synovial production and flow and therefore potentially reduces and reverses the processes of thinning and softening of damaged articular cartilage due to injury (Lederman, 2005). There is however no direct evidence to date demonstrating mobilisation effect on articular cartilage repair and further investigations regarding such effects would require investigation into the required force of application, dose of application, speed of application and type of manual therapy technique applied.
The effects of mobilisation on pain mediation

Various studies have shown mobilisation to have a hypoalgesic effect (Cassidy et al., 1992; McLean et al., 2002; Sluka & Wright, 2001). However, the mechanism by which mobilisation affects pain is not clearly understood. Early theories drew heavily on Melzack and Wall’s “pain gate control theory” (Melzack & Wall, 1965) which proposed that inhibition of nociceptive input at the spinal cord level is achieved by affecting the neural input via large myelinated afferent neurons. Later theories suggest mobilisation may have a local effect on the chemical environment and therefore may favourably influence inflammatory mediators (Sambajon et al., 2003). Another study concluded the hypoalgesic effect of mobilisation may be mediated by descending pain inhibition pathways from the midbrain via the release of serotonin and noradrenalin (Skyba, Radhakrishnan, Rohlwing, Wright, & Sluka, 2003). More recent theories now propose pain mediation involves the interaction of neurophysiological responses related to both the peripheral nervous system and the central nervous system (CNS) at the spinal and supraspinal level rather than be the result of a singular mechanism (Bialosky, Bishop, Robinson, Zeppieri Jr, & George, 2009; Moseley, 2003; Moss, Sluka, & Wright, 2007; Schmid, Brunner, Wright, & Bachmann, 2008). A systematic review by Coronado et al (2012) further supports the interaction between the CNS and peripheral pathways but does conclude that further investigations into the mechanisms of manual therapy pain modulation is required. Further to improving the understanding the mechanisms of future investigations also need to explore the interactions between mobilisation types and treatment dose, as little currently is understood about which type of manual therapy techniques applied in combination within the clinical setting are most effective at pain mediation (Krouwel, Hebron, & Willett, 2010).

Extrapolation of the therapeutic effects of spinal techniques to techniques concerning the ankle

Numerous systematic reviews concerning manual therapy and the spine exist whilst in contrast Brantingham et al (2009) and van der Wees et al (2006) only two systematic reviews that appear to have been conducted concerning the effects of manual therapy techniques on the ankle. The scarcity of literature pertaining to the effects of manual therapy is further highlighted by studies by Anderson et al (2003), Fryer et al (2002) and López-Rodríguez et al. A consequence of the limited research is manual therapists applying manipulation and mobilisation techniques to peripheral joints with expectations of affecting a similar therapeutic response to what has been demonstrated in research concerning spinal joints (Andersen et al., 2003). This is referred to by Bogduk et al (2004) as extrapolation, which describes using techniques shown to be useful for one anatomical region and applying to another region anticipating the same therapeutic effect. It is therefore not only
important for further studies explore the effects of manual therapy techniques at the ankle due to the anatomical, physiological and pathological differences between the ankle and spinal joints but also for developing effective treatment protocols for the injured ankle.

**Normal ankle anatomy and function**

This section provides a brief overview of the anatomy and function of the ankle which includes reference to the proximal tibiofibular joint due to its relationship with the normal function of the ankle. Clinical understanding of the normal structure and function at the ankle is useful for understanding both restricted dorsiflexion ROM and JPS dysfunction at the ankle following an ankle sprain which is the purpose of this review.

**Clinical anatomy and biomechanics of the ankle**

The talocrural joint is a uniaxial, modified hinge, synovial joint located between the wedged shaped talus, the medial malleolus of the tibia, and lateral malleolus of the fibula (Dananberg, 2004; Magee, 2007). Kapandji (1987, p. 160) describes the joint as being “analogous to a tenon and mortise type joint, with the talar or tenon being tightly fitted into the tibiofibular mortise.” Medially the joint is supported by the medial collateral ligament (also known as the deltoid ligament because of its shape) described by Norkus and Floyd (2001) as consisting of four bands: the anterior tibiotalar, the posterior tibiotalar, the tibiocalcaneal, and the tibionavicular. The lateral aspect of the joint consists of three identifiable lateral collateral ligaments (anterior and posterior talofibular, and calcaneofibular) (Kisner, Colby, & Library, 2007).

The hinge joint is described as allowing for one degree of freedom of movement, both in plantar flexion and DF (Palastanga, Field, & Soames, 2006). However, due to the shape of the talus plantarflexion and DF should be more accurately described as being helical rather than a pure hinge swing movement (Loudon & Bell, 1996).

The physiological motion of DF causes accessory motion of the talus within the joint. Accessory motion is the movements within the joint which cannot be voluntarily reproduced, but are necessary for full active movement and normal function (Cochrane, 1987). The ankle is most stable in DF due to the shape of the talus, shaped wider anteriorly than posteriorly. Dorsiflexion forces the talus to glide posteriorly and externally rotate, wedging between the malleoli allowing minimal inversion or eversion (Denegar, Hertel, & Fonseca, 2002). The wedging of the talus forces an increase in distance between the malleoli of the mortise to accommodate the talus in DF (Close, 1956; Dananberg, 2004).
The role of the proximal tibiofibular joint is to both transmit and dissipate the torsional loads transferred through the fibula from the ankle (Eichenblat & Nathan, 1983; Espregueira-Mendes & Vieira da Silva, 2006). Mobility of the fibula at both the proximal and distal tibiofibular joints enables the talus to posteriorly rotate fully into the ankle mortise during DF. The relationship between the three joints during plantarflexion and DF is summarised in Table 1. Dorsiflexion causes the fibula to externally rotate and glide superiorly (Bozkurt et al., 2003; Dananberg, 2004; Scott, Lee, Barsoum, & Van Den Bogert, 2007). Conversely, plantarflexion causes the talus to glide anteriorly and internally rotate whilst the fibula glides inferiorly (Hubbard, Kramer, Denegar, & Hertel, 2007; Soavi et al., 2000). Therefore, due to the relationship between the mechanics of the proximal tibiofibular joint and ankle, normal function at the proximal tibiofibular joint is essential to normal dorsiflexion ROM at the ankle.

**Table 1. The component movements of dorsiflexion and plantarflexion**

<table>
<thead>
<tr>
<th>Joint Position</th>
<th>Dorsiflexion</th>
<th>Plantarflexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal tibiofibular Joint</td>
<td>Fibula glides superiorly</td>
<td>Fibula glides inferiorly</td>
</tr>
<tr>
<td>Distal tibiofibular Joint</td>
<td>Superior glide of tibia and fibula</td>
<td>Inferior glide of tibia and fibula</td>
</tr>
<tr>
<td>Talocrural Joint</td>
<td>Talus posterior medial glide on tibia</td>
<td>Talus anterior lateral glide on tibia</td>
</tr>
</tbody>
</table>

Reproduced from Loudon and Bell (1996, p. 174) with permission from the Journal of Athletic Training.

**Joint position sense**

The following section introduces JPS as a measure of proprioception and then follows with a discussion concerning the mechanisms associated with JPS.

Proprioception is described by Lephart et al (1997) consisting of 2 sensory components: i) the sensation of joint movement (kinaesthesia); ii) the sensation of joint position. Later studies have included a third component; sense of force (Docherty, Arnold, Zinder, Granata, & Gansneder, 2004; Riemann & Lephart, 2002). The importance of proprioception is that it allows for the sensation of body movement and position (Hertel, 2008).

The perception of joint movement requires the integration of neural input to the central nervous system (CNS) from afferent information provided by mechanoreceptors, visual and vestibular receptors to generate a motor response (Lephart et al., 1997; Yamashita, Takebayashi, Sekine, Tsuji, & Katose, 2006). This integration of the neural input occurs within the CNS at three distinct levels of
motor control: spinal level, brainstem and the higher brain centres (Yamashita et al., 2006). The output from the CNS equates to conscious awareness of joint position and joint motion, unconscious joint stabilisation through protective spinal mediated reflexes, and the maintenance of posture and balance (Lephart et al., 1997; Yamashita et al., 2006). The integration of the peripheral and CNS mechanisms associated with JPS are described by Strimpakos (2009) as being essential to normal functioning in activities of sport, daily living and work-related tasks. However there appears to be an absence of literature exploring the mechanisms and role JPS may have specific to the different types of activities performed.

**Mechanisms of joint position sense**

The mechanoreceptors that provide the afferent information of JPS to the CNS include muscle spindles, joint receptors, cutaneous receptors and golgi tendon organs and are found within ligamentous, articular, cutaneous and muscle tissue (Lephart et al., 1997; Riemann, 2002). The joint capsule contains several types of joint receptors including Ruffini, Paciniform, golgi tendon and free nerve endings (Wyke, 1967). These articular mechanoreceptors can be classified as either rapidly adapting or slowly adapting (Strimpakos, 2009). The rapidly adapting mechanoreceptors are responsible for providing information relating to joint motion, whilst JPS and sensation are mediated via the slow adapting receptors (Lephart, Pincivero, & Rozzi, 1998). The rapidly adapting receptors such as Paciniform corpuscles, are associated with detection of acceleration, deceleration, or any sudden change in deformation of the mechanoreceptor (Leaphart et al., 1997; Strimpakos, 2009). The slow adapting receptors include secondary spindle endings and tendon organs in muscle, tendon organs and ruffini spray endings (Gilman, 2002). The mechano-receptive free nerve endings in joints are stimulated by extreme joint movements (Gilman, 2002), and are not thought to contribute significantly to position and movement sense (Strimpakos, 2009).

The muscles, tendons and musculotendinous junctions have two types of muscle receptors: the muscle spindles and golgi tendon organs (Grigg, 1994; Stefanini & Marks, 2003) providing neural input regarding joint position together with information received from the articular receptors (Lephart et al., 1998). The muscle spindles detect stretching associated with joint movement and contribute to the maintenance of appropriate muscle tension via the monosynaptic stretch reflex (Yamashita et al., 2006). The golgi tendon organs respond to any traction force on the tendons (Yamashita et al., 2006) by mediating the contractile force or effort from muscle fibres (Gilman, 2002). There are also superficial cutaneous afferents found within the skin. However, they are thought to contribute minimally to joint proprioception (Lephart et al., 1998).
Joint position sense at the ankle

There is a lack of consensus in the literature concerning which mechanoreceptors are the primary afferent sources of proprioception within the ankle. Traditionally, the joint capsule and ligaments have been thought to be the primary source of JPS due to the concentration of articular nerve fibres found within them (Freeman & London, 1965; Safran, Benedett, Bartolozzi III, & Mandelbaum, 1999). More contemporary evidence suggests that muscle spindle receptors are the principal source of JPS input (Gilman, 2002; Macefield, Gandevia, & Burke, 1990). However, Gross (1987) hypothesised that in order for muscle spindle receptors to function as the principal source of JPS would require the CNS to process complex afferent and efferent pathways from both agonist and antagonist muscles receptors unlike the efficient, streamlined “linear” pathways from joint receptors. Since Gross (1987) argument there has been no further evidence to support the hypothesis.

The conflicting views regarding which receptors play the primary role in JPS is reflected by the difficulty of studying joint mechanoreceptors in vivo (Riemann & Lephart, 2002). The role of mechanoreceptors may be individualised to the location and function of the joint concerned. Interestingly a body of research has demonstrated that both mechanoreceptors and muscle spindles may compensate for each other if afferent input from one type is impaired (Kynsburg, Halasi, Tallay, & Berkes, 2006; South & George, 2007). Konradson, Ravn & Sorensen (1993) showed that even if afferent feedback from the receptors within the joint was blocked through local anaesthesia JPS still persisted. The ability to still perceive joint position under anesthesia is thought to be continued through the afferent input supplied by the unaffected muscle mechanoreceptors (Konradsen et al., 1993). This suggests that JPS therefore may not be reliant on a primary source of afferent feedback but be determined by the input from muscle spindles, joint capsule and ligament mechanoreceptors all interacting collectively (Hertel, 2000; Konradsen et al., 1993). More recently, it has been shown that central motor programming within the CNS may have a greater influence on JPS than research has previously acknowledged (Riemann, Myers, Stone, & Lephart, 2004). Therefore implications for future studies should include how therapists can rehabilitate JPS deficit in the injured ankle through the integration of both the CNS and peripheral JPS mechanisms.

Ankle joint injury

The talocrural joint has greater stability than other diarthrodial joints (such as the knee and shoulder) due to its structural anatomical features and the combination of weight-bearing and axial loading at the joint (Norkus & Floyd, 2001). Failure of the foot to control and absorb forces during dynamic and functional activity can result in medial ankle sprains; lateral ankle sprains; syndesmotic
sprains; midfoot sprains; fifth metatarsal fractures; and stress fractures of the fibula, calcaneus, and navicular bones (Saluta & Nunley, 2006). The focus of this literature review concerns lateral ankle sprains hence the topics of syndesmotic sprains, medial sprains and the following topic on fractures and avulsions will only be briefly introduced.

**Epidemiology of ankle sprain**

Ankle sprains are common, for instance, in the United States the incidence of ankle injuries within the general population is estimated to be 23,000 ankle sprains per day, which equates to approximately 1 sprain per 10,000 people each day (Hale & Hertel, 2005; Leavey, 2006). A review of epidemiological studies of sports injury from 1977 to 2005 found the ankle to be the second most commonly injured body site after the knee, and ‘ankle sprain’ to be the most common type of ankle injury (Fong, Hong, Chan, Yung, & Chan, 2007). Baumhauer, Alosa, Renström, Trevino, & Beynnon (1995) report that 75% of all ankle injuries are recorded as ligament injuries and 85% of those ankle sprains to be caused by inversion trauma clinically described as lateral ankle sprain. In New Zealand claims cost the Accident Compensation Corporation (ACC) $109,126,312 in the 2009-2010 financial year, with injuries to females costing $47,144,330 compared with $61,981,983 for males according to ACC (personal communication, 20 July, 2011). The recurrence rates of ankle sprains are high, with one study indicating that as many as 75% of initial lateral ankle sprains leading to repetitive sprains and chronic symptoms (Hubbard & Wikstrom, 2010). Given the high incidence and substantial direct costs of ankle injury there is a clear rationale for pursuing a more complete understanding of the mechanisms of injury, dysfunction, prevention and rehabilitation.

**Ankle ligamentous sprain**

The following ligaments to be described include the medial (deltoid) ligament, the lateral ligaments and ligaments of the syndesmosis, all of which support the ankle joint. Injury to any of these ligaments is likely to impair their normal function of providing support, proprioception, and guiding the direction and amplitude of motion within the talocrural joint (Safran et al., 1999).

**Lateral ligamentous sprain**

The lateral ankle ligaments include the anterior talofibular ligament (ATFL), the calcaneofibular ligaments (CFL) and the posterior talofibular ligament (PTFL). The most frequent mechanism of damage to the lateral ankle ligaments is one of excessive ankle inversion with the foot in plantar flexion and internal rotation (Andersen et al., 2003; Hubbard & Hertel, 2006). The position of the talus in plantar flexion combined with internal rotation of the foot decreases the bony stability at
the ankle on foot strike during gait (Liu & Nguyen, 1999). The soft tissue structures, such as the lateral talocrural joint capsule, the lateral ligaments and the distal and proximal tibiofibular joints are damaged if the resistance to the force of the body weight that would normally be absorbed within the articular structures of the talocrural joint is exceeded (Denegar & Miller, 2002; Liu & Nguyen, 1999). Of the three lateral ligaments, the ATFL and CFL of the lateral ankle are most commonly damaged (Hertel, 2008), and the ATFL is the most vulnerable to damage due to its low resistance to strain (Kumai, Takakura, Ruﬁai, Milz, & Benjamin, 2002). It is unclear whether the vulnerability of ATFL is due to its structural properties or molecular composition (Kumai, Takakura, Ruﬁai, Milz, & Benjamin, 2002). In contrast, the strong PTFL has the lowest likelihood of injury (amongst the lateral ankle ligaments) (Mangwani, Hakmi, & Smith, 2001).

Medial ligamentous sprain
The medial (deltoid) ligaments of the ankle consist of both superficial and deep layers. The superficial part is made up of the tibionavicular, the tibiocalcaneal and the superficial tibiotalar ligaments, while the deep part comprises the deep anterior and posterior tibiotalar ligaments (Pankovich & Shivaram, 1979). Due to the anatomical structure and strength of the medial ligaments, sprains are less frequent. The medial ligaments are, however, vulnerable to injury if the ankle is forced into eversion, and also damaged as a result of compressive forces accentuated through the medial aspect of the ankle from excessive inversion (Glasgow, Jackson, & Jamieson, 1980; Van Dijk, Bossuyt, & Marti, 1996). Complete tears of the medial ligament may occur in combination with ankle fractures when the foot is forced into eversion (Renström & Konradsen, 1997).

Syndesmotic sprain (high ankle sprain)
Syndesmotic sprains are sometimes referred to as “high sprains” (Norkus & Floyd, 2001; Renström & Konradsen, 1997) and are associated with the injury to the ligaments and interosseous membrane that maintain the integrity of the distal tibioﬁbular joint. The ligaments of the distal tibioﬁbular joint include the anterior and posterior tibioﬁbular ligaments, transverse tibioﬁbular ligament and interosseous ligament associated with the interosseous membrane (Dubin, Comeau, McClelland, Dubin, & Ferrel, 2011). A syndesmotic sprain can occur when the foot is forced into one of the following positions: external rotation, hyper-dorsiflexion (Mulligan, 2011), excessive inversion or eversion (Kennedy, Sama, & Sigman, 2000). The incidence of syndesmotic sprains is reportedly lower than that of lateral ankle sprains, and in the literature is reported in the ranges; 1 to 11% (Norkus & Floyd, 2001). The mechanism of injury involves large magnitudes of force and is
associated with high intensity impact sports (Mulligan, 2011; Norkus & Floyd, 2001). Syndesmotic sprains often occur in combination with tibial fractures and lesions to the deltoid ligament rather than in isolation (Renström & Konradsen, 1997). Both medial and syndesmotic sprains are considered to be severe injuries that may require surgical intervention (Groth, Guyton, & Schon, 2010).

**Fractures and avulsions**

When the ankle is forced into excessive inversion, the resultant compressive forces to the medial aspect of the ankle can cause a medial compression fracture (Schepers, van Schie-van der Weert, de Vries, & van der Elst, 2011). Other fractures that can occur include chondral fractures of the talus, osteochondral fractures in the talocrural joint (Mangwani et al., 2001) and fractures to the 5th metatarsal (Mack, 1982; Schepers et al., 2011). An avulsion fracture occurs when a fragment of bone breaks off at the site of a tendon or ligament attachment due to excessive force through injury. According to Amendola and Bonasia (2010) avulsion fractures are often associated with ankle sprains.

**Lateral ankle sprains**

Classification of lateral ankle sprains

An acute ankle injury is characterised by tissue injury, pain, swelling, and joint dysfunction (Whitman, Childs, & Walker, 2005). The literature varies on the method of grading ankle sprains; Brukner and Kahn (2010) grade an ankle sprain on the degree of laxity found in the ankle joint, while other methods are based on the number of ligaments sprained (Lynch, 2002). A more comprehensive classification method is based on the level of severity of laxity, graded on a 1 to 3 scale according to severity with Grade 3 being the most severe (Lynch, 2002; Renström & Konradsen, 1997; Safran et al., 1999). A Grade 1 injury involves stretch of the ligament without macroscopic tearing, the presence of minor swelling or tenderness, slight or no functional loss and no joint instability. Grade 2 injuries are incomplete macroscopic tear of the ligament with associated pain, swelling, and tenderness, possible reduction in function and mild or moderate instability of the joint. A Grade 3 injury associated with a complete rupture of the ligament with severe swelling, haemorrhage and tenderness. There is also loss of weight bearing ability on the foot, limited function, and considerable abnormal motion and instability of the joint (Renström & Konradsen, 1997, pp. 12, 13). Fallat, Grimm and Saracco (1998) report that 71.3% of ankles sprains are Grade 1 with Grade 2 and 3 accounting for 9.5% and 2.9%, respectively.
Natural history of lateral ankle sprains

The time taken for an ankle to recover full functionality and become asymptomatic following a sprain is inversely proportional to the severity and grade of the injury (Safran et al., 1999). The injured ligaments undergo three stages of healing (Tiling, Bonk, Höher, & Klein, 1994):

- **Phase 1**, acute inflammation and scar tissue composition, occurs during the first 2 to 4 days
- **Phase 2**, repair and regeneration, starts from 2 to 4 days after the injury, and lasts until approximately 6 weeks after the injury
- **Phase 3**, remodelling or maturation of tissue, starts after at least 3 weeks and requires at least 12 months for the final stage of maturation and remodelling of ligaments.

Based on the three tiered grading system Grade 1 sprains take an average 7 to 14 days to heal, Grade 2 injuries 2 to 6 weeks, and Grade 3 injuries take between 4 to 26 weeks in order to resume athletic activities (Puffer, 2001).

Clinical assessment of ankle sprains

The assessment of ankle injuries relies on measures or tests such as ROM, strength, functional limitations, balance, JPS and reflexes (Hertel, 2000). Specific orthopaedic tests include the anterior drawer test and talar tilt test (Magee, 2008). The anterior drawer test assesses for disruption or instability of the ATFL, while the inversion stress test assesses for the integrity of the CFL (Mangwani et al., 2001). The anterior drawer test is the most common clinical test for assessing ligament integrity (Tohyama, Yasuda, Ohkoshi, Beynnon, & Renstrom, 2003), with a sensitivity of 73% and a specificity of 97% (Van Dijk, Lim, Bossuyt, & Marti, 1996). Van Dijk (2002) reports pain on palpation of the ATFL in conjunction with a positive anterior draw test and the presence of haematoma discoloration has a sensitivity of 100% and specificity of 77%. The effectiveness of both tests rely on the practitioner’s palpatory awareness and experience; currently there is no alternative clinical objective measure (Hubbard & Hertel, 2006). The accuracy of diagnosis is often compromised in the first 48 hours following an ankle sprain because of pain and swelling, therefore it is recommended that a more accurate assessment should be made 4 to 7 days following injury (Renström & Konradsen, 1997; Van Dijk, Lim, et al., 1996).

Treatment of acute ankle sprains

The aim of rehabilitation after injury is to restore normal function of the ankle joint and the surrounding soft tissues. The conventional management of acute ankle sprains typically involves rest, ice, compression, elevation (RICE) followed by functional rehabilitation (Hubbard & Hicks-Little,
Despite restoration of dorsiflexion ROM though conventional treatment, the methods neglect the presence of impaired or dysfunction of talocrural joint arthrokinematics (Denegar et al., 2002; Whitman et al., 2005). It has been estimated 55% to 75% of patients experience residual symptoms such as limited ROM or persisting pain up to 18 months following the initial onset of injury (Braun, 1999). Furthermore a systematic review by van Rijn et al. (2008) reports 36% to 85% of patients take up to 3 years for full recovery. Therefore there is a need to further develop the current approaches to ankle sprain treatment.

## Ankle Dysfunction

For the purpose of this review ankle dysfunction will refer to the altered mechanics or function (or both) to the ankle joint which may persist long after the healing of damaged tissue structures following a lateral ankle sprain (Hubbard, Olmsted-Kramer, Hertel, & Sherbondy, 2005; Renström & Konradsen, 1997). The result of an ankle sprain can disrupt the mechanics of the joint causing instability, and either hyper or hypomobility within the joint (Denegar & Miller, 2002; Hubbard & Hertel, 2006).

The following section will therefore define and describe ankle instability and the concepts of both mechanical and functional ankle instability. Then the terms hypermobility and hypomobility associated with ankle dysfunction will be discussed, and the relationship between hypomobility and ankle instability will be considered. The last two topics address altered ankle proprioception and altered fibular arthrokinematics following an ankle sprain.

### Ankle Instability

Ankle joint dysfunction whether it be hyper or hypomobility can cause mechanical and/or functional instability (Hubbard et al., 2005). Tropp (2002) describes two types of ankle instability both of which are thought to be contributors to recurrent ankle sprain:

#### Mechanical Ankle Instability

Ankle movement beyond the physiological limit of the ankle’s ROM is defined as mechanical ankle instability (MAI) (Mangwani et al., 2001; Tropp, 2002). Mechanical ankle instability can be caused by pathological laxity, arthrokinematic change such as clinically identifiable joint restriction, and/or synovial and degenerative changes (Hertel, 2002).
Functionally Ankle Instability

Functional ankle instability (FAI) is defined by Tropp (2002) as a subjective feeling of instability or recurrent symptomatic ankle sprains (or both) caused by both proprioceptive and neuromuscular deficits. The symptoms of FAI include instability, weakness, pain, and difficulty in performing functional tasks (Freeman & London, 1965). There appears to be a strong evidence of a relationship between sensorimotor deficits and FAI following an ankle sprain supported by the conclusions of the systematic review with meta-analysis by Munn (2010) which critically appraised and pooled data from 53 studies.

Chronic ankle instability results from dysfunction at the ankle due to FAI or MAI or a combination of the two (Hertel, 2002; Tropp, 2002). The clinical picture of chronic ankle instability includes the development of repetitive ankle sprains and persistent symptoms after an initial injury (Hertel, 2002; Hubbard & Hertel, 2006). Between 20% and 40% of people who experience ankle injuries develop chronic instability and experience a repeat ankle sprain (Freeman & London, 1965; Karlsson, Bergsten, Lansinger, & Peterson, 1988). If chronic ankle instability is not addressed, changes to normal joint arthrokinematics are hypothesised to predispose to degeneration of the ankle joint and therefore an increased risk of osteoarthritis (Hubbard & Hicks-Little, 2008). There is however no direct evidence to support a direct link to osteoarthritis nor is there any study quantified the incidence of osteoarthritis following a history of ankle sprain.

Ankle hypermobility

Following an ankle sprain, damage to the soft tissue structure can result in increased laxity at the ankle joint and cause hypermobility or MAI (Denegar & Miller, 2002; Hertel, 2002). Long term joint instability can result if damaged ligaments heal in an elongated position (Hubbard et al., 2005). The consequence of joint laxity is a change in the mechanics of accessory ankle movement and in combination may produce an altered axis of rotation of the joint (Denegar & Miller, 2002). The altered mechanics may cause instability at the ankle joint and alter proprioceptive input which later will be discussed.

Ankle hypomobility

Hypomobility at the ankle joint refers to restriction in joint movement, whether the restriction is physiological or accessory joint movement (Hubbard & Hertel, 2006). The loss of physiological dorsiflexion ROM may be due to soft tissue structures such as muscles, ligaments, joint capsule or by the inability of the talus to glide posteriorly within the mortise (Denegar et al., 2002). Restriction in
movement of the talus within the talocrural joint may be a result of the talus being forced anteriorly by injury to the ATFL, or the presence of post injury scar tissue or swelling (Denegar et al., 2002; Hubbard & Hertel, 2006). Following injury, accessory motion within the talocrural joint may also become restricted and force an abnormal axis of movement within the talocrural joint (Denegar & Miller, 2002; Hubbard & Hertel, 2006). Damaged soft tissue structures following the ankle sprain may heal but restriction in joint movement due to joint dysfunction may persist (Hubbard et al., 2005).

This review found limited research that addresses sagittal plane mobility (dorsiflexion ROM) at the ankle following an ankle sprain which may reflect current focus in manual therapy rehabilitation of the lateral support structures of the ankle and therefore focus on coronal plane mobility. Therefore there is a need for further investigation into treatment approaches that include assessment and treatment for joint dysfunction in the sagital plane.

**The relationship between hypomobility and ankle instability**

Hypomobility of the talocrural joint may cause both MAI and FAI of the ankle (Denegar & Miller, 2002). Loss of dorsiflexion ROM may cause gait dysfunction and increase the risk of ankle sprains (Collins, Tey, & Vicenzino, 2004; Hertel, 2000; Leanderson, Wykman, & Eriksson, 1993; Pope, Herbert, & Kirwan, 1998). The association between restricted dorsiflexion and increased risk of ankle sprain is further supported by a systematic review by De Noronha, Refshauge, Herbert and Kilbreath (2006) who reported that dorsiflexion ROM as the best predictor of ankle sprains. The review included a study by Pope et al (1998) which reported that subjects with DF of 34 degrees (least flexible ROM measured in participants) had a five times higher risk of suffering an ankle sprain compared with those exhibiting unrestricted dorsiflexion ROM (RR=4.97, 95% CI=1.5-14.5). Pope et al (1998) fails to quantify at what angle DF is considered to be unrestricted. Furthermore this study used a standing measure of DF using trigonometry to estimate DF angle measures. The measure procedure has been previously by reported by Montgomery et al (1989) to overestimate measures by 10 degrees although Pope et al (1998) did not correct for this error.

Of interest, displacement of the talus as little as 1mm following an ankle fracture or ligament injury has been reported to reduce the ankle’s weight bearing surface by 42.3% (Ramsey & Hamilton, 1976), which may additionally increase the risk of degenerative changes at the ankle over time (Safran et al., 1999). The consequence of minimal displacement of the talus provides further rationale for the application of manual therapy techniques in order to restore normal ROM at the ankle.
Altered proprioception at the ankle

Freeman (1965) was the first to theorise that damage to the mechanoreceptors within the ankle joint may impair proprioception. According to Freeman (1965), the tensile strength of the joint receptors are less than that of the connective tissue in which they are embedded. Therefore, damage from an ankle sprain may not only damage joint ligaments and musculature, but also the sensory nerve fibres within the joint capsule (Docherty, Moore, & Arnold, 1998; Freeman & London, 1965; Konradsen et al., 1993). Loss of accessory or physiological ROM at the talocrural joint may also alter motor control of the joint due to the disruption in neural feedback provided from mechanoreceptors embedded in the abnormally stressed tissues (Denegar & Miller, 2002; Hubbard & Hertel, 2006).

Any alteration or impairment in proprioceptive input requires the motor control programmes to compensate (Denegar & Miller, 2002; Hubbard et al., 2005). Failure to compensate can cause ankle instability (Hubbard et al., 2005) and thereby increase the risk of a sprain at the ankle (Glencross & Thornton, 1981; Konradsen, Olesen, & Hansen, 1998). It has been previously thought that the lateral muscle group of the ankle (peroneals) may also contribute to instability if there are delayed and diminished reflex responses (Delahunt, 2007). However, a literature review by Delahunt (2007) concluded that the reflex responses are too slow to control joint stability during dynamic movement. Therefore the relevance and effectiveness of functional exercise rehabilitation aimed at improving the reflex response of the injured ankle needs further investigation.

Dysfunction of fibular arthrokinematics

The consequence of an inversion sprain at the ankle is a possible dysfunction at both the inferior tibiofibular joint (Kavanagh, 1999; Mulligan, 1999) and superior tibiofibular joint (Denegar & Miller, 2002; Loudon & Bell, 1996). Restriction in normal fibular translation has been shown to reduce dorsiflexion ROM at the talocrural joint (Dananberg, 2004). Furthermore the fibula’s role in maintaining the ankle mortise stability during weight-bearing may also be directly affected (Denegar & Miller, 2002; Norkus & Floyd, 2001). The described dysfunction provides basis for the application manual therapy to the superior and inferior tibiofibular joints, as described in several manual therapy texts (Greenman, 2003; Hartman, 1998).

Objective measurement of ankle function

The following section concerns the various measure of dorsiflexion used within the literature and evaluates the reliability and validity of these procedures.
Dorsiflexion measures
Identifying restriction at the talocrural joint is clinically assessed through physical examination of the ranges of DF and plantarflexion (Greenman, 2003; Moseley & Adams, 1991). The method and equipment used to assess DF varies between studies (refer to Table 2), and is influenced by factors such as practicality, expense, time and advances in technology. The variations in methodology between the studies in this literature review highlight the need for a standardised approach to DF which is both reliable and accurate.

Research undertaken by Green et al (2001), Nield, Davis, Latimer, Maher & Adams (1993), Fryer et al (2002), and Anderson et al (2003) evolved their method of passive ankle DF measurement from Moseley and Adams (1991). Moseley and Adams (1991) pioneered a unique DF measure, applying a standardised torque to DF end of range measures allowing for improved reliability and accuracy of measurements. The participants in the study were positioned supine, the knee extended with an acrylic foot plate called a Lidcombe template attached to the participant’s foot. The footplate ensured the perpendicular distance between the force applied via a spring balance (the applied torque) and the talocrural joint was constant. Range of motion measures of DF were assessed using photographic stills rather than use of goniometric measures. An earlier study by Fish and Wingate (1985) supports the use of photographic stills finding the accuracy of photography to be superior in accuracy to goniometric measures. The Fish and Wingate (1985) study found visual estimation of reading analogue scales on a goniometer to be open to human error, while photography was found to be more accurate and an approach which inexperienced users could accurately use. Moseley and Adams (1991) reported their method to have a high inter-relater and repeated measures reliability (ICC = 0.97, no indication of 95% CI for retest error reported).

Nield et al (1993) modified Moseley and Adams (1991) method, positioning the participant in supine with leg flexed at 90 degrees and using a load cell transducer to apply the torque. Photographic stills were used to assess the end of range DF measures. Nield et al (1993) demonstrated the method to have high reliability with an ICC of 0.97 (no associated measures of precision regarding confidence levels were published). Green et al (2001) followed Moseley and Adams (1991) using a standardised torque and taking ankle measures with the leg extended, however, the Lidcombe template was altered by use of a hinge to restrict movement at the talocrural joint. Dorsiflexion measurements were assessed using a hydrogoniometer; and measures recorded at the angle when the participant first experienced pain. The measuring procedure by Green et al (2001) was reported to have a high reliability with an ICC of 0.94 although no associated measures of precision were published.
Studies by Fryer et al (2002), and Anderson et al (2003) positioned participants in supine with the leg flexed as described by Nield et al (1993). Fryer et al (2002) and Anderson et al (2003) both used a dynamometer to apply the torque to the foot plate, and end of range ROM dorsiflexion measures were taken from stills using a video camera. Fryer et al (2002) reported the repeatability of the measurements to have high reliability with an ICC of 0.97 and the percentage of inter-tester agreement to be 77% (no associated measures of precision were published).


Participant positioning within the four studies varied with DF measures taken either supine, prone or sitting. Dananberg et al (2000) and Whitman et al (2005) both positioned their participants supine with leg extended, Whitman and et al however included measures with the participant seated with the leg flexed at 90 degrees at the knee. The studies by Pellow and Brantingham (2001) and Venturini et al (2007) had participants positioned in prone taking measures with the leg extended. Thoms & Rome (1997) compared the effect of differences in leg position on the reliability of active DF measures finding no significant difference between prone and supine measures. Additionally Thoms and Rome reported significant differences in ROM when comparing supine to sitting and prone to sitting. Greater ROM in DF measures and errors were also observed with the knee in flexion sitting compared to extension. Thoms and Rome (1997) attributed the increased ROM measures to the decrease in tension of gastrocnemius with the leg in flexion and errors due to the knee joint not being immobilized when in flexion. Authors of studies that take dorsiflexion ROM measures with the leg in a flexed position argue that it reduces the influence of gastrocnemius allowing for greater sensitivity of ROM measures at the talocrural joint (Andersen et al., 2003).

measuring procedure. Venturini et al (2007) however reported the intra-examiner reliability of their measurement method to be high (ICC 0.98)(no associated measures of precision were published).

Both Ricketts (2005) and Taylor (2008) followed on from Fryer et al (2002) and Anderson et al (2003) in their DF assessment method, further modifying the DF measure through use of a electrogoniometer attached to a foot plate rather than photography to take dorsiflexion ROM measures. Photographic imagery is subject to potential human error with possible errors in using a non-standardised position of each subject for photos and errors in markings of anatomical landmarks. In contrast, measurement with a electrogoniometer has been previously validated by McLaughan and Vaughan (2004), who found the electrogoniometer to be an accurate measurement method largely free of human error. Taylor (2008) confirmed the reliability of measurement using an electrogoniometer and reported an “almost perfect” test-retest coefficient (ICC=0.97).

Collins et al (2004), Vicenzino et al (2006), and O’Brien and Vicenzino (1998) used an alternative assessment method of dorsiflexion ROM, a non-angular weight-bearing measure described as the DF lunge test. The DF lunge test was developed by Bennell et al (1998) and measures the distance from the furthest point from which the patient can touch a wall with the knee during a lunge whilst maintaining heel contact with the ground, the distance is measured from the 2nd toe to the wall. Collins et al (2004) believes this to be comparable in sensitivity to non-weight-bearing DF measures. However, Taylor (2008) disputes the effectiveness of the lunge test measure, because it is not a specific measure of ROM at the talocrural joint, and because other variables concerning the patient’s morphology such as hip and knee mobility and body shape, may influence the outcome measures.

**Joint position sense measures**

The assessment of proprioception within musculoskeletal research is evaluated by JPS, kinesthesia or sense of tension (Riemann, Myers, & Lephart, 2002), with JPS being the most commonly utilised measure (Hopper, Whittington, & Chartier, 1997; Westlake & Culham, 2006). JPS is a measure of the participant’s ability to reproduce predetermined angles, whether passively or actively. Konradsen et al (2002) observes that JPS measures are commonly reported in research by mean absolute error value of joint position assessment values or the real errors with corresponding standard deviations about the mean.

Glencross and Thornton (1981) was the first study to evaluate JPS in subjects with a history of ankle sprain. The symptomatic ankle results displayed substantial error in angle reproduction in comparison to the participant’s asymptomatic ankle. The majority of subsequent studies further
demonstrate a clear relationship between impaired joint function at the ankle and JPS deficit (Boyle & Negus, 1998; Docherty et al., 1998; Glencross & Thornton, 1981; Konradsen et al., 1998; Konradsen et al., 1993; Tropp, 2002; Yokoyama, Matsusaka, Gamada, Ozaki, & Shindo, 2008) with the exception of the inconclusive findings by Gross (1987) and Holme et al (1999). The use of JPS assessment as a reliable measure is supported by Hopper et al (1997), Westlake and Culham (2006) and Deshpande (2002) however this contrasts to the poor to moderate findings reported by earlier studies by Szczerba et al (1995) and Perrin (1995). According to Konradsen (2002) threshold levels for detection of joint movement at the ankle are less than 2°, therefore JPS methodology needs to be both sensitive and accurate. There is however, no widely accepted approach to JPS assessment with studies differing widely in the predetermined target angles to be matched, the number of target angles, the plane of motion in which to reproduce the angles, the equipment used, and whether active or passive ROM is assessed.

Other differences between studies include the plane of motion used for JPS measures. The differing planes of motion include: plantarflexion and dorsiflexion (Deshpande, Connelly, Culham, & Costigan, 2003; Glencross & Thornton, 1981; Westlake & Culham, 2006), inversion/eversion (Close, 1956; De Noronha, Refshauge, Kilbreath, & Crosbie, 2007; Docherty et al., 2004; Konradsen et al., 1993; South & George, 2007), plantar inversion (Yokoyama et al., 2008) and plantar flexion/eversion (Spanos, Brunswic, & Billis, 2008). A systematic review by Munn et al (2010) of sensorimotor deficit and FAI suggests JPS deficit may not be consistent through all movement planes therefore it is difficult to draw any conclusions from the outcomes between the studies.

Target angles also vary within studies, as do the number of angles targeted. The chosen target angles, should avoid extreme ranges of joint motion so to minimize unwarranted input from cutaneous receptors. Studies vary how the participants were positioned and the target angles reproduced. Thornton and Cross (1981) passively moved their participants' ankles to the target angle then required the participants to actively reproduce the angle required. In contrast, Docherty et al (2004) and Spanos et al (2008) both assessed active to active JPS, which involves the participants actively moving their own ankle to the target angle then actively trying to reposition their ankle to the target ankle. Other studies used passive to passive JPS (Yokoyama et al., 2008), or passive to active JPS (Lee & Lin, 2008; South & George, 2007) measures.

Another example of differences amongst JPS studies is the wide variety of equipment employed including use of: a foot plate which participants stand on (De Noronha et al., 2007; Deshpande et al., 2003), goniometer (Glencross & Thornton, 1981; Konradsen et al., 1993), electrogoniometer
(Docherty et al., 2004; Spanos et al., 2008) an isokinetic dynamometer (Gross, 1987; Lee & Lin, 2008; South & George, 2007), a foot slope box (Kynsburg et al., 2006; Robbins, Waked, & Rappel, 1995) and a ‘3D Ankle Position System’ consisting of two cameras and a platform on which participants placed their foot (Yokoyama et al., 2008).

Further differences within the JPS studies include the assessment position with participants measured either in weight-bearing or non-weight-bearing positions. Studies that assessed JPS non-weight bearing used either a seated position with leg flexed to 90° (De Noronha et al., 2007; Yokoyama et al., 2008) while other studies assessed participants supine with the leg flexed (Gross, 1987; Konradsen et al., 1993). Positioning the leg in a flexed position is thought to isolate JPS measures to the ankle, whereas the leg extended position is likely to activate the gastrocnemius muscle potentially causing interference in JPS measures due to an increase in muscle spindle discharge (Westlake & Culham, 2006). Robbins et al (1995) and Kynsburg et al (2006) adopted the use of weight bearing arguing it is a functional measure that better represents how the ankle is subjected to forces on landing during gait. However, Westlake and Culham (2006) argue that non-weight bearing measures more closely reflects gait, suggesting that proprioceptive awareness is just as important during the non weight-bearing swing phase of locomotion in order to prevent falls and subsequent injuries.

Despite Konradsen et al (2002) commenting that no study methods are superior to the other the variability of measurement procedures and equipment and participant positioning across the studies reviewed makes comparisons difficult. Furthermore the speed of angle reproduction for the involved outcome measures is rarely specified within the studies, this is important because the speed will determine whether one is assessing the fast or slow adapting proprioceptive receptors (Munn et al., 2010). The reason for studies avoiding to specify speed within their measuring procedures is probably because it is technically difficult in control.

In conclusion, it is evident that a standardised approach needs to be agreed to allow for better interpretation and understanding of future investigations concerning JPS.
Studies reporting the effects of manual therapy techniques on dorsiflexion range of motion and joint position sense at the talocrural joint

This section is divided into four main topics. The first two topics concern studies that have investigated the effects of: i) manipulation; and ii) mobilisation on dorsiflexion ROM at the talocrural joint. The research discussed within the first two topics has been further divided between those who involved participants with symptomatic ankles compared to those who recruited asymptomatic ankles. The third topic concerns two studies that used a type of manual therapy technique classified in the Osteopathy literature as ‘indirect’. Indirect techniques are defined as techniques that work away from the barrier in order to decrease the tension in the barrier as opposed to direct techniques as which engage a barrier and work against it to release restrictive tissue or a restrictive joint (Stone, 1999). The techniques of mobilisation and manipulation are classified as ‘direct’ techniques. Following the third topic a brief summary follows concluding the findings of the literature discussed within the three topics.

A fourth topic addresses research investigating the effects of manipulation and mobilisation techniques on stabilometry at the talocrural joint. All the individual studies within each topic have been described in chronological order. However the order may slightly vary where one study is in response to another. The effect sizes have been referred to when reported, and a summary of all the studies and reported effect sizes are presented in Table 2. Effect sizes were estimated by the author for studies that did not report them. See Table 2 for a summary of the literature reviewed.
Table 2. Summary of literature reviewed.

<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Study Design</th>
<th>Symptomatic/Asymptomatic Subjects</th>
<th>Sample Size</th>
<th>Intervention Control Procedure</th>
<th>Sham Measures Tool</th>
<th>Outcome Measurement</th>
<th>Conclusions Results</th>
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<tbody>
<tr>
<td>Nield, S., Davis, K., Latimer, J., Maher, C., &amp; Adams, R. (1993). The effect of manipulation on range of movement at the ankle joint.</td>
<td>Randomised Controlled Trial</td>
<td>Asymptomatic 1 ankle control the other experimental</td>
<td>20 Male 13 Female</td>
<td>Single longitudinal talocrural manipulation. Considered successful if gapping or crack heard.</td>
<td>No</td>
<td>Ankle DF ROM measured using adapted Moseley and Adams (1991) method using Lidcombe template. Camera was used to record ankle position and simultaneous force readout. ICC 0.97</td>
<td>No change between control and experimental. (Unable to calculate effect size) Means not provided for ROM</td>
</tr>
<tr>
<td>Dananberg, H. J., Shearstone, J., &amp; Guiliano, M. (2000). Manipulation method for the treatment of ankle equinus.</td>
<td>Non randomized, non controlled trial</td>
<td>Symptomatic Patients with ankle equinus</td>
<td>22 Male 10 Female</td>
<td>Fibular head manipulation followed by longitudinal talocrural manipulation.</td>
<td>No sham</td>
<td>Ankle DF measured using a goniometer and active assisted ROM.</td>
<td>Increase in ROM of motion of all subjects following manipulation. (p&lt;0.001) 99%CI 1 degree to 17 degrees. (Unable to calculate effect size) Means not provided for ROM</td>
</tr>
<tr>
<td>Green, T., Refshauge, K., Crosbie, J., &amp; Adams, R. (2001). A randomized controlled trial of a passive accessory joint mobilisation on acute ankle inversion sprains.</td>
<td>RCT</td>
<td>Patients treated every second day (maximum 2 weeks).</td>
<td>41 Male 26 Female 12 Male 12 Female Lost 3 Subjects in the experiment al group to follow up.</td>
<td>All received RICE protocol and wore tubular bandage. 3rd session all taped. Gentle oscillatory technique end of range –AP.</td>
<td>No sham, the control group had RICE Protocol.</td>
<td>DF: Measured using Lidcombe template with a hydrogoniometer and a spring balance to apply uniform torque. Gait: stride speed, step length, and single support time. (ICC 0.94)</td>
<td>Fewer treatments required in experimental group to gain pain free dorsiflexion than those only using RICE. Experimental (df =0.44) Control (df =0.09) (p&lt;0.01)</td>
</tr>
<tr>
<td>Pellow, J. E., &amp; Brantingham, J. W. (2001). The efficacy of adjusting the ankle in the treatment of subacute and chronic grade I and grade II ankle inversion sprains.</td>
<td>A single blind, comparative, controlled pilot study</td>
<td>Patients recruited from the public at Chiropractic Clinic with chronic and subacute grade 1 and 2 ankle inversion</td>
<td>36 Male 18 Female 11 Male 5 non compliant 1 excluded due to injury</td>
<td>Ankles mortise separation adjustment, maximum 8 treatments over 4 weeks.</td>
<td>No sham. Control group received 5 minutes of detuned ultrasound</td>
<td>DF: measure with goniometer in prone and active movement from patient. Pain: algometer test. MacGill Pain Questionnaire. Numerical Pain Rating Scale. Functional Evaluation Scale</td>
<td>Both groups improved. Adjustment group showed significant differences for pain, increased range of motion (p&lt;0.001) and ankle function. Adjustment better than ultrasound. (Unable to calculate effect size)</td>
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<td>Study</td>
<td>Design</td>
<td>Group</td>
<td>Outcome</td>
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<td>Fryer, G. A., Mudge, J. M., &amp; McLaughlin, P. A. (2002). The effect of talocrural joint manipulation on range of motion at the ankle.</td>
<td>A randomized controlled and blinded study</td>
<td>Asymptomatic volunteers</td>
<td>41</td>
<td>15 male 26 female</td>
<td>Single short lever HVLA distractive thrust to talocrural joint.</td>
<td>No sham. Control group lay on table for the same time period.</td>
<td>HF: using adapted Moseley and Adams (1991) method. Standardized torque applied using handheld dynamometer. Digital video was used to record readings then analyzed with motion analysis software. Joint was preconditioned. Gap and Pop of joint recorded. (ICC 0.95)</td>
</tr>
<tr>
<td>Andersen, S., Fryer, G., &amp; McLaughlin, P. (2003). The effect of talocrural joint manipulation on range of motion at the ankle joint in subjects with a history of ankle injury.</td>
<td>A randomized controlled and blinded study</td>
<td>Symptomatic, history of lateral ligament sprain.</td>
<td>52</td>
<td>23 male 29 female</td>
<td>Single short ever HVLA Distractive thrust to talocrural joint</td>
<td>No sham. Control group lay on table for the same time period.</td>
<td>DF: using adapted Moseley and Adams (1991) method. Standardized torque applied using handheld dynamometer. Digital video used to record readings then analyzed with motion analysis software. Joint was preconditioned. Gap and pop of joint recorded. (ICC 0.97.)</td>
</tr>
<tr>
<td>Collins, N., Teys, P., &amp; Vicenzino, B. (2004). The initial effects of a Mulligan’s mobilization with movement technique on dorsiflexion and pain in subacute ankle sprains.</td>
<td>Double blind randomized controlled trial incorporated repeated measures into a crossover design. Each participant was his or her own control.</td>
<td>Symptomatic. Required grade 2 ankle sprain on average 40 days prior to testing.</td>
<td>16</td>
<td>8 males 8 females</td>
<td>MWM to talocrural joint 3 sets of 10 repetitions applied.</td>
<td>Placebo: Similar to treatment condition Control: Held stance for same period of time.</td>
<td>DF: knee to wall principle- distance 2nd toe to wall measured in mm. Pressure pain: algometry. Hot and cold thermal pain threshold: used Thermostest system.</td>
</tr>
<tr>
<td>Whitman, J. M., Childs, J. D., &amp; Walker, V. (2005). The use of manipulation in a patient with an ankle sprain injury not responding to conventional management: a case report.</td>
<td>Case Report</td>
<td>Symptomatic. The patient was a 27-year old volleyball player who had suffered from an ankle sprain three weeks prior to her first visit to physical therapy</td>
<td>1 female</td>
<td>Manipulation mobilisation techniques. Proximal fibula head manipulation. Rear foot distraction manipulation. Lateral glides. Talocrural AP mobilisation. Ankle inversion/eversion mobilisation. DF self mobilisation BLT technique to ankle complex and the tibiofibular articulations and interosseous membrane</td>
<td>No</td>
<td>DF, Plantarflexion, Inversion and Eversion: measured with goniometry. Foot and Ankle Ability Index. Patient Specific Functional Scale.</td>
<td>Manipulation and mobilisation techniques may allow quicker improvement of function and decrease in pain in patients unresponsive to conventional management. (Unable to calculate effect size) Case study</td>
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<td>Study</td>
<td>Design</td>
<td>Subjects</td>
<td>Procedure</td>
<td>Outcome</td>
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<td>Ricketts, S. (2005). The effect of an indirect technique on ROM at the ankle.</td>
<td>Randomized, controlled and blinded study.</td>
<td>Asymptomatic.</td>
<td>40 9 males 31 females</td>
<td>BLT technique to ankle complex and the tibiofibular articulations and interosseous membrane. No sham. Control group stayed for same time in the treatment room. DF: Measured using a 3DM electrogoniometer with standard torque applied with handheld dynamometer. BLT did not produce a significantly greater increase in DF ROM compared to the no treatment group. Experimental (d = 0.38) Experimental plus 30mins (d = 0.43) Control (d = 0.35) Control plus 30mins (d = 0.27)</td>
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<td>Venturini, C., Penedo, M. M., Peixoto, G. H., Chagas, M. H., Ferreira, M. L., &amp; de Resende, M. A. (2007). Study of the force applied during anteroposterior articular mobilization of the talus and its effect on the dorsiflexion range of motion.</td>
<td>Exploratory methodological study.</td>
<td>Asymptomatic</td>
<td>25 15 female 10 males</td>
<td>Anterior posterior mobilisation of talocrural joint – 30secs duration No Sham. No control group, left ankle used as control Active DF, Using a biplane goniometer A linear force-displacement relationship during Maitland grades III and IV passive joint mobilisation was not observed. The mobilisation caused an immediate increase in ankle dorsiflexion ROM. Experimental (d = 0.21) Control (d = 0.12)</td>
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<td>Taylor, N. (2008). Effects of the 'Still technique' on dorsiflexion at the talocrural joint in patients with a history of ankle injury.</td>
<td>Randomized, controlled and blinded study.</td>
<td>Symptomatic</td>
<td>32 19 males 13 females</td>
<td>The ‘Still’ technique applied to the talocrural joint. Sham used. DF: measures of passive DF ROM were collected using a electrogoniometer with a standardised torque applied with a dynamometer. Overall application of the Still technique did not substantially alter ROM at the talocrural joint in all subjects; however some subjects did show a response to treatment. Experimental (d = 0.34) Control (d = 0.10)</td>
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<td>O’Brien, T., &amp; Vincenio, B. (1998). A study of the effects of Mulligan’s mobilization with movement treatment of lateral ankle pain using a case study design.</td>
<td>Case Study – two single system design; Subject 1 underwent an ABAC protocol while subject 2 underwent an BABC protocol (A - no treatment phase, B - treatment phase, C - the post-treatment return to sport phase).</td>
<td>Symptomatic</td>
<td>2 males</td>
<td>Posterior glide to the distal fibula, while the patient actively inverted the ankle several times No Sham. The ABAC was used as the control DF: standing knee to wall test. Modified Kaikkonen test Inversion ROM Visual analogue scale for pain and function. A significant effect in ROM of DF was observed in the subject who received the treatment. Pain and function also was improved. Unable to calculate effect size because case study</td>
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<td>Authors</td>
<td>Study Design</td>
<td>Intervention</td>
<td>Comparison</td>
<td>Outcome</td>
<td>Abbreviations</td>
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<tr>
<td>Vicenzino, B., Branjerdporn, M., Teys, P., &amp; Jordan, K. (2006)</td>
<td>A double blind randomised crossover control experiment</td>
<td>Symptomatic</td>
<td>16</td>
<td>Compared the effects between a weight bearing and non weight bearing posterior talar glide</td>
<td>DF: standing knee to wall test. Posterior talar glide using a inclinometer. Both the weight-bearing and non–weight-bearing MWM treatment techniques improved weight-bearing dorsiflexion by 26% ($P &lt; .017$), compared to 9% for the control condition. Experimental Group: -weight bearing MWM ($d = 0.4$) -non weight bearing MWM ($d = 0.3$) Control Group ($d = 1.6$)</td>
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<td>Alburquerque-Sendín, F., Fernández-de-las-Peñas, C., Santos-del-Rey, M., &amp; Martín-Vallejo, F. J. (2008).</td>
<td>Randomised single blind and controlled study</td>
<td>Asymptomatic</td>
<td>62</td>
<td>Bilateral distractive talocrural joint manipulation</td>
<td>No. Control group had no intervention Stabilometry: Using Foot work force platform Bilateral talocrural joint manipulation did not modify standing stability.</td>
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Abbreviations: (DF) Dorsiflexion, (HVLA) High Velocity Low Amplitude, (MWM) Mobilisation with Movement, (AP) Anterior/Posterior, (BLT) Balanced ligamentous tension, (ROM) Range of Motion, (RICE)Rest Ice Compression Elevation, (ICC) Intraclass correlation coefficient, ($d$) effect size, ($d_0$) estimate effect size calculated by author [using $d = \frac{x_2 - x_1}{sd_2 + sd_1}/2$].

Studies reporting the effects of manipulation on dorsiflexion range of motion at the talocrural joint manipulation

Asymptomatic participants
Two studies have reported the effects of manipulation on dorsiflexion ROM at the ankle in asymptomatic research participants (Fryer et al., 2002; Nield et al., 1993). Nield et al (1993) was the first to pioneer research into the effects of manipulation of the talocrural joint on range of DF. The intervention involved a single manipulation applied to the ankles of 20 asymptomatic subjects. One ankle was arbitrarily selected to be the experimental ankle, the other the control. Nield et al (1993) took the dorsiflexion ROM measures using five incrementally increasing torques. The results of the study failed to identify any change in ROM following manipulation; however, the ROM measures were shown to be reliant on the magnitude of the torque applied. The introduction of the use of a standardised torque was influential to improving the reliability of DF measures in subsequent studies that followed on from Nield et al (1993).

There was a large gap of approximately 10 years before another study concerning the effects of manipulation on the ankle. The gap likely reflected the preoccupation of manual therapy researchers with spinal manipulation studies and ignoring investigating the effect of manual therapy techniques on the peripheral joints. Fryer et al (2002) appears to be the first to follow on from Nield et al (1993) using 41 asymptomatic patients and a single HVLA thrust, applying the intervention to the participants most restricted ankle (relative to the other ankle). The 41 subjects were divided between a control and experimental group, the control group receiving no intervention. However unlike Nield’s (1993) application of successive increasing torques for DF measures Fryer et al (2002) used a single standardised torque. Fryer et al (2002) described their method of ROM measure as ‘objective and reliable’ but also suggested that a limitation of their measurement procedure was the inability to accurately detect small changes in range. The results of Fryer et al’s (2002) study reported no change in ROM between the control and experimental group.

Symptomatic participants
Three of the four studies reviewed, investigated the effects of manipulation on symptomatic participants with a history of lateral ankle sprain with the exception of Dananberg et al (2000) whose participants had ankle equinus (a structural ankle abnormality). The type and number of techniques employed varies amongst the studies; Anderson (2003), Pellow and Brantingham (2001) used a

Andersen et al (2003) replicated the same methods as Fryer et al (2002) on participants with a history of ankle injury. The participants were required not to have experienced an ankle sprain within six months prior to testing. The results of the study found no significant change (p=0.84) between the control group and experimental group when comparing the change in DF post intervention.

Two studies that did demonstrate significant statistical effects after manipulation of the talocrural joint were those undertaken by Dananberg et al (2000) and Pellow and Brantingham (2001). Uniquely to all other studies examining the effects of manipulation on dorsiflexion ROM both studies required their participants to actively move their ankle for the dorsiflexion ROM measures. Pellow and Brantingham (2001) required their 36 participants to actively DF while the examiner moved the foot passively to perform the pre and post dorsiflexion ROM measures. Dananberg et al (2000) differed by requiring the 22 participants to actively DF their ankle themselves by pulling on a cloth cord around their foot. The credibility of the method is poor since the magnitudes of the ROM measures are influenced by how hard the participants choose to pull individually; and therefore it is likely participants could have pulled harder post intervention due to their own expectations of improved ROM following the intervention. The two studies both measured DF with a goniometer with the participants positioned with their leg extended. Positioning the leg extended, however, means dorsiflexion ROM measures could be potentially influenced by the engaged gastrocnemius and soleus muscle tension.

Dannenberg et al’s (2000) study demonstrated that the combination of two lower limb manipulations (HVLA thrust on the proximal tibiofibular and talocrural joints respectively) and a traction technique of the talocrural joint increased dorsiflexion ROM at the ankle. The positive outcome of the study arguably could have been influenced by the use of three techniques compared to those studies that used a single technique. The limitation is therefore not being able to specifically attribute the effects to the different techniques involved, however it does more closely represent more closely typical practice, another factor to consider may have been the difference in therapeutic technique employed because Anderson et al (2003) suggests that the sustained traction may have produced a more effective viscoelastic change in the ankles soft tissue structures when compared to the application of HVLA thrust techniques. No control group or sham was used in the study. The participants were not blinded to receiving the intervention therefore, it is unknown if the
outcome measures could have been influenced by the participants expectation of a therapeutic outcome following the intervention. In contrast Pellow and Brantingham’s (2001) experimental group received a single HVLA thrust to the talocrural joint over four separate weeks while the control group received a sham of detuned ultrasound. The outcome measures included dorsiflexion ROM, and a questionnaire concerning pain and functional outcomes. Pellow and Brantingham’s (2001) findings suggested a HVLA thrust technique administered over a successive period of treatments is an effective form of treatment for Grade 1 and Grade 2 ankle sprains. Furthermore there was an absence of a control group hence it is unknown whether the outcome was influenced by the treatment or simply by natural history of healing over the 4 week study period.

Whitman et al (2005) used a case report involving a 27 year old volleyball player who presented with an inversion sprain of three weeks duration. Over the three weeks prior to participation the participant had been unresponsive to conventional treatment involving RICE, self-taping and strengthening exercises. The patient received a variety of manipulative and mobilisation techniques in conjunction with home exercises. Whitman et al (2005) reported immediate positive effects following the intervention including improved dorsiflexion ROM, decreased pain levels and improved ankle function. However due to the combination of various techniques and exercises employed it is impossible to draw any conclusions as to the effectiveness of each specific technique. The publication of this case study of a common presentation in a ‘prominent journal’ serves as an illustration of the relative immaturity of clinical research in the field of manual therapy, and ankle joint injury.

**Studies reporting the effects of mobilisation on dorsiflexion range of motion at the talocrural joint**

Asymptomatic participants

Venturini et al (2007) studied the relationship between force and displacement during passive anterior posterior mobilisation of the talus and the effect on dorsiflexion ROM at the ankle. Participants included 35 healthy participants all of whom had their right ankles assessed. The dorsiflexion ROM measures were made using a handheld goniometer. The results showed a 2° increase in dorsiflexion ROM at the ankle post intervention. A limitation of the study included examining the immediate effects of mobilisation and it is therefore unknown whether the effect persisted long term.
Symptomatic participants
O’Brien and Vicenzino (1998) would appear to have been the first to have investigated the effect of a mobilisation technique on the talocrural joint. The study examined the immediate effects of mobilisation with movement (MWM) on two participants in a single case study design. Mobilisation with movement was developed by Mulligan (1993) and is now commonly practiced within the profession of physiotherapy however, at the time of this study MWM was a new concept and rarely used in the clinical setting for the treatment for acute ankle sprains (O’Brien & Vicenzino, 1998). The two participants recruited were required to have suffered an ankle sprain within the three days of the study. Both participants received a MWM posterior glide technique to the distal tibiofibular joint, with the participants required to invert the foot during the application of the technique. The approach requires the accessory mobilisations applied by both the practitioner and the patient’s active movement. Outcome measures of this study included pain, inversion ROM and DF measures. Dorsiflexion measures were assessed during weight-bearing in DF using the standing knee to wall test described by Bennell et al (1998). The authors claim the participants were found to have recovered dorsiflexion ROM more quickly than if natural history was left to run its course. However the claim is speculative because no control was used to compare the course of natural history to the effect of the intervention – a limitation of the design.

Green et al (2001) was the first investigation to have used a randomised controlled study design. The study investigated whether the use of an anterior posterior mobilisation at the talocrural joint improved pain free ROM, dorsiflexion ROM and gait compared to the RICE treatment protocol on participants with an acute ankle sprain. Green et al (2001) recruited 41 participants with acute lateral ankle sprains of less than 72 hours duration. Participants were divided between a control and experimental group. Those assigned to the control group received the ‘RICE’ protocol whereas the experimental group received an anterior posterior mobilisation of the talocrural joint in addition to the RICE protocol. The participants received treatment every 2 days up to a maximum of 2 weeks. Participants were discharged from treatment within the 2 week period if they had reached full pain free dorsiflexion ROM. The study by Green et al (2001) is the only one of the studies using mobilisation as an intervention which used a standardised torque for dorsiflexion ROM measures as recommended by Mosely and Adams (1991). A hydrogoniometer attached to a footplate (modified Lidcombe template) was used for taking angle measurements. The results showed the experimental group required less treatment and had a greater improvement in dorsiflexion ROM compared to the control group. Despite the positive findings, the improved dorsiflexion ROM observed may be explained by the natural history of tissue repair following an acute injury.
Unlike the previous studies Collins et al (2004) explored the effects of MWM technique weight bearing on dorsiflexion ROM on participants with a history of acute ankle sprains. Collins et al (2004) additionally investigated the physiological effects of the MWM technique on pain hypoalgesia using both pressure and thermal pain threshold testing to substantiate Mulligan (1993) claims of rapid pain free ROM following MWM. The 14 participants recruited were divided into experimental and control groups. The control group received a sham treatment to their symptomatic ankles, all participants non-symptomatic ankle were used as a separate non-treatment control group. The MWM technique utilised was a weight-bearing posterior anterior glide applied through use of a treatment belt placed around the participant’s distal tibia fibular joint and tensioned by the therapist’s body weight. Three sets of 10 repetitions were used with a one minute interval between sets. Dorsiflexion ROM was assessed using Bennell’s (1998) standing DF lunge test. The study reported a significant effect on dorsiflexion ROM but results showed no effect on pressure pain and thermal pain thresholds.

A follow-up study by Vicenzino et al (2006) explored the effects and mechanisms of MWM at the ankle in a way no other study had previously done. Vicenzino et al (2006) evaluated for any difference in effectiveness between weight-bearing and non-weight-bearing MWM techniques on the posterior glide of the talus and dorsiflexion ROM. Participants were required to have a history of ankle sprain including a restriction in dorsiflexion ROM between the symptomatic and asymptomatic ankle of at least 20mm using Bennell’s (1998) knee to wall DF lunge test. Dorsiflexion ROM measures were taken pre and post intervention using the DF knee to wall lunge test. The study reported an intra-tester reliability ICC of 0.95 for DF measures. The study found little difference on ROM between the two techniques however both had a significant effect on posterior glide of the talus. The effect sizes reported by Vicenzino et al (2006) were large for the weight bearing and non weight bearing techniques on the posterior glide of the talus (estimated to be 0.8 and 0.9 respectively). In comparison the effects of the techniques on dorsiflexion were less strong showing the weight bearing and non weight bearing techniques having a small to moderate effect (0.4 and 0.3, respectively).

Studies reporting the effects of indirect techniques on dorsiflexion range of motion at the talocrural joint
The following two studies by Ricketts (2005) and Taylor (2008) have each used distinctly different types of techniques which are classified by osteopaths as indirect techniques.

Asymptomatic participants
Ricketts (2005) used a balance ligamentous technique (sometimes referred to as ‘BLT’) classified as an indirect technique (Parsons & Marcer, 2006). Ricketts (2005) intervention involved treating the ankle and interosseous membrane rather than a single technique directed towards a single aspect of the ankle. Ricketts (2005) recruited subjects that had a pretreatment discrepancy range of 6° between their right and left ankle. The study failed to demonstrate that the intervention had an effect on change of ROM at the ankle.

Symptomatic participants
Taylor (2008) recruited participants with a history of ankle injury attained within the previous 5 years. The study selected the symptomatic ankle and used Bennell et al (1998) knee to wall measurement to confirm if the symptomatic ankle was comparatively more restricted in ROM than the contralateral ankle. The participants were divided into control and intervention groups with 16 in total per group. The intervention was a single application of a novel technique called the ‘Still’ technique which uniquely begins as an indirect technique but ends as a direct technique (Van Buskirk, 2000). A sham technique was employed in an effort to ensure participants were blinded to group allocation. Pre and post DF measures were taken from the most restricted ankle, and were not compared to the participants opposite ankle. Taylor (2008) adopted the same measuring procedure as used by Ricketts (2005) which was reported to have excellent reliability. The finding of the study reported a ‘moderate’ effect (d=0.34) but was underpowered (1-β=0.245). Taylor (2008) undertook secondary analysis to identify three experimental group subgroups: those who demonstrate an increase ROM: participants who demonstrated no change, and participants who demonstrated decrease dorsiflexion ROM. Five of the 16 participants in the experimental group demonstrated ROM greater than the estimated smallest detectable distance in comparison to one in the sham group. Taylor (2008) estimated that an additional 56 participants to both the control and experimental group would be required to give sufficient statistical power to draw definitive conclusions.

Summary of literature concerning the effects of manual therapy techniques on dorsiflexion range of motion at the talocrural joint
In summary the studies using single mobilisation techniques are more effective at changing ROM at the talocrural joint compared to the studies using single HVLA thrust techniques and indirect techniques which produced small observable effects on dorsiflexion. The studies by Dananberg et al (2000), Whitman et al (2005) and Brantingham et al (2009) all applied either a combination of techniques or applied techniques successively over a set time period, and demonstrated to have increased dorsiflexion ROM at the talocrural joint.

The inability of the single technique manipulation and indirect technique studies to have an immediate effect on dorsiflexion range of motion reflected two issues with single technique studies: 1) dose(time); 2) limited external validity – not representative of clinical practice. The speed of the techniques applied may be a reason for the differences observed between single mobilisation technique studies and single HVLA thrust studies. Venturini et al (2007) suggests the speed of a single HVLA thrust technique may be too fast to effect a viscoelastic change in ROM at the ankle in comparison to the application of a mobilisation technique. The effectiveness between techniques is also likely to be dependent on the magnitude of force applied. Both Taylor (2008) and Ricketts (2005) did not demonstrate an improved dorsiflexion range of motion which may be because indirect techniques are of insufficient force to effect a change on the soft tissue structures at the ankle joint. Furthermore the outcome of Ricketts (2005) study may have been influenced by investigating the effects of BLT on an asymptomatic population. Ricketts (2005) describes the BLT as being clinically useful in situations where direct techniques may be of less use when patients are in acute pain. Therefore there are questions as to why Ricketts chose to investigate the effects of a technique such as BLT on an asymptomatic population. Furthermore the results of the studies concerning the immediate effects of a single technique would appear less effective at improving ROM at the ankle than those studies which used multiple techniques or applied the technique/s successively over a set period of time. This highlights the issue of limited external validity of such studies because application of a single technique study does not represent what happens in the clinical situation where the practitioner incorporates several techniques over a length of time in order to achieve the desired therapeutic effect (Patterson, 2002; Ricketts, 2005). Therefore future studies should focus on multiple techniques literature applicable to clinical practice rather than continue to investigate single techniques.

Overall the majority of early studies compromised internal validity by failing to control torque for DF ROM measures. For example the entire mobilisation studies reviewed failed to use a constant torque apart from Green et al (2001). Other studies that made use of goniometers for dorsiflexion ROM measures are subject to human error and the standing knee to wall measure used by Collins et
al (2004), O’Brien and Vicenzino (1998) and Vincenzino et al (2006) may, arguably, not be a specific measure of dorsiflexion ROM at the talocrural joint. The later studies by Taylor (2008) and Ricketts (2005) used more robust methods of dorsiflexion ROM measures however there were limitations in the studies in regards to the clinical relevance of investigating single techniques. Drawing clear conclusions concerning the effectiveness of both manipulation and mobilisation techniques is hindered by the majority of studies failing to report effect sizes, in addition most studies were statistically under powered’.

**Studies reporting the effects of mobilisation and manipulation on stabilometry at the talocrural joint**

Previous studies have examined the effects of rehabilitation protocols, strapping and bracing on JPS on participants with a history of ankle sprain (Docherty et al., 1998; Heit, Lephart, & Rozzi, 1996; Kynsburg et al., 2006), however, there appears to be no studies in the indexed literature investigating the effects of mobilisation or manipulation on JPS. The studies by López-Rodríguez et al (2007) and Alburquerque-Sendín et al (2009) examined the effects of talocrural joint manipulation and mobilisation using stabilometry but stabilometry is not a direct measure of proprioception. López-Rodríguez et al (2007) assessed the immediate effects of talocrural joint manipulation on stabilometric and baropodometric outcomes in participants with Grade 2 ankle sprains (n=35 male, and n=17 female field hockey players), the asymptomatic ankle was used as a control. The intervention included two manipulations; a talocrural joint HVLA thrust manipulation and secondly a posterior gliding mobilisation (termed ‘manipulation’) at the talocrural joint. The findings indicated a small change following the intervention with differences between the intervention group pre and post measures on posterior load (p=0.15) and bilateral anterior load (p=0.2).

In a later study by the same research group Alburquerque-Sendin et al (2009) assessed the effect of a bilateral HVLA thrust of the talocrural joint on 62 asymptomatic participants using the same stabilometric measures as the earlier study conducted by López-Rodríguez et al., 2007. The study differed in that a control group was used and the experimental group received a single HVLA thrust technique to each ankle. The results of the study found there was no significant effect on standing stability. However the study concluded outcome measures may have been affected by the small sample size and intra subject variability.

In summary the different findings between the two studies could be attributed to whether the participant’s ankles were symptomatic or not. Therefore despite the limited research, from the results it appears that asymptomatic and symptomatic ankles may respond differently to
manipulation or mobilisation. Considering no studies were found concerning JPS and only two studies were found using stabilometry as an outcome measure, it is evident for future research to investigate the effects of manual therapy techniques on JPS on participants with a history of ankle sprain. Furthermore future research needs to utilise a more accurate and specific measure of change in JPS at the ankle. The use of stabilometry arguably does not isolate variations in JPS to the ankle region and may involve other factors such as visual and vestibular cues, neuromuscular control and the influence of other joints.

Conclusions

The studies investigating the effects of manual therapy techniques on dorsiflexion ROM at the ankle have evolved erratically with few studies systematically building on earlier work. The disjointed development is reflected in the wide variability between study designs, interventions, intervention dose, equipment and measuring procedures employed. Progress in this field has been slow. Some 15 years after Nield et al’s (1993) study there is still single technique studies such as Taylor (2008) being undertaken. There have been few multiple technique studies or studies that have investigated the effects of mobilisation or manipulation techniques integrated into treatments within the clinical setting.

The studies that have examined the effects of mobilisation at the talocrural joint have all concluded improved dorsiflexion ROM at the ankle. In contrast the studies that used single HVLA thrust techniques in contrast had mixed outcomes. There is an absence of investigations into examining the effects of manual therapy techniques on JPS. Although an earlier study by López-Rodríguez et al (2007) confirmed manipulation did “exert proprioceptive effects”, the outcome measure of stabilometry is not considered a direct measure of proprioception.

In conclusion further research is needed to confirm whether a combination of manual therapy techniques can increase the range of DF, and improve JPS on participants with a history of lateral ankle sprain. Section 2 of this thesis reports an experimental investigation into the immediate effects of a combination of manual therapy techniques in participants with a history of lateral ankle sprain.
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Note: The following manuscript was prepared in accordance with the Instructions for Authors for the International Journal of Osteopathic Medicine [see Appendix E]. The required word limit and references have been exceeded in order for full evaluation and discussion of the results in this thesis.
The immediate effects of manual therapy on dorsiflexion and joint position sense at the talocrural joint in participants with a history of lateral ankle sprain

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ABSTRACT

Objective: To determine the immediate effect of manual therapy on dorsiflexion and joint position sense at the talocrural joint in participants with a history of lateral ankle sprain.

Design: A randomised, assessor blinded, sham controlled experimental design.

Participants: Seventeen volunteers (10 males, 7 females; mean age=32.6 y, SD=10.0) with a history of ankle injury recruited from a university population.

Methods: Participants with a history of ankle injury were randomly allocated to sham and genuine intervention groups. Participants in the genuine intervention group received mobilisation of the talocrural and proximal tibiofibular joints, and manual traction to the talocrural joint within a single session. Those in the sham intervention group received a sham intervention designed to mimic the genuine intervention techniques. Pre-test and post-test measures of passive dorsiflexion range of motion (ROM) and joint position sense (JPS) were collected using an electrogoniometer. Pre and post test measures were taken of all participants’ symptomatic and asymptomatic ankle.

Results: Dorsiflexion: The symptomatic ankle of the genuine intervention group revealed a significant increase in dorsiflexion ROM of 3.5° (T = 7.0, z = -2.09, p = 0.04, r = 0.79) following the genuine intervention. The increase in dorsiflexion ROM exceeded the typical error of measurement (TE) = 1.73°. The symptomatic ankle of the sham intervention group showed a trivial change of 0.3° (T = 9.0, z = -0.51, p = 0.40, r = 0.32), following the sham intervention. Joint position sense: Interpretation of the JPS results for both allocation groups was hindered by: ‘poor’ to ‘moderate’ reliability of JPS measurement procedure for each of the three target angles; the JPS error results were not statistically different after the sham or genuine intervention and were associated with ‘small’ effect sizes. Interpretation of JPS changes were compromised by low power.

Conclusion: This study found that the combination of three manual therapy techniques had a small but significant effect on improving dorsiflexion ROM, however, the results were inconclusive concerning JPS at the ankle in participants with a history of lateral ankle sprain. Further investigation is required to determine whether the techniques examined can, when delivered within the context of a clinical treatment plan, contribute to the treatment and rehabilitation of lateral ankle sprains.

MeSH Keywords:

Ankle injuries; Manipulative therapy; Musculoskeletal manipulations; Joint flexibility; Articular arthrometry; Strains and sprains
INTRODUCTION

Lateral ankle sprains are amongst the most common injuries within the physically active population. The incidence of ankle injuries within the general population is high; 23,000 ankle sprains are estimated to occur each day in the United States, which equates to approximately 1 sprain per 10,000 people every day.\(^1,2\) The consequence of an ankle sprain is typically altered arthokinematics of the talocrural joint and is clinically characterised by loss of dorsiflexion (DF).\(^3\) Hypomobility of the talocrural joint may remain long after damaged soft tissue structures associated with the sprain have healed. This hypomobility can lead to chronic instability, abnormal proprioception,\(^3-5\) and it has also been associated with increased risk of further sprain and potential fracture.\(^6\)

Currently the conventional management approach to rehabilitation of ankle sprains ignores the role of impaired accessory movement which may increase the susceptibility to recurrent injury.\(^7\) Hoch and McKeon\(^8\) suggest any restriction in range of accessory and/or physiological motion at the ankle should be addressed using manual therapy. To date, research surrounding manual therapy of the talocrural joint has produced conflicting results and therefore its effectiveness remains unclear. Collins et al,\(^9\) O’Brien and Vicenzino\(^10\) and Vicenzino et al\(^11\) have all demonstrated increases in DF following the application of a single mobilisation technique to the talocrural joint in participants with a history of lateral ankle sprain. Other manual therapy techniques have also been investigated, Anderson et al\(^12\) used single high velocity low amplitude (HVLA) thrust; and Taylor\(^13\) used a novel technique called the ‘Still’ technique, although both studies reported no change in DF. Other studies\(^7,14-16\) combining the application of multiple treatment techniques have demonstrated improvements in DF following successive treatments which highlights the importance of investigating combinations of technique that might be more representative of how manual therapy applied in the clinical setting.

There appears to be an absence of research that investigates the effects of manual therapy techniques on joint position sense (JPS) at the talocrural joint. Two studies, however, examined the effects of manipulation at the talocrural joint on standing posture using stabilometry – an indirect measure of JPS.\(^14,15\) López-Rodríguez et al\(^15\) report that manipulation at the talocrural joint redistributed the standing load on participants with a history of ankle sprain. A subsequent study\(^14\) by the same research group found no evidence of an effect following the bilateral manipulation at the talocrural in healthy participants. There is currently an insufficient volume of research to serve as an evidence base for the use of mobilisation or manipulation to restore JPS in ankles with a history of lateral ankle sprain. Therefore the purpose of this study was to determine the immediate effect of a combination of three manual therapy techniques on dorsiflexion ROM, and JPS at the talocrural joint in participants with a history of ankle sprain.
METHODS

Study flow
A randomised, assessor blinded, sham controlled experimental design was used to assess the immediate effects of three manual therapy techniques on DF and JPS at the talocrural joint in participants with a history of lateral ankle sprain (see Figure 1).

Figure 1. Flowchart of study. (Abbreviations: DF = Dorsiflexion; JPS = Joint Position Sense)
Participants
Participants volunteered for the study in response to advertisements distributed around Unitec NZ campus. For the inclusion participants were required to satisfy 3 criteria which were:

1. Self reported history of inversion ankle sprain of Grade 1 or 2 severity within the last 5 years (Grading criteria based on Renstrom and Konradsen)\(^1\)
2. Aged between 20 and 45 years
3. Have of less than 16.5° active dorsiflexion at the talocrural joint non-weight bearing.

Participants were excluded from the study if one or more of the following were positive:

1. A history of inversion ankle sprain in the preceding 6 months
2. The presence of pain or other pathology local to the ankle
3. Currently receiving treatment of a lower limb complaint; or had received treatment within the preceding 6 months
4. Reported any history of ankle or foot surgery
5. Presence of a rheumatological, neurological disease or knowingly had any condition that negatively influenced the integrity of the joints, muscles or nerves.

Practitioner
A practising registered osteopath (TM) with 8 years clinical experience was recruited to deliver the sham and genuine techniques.

Assessor
The principal investigator (NA) performed the role of the assessor in the experiment.

Ethics
All participants gave written informed consent. The study was approved by the Unitec Research Ethics Committee, UREC registration number: 2009 - 998.
Group allocation

The participants were allocated to the genuine or sham intervention group by lottery, without the presence of the assessor. The lottery involved the practitioner selecting a numbered chip from an opaque bag containing 20 chips, an odd number indicating allocation to the sham intervention group and an even number the genuine intervention group. The chip was discarded following the draw. The assessor was blinded to the participant’s group allocation throughout the course of the data collection process.

Outcome measures

The immediate effects of manual therapy at the ankle were assessed using two measures: 1) DF; and 2) JPS. The assessment of DF was undertaken according to the method described by Taylor\textsuperscript{13} and Ricketts\textsuperscript{17} (see Figure 2). A handheld force dynamometer (model: Chatillon, Ametek, Inc., Largo, FL, USA) was used to apply force to an acrylic footplate securely attached to the participants foot with webbing straps. The use of the dynamometer was to ensure the application of a constant torque. Measurement of DF angle was assessed using an electrogoniometer (Model: 3DM, MicroStrain, Inc., Williston, VT, USA) attached to the footplate. Data from the electrogoniometer was recorded using a personal computer running customised software (Labview, National Instruments, Austin, Texas, USA).

![Figure 2. Experimental setup.](image)

The participant was positioned supine on the plinth with the leg flexed at 90° and leg strapped to the support stand (D). The acrylic footplate (B) was strapped to the foot and the electrogoniometer (A) was attached to the footplate. Dorsiflexion of the talocrural joint was performed using the force dynamometer (C). Image used with permission from Taylor\textsuperscript{13}. 

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Dorsiflexion measure

Pre and post intervention measures of DF were made using the same testing position. The testing was always performed on the symptomatic ankle first. The testing position required the participant to lie supine on a plinth with the hip and knee at 90° of flexion. The ankle was initially preconditioned by applying DF three consecutive times in order to achieve repeatable measurements as recommended by Nield et al.\textsuperscript{18}

The dynamometer was used to apply a passive torque to move the ankle complex into end of range DF three consecutive times. The highest dynamometer force value of the three pre measures was used as the experimental value for applying torque for the three pre DF measures. Three consecutive measures of DF were made, the magnitude of the angles recorded by the electrogoniometer.

Joint position sense measure

The participants remained in the same DF test position with the acrylic foot plate attached to the participant's foot including use of the electrogoniometer for the JPS error measures. Visual input was controlled by requiring participants to wear a blackened out ski mask for all JPS testing. From a neutral position the participants were required to move their ankle at a “slow self-selected velocity” to reproduce one of the three target angles. The order of the target angle reproduction was randomised. The three target angles (5° plantarflexion, 10° plantarflexion, and 5° dorsiflexion) were arbitrarily selected to avoid extreme ranges of movement to minimise additional sensory input from cutaneous receptors rather than the receptors located more deeply.\textsuperscript{19} The ankle was passively moved by the assessor to demonstrate the target angle (using the electrogoniometer), and the participant was instructed to maintain the position for 5 s duration. Participants then actively moved their ankle through full range of active DF and plantarflexion, and after returning to neutral attempted to reproduce the target angle. The participants verbally indicated and ceased the active movement once they perceived achieving the target angle. Each participant undertook three attempts at each target angle following the same protocol. The same procedure followed for pre measures of each participants’ asymptomatic ankle. For each trial the electrogoniometer was used to record the angle at which the participant judged the target angle to be. The magnitude of difference between the target angle and participants selected angle was then calculated and defined as joint position sense error (JPS error).
Reliability of measurement

Method of reliability
A test–retest repeated measures design was used on separate asymptomatic samples to assess the reliability of the dorsiflexion ROM measures (n=15) and reliability of the overall JPS error measures (n=10), and individually for each of the three target angles (5° dorsiflexion, 5° plantarflexion and 10° plantarflexion). Three consecutive trials of ankle DF and absolute JPS error were measured within the same session for each of the participants. The reliability of the DF and absolute JPS measures were calculated using intraclass correlation coefficients (ICC) and smallest detectable difference (SDD). The ICC and the typical error (TE) were calculated using the spreadsheet published by Hopkins. Descriptors for the magnitudes of reliability coefficients (ICCs) were those of Hopkins. The smallest detectable difference (SDD) was calculated using the formula $SDD = 1.96 \cdot \overline{Z} \cdot SEM$.

Reliability of dorsiflexion measures
The results showed the DF measure to have excellent reliability (ICC = 1.0; 95% CI=0.99 to 1.00) with the TE = 1.73° and SDD = 4.8°.

Reliability of joint position sense measures
The results for JPS sense showed overall reliability (pooling all target angles) to be moderate (ICC = 0.64; 95% CI=0.34 to 0.85) with the TE = 3.05° and SDD = 8.4°. The reliability of measures for the target angle of 5° dorsiflexion were ‘high’ (ICC = 0.84; 95% CI=-0.21 to 0.67) TE = 3.23° and SDD = 9.0°. However for 5° plantarflexion the reliability was shown to be ‘moderate’ (ICC = 0.52; 95% CI =0.04 to 0.78) with TE = 2.06° and SDD = 5.7°. Reliability of the measures for 10° plantarflexion were calculated to be ‘poor’ (ICC = 0.05; 95% CI=-0.47 to 0.50) TE = 0.98° and SDD = 2.7°.
The interventions

The genuine intervention

The genuine intervention consisted of three techniques described in the manual therapy literature for treatment of impaired ankle DF22-24 (Figure 3). Each technique was performed for 30 s duration in the order of superior tibiofibular mobilisation, talocrural mobilisation and talocrural traction.

Figure 3. Illustration of techniques used in the genuine intervention. Panel A: Superior tibiofibular mobilisation. The thenar eminence of the top hand (TH) rests anteriorly over the superior head of the fibular and fingers grip around the posterior aspect of the fibular head. The fibular was mobilised parallel to the joint plane. The support hand (SH) stabilises the tibia. Panel B: Talocrural mobilisation. The TH grips the distal tibia uses a ‘push pull’ action in an anterior-posterior direction. The SH grips the calcaneal bone to stabilise the foot and maintain the foot in neutral dorsiflexion. Panel C: Talocrural traction. The elbow of the practitioner’s lower arm braces against their own thigh resting on treatment table so that the lower arm acts as a lever. The TH draws the foot into dorsiflexion while the SH stabilises the foot gripping the calcaneal bone.

Sham intervention

The sham procedure was developed and piloted in conjunction with the experiment practitioner and then rehearsed on 2 volunteers prior to the study. The sham techniques were designed to closely mimic the three techniques of the genuine intervention, requiring the practitioner to move the ankle in such a way as to simulate the genuine techniques but move the joints in mid-ranges and avoid end range movements. The three techniques used in the sham were undertaken in series, each for 30 s duration.
Testing Procedure

Intervention application
The assessor then removed the participant's leg from the testing position for the outcome measures. The assessor left the room while the participant remained on the plinth supine. The practitioner then performed the genuine or sham intervention on the participant's symptomatic ankle depending on the participant's group allocation.

Post joint position sense and dorsiflexion measures
The assessor then re-entered the room and post measures for both DF and JPS were then repeated for the symptomatic then asymptomatic ankle using the same protocol as described for the pre-measures. Post DF measures used the same peak dynamometer force used for applying torque for the three pre DF measures. The post JPS used the same target angles presented in a randomly determined order.

Data analysis
Figure 4 illustrates the experimental design and identifies the key contrasts between the sham and genuine intervention groups. The mean change of dorsiflexion ROM was calculated from three trial measures, and the mean error score for each target angle for JPS from three trial measures was used for subsequent data analysis. The results of the outcome measures of dorsiflexion ROM are expressed in degrees (°) for the pre and post measures for each test condition. The results of the pre and post JPS measures at each of the three target angles (5° DF, 5° plantarflexion and 10° plantarflexion) are expressed as the absolute JPS error scores in degrees (°) for each of the test conditions.

Comparison and interpretation between the two dependant (pre and post) non-normally distributed data sets for both DF and JPS outcome measures was made using the non-parametric Wilcoxon matched pairs test. The final interpretation of outcome measures have been expressed using the median, 25 and 75% percentiles for both the DF and JPS measures. The magnitude of the effect size (r) between the data sets was calculated using formula $r = \frac{Z}{n}$ as described by Field,25 and interpreted according to Hopkins21 guidelines. Hopkins21 considers effect sizes between 0 and 0.2 as ‘trivial’; > 0.2 to 0.6 as ‘small’; between 0.6 and 1.2 as ‘moderate’; and ≥ 1.2 ‘large’. Statistical significance was set at the $p < 0.05$ level.
For contrasts where no significant difference was identified post hoc power was calculated using G*Power (v.3.1)\textsuperscript{26} (parameters: non-parametric, \( \alpha =0.05 \); 2 tailed test).

All raw data was tabulated in Microsoft Excel while statistical analysis was performed using SPSS for Microsoft Windows (v.18; SPSS, IBM, New York, USA).
Figure 4. Experimental Design. The figure displays the key contrasts between the genuine intervention and sham intervention groups. The assessment of dorsiflexion range of motion measures were taken first followed by the joint position sense measures. See text for further details.
RESULTS

Dorsiflexion
The pre and post measures for both the sham and genuine intervention groups are displayed in Figure 5.

The results for the symptomatic ankle in the genuine intervention group revealed a significant increase in dorsiflexion ROM from the pre ROM measures (Mdn = 9.30°) compared to the post dorsiflexion measures (Mdn = 12.75°), T = 7.0, z = -2.09, p = 0.04, r = 0.79. The results for the asymptomatic ankle in the genuine intervention group revealed minimal change from the pre dorsiflexion ROM measures (Mdn = 9.85°) compared to the post dorsiflexion ROM measures (Mdn = 9.90°), T = 22.50, z = -0.51, p = 0.61, r = 0.19.

The results for the symptomatic ankle in the sham intervention group revealed a minimal decrease from the pre dorsiflexion ROM measures (Mdn = 13.90°) compared to the post dorsiflexion ROM measures (Mdn = 13.60°), T = 9.0, z = -0.51, p = 0.40, r = 0.32. The results for the asymptomatic ankle in the sham intervention group revealed a minimal decrease from the pre dorsiflexion ROM measures (Mdn = 12.20°) compared to the post dorsiflexion ROM measures (Mdn = 11.90°), T = 10.50, z = -0.55, p =0.55, r = 0.22.
Figure 5. Boxplot graph showing pre and post dorsiflexion ROM measures for both the sham and genuine intervention groups asymptomatic and symptomatic ankles. The graph displays the median (Mdn), 25th percentile, 75th percentile and the whiskers represent min and max values. See text for effect size (r) and median (Mdn) values.
Joint position sense

5° dorsiflexion (See Figure 6): The results for the symptomatic ankle in the genuine intervention group revealed a minimal increase from the pre JPS error measures (Md = 1.6°) compared to the post JPS error measures (Md = 2.0°), T = 18.0, z = -0.97, p = 0.33, r = 0.11. The results for the asymptomatic ankle in the genuine intervention group revealed a minimal decrease from the pre JPS error measures (Md = 2.45°) compared to the post JPS error measures (Md = 1.5°), T = 8.0, z = -1.99, p = 0.05, r = 0.01. The results for the symptomatic ankle in the sham intervention group revealed no change from the pre JPS error measures (Md = 1.8°) compared to the post JPS error measures (Md = 1.8°), T = 6.0, z = -0.69, p = 0.41, r = 0.26. The results for the asymptomatic ankle in the sham intervention group revealed a minimal increase from the pre JPS error measures (MDN = 1.8°) compared to the post JPS error measures (Md = 2.5°), T = 12.00, z = -0.34, p = 0.74, r = 0.28. Post hoc analysis of statistical power for the symptomatic ankle in the genuine intervention group revealed an observed power of 0.16.

5° plantarflexion (See Figure 7): The results for the symptomatic ankle in the genuine intervention group revealed a minimal decrease from the pre JPS error measures (Md = 2.7°) compared to the post JPS error measures (Md = 2.5°), T = 21.00, z = -0.66, p = 0.51, r = 0.16. The results for the asymptomatic ankle in the genuine intervention group revealed a minimal increase from the pre JPS error measures (Md = 2.8°) compared to the post JPS error measures (Md = 3.4°), T = 11.50, z = -1.30, p = 0.19, r = 0.61. The results for the symptomatic ankle in the sham intervention group revealed a minimal decrease from the pre JPS error measures of JPS (Md = 1.9°) compared to the post JPS error measures (Md = 2.6°), T = 9.00, z = -0.31, p = 0.75, r = 0.28. Post hoc analysis of the genuine intervention groups symptomatic ankle data revealed an observed power of 0.07.

10° plantarflexion (See Figure 8): The results for the symptomatic ankle in the genuine intervention group revealed an increase from pre JPS error measures (Md = 3.9°) compared to the post JPS error measures (Md = 5.8°), T = 6.50, z = -2.14, p = 0.03, r = 0.001. The results for the asymptomatic ankle in the genuine intervention group revealed a decrease from pre JPS error measures (Md = 2.6°) compared to the post JPS error measures (Md = 4.8°), T = 9.0, z = -1.99, p = 0.05, r = 0.04. The results for the symptomatic ankle in the sham intervention group revealed a minimal increase from pre JPS error measures (Md = 4.2°) compared to the post JPS error measures (Md = 4.3°), T = 6.50,
$z = -0.27, p = 0.79, r = 0.30$. The results for the asymptomatic ankle in the sham intervention group revealed an increase from pre JPS error measures (MDN = 2.8°) compared to the post JPS error measures (Mdn = 3.4°), $T = 9.0, z = -0.31, p = 0.75, r = 0.28$. Post hoc analysis of the genuine intervention groups symptomatic ankle data revealed an observed power of 0.05.

**Figure 6.** Boxplot graph for target angle 5° dorsiflexion showing the absolute JPS error (°) pre and post measures for both the sham and genuine intervention groups asymptomatic and symptomatic ankles. The graph displays the median (Mdn), 25th percentile, 75th percentile and the whiskers represent min and max values of the data. See the text for effect size ($r$) and median (Mdn) values.
Figure 7. Boxplot graph for target angle 5° plantarflexion showing the absolute error JPS (°) pre and post measures for both the sham and genuine intervention groups asymptomatic and symptomatic ankles. The graph displays the median (Mdn), 25th percentile, 75th percentile and the whiskers represent min and max values of the data. See text for effect size (r) and median (Mdn) values.
Figure 8. Boxplot graph for target angle 10° plantarflexion showing the absolute JPS error (°) pre and post measures for both the sham and genuine intervention group’s asymptomatic and symptomatic ankles. The graph displays the median (Mdn), 25th percentile, 75th percentile and the whiskers represent min and max values of the data. See text for effect size (r) and median (Mdn) values are described in the results section.
Results summary

Dorsiflexion
The results showed the application of the three genuine techniques (proximal tibiofibular mobilisation, talocrural anterior posterior mobilisation and talocrural joint traction) produced an immediate increase in dorsiflexion ROM (3.5°) in participants with a history of lateral ankle sprain. The sham intervention group showed a trivial decrease (0.3°) following the sham intervention. The effect size for the genuine intervention group (r = 0.79) was 'large' and contrasts to the 'small' effect size for the sham (r = 0.32). In addition the change of 3.5° exceeded the typical error (TE=1.73°) suggesting the observed change in DF for the genuine intervention group is attributable to the intervention. No effect on dorsiflexion ROM was observed for asymptomatic ankles in either group.

Joint position sense
Target angle 5° dorsiflexion. The 5° target angle JPS error measures showed JPS error increased following the application of the intervention to the symptomatic ankle in the genuine intervention group. The observed difference between pre and post measure was 0.4°. In comparison the symptomatic ankle in the sham intervention group that received the three sham techniques displayed no change in median JPS error. Changes were observed for the asymptomatic ankles in both the sham and genuine intervention groups despite having received no intervention. The post measure data revealed JPS error results to increase by 0.7° for the asymptomatic ankle in the sham intervention group, and to decrease by 0.95° for the asymptomatic ankle in the genuine intervention group.

The JPS measure for the target angle 5° DF was shown to have ‘small’ to ‘moderate’ reliability (ICC = 0.31; 95% CI=-0.21 to 0.67). The observed effects following the genuine techniques to the genuine intervention group were less than the TE = 3.23°. Furthermore the effect sizes for the genuine intervention group data were ‘trivial’ for both the asymptomatic (r = 0.01) and symptomatic ankle (r = 0.11). Therefore in summary the three genuine techniques were shown to have a ‘trivial effect’ on JPS error for the target angle 5° DF in participants with a history of lateral ankle sprain.

Target angle 5° plantarflexion. For the symptomatic ankle, the genuine technique improved median JPS error measures by 0.2° in comparison to the sham technique median JPS measures increase of 1.4°. The post measures for JPS errors for the asymptomatic ankle showed a small increase in JPS error for both sham (Mdn increase = 0.6°) and genuine (Mdn increase = 0.3°).
Reliability for the JPS error measures concerning the target angle 5° plantarflexion were shown to be ‘moderate’ (ICC = 0.52; 95% CI=0.04 to 0.78). The observed effects for JPS error following intervention to both the sham and genuine intervention groups were not significant being within the TE of 2.06°. Furthermore the effect sizes for the data sets were ‘small’ with the exception for genuine intervention groups asymptomatic data that was calculated to have a moderate effect (r = 0.61). In summary the genuine intervention was shown to have no effect on JPS error for the target angle 5° plantarflexion in participants with a history of lateral ankle sprain.

Target angle 10° plantarflexion. The genuine intervention group’s symptomatic ankle post measures of JPS error demonstrated an increase of 1.9° following the genuine intervention. In comparison the sham intervention group’s symptomatic ankle demonstrated a minimal increase of 0.1° following the sham intervention. The genuine intervention group’s asymptomatic ankle showed a greater increase in post JPS error compared to the symptomatic ankle (increase of 2.2°). The sham intervention group’s asymptomatic ankle revealed a small increase in JPS error of 0.6°.

The genuine intervention groups symptomatic ankle JPS error increase of 1.9° following the experiments intervention is greater than the TE = 0.98, however the reliability of the measures of the JPS error for the target the angle of 10° plantarflexion were calculated to be poor (ICC = 0.05; 95% CI=-0.47 to 0.50). The wide CI makes interpretation of the effects of the genuine interventions effect on JPS error for 10° plantar flexion unclear. Furthermore the effect size was ‘practically zero’ r = 0.001 as were the effect sizes estimated for each of the other data sets.

Summary. Following the genuine intervention JPS error for target angles 5° DF and 10° plantarflexion became worse, whereas 5° plantarflexion JPS error improved. There was no evidence of JPS deficit when comparing the symptomatic ankle to the asymptomatic ankle pre measures for both allocation groups. Statistical analysis revealed the JPS error results for all target angles to have poor statistical significance, revealing ‘small’ effect sizes. In addition the reliability for the 5° DF, 5° plantarflexion and 10° plantar flexion JPS error measures were ‘poor’ to ‘moderate’. The overall reliability of the three target angles was calculated to be moderate (ICC = 0.64; 95% CI =0.34 to 0.85).
DISCUSSION

Overview
This study employed a randomised, assessor blinded, sham controlled experimental design to investigate the immediate effects of a combination of three manual therapy techniques on ROM and JPS at the talocrural joint in participants with a history of lateral ankle sprain.

The main findings of this study show that the combination of three manual therapy techniques had a significant effect on dorsiflexion ROM, although, change in JPS in response to intervention did not exceed measurement error.

The literature concerning the effect of manual techniques on dorsiflexion ROM does not address the level of change required to be clinically useful. Therefore the clinical relevance of the magnitude of change of DF observed in this study is unclear despite the small but statistically significant effect.

The findings of this study are consistent with those found in 7 of the 9 previous studies 7, 9-13, 27-29 which examined the effects of manual therapy on dorsiflexion ROM on participants with symptomatic ankles. Within the 7 studies that reported beneficial changes in ROM outcomes; 57, 9-11, 28 used the application of mobilisation techniques and 2 studies27, 29 included the application of manipulation techniques. However the differing designs, measurement protocols and therapeutic techniques make direct comparisons invalid.

The 3.5° increase in ROM following genuine intervention in this study is of a similar magnitude to that observed by Green et al28 who reported a 4.3° change after just one treatment session. Green et al5 study was undertaken in a clinical setting using mobilisation in conjunction with rest ice compression elevation (the ‘RICE’ protocol) in acute patients that received a series of treatment sessions over 2 weeks. Whitman et al7 reports a case study examining the effects of treatment incorporating a combination of mobilisation and manipulation with other rehabilitation methods over a series of sessions. Research by Collins et al,9 O’Brien and Vincenzino,10 and Vicenzino et al11 all investigated the effect of single mobilisation techniques, however, the measure of dorsiflexion ROM was assessed using Bennell et al’s30 standing lunge test. All of these studies are characterised by different methods in both treatment methods and measurement therefore comparisons between them and this study are not easily made although observed small changes in range of motion DF.

Two studies27, 29 which investigated the effects of manipulation used high velocity low amplitude thrust techniques (HVLA), also reported significant effects on DF, however, neither study reported
an effect size (effect sizes could not be estimated by author). Pellow and Brantingham\textsuperscript{29} used a single HVLA thrust at the talocrural joint over a series of treatments. Dananberg et al’s\textsuperscript{27} intervention also consisted of three techniques applied to the same joints as the current study. Dananberg et al’s\textsuperscript{27} study applied a single HVLA thrust rather than mobilisation to both the proximal tibiofibular joint and talocrural joint and also used the talocrural joint traction technique. However, Dananberg et al’s\textsuperscript{27} results are difficult to interpret, due to doubts over the validity of the measuring procedure. The dorsiflexion ROM measuring procedure is dubious because the participants actively assisted the measures by applying the torque themselves, and did not control for participants being able to apply more force in post measures. Notwithstanding the methodological quality issues, collectively the results of Dananberg et al,\textsuperscript{27} Pellow and Brantingham,\textsuperscript{29} Green et al,\textsuperscript{28} Whitman et al\textsuperscript{7} and this current study all demonstrate the use of multiple techniques or successive treatments which are more representative of usual clinical practice in contrast to the application of a single technique.

Within the 9 studies that investigated the effects manual therapy on dorsiflexion ROM on symptomatic participants; both Taylor\textsuperscript{13} and Andersen et al\textsuperscript{12} were the only 2 studies who both failed to observe a change in DF which may be a consequence of the type of intervention employed. Taylor\textsuperscript{13} used a novel technique identified as ‘the Still technique’ and described as “the tissues or joint being treated needs to be placed into a position of ease such that the tissues become relaxed or balanced, a force vector is applied and then by moving through its range of motion towards the restriction the tissue tension is reduced and the barrier engaged and passed through to improve mobility.”\textsuperscript{13a} The forces involved in the technique described by Taylor\textsuperscript{13} may have been of insufficient magnitude to cause a viscoelastic change in the soft tissue structures which occurs in response to mechanical stress, the amount of change depending on the magnitude of force applied, the velocity of the technique and duration of the application of the technique.\textsuperscript{31} Additionally, in the clinical context, appropriate mechanical loading is essential to promote fibroblast activity that in turn produces collagen, elastin cytokines and growth factors.\textsuperscript{32} Research is unclear in quantifying the optimal force loading in the application of manual techniques. Studies have demonstrated the magnitudes of forces applied from manual techniques vary from 33N up to 887N.\textsuperscript{33-35} According to Threlkeld\textsuperscript{31} the application of manual therapy techniques must be of sufficient magnitude to cause micro-failure in order to achieve a permanent change in the elongation of the connective tissue. However it is also thought that the application of manual therapy techniques of lighter force may influence the mechanoreceptors which regulate the tonus of muscle.\textsuperscript{36} In contrast to mobilisation techniques, HVLA techniques use low amplitude but high velocity to effect change. In contrast to
the documented evidence of the effectiveness of HVLA techniques in spinal studies\textsuperscript{35} Andersen et al\textsuperscript{12} research demonstrated no effect following an HVLA technique applied to the talocural joint. According to Venturini et al\textsuperscript{37} the outcome of Anderson et al\textsuperscript{12}’s study indicates that the HVLA technique may have been too fast to influence a change in viscoelastic tissues. Triano\textsuperscript{18} remarks that viscoelastic change is more likely to occur at slower speeds allowing the properties within the tissue structures to change.

The current study examined the immediate post-intervention effects however whether the observed effects persist over longer periods of time was not investigated. To effect longer term change in the viscoelastic properties of ankle soft tissue structures using manual therapy techniques, micro-failure must occur.\textsuperscript{31} Threlkeld\textsuperscript{31} recommends that to be confident of permanent change manual therapy technique studies should observe post intervention measures over a 24 hr period. The soft tissue will return to its original resting length over 24 hours if the techniques applied have failed to exceed the elastic limits of the tissue.

Confidence in the effect of the genuine intervention’s on DF is reinforced by the use of a control group in the study design and high level of reliability of dorsiflexion ROM measures. Collins et al\textsuperscript{9} was the only study of the 7 studies investigating the effects of mobilisation or manipulation on symptomatic participants to have utilised a sham intervention. Incorporating the use of a sham intervention is an essential component of a robust study design when investigating manual therapy technique studies.\textsuperscript{39} It is crucial that sham techniques be credible alternatives to the genuine intervention otherwise unpredictable effects caused by the sham may result.\textsuperscript{40} The sham intervention for this study followed Noll et al’s\textsuperscript{41} recommendation that effective sham treatment techniques should closely mimic the genuine intervention in application to the same body location, duration and sequence. The absence of change in dorsiflexion ROM following the sham implies that changes in ROM associated with the genuine techniques were not due to or other non-specific effects such as those associated with touch,\textsuperscript{42} expectation bias,\textsuperscript{43} or other factors. The inert nature of the sham intervention techniques applied was reflected in the data analysis demonstrating no effect on post dorsiflexion ROM measures. In contrast the outcomes of the 6 other studies\textsuperscript{7, 10, 11, 27-29} investigating the effects of mobilisation or manipulation on dorsiflexion ROM cannot be confidently attributed to the interventions as they are not adequately controlled. None of those studies can rule out the possibility of observed post-treatment changes arising from expectation or other forms of bias.
The genuine intervention did not alter JPS at the ankle in participants with a history of lateral ankle sprain. This finding conflicts with common manual therapy clinical practice which claims improvements in JPS are an important therapeutic effect following restoration of restricted joint movement.\textsuperscript{24,44} Furthermore, no JPS deficit was observed when comparing the symptomatic ankles measures to the asymptomatic ankles measure in both allocation groups despite all participants having a history of lateral ankle sprain. This finding is consistent with those of Gross\textsuperscript{45} and Holme et al\textsuperscript{46} who report that impaired joint function is not reflected in impaired JPS sense. An experimental intervention is unlikely to have a therapeutic effect on an ankle that has no measurable JPS deficit.

A weakness of this current study was participants self selected the velocity of movement to reproduce the target angle. If too slow, measures are likely to target the slow adapting mechanoreceptors rather than the fast adapting mechanoreceptors which are thought to be more relevant to mechanisms of ankle sprain.\textsuperscript{47} Another weakness in the design of this study is the extent to which participants believed the sham they received was ‘real’ was not quantified.

Surprisingly, only two studies to date have examined the effects of manual therapy techniques on ankle proprioception.\textsuperscript{14,15} Both studies used stabilometry (an indirect measure of proprioception) to quantify the effects of manual therapy on proprioception at the ankle. Conclusions drawn from observations in studies using indirect measures to assess the effects of manual therapy technique cannot specifically attribute changes to the ankle. Indirect measures of proprioception are used in the majority of studies concerning the effects of ankle sprain rehabilitation on proprioception, quantifying proprioception measures through methods of postural sway,\textsuperscript{48} wobble boards\textsuperscript{49} or single leg standing.\textsuperscript{50}

The lack of research concerning effects of manual therapy on JPS at the ankle may reflect the difficulty of isolating measures specific to the ankle joint mechanoreceptors. Furthermore JPS investigations to date have been pre occupied with the importance of peripheral sources of JPS and neglected the influence of the central nervous system (CNS) following injury.\textsuperscript{51,52} Freeman’s\textsuperscript{53} 1965 theory that the ankle JPS afferent feedback originates from ankle joint mechanoreceptors is probably outdated in light of more recent theories. Riemann and Lephart\textsuperscript{51} comment that the mechanisms of JPS are more complex than a simple input and output from the periphery to the CNS as traditional models of JPS would lead us to believe.

Research concerning the influence of the CNS and fine motor control shows the ability of the CNS to use pre-programmed movement patterns in order to predict high speed movements negating the need for feedback from the periphery.\textsuperscript{54} It is possible that such pre-programmed movements may
be operant in peripheral joint injury such as ankle sprain. Previous studies have demonstrated people who are peripherally deafferented (due to disease) still retain the ability to perform simple tasks and posture thought to be due to pre-programmed movement controlled from the CNS.\textsuperscript{55,56} Therefore it is plausible impaired or damaged afferent feedback from the ankle joint mechanoreceptors following injury may be well compensated for, demonstrating an important survival mechanism to avoid permanent impairment. It is evident that further understanding of the mechanisms of JPS is needed. The outcomes from this study further inform the view that the priority of ankle rehabilitation is probably not restoration of JPS and therefore clinical treatments should be focusing on other aspects of clinical rehabilitation.

**Recommendations**

Further investigation should investigate whether the significant change in DF observed following the three techniques is clinically applicable. Therefore a treatment study design could provide insight into the effectiveness of the manual therapy techniques in terms of dosage and spectrum of response. The case study by Whitman et al\textsuperscript{7} using manual therapy in conjunction with in conjunction with the ‘conventional method’ of home exercises may improve treatment effectiveness over a shorter duration. Treatment of the ankle in the clinical setting could benefit from exploring methods to optimise the use of passive manual techniques in conjunction with other more actively oriented methods of ankle rehabilitation such as exercise and movement based approaches. Therefore a useful study design would include comparing passive and active approaches, and the effect of both in combination.

**CONCLUSION**

This study found that the combination of three manual therapy techniques had a small but significant effect on dorsiflexion ROM but no observable change in JPS error at the ankle in participants with a history of lateral ankle sprain. The change in ROM was observed immediately following the genuine intervention so it is unknown if the effects are permanent. Furthermore this was a technique study so further investigation incorporating the techniques within a treatment paradigm is required to determine whether the techniques can, in combination with other approaches, contribute to the treatment and rehabilitation of lateral ankle sprains within the clinical environment.
ACKNOWLEDGEMENTS

The author also thanks Tony Mullany (TM) for his expertise in the application of the genuine and sham interventions, and the participants who volunteered to be a part of this study.
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SECTION III: APPENDICES
APPENDIX A: Participants characteristics

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### 5° Plantarflexion Joint Position Sense Reliability Data

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APPENDIX D: Ethics resources

Information sheet

The immediate effects of manual therapy treatment on dorsiflexion range of motion and joint reposition sense at the talocrural joint in people with a history of lateral ankle sprain

Information Sheet

About this research

You are invited to take part in a research project that is investigating an osteopathic treatment for the ankle joint.

This study investigates whether the treatment changes the range of movement and joint reposition sense at the ankle joint. You will be randomly selected into either a control or experimental group. You will not know which group you have been assigned to, only the practitioner applying the treatment will be aware of your group allocation. To ensure that you are unaware of your group allocation an alternative treatment will be used if you are selected in the control group. The alternative treatment will mimic the experimental group’s treatment but is not expected to have any therapeutic effect.

The research will take place at Unitec (3rd floor, building 115, Entry 4, Carrington Road, Mt Albert, Auckland) involves you attending two sessions.

Session 1

Meeting with the researcher for a brief initial screening to ensure eligibility for the project (10min). The screening involves completing a self questionnaire and the researcher measuring the degrees of movement of your ankle. The degrees of movement will be measured using an electrogoniometer.

Signing the consent form once all information has been received and provided you meet the inclusion requirements as assessed in the initial screening.

Session 2

Attending the data collection session taking approximately 20 minutes.
Avoiding any treatment, exercise or any exercise related activity (running etc) on the day of testing, which could stress the ankle joint.

The data collection in session 2 involves:

Firstly ankle movements will be measured by the principle researcher using an electrogoniometer that measures the degrees of motion the ankle moves in. You will be asked to lie on a plinth with knee flexed to 90 degrees, and supported in a brace. A foot plate on which the electrogoniometer is fixed will be attached to your ankle. The researcher will then assess the range of movement of the ankle joint using a dynanometer.

Secondly the Joint Reposition Sense at your ankle will be recorded. You will be required to reproduce 3 given angles of movement of the ankle. The measure will require blocking your vision of your ankle using a screen placed across your body. Your accuracy of reproducing the given angles will be recorded. A total of 9 measures will be recorded.

Next a manual therapy treatment will be applied to the ankle by a qualified manual therapist.

The ankle range of movement will be measured again, followed by the ability to reproduce 3 given angles as mentioned in steps one and step two.

All techniques used in this study are commonly used by manual therapists to restore tissue health and mobility at the ankle. No pain or adverse reaction should result from the techniques. If any pain is experienced during the treatment the treatment will be stopped and no further treatment will be applied. If in the unlikely event that an injury occurs through research participation, appropriate care will be organised (at the participants expense), including any required onward referral for healthcare.

The Researcher

The primary researcher is Nathan Alanson

This project is being supervised by Rob Moran and Dr Andrew Stewart.

You have the right to not participate, or withdraw from this research project at any time until the beginning of data analysis. This can be done by phoning us or by telling us when we contact you that you do not want to participate.

Getting help

Please contact either one of us should you have any questions about this project.

Nathan Alanson: Rob Moran:
Email: nathan_alanson@hotmail.com rmoran@unitec.ac.nz
Mobile: 021 25206161 09 815 4321 ext 8642
Information and concerns

If you want further information about the project or if, at any time you are concerned or confused about the research project you can call or email Nathan Alanson at the above address.

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.

Confidentiality

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

Anonymity – participants will not be identified in any way connected to this research. Their names will be collected, however they will only be known to the researcher. All details will be stored either in a locked filing cabinet or password protected files; only the researcher will have access.

Data Storage – Data will be securely stored both electronically and on paper as described above. Names of participants will be separated from this data to maintain anonymity. All data will be destroyed after a period of five years in an appropriate manner, in accordance with Unitec New Zealand policy.

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.

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

UREC REGISTRATION NUMBER: (998)
This study has been approved by the UNITEC Research Ethics Committee from 1st September 2009 to 31st August 2010. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 7248). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Consent form

The immediate effects of manual therapy treatment on dorsiflexion range of motion and joint reposition sense at the talocrural joint in people with a history of lateral ankle sprain

Consent Form

This research project investigates the efficacy of an osteopathic technique on the range of motion of the ankle. The research is being undertaken by Nathan Alanson from Unitec New Zealand, and will be supervised by Rob Moran and Associate Professor Andrew Stewart.

Name of Participant:…………………………………………………………………

I have seen the Information Sheet dated……………………………for people taking part in the study, title. "The immediate effects of manual therapy treatment on dorsiflexion range of motion and joint reposition sense at the talocrural joint in people with a history of lateral ankle sprain." I have had the opportunity to read the contents of the information sheet and to discuss the project with the researcher and I am satisfied with the explanations I have been given. I understand that I can withdraw from the study up until the point at which data analysis is started, if for any reason I want to do this. I may withdraw up until the point at which data analysis is started (approximately 10 days after the data collection session) and this will in no way affect my access to the services provided by Unitec New Zealand or any other support service.

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.

Nathan Alanson (ph. 09 8460575/ nathan_alanson@hotmail.com)

Signature………………………………………… Participant ……………………..(date)

Project explained by……………………………………………………………………

Signature………………………………………..…………………………………….(date)

The participant should retain a copy of this consent form.

UREC REGISTRATION NUMBER: (998)
This study has been approved by the UNITEC Research Ethics Committee from 1st September 2009 to 31st August 2010. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 7248). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Screening questions

Please circle the appropriate option or complete details in the corresponding boxes.

Name: ………………………………………………………………………………………………

Gender: Female/Male

Date of Birth: 

Have you sprained your ankle in the last 5 years? 

Which ankle did you sprain? 

Have you received or been receiving treatment for the ankle within the preceding 6 months? 

How did you sprain your ankle?


Did you have any feelings of instability/ or ‘giving away’ following the sprain? Yes/No

Could you walk immediately after spraining your ankle? Yes/No

Did you receive medical treatment for the ankle? Yes/No

If yes what?


How long did you receive treatment for? Number of weeks/sessions/months

Have sprained the ankle more than once? Yes/No
if yes how many times?  

Do currently experience any pain in the ankle you have sprained?  Yes/No

Have you received any surgery of the ankle or foot?  Yes/No

Do you have a medical condition that may put you at risk from partaking in the study?

Medical conditions that could put you at risk include:

RA (Rheumatoid Arthritis), osteomyelitis, Inflammatory joint disease, Osteoarthritis, Gout, Reitiers Syndrome, Ulcerative colitis  Yes/No
Data collection sheet

*Completed by Researcher.*  

Subject No:……..

Height (cm):  

Weight (kg):  

Ankle to be assessed:  **left/right**

Dorsiflexion Screen measurement – Less than 16.5 degrees  

Yes/No

Symptomatic Ankle

Dynamometer reading (from preconditioning ankle)

Max reading =  

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Asymptomatic ankle

Dynanometer reading (from preconditioning ankle)

Max reading =  

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Have you ever sprained your ankle?

Has it been within the last 5 years?

Is your age between 20 and 45?

If yes, would you be interested in participating in a research project?

The research project is investigating whether an osteopathic treatment changes the range of movement and joint reposition sense at the ankle. You will be required to attend two sessions at Unitec (Student Osteopathic Clinic, Entry 3, Carrington Road, Mt Albert). Session 1 involves meeting with the researcher for a brief initial screening to ensure eligibility for the project (5 minutes). Session 2 involves the data collection session taking approximately 30 minutes.

The research project is undertaken by Nathan Alanson as partial fulfilment of the requirements for the degree of Masters of Osteopathy.

Please contact the Principle Researcher Nathan Alanson for further details.

Ph 021 2520616 or evenings 8460575, nathan_alanson@hotmail.com

UREC REGISTRATION NUMBER: (998)

This study has been approved by the Unitec Research Ethics Committee from 1st of September 2009 to 31st August 2010. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (Tel: + 64 9 815-4321 ext 7248 or by email ethics@unitec.ac.nz). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
APPENDIX E: Instruction for authors manuscript submission to the International Journal of Osteopathic medicine

An official journal of:
- General Osteopathic Council (UK)
- Australian Osteopathic Association
- Ontario Association of Osteopathic Manual Practitioners
- Society for Promotion of Manual Practice of Osteopathy

Officially recognised by the Commission for Osteopathic Research, Practice and Promotion (CORPP)

Guide for Authors

The Editors of the Journal welcome contributions for publication from the following categories:
Letters to the Editor and Editorials, Reviews and Original Research articles, Commentaries, Clinical Practice articles (Case Studies) with educational value and Protocols.

The Guidelines are separated into the following sections:
A Online Submission
B Types of Contributions
C General Guidance
D Preparation of the Manuscript
E Specific Guidance for Original Research Articles
F Specific Guidance for Protocols
G Post Acceptance

(A) ONLINE SUBMISSION
Submission to this journal proceeds totally online at (http://ees.elsevier.com/ijom). You will be guided stepwise through the creation and uploading of the various files. The system automatically converts source files to a single Adobe Acrobat PDF version of the article, which is used in the peer-review process. Please note that even though manuscript source files are converted to PDF at submission for the review process, these source files are needed for further processing after acceptance. All correspondence, including notification of the Editor's decision and requests for revision, takes place by e-mail and via the Author's homepage, removing the need for a hard-copy paper trail.

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.

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the
written consent of the Publisher.

(B) TYPES OF CONTRIBUTIONS - word limits exclude tables, figures and references.

Letters to the Editor (up to 1,000 words)
As is common in biomedical journals the Editorial Board welcomes critical responses 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 (2,000 - 5,000 words)
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; or (ii) a critical or systematic review that seeks to summarise or draw conclusions from the established literature on a topic relevant to osteopathic medicine.

Short review (1,500-3,000 words)
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 critical or systematic review paper. These papers typically place more emphasis on outlining areas of deficit in the current literature that warrant further investigation.

Research Note (up to 1,500 words)
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. Includes further clarification of an experimental protocol after addition of further controls, or statistical reassessment of raw data.

Preliminary Findings (1,500-2,500 words)
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 (up to 2,000 words)
Includes articles that do not fit into the above criteria as original research. Includes commentaries 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.

i. 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 (e.g.
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.

ii. 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.

iii. 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.

Protocols (1,500 - 2,000 words)
The IJOM accepts the submission of protocols of randomised interventions, systematic reviews and meta-analyses, observational studies, and selected phase I and II studies (novel intervention for a novel indication; a strong or unexpected beneficial or adverse response; or a novel mechanism of action), with the overall aim to encourage good principles in clinical research design.

The editors are looking for studies that will appeal to a wide general readership. The question being addressed and the planned design and analysis will need to be as original as possible, topical, and valid. All protocols will be subject to the journal’s usual peer review process.

(C) GENERAL GUIDANCE
Submission Declaration
Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the written consent of the copyright-holder.

Ethical considerations
Human subjects. Work on human beings that is submitted to The International Journal of Osteopathic Medicine should comply with the principles laid down in the declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. The manuscript should contain a statement that the research has been approved by the appropriate ethical committees related to the institution(s) in which it was performed and that subjects gave informed consent to
the work. Studies involving experiments with animals must state that their care was in accordance with institution guidelines. Patients’ and volunteers’ names, initials, and hospital numbers should not be used. In a case report, the subject’s written consent should be provided. It is the author’s responsibility to ensure all appropriate consents have been obtained.

Patient anonymity. Studies on patients or volunteers require ethics committee approval and informed consent which should be documented in the manuscript.

Patients have a right to privacy. Therefore identifying information, including patients’ images, names, initials, or hospital numbers, should not be included in videos, recordings, written descriptions, photographs, and pedigrees unless the information is essential for scientific purposes and you have obtained written informed consent for publication in print and electronic form from the patient (or parent, guardian or next of kin where applicable). If such consent is made subject to any conditions, Elsevier must be made aware of all such conditions. Evidence of written consent must be provided to Elsevier on request.

Even where consent has been given, identifying details should be omitted if they are not essential. If identifying characteristics are altered to protect anonymity, such as in genetic pedigrees, authors should provide assurance that alterations do not distort scientific meaning and editors should so note.

Authors submitting manuscripts as Case Reports, Case Problems, and Evidence in Practice should ensure that they have received consent from patients who are the subject of such reports. A statement to this effect should be included in the manuscript.

If such consent has not been obtained, personal details of patients included in any part of the paper and in any supplementary materials (including all illustrations and videos) must be removed before submission.

Role of the funding source
You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication. If the funding source(s) had no such involvement then this should be stated. Please see http://www.elsevier.com/funding .

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inappropriately influence (bias) their work. Examples of potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

Acknowledgments
In the appendix one or more statements should specify (a) contributions that need acknowledging, but do not justify authorship (b) acknowledgments of technical support (c) acknowledgments of financial and material support, specifying the nature of the support. Persons named in this section must have given their permission to be named. Authors are responsible for obtaining written permission from those acknowledged by name since readers may infer their endorsement of the data and conclusions.

Sponsored Articles
The IJOM now offers authors the option to sponsor non-subscriber access to individual articles. The access sponsorship contribution fee per article is $3,000. This contribution is necessary to offset publishing costs - from managing article submission and peer review, to typesetting, tagging and indexing of articles, hosting articles on dedicated servers, supporting sales and marketing costs to ensure global dissemination via ScienceDirect, and permanently preserving the published journal article. The sponsorship fee excludes taxes and other potential author fees such as colour charges which are additional.

Authors can specify that they would like to select this option after receiving notification that their article has been accepted for publication, but not before. This eliminates a potential conflict of interest by ensuring that the journal does not have a financial incentive to accept an article for publication.

English Language Service
Please write your text in good English. Authors who require information about language editing and copyediting services pre- and post-submission please visit http://www.elsevier.com/languagopolishing or our customer support site at http://epsupport.elsevier.com for more information. Please note Elsevier neither endorses nor takes responsibility for any products, goods or services offered by outside vendors through our services or in any advertising. For more information please refer to our Terms &Conditions: http://www.elsevier.com/termsandconditions.

Review Process
The decision to publish a paper is based on an editorial assessment and peer review. Initially all papers are assessed by an editor of the journal. The prime purpose is to decide whether to send a paper for peer review and to give a rapid decision on those that are not.

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State the purpose of the article. Summarise the rationale for the study or observation. Give only strictly pertinent references and do not review the subject extensively. Do not include data or conclusions from the work being reported.

Materials and Methods
Describe your selection of observational or experimental participants (including controls). Identify the methods, apparatus (manufacturer’s name and address in parenthesis) and procedures in sufficient detail to allow workers to reproduce the results. Give references and brief descriptions for methods that have been published but are not well known; describe new methods and evaluate limitations.

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Present results in a logical sequence in the text, tables and illustrations. Do not repeat in the text all the data in the tables or illustrations. Emphasise or summarise only important observations.

Discussion
Emphasise the new and important aspects of the study and the conclusions that follow from them. Do not repeat in detail data or other material given in the introduction or the results section. Include implications of the findings and their limitations, and include implications for future research. Relate the observations to other relevant studies. Link the conclusion with the goals of the study, but avoid unqualified statements and conclusions not completely supported by your data. State new hypothesis when warranted, but clearly label them as such. Recommendations, when appropriate, may be included.

Conclusion
A summary of the pertinent findings and, relevance of the study and implications of the study for future research.

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AB conceived the idea for the study. AB and CD contributed to the design and planning of the research. All authors were involved in data collection. AB and EF analysed the data. AB and CD wrote the first draft of the manuscript. EF coordinated funding for the project. All authors edited and approved the final version of the manuscript.

(F) SPECIFIC GUIDANCE FOR PROTOCOLS

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- Aim(s).
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- Statistical analysis - including sample size and power calculations; type of analysis; statistical testing.
- Ethical issues - including ethics committee approval; informed consent form and information sheet.
- Publication plan.
- Time required - an estimation of the time required to run the protocol should be given per separate step and for the whole protocol, including reporting.
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