Declaration

Name of candidate: Demelza Scott-Weekly

This thesis entitled *Short-term influence of a percussive soft-tissue technique on active weight-bearing dorsiflexion and Achilles tendon excursion: A case series* is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy

Candidate’s declaration

I confirm that:

- This thesis represents my own work;
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2015-1009

Candidate Signature: ……………………………………………..Date: …………………

Student number: 1325754
Short-term influence of a percussive soft-tissue technique on active weight-bearing dorsiflexion and Achilles tendon excursion: A case series

Demelza Scott-Weekly

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List of Abbreviations and Symbols

ADF active weight-bearing dorsiflexion
AOI ankle of interest
AT Achilles tendon
CI Confidence Interval
d Effect size (Cohen’s d)
deg degrees
ICC Intraclass correlation coefficient
hr hours
MDC minimal detectable change
min minutes
mm millimetre
MTJ muscular tendinous junction
n sample size
p probability value
s seconds
SD Standard deviation
SEM standard error of measurement
USI Ultrasound imaging
WBLT weight-bearing lunge test
Abstract

Short-term influence of a percussive soft-tissue technique on active weight-bearing dorsiflexion and Achilles tendon excursion: A case series

Background: Restriction of lower limb dorsiflexion has been associated with poor musculoskeletal outcomes. Impairment to soft tissue sliding of the tendo-Achilles region is one possible cause of decreased dorsiflexion. Anecdotally, a novel percussive soft tissue technique has been used to increase tissue sliding and improve dorsiflexion range.

Aim: To explore the effects of a percussive soft tissue technique applied to the tendo-Achilles region of healthy participants with reduced dorsiflexion, as measured by pre- post changes in active weight-bearing dorsiflexion (ADF), and Achilles tendon (AT) excursion as measured by high-resolution, B-mode, real-time ultrasound imaging.

Design: Six n=1 case studies were undertaken using a pre-post repeated measures design for the purpose of hypothesis generation.

Methods: A novel percussive soft tissue technique was administered once on Day 1 and once on Day 4. Pre-post comparisons of ADF and AT excursion were made on Day 1, Day 4 and Day 8. Findings were interpreted using a minimal detectible change (MDC) established as 1.76 deg for ADF, and 0.64mm for AT excursion.

Results: Six healthy participants (M = 3, F = 3, mean age 27.2 ± 6.3 years, mean height 1.75 ± 1.1 m, median body weight = 75kg [range 62 to 98 kg]) with reduced ADF participated in the study. Mean change in ADF pre-post for Day 1 was 6.15 deg (d=0.81), pre-post for Day 4 was 3.10 deg (d=0.37), and between pre-intervention Day 1 and follow up Day 8 was 11.29deg (d=1.49). Between pre-intervention Day 1 and follow-up Day 8, 3 participants increased AT excursion, 2 participants decreased AT excursion, and change was unclear (<MDC) for 1 participant.

Conclusions: All participants showed improvement in ADF as a result of the intervention. Achilles tendon excursion was improved for some participants and not others. These findings provide evidence to support further research with more power to investigate the influence of the percussive soft tissue technique on AT excursion and ADF.

Keywords: Sliding surfaces mobility, manual therapy, Achilles tendon, dorsiflexion
Introduction to the Thesis

Dorsiflexion in the lower limb is an important functional movement that results in the dorsum of the foot approximating with the anterior surface of the leg. Dorsiflexion can occur at the talocrural joint, also known as the ankle joint (Drake, Lee, Vogl, Mitchell, & Gray, 2005), the subtalar joint, and at the midtarsal joints (Gatt, 2012). The majority of the dorsiflexion movement occurs at the forefoot compared to the hindfoot (Gatt, Chockalingam, & Chevalier, 2011).

Several different structures have been implicated as potentially causing a reduction of dorsiflexion including neurological (Hägglund & Wagner, 2011), articular (Denegar, Hertel, & Fonseca, 2002; Hoch, Staton, & McKeon, 2011), capsular (Denegar et al., 2002; Lui, Chan, & Chan, 2006), soft tissues, including the gastrocnemius and soleus muscles, and the associated fascia (Denegar et al., 2002; Digiovanni, Holt, Czerniecki, Ledoux, & Sangeorzan, 2001; Grieve et al., 2011). This thesis focuses purely on the soft tissue tissues associated with dorsiflexion.

Loss of dorsiflexion can lead to health issues, consequently associated with loss of meaningful activities (Charles, Scutter, & Buckley, 2010; Gilbreath, Gaven, Van Lunen, & Hoch, 2014; Gross, 1995; Pope, Herbert, & Kirwan, 1998). Reduced dorsiflexion increases the risk of falling in older adults, thereby increasing morbidity (Nitz and Low Choy 2004).

There are numerous interventions employed to improve dorsiflexion range. Commonly used techniques directed at the Achilles tendon including manual therapy and exercise, to a home exercise program (Cleland, Mintken et al. 2013), massage and mobilisation Techniques (Green 1989, Vaillant, Rouland et al. 2009), stretching program (Samukawa, Hattori et al. 2011, Johanson, Armstrong et al. 2015), frictional technique (Kelly 1997, Mobarakeh and Hafidz 2015), Thai massage (Klumkool, Sintara et al. 2014), and petrissage and tapotement massage (McKechnie, Young et al. 2007). Recently, a novel percussive myofascial technique has been described for improving dorsiflexion (Starrett, 2011) and although anecdotally effective in clinical application, there has been no controlled investigation of the technique reported to date.

Dorsiflexion can be measured actively or passively, and in a variety of different positions including sitting, standing, prone, and supine. Of these, active weight-bearing dorsiflexion is more closely associated with functional movements than with non-weight-bearing dorsiflexion tests (Whitting, Steele, McGhee, & Munro, 2013). Foot and ankle function are required in
routine activities of daily living such as descending stairs, walking, kneeling and numerous sporting activities (Charles et al., 2010; Gross, 1995). Several different tools have been developed to measure dorsiflexion (Jonson & Gross, 1997; Pellow & Brantingham, 2001, Denegar et al., 2002; Ekstrand, Wiktorsson, Oberg, & Gillquist, 1982; Munteanu, Strawhorn, Landorf, Bird, & Murley, 2009, Bennell et al., 1998; Powden et al., 2015) but of these, the weight-bearing lunge test is best reflection of functional demands (Powden, Hoch, & Hoch, 2015).

Fascia is the generic label for a range of fibrous collagenous tissues which are interconnected as a 3-dimensional body-wide tensile network providing both stability and support to muscles and organs (Findley, Chaudhry, Stecco, & Roman, 2012; Schleip, Jäger, & Klingler, 2012). Moreover, fascia also allows for low friction movement of muscles and fascial layers (Findley et al., 2012; Schleip et al., 2012). Describing this function of reducing inter-tissue friction, the terms ‘sliding’ and ‘gliding’ have been used interchangeably in the literature. In this thesis the term sliding will be used.

Dysfunction of fascia has been described in the literature as the sliding ability of adjacent tissue layers is thought to be impaired. In relation to dorsiflexion, fascial dysfunction might be one possible mechanism for reduced dorsiflexion, characterised by impaired sliding of the Achilles tendon which may result in reduced tendon excursion (Chaitow, 2014; Findley, 2011; Kwong & Findley, 2014; C. Stecco et al., 2011). Until recently there have been few tools available to investigate claims that reduced Achilles tendon excursion is associated with reduced dorsiflexion. However, a recent study by Davies (2014) found that high-resolution B-mode ultrasound imaging, in conjunction with a frame-by-frame cross-correlation algorithm, can reliably quantify Achilles tendon excursion. The availability of high-resolution ultrasound, together with software to conduct measures of sliding between adjacent layers, enabled an exploratory investigation into the possible mechanism by which a novel percussive myofascial technique might alter dorsiflexion.

**Organisation of thesis**

The thesis is divided into three sections.

Section I is a review of the literature exploring the importance of dorsiflexion, issues with dorsiflexion terminology, major interventions to improve dorsiflexion range, the mechanisms
of how dorsiflexion directed interventions may influence fascia, fascial dysfunction, ankle range and normative values for dorsiflexion, measurements for dorsiflexion, quantification of soft tissue sliding, other influences on fascia and Achilles tendon excursion. The review provides a justification for the study reported in Section II, and also supports the methodological design and tools used in the study. Section I is divided in two parts. Part A is a narrative review of the literature. The importance of dorsiflexion range is explored, along with the interventions commonly employed to influence it. Fascia and fascial dysfunctions are then considered, examining how fascial dysfunctions to the Achilles tendon sliding may affect dorsiflexion range. The normative values of dorsiflexion are examined and common measurements for dorsiflexion described including the weight-bearing lunge test. The investigation into the visualisation and quantifying fascia sliding with consideration to Achilles tendon excursion using high-resolution B-mode ultrasound imaging and frame-by-frame cross-correlation algorithms are reported. The impact of age and gender on fascia are also described.

Part B contains a critical appraisal of the literature on soft tissue interventions aimed at the tendo-Achilles region to influence dorsiflexion. The Downs and Black Appraisal Checklist (Downs & Black, 1998) was used to review the studies identified.

Section II is a manuscript reporting an exploratory study into the effects of a novel percussive myofascial technique applied to the tendo-Achilles region and the effects on Achilles tendon excursion and active weight-bearing dorsiflexion. The manuscript is formatted according to the Journal of Bodywork and Movement Therapies Guide for Authors, available for viewing here: http://goo.gl/Xbul4F.

Section III is the Main Thesis Appendices which includes the appendices for Section I, Section II, Ethics Approval Letter, Participant Information Sheet, and Participant Consent Form.
Section I: Literature Review
1. **Part A - Review of Literature**

1.2 **The importance of dorsiflexion**

Adequate dorsiflexion range is required to safely and successfully execute activities of daily living and sporting tasks. It has been reported that a minimum of 10 deg dorsiflexion at the ankle is required to sustain normal gait (Charles et al., 2010; Gross, 1995). Kneeling, and descending stairs necessitate more than 10 deg of dorsiflexion (Lindsjö Ulf, Danckwardt-Lillieström, & Sahlstedt, 1985). Less than 10 deg dorsiflexion is associated with dysfunctional compensatory gait patterning, and increases forefoot pressure (Charles et al., 2010; Pope et al., 1998).

Furthermore, loss of dorsiflexion is a strong predictor for injury and can predispose to a number of musculoskeletal health conditions (Charles et al., 2010; Gross, 1995; Pope et al., 1998). Decreased dorsiflexion may lead to medial knee displacement (Bell, Padua, & Clark, 2008; Rabin, Kozol, Spitzer, & Finestone, 2013; Sigward, Ota, & Powers, 2008), increased anterior cruciate loading and risk of injury (Fong, Blackburn, Norcross, McGrath, & Padua, 2011), patellar tendinopathy (Backman & Danielson, 2011), chronic plantar heel pain (Irving, Cook, & Menz, 2006), iliotibial band syndrome (Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999), medial tibial stress syndrome (Kaufman et al., 1999), patellofemoral pain syndrome (Lun, Meeuwisse, Stergiou, & Stefanyshyn, 2004; Rabin et al., 2013; Waryasz & McDermott, 2008), mid portion Achilles tendinopathy (Rabin, Kozol, & Finestone, 2014), sprains and fractures in children (Tabrizi, McIntyre, Quesnel, & Howard, 2000), and an increase in falls in older adults (40-80 years of age) (Menz, Morris, & Lord, 2006; Nitz & Low Choy, 2004). Dorsiflexion has also been shown to be associated with plantar fasciopathy (Riddle, Pulisic, Pidcoe, & Johnson, 2003), lateral ankle sprains (Basnett et al., 2013), and chronic ankle instability (Denegar & Miller III, 2002; Drewes, McKeon, Kerrigan, & Hertel, 2009).

The association between limited dorsiflexion and falling deserves special mention as it may increase the incidence of falls in older adults (40 – 80 years of age). In New Zealand, no-fault personal injury costs for visitors and residents are covered the Accident Compensation Corporation (Accident Compensation Corporation, 2016a). Between July 2015 and June 2016, the Accident Compensation Corporation recorded approximately 305,126 new paid injury claims, and 397,471 active claims (includes ongoing and new claims) for adults (40-79 years of age) relating to injuries caused by falls (Accident Compensation Corporation,
The cost of these claims for adult fall injuries was around $557,583,160 during the July 2015 - June 2016 financial year (Accident Compensation Corporation, 2016b).

Loss of dorsiflexion can compromise health and quality of life through the loss of physical activity after injury (Gilbreath et al., 2014). Almost 65% of people modify their physical activity for some years after an initial ankle sprain (Gilbreath et al., 2014). Chronic ankle instability results from up to 70% of individuals who maintain an ankle sprain (Gilbreath et al., 2014). Limitations in dorsiflexion can potentially predispose to secondary injuries and health consequences which can result in loss of meaningful participation in activities of daily living and its associated financial cost and personal suffering.

1.3 **Issues with dorsiflexion terminology: When is ankle dorsiflexion not ankle dorsiflexion?**

According to Gatt (2012), there are three types of dorsiflexion: ankle dorsiflexion, hindfoot dorsiflexion, and foot dorsiflexion. In all three types, movement occurs in the sagittal plane resulting in the approximation of the dorsum of the foot and the anterior tibia. Differences between the three types of dorsiflexion are linked to the location of movement. In ankle dorsiflexion, movement occurs only at the talocrural joint, and Gatt (2012) suggests that ankle dorsiflexion requires the midtarsal joint to be ‘locked’ and a neutral positioned subtalar joint to occur. Hindfoot dorsiflexion occurs in the talocrural joint and the subtalar joint, and foot dorsiflexion involves the talocrural, subtalar and midtarsal joints.

Dorsiflexion can be measured either passively or actively. Because ankle dorsiflexion occurs at the talocrural joint, to accurately measure ankle dorsiflexion, the angle between talus and tibia needs to be measured. A flaw with commonly used dorsiflexion measures is that the talocrural measurement is not isolated to the talocrural joint, resulting in the movement being measured as either foot dorsiflexion or hindfoot dorsiflexion (Gatt, 2012). Although attempts have been made in studies to minimise the movement at the talocrural joint by placing the foot in subtalar neutral position when assessing dorsiflexion range (Dananberg, 2004), movement can still occur at the subtalar joint (Gatt & Chockalingam, 2012). A pronated foot may increase ankle dorsiflexion by up to 10 deg (Tiberio, Bohannon, & Zito, 1989; Woodburn, 1991).

Dorsiflexion is often not well classified, with unclear definitions of dorsiflexion being reported, correct definition and classification is important in assessing the outcome of the type intervention carried out, in addition to compare the results between different studies.
Various studies have mismatch in their definition of dorsiflexion and actual outcome measurements (Collins, Teys, & Vicenzino, 2004; Fryer, Mudge, & McLaughlin, 2002; Gajdosik, Vander Linden, McNair, Williams, & Riggin, 2005; Grieve, Cranston, et al., 2013; Halperin, Aboodarda, Button, Andersen, & Behm, 2014; Hoch et al., 2011; M. Johanson, Baer, Hovermale, & Phouthavong, 2008; Kang et al., 2015; Macklin, Healy, & Chockalingam, 2012; Marrón-Gómez, Rodríguez-Fernández, & Martín-Urrialde, 2015; McKechnie et al., 2007; O'Brien & Vicenzino, 1998; Reid, Birmingham, & Alcock, 2007; Riddle et al., 2003; Samukawa et al., 2011; Wheeler et al., 2013; Yoon, Hwang, An, & Oh, 2014). In many studies, it is claimed that dorsiflexion is measured but the measurement tool does not isolate the talocrural joint, and other joints (eg. hindfoot) are also being measured. The unclear use of dorsiflexion terminology has resulted in inconsistency in interrupting the literature.

1.4 What are the major interventions to improve dorsiflexion range?

Most interventions to improve mobility of the ankle and improve dorsiflexion occur in the form of rehabilitation delivered by allied health professionals such as physical therapists, podiatrists, and osteopaths. Therapeutic interventions can be grouped into active or passive therapies. Active therapies include stretching (Johanson et al., 2015; Samukawa et al., 2011; Youdas et al., 2009), eccentric loading (Allison & Purdam, 2009; Samukawa et al., 2011) and neuromuscular training (Petersen et al., 2013). Passive therapy intervention of the ankle includes electrotherapy (Michlovitz, Smith, & Watkins, 1988; Terada et al., 2013), therapeutic ultrasound (Terada et al., 2013; Williamson, George, Simpson, Hannah, & Bradbury, 1986), manual and manipulative therapy (Cleland et al., 2013; Terada et al., 2013; Vaillant et al., 2009).

Specific examples of passive manual therapies include mobilisation (Collins et al., 2004; Gilbreath et al., 2014; Hedlund, Nilsson, Lenz, & Sundberg, 2014; Holland, Campbell, & Hutt, 2015; Kang et al., 2015; Marrón-Gómez et al., 2015; Teixeira, Pires, Silva, & de Resende, 2013), manual traction (Parhate & Choudhari, 2015), and soft tissue techniques (Behm, 2007; Grieve, Barnett, Coghill, & Cramp, 2013; Grieve, Cranston, et al., 2013; Halverson, 2009; Klumkool et al., 2014; Singh & Mehta, 2015; Vaillant et al., 2009). In further considering soft tissue techniques, there are a number of techniques including trigger point release (Grieve, Barnett, et al., 2013; Grieve, Cranston, et al., 2013), soft tissue massage (Green, 1989; Elizabeth Kelly, 1997; Klumkool et al., 2014; McKechnie et al.,
2007; Mobarakeh & Hafidz, 2015; Vaillant et al., 2009), and myofascial release (Halperin et al., 2014). There are a range of different approaches directed at the ankle to improve dorsiflexion range (see Main Thesis Appendix A for a summary table for soft tissue techniques to improve dorsiflexion. Although other outcome measures may have been used by other studies, only dorsiflexion was included in the table)

1.5 Fascial techniques

Fascia has been identified as being involved in soft tissue sliding (Bhattacharya, Barooah, Nag, Chaudhuri, & Bhattacharya, 2010; Van der Wal & Jacob, 2009). The terminology of ‘fascia’ in the literature is variable with many different definitions (Benetazzo et al., 2011; Findley, 2009; Guimberteau, Delage, McGrouther, & Wong, 2010; Langevin, Helene, & Peter, 2009; Standring, 2008; Stecco et al., 2006). Benetazzo et al. (2011) limited the definition of fascia to connective tissue, with multiple different dominant fibre directions densely banded together. Whereas, the 40th edition of Gray's Anatomy – The Anatomical Basis of Clinical Practice, describes fascia as strands/bands of connective tissue that are visible to the unaided eye (Standring, 2008). According to Gray's Anatomy (Standring, 2008), fascia and aponeuroses are two separate structures. However, dividing aponeuroses and fascia into different categories is not possible in some areas of the body where the two tissues are blended (Schleip et al., 2012; Van der Wal & Jacob, 2009). Aponeuroses often blend with tendons, and join with ligamentous and capsular tissues near where they attach thereby avoiding direct attachment into bone (Schleip et al., 2012; Van der Wal & Jacob, 2009).

In an attempt to clarify the terminology associated with fascia, a wide encompassing classification for fascia was proposed at the 2007 Fascial Research Congress (Findley, 2009, p. 1):

“Fascia is the soft tissue component of the connective tissue system that permeates the human body. . . . The scope of our definition of and interest in fascia extends to all fibrous connective tissues, including aponeuroses, ligaments, tendons, retinaculae, joint capsules, organ and vessel tunics, the epineuria, the meninges, the periostea, and all the endomysial and intermuscular fibres of the myofasciae.”

In a commentary paper, Langevin et al. (2009) argued that the 2007 Fascial Research Congress definition of fascia should exclude ligaments and tendons as the authors consider the separate definition of ligaments and tendons to be useful in distinguishing their qualities separate to fascia. However, Langevin et al. (2009) recognised that fascia does blend with
ligaments and tendons, and that close to their attachments, tendons become ‘fascia’. Langevin et al. (2009) suggests that ‘fascia’ should include the following specific terms to distinguish the differences within fascial tissue: dense connective tissues, non-dense or areolar tissues, endomysium, perimysium, intramuscular and extra muscular aponeurosis, intermuscular septa, interosseal membrane, periosteum, neurovascular tract, epimysium, deep fascia and superficial fascia.

Further to Langevin et al.’s (2009) work, a review by Schleip et al. (2012) recommended that the most comprehensive definition of fascia includes the following characteristics. A range of fibrous collagenous tissues which are interconnected as a 3-dimensional body-wide tensile network providing stability which includes: annulus fibrosis of vertebral disks, intermuscular fibres of the myofascia, septa, aponeuroses, retinaculae, joint capsules, superficial fascia organ and vessel tunics, periosteum, dura mater, endomysium, perineurium, ligaments, and tendons. This definition has been adopted when referring to the subject of fascia in this thesis.

The types of fascia that are often examined in the literature are superficial fascia and deep fascia (Benjamin, 2009; Guimberteau et al., 2010; C. Stecco et al., 2006). Superficial fascia contains areolar loose connective tissue, which is found throughout the body as a continuous system, often located beneath the skin (Guimberteau et al., 2010). Deep fascia consists of dense fibrous layers and is found surrounding tendons and muscles (Findley, 2011; Guimberteau et al., 2010; Stecco et al., 2011).

Fibroblasts are the primary cells in fascia, and Type I collagen is the main protein, (Findley, 2011; Grinnell, 2008, Langevin, Bouffard, et al., 2011). Depending on the tension amongst the extracellular matrix and the cell, fibroblasts can synthesise, coordinate and remodel collagen (Findley, 2011; Grinnell, 2008). The behaviour and appearance of fibroblasts depend on the amount of tension experienced. Individual fibroblasts can alternate between two morphologies depending on the stress experienced (Findley, 2011). In situations where the cell experiences low tension, fibroblasts connect to adjacent cells through gap junctions, and collagen matrix synthesis is low (Findley, 2011). When the cell is in a high tension matrix, cell proliferation, and collagen synthesis increases, and the fibroblast cell body becomes larger (Findley, 2011; Grinnell, 2008).

The collagen matrix may be remodelled by adjacent fibroblasts and this remodelling has been observed occurring within minutes of stress in the areolar connective tissue (Langevin,
Bouffard, et al., 2011). Extensive matrix contraction remodelling can happen due to the spread of local remodelling by the fibroblasts (Findley, 2011). Focal adhesions and stress fibres are formed as the result of a fibroblast under tension, and are not observed in low tension matrix fibroblasts (Grinnell, 2008). Focal adhesion and stress fibre are not defined by Grinnell (2008), and it is not noted whether such states are dysfunctional. Also located within the connective tissue network are immune, vascular and nervous cells which may be pathologically affected by dysfunctional connective tissue tension (Langevin, Bouffard, et al., 2011).

Fascia allows for tissue excursion by separating structures (Bhattacharya, Barooah, Nag, Chaudhuri, & Bhattacharya, 2010; Van der Wal & Jacob, 2009). Skeletal muscles and tendons can move in states of low friction due to the surrounding loose, areolar connective tissue ‘which divides muscle fibres, and allow for the sliding movement of muscles and tendons’ (Benjamin, 2009; Guimberteau et al., 2010; Stecco et al., 2011; Stecco et al., 2006). Lubrication is provided by microvacuolar fascia (Guimberteau et al., 2010). The microvacuolar system is comprised of polyhedral spaces surrounded by numerous fibres adhered with lubricating fluid (Guimberteau et al., 2010). The microvacuoles have the ability to deform, can split and reform, and are capable of compression and multidirectional expansion due to the polyhedral shape (Guimberteau et al., 2010). The microvacuolar system allows muscle, dense fascia, and tendon to function independently of the dermal tissues, while connecting the different tissues (Guimberteau et al., 2010). The microvacuolar system plays an important role in tendon excursion, as the microvacuoles maintain continuity with the overlying skin and dermis while the tendon moves without causing deformation to the skin (Guimberteau et al., 2010). In most areas of the body (including lower limb), thin membranes divide the sliding tissue into three layers, present in most areas of the body, including the lower limb (Abu-Hijleh, Roshier, Al-Shboul, Dharap, & Harris, 2006). The deepest layer is linked to tendons and exhibits the largest amount of gliding. Nerves and large veins reside in the middle layer, while the most superficial layer has the highest fat content (Abu-Hijleh et al., 2006). Tissue distortion of the microvacuolar system, which allows sliding, is possible due to the gel-like qualities of the high proteoglycan content of the tissues (Guimberteau et al., 2010). When dehydrated the microvacuolar system becomes fibrotic (Guimberteau et al., 2010) which may suggest a role for adequate hydration for optimum soft tissue function.

Between skeletal muscle and the deep fascia is a layer of superficial fascia with a high
concentration of glycosaminoglycan hyaluronic acid (Kwong & Findley, 2014). It has been theorized that hyaluronic acid and water allow for the frictionless sliding between fascia and muscles, and that any alteration to the hyaluronic acid may restrict the soft tissue sliding, potentially producing myofascial pain, and modified fascial receptor behaviour (Kwong & Findley, 2014; A. Stecco, Gesi, Stecco, & Stern, 2013). It is believed that there is a cessation in the production of hyaluronic acid by the fascia when the underlying muscle is damaged (Findley, 2011). It has been theorized that the sliding ability of the dense fascia and muscle may become compromised if the superficial fascia between the two tissues layers increase in density due to close-packed hyaluronic acid (Stecco et al., 2011) although the circumstances in which this may happen were not reported by the authors.

1.6 Fascia dysfunction

Although the mechanisms that underpin concepts of dysfunctional fascia are not completely understood, fascia is considered dysfunctional if there is a lack of sliding between layers, which has the potential to alter proprioception, and gait through altered mechanoreceptor function (Chaitow, 2014; Findley, 2011; Kwong & Findley, 2014; Stecco et al., 2011).

Manual therapy techniques are assumed to improve fascial sliding (Findley, 2011), probably through increasing production of hyaluronic acid (Roman, Chaudhry, Bukiet, Stecco, & Findley, 2013), repeated therapy may stimulate fascial reorganisation (Benjamin, 2009; Grinnell, 2008). Roman et al. (2013) evaluated hyaluronic acid flow within and around fascia during different types of myofascial techniques (tangential oscillation, constant sliding, and perpendicular vibration) using a 3-dimensional mathematical model incorporating the squeeze film lubrication theory in fluid mechanics. Roman et al. (2013) calculated that increases in hyaluronic acid and a decrease in adhesions within the fascia may occur in response to myofascial treatment. Deformation of the fascia may occur due to physical manipulation of the fascia as seen in manual therapy, due to the external load applied to the skin and the underlying tissues, potentially resulting in changes to the extracellular matrix and the fibroblasts resulting from mechanical, structural and functional modulation (Benjamin, 2009; Grinnell, 2008).

Soft tissue manual therapy has been observed to treat fascial dysfunctions (Ercole, Antonio, Ann, & Stecco, 2010; Fink, Schiller, & Buhck, 2012, Schulze, Finze, Bader, & Lison, 2014; Tozzi, Bongiorno, & Vitturini, 2011). Ercole, Antonio et al. (2010) assessed points of fascia density of the low back using palpation, then timed how long it took for
practitioner perceived fascial density to decrease and participant reported pain to halve employing the Fascial Manipulation technique. Fink, Schiller et al. (2012) preformed a randomised controlled trial (n=60) on participants with frozen shoulder, comparing the effects of ‘fascial distortion model’ guided treatment for frozen shoulder and ‘conventional manual therapy’. Fink, Schiller et al. (2012) observed that both interventions improved shoulder mobility, the fascial distortion model required less time for changes to occur and had greater improvements than conventional manual therapy. A prospective case control study (n=32) investigating the effect of the ‘Fascial Distortion Model’ directed at the crural fascia of participants with medial tibial stress syndrome found significant decrease in pain ratings (p < 0.001) and improved exercise tolerance (p < 0.001) (Schulze, Finze et al. 2014). Tozzi, Boniglino et al. (2011) investigated the effect of manual fascial techniques (myofascial release and fascial unwinding) on fascial sliding of the neck in participants with neck pain (n=30), and the low back in participants with low back pain (n=30), compared with an asymptomatic control group (n=30), utilising dynamic ultrasound to measure landmarks pre and post intervention. Significant change was observed for the low back in participants with low back pain (p < 0.001), and for the neck in participants with neck pain (p < 0.001).

Subsequently, soft tissue fascial techniques are effective in treating fascial dysfunction in other areas of the body. There is the potential that soft tissue fascial techniques can improve fascial dysfunctions inhibiting the sliding of the AT. Thus, if AT excursion is not being impeded by adhesions of sliding layers then dorsiflexion range may also be improved.

1.7 Ankle range and normative values for dorsiflexion

Within the literature there are discrepancies about what is considered the normal dorsiflexion range, with differences in values for passive range between 11 – 20 deg(Cornwall & McPoil, 1999; Hoppenfeld & Hutton, 1976; Kapandji, 2010; Magee, 2006; Soucie et al., 2011), and differences in values for active range (Boone & Azen, 1979; Weir & Chokalingam, 2007), while values for active dorsiflexion range are between 13 and 23 deg (Boone & Azen, 1979; Weir & Chokalingam, 2007). The reason for the differences in these ranges is the use of different methods by different researchers/practitioners.

As mentioned earlier (see Issues with dorsiflexion terminology: When is ankle dorsiflexion not ankle dorsiflexion?), the measurement of dorsiflexion range depends on whether an attempt has been made to reduce subtalar pronation through adopting a subtalar neutral
Differences in dorsiflexion range value also occur between a bent knee and straight knee, weight-bearing and non-weight-bearing, and active and passive measures (Baggett & Young, 1993; Rabin & Kozol, 2012). There is a poor correlation between weight-bearing and non-weight-bearing dorsiflexion range (Rabin, Kozol, Spitzer, & Finestone, 2015). Differences between reported normative values result in variation in dorsiflexion range, this indicates that it is impossible to use the resulting values interchangeably to represent a single normative value. As a consequence of different measures, interpreting normative dorsiflexion values from the literature is difficult, and comparisons should only be made between similar testing states (i.e., weight-bearing, knee extended, subtalar neutral position, active or passive movement).

In a study by Weir and Chokalingam (2007), the possible expected dorsiflexion range required for normal gait was investigated and the weight-bearing dorsiflexion of n=13 healthy men and women measured. Images from five infra-red cameras with markers on the shank, foot, and thigh, were compared to the subtalar neutral position, and a goniometer was used to establish maximum weight-bearing dorsiflexion range. The results ranged between 12.43 deg and 22.53 deg required for walking and suggest that there is a greater variability in the dorsiflexion range needed for walking than the previously reported 10 deg.

1.8 Measurements for Dorsiflexion

Whitting et al. (2013), a cross-sectional study investigating the relationship between passive measures of dorsiflexion stiffness, and weight-bearing dorsiflexion range of motion, recommended the use of active weight-bearing measures for dorsiflexion range as it more closely resembles the function of the ankle during activities of daily living (jumping, walking, and running) than non-weight-bearing measures.

Active measurements for dorsiflexion range include prone with a goniometer (Jonson & Gross, 1997; Pellow & Brantingham, 2001), a weight-bearing position with the knee extended (Denegar et al., 2002; Ekstrand, Wiktorsson, Oberg, & Gillquist, 1982; Munteanu,
Strawhorn, Landorf, Bird, & Murley, 2009), and through a weight-bearing lunge test (WBLT) (Bennell et al., 1998; Powden et al., 2015).

The prone with goniometer measure involves the participant lying prone and the knee extended. The participant actively dorsiflexes the foot to end of range, and a goniometer is then used to measure dorsiflexion, the goniometer arms are aligned with the head of the fibula and the fifth metatarsal (Jonson & Gross, 1997). Gatt and Chockalingam (2011) performed a systematic review of the clinical assessments of ankle joint dorsiflexion which found goniometry to be an unreliable measure of dorsiflexion range. The weight-bearing position with the knee extended, is a reliable measure of active weight-bearing dorsiflexion (Ekstrand et al., 1982; Munteanu et al., 2009). The knee is extended to include the influence of the gastrocnemius muscle on dorsiflexion in the weight-bearing position with the knee extended. The WBLT is a reliable and valid test of active weight-bearing dorsiflexion if measured with the foot adjacent to the wall, and the knee lunged forward towards the wall until the heel can no longer maintain contact with the ground (Powden et al., 2015). A systematic review of the literature performed by Powden et al. (2015) found that inter-rater reliability (ICC = 0.65 to 0.99) and intra-rater reliability (ICC = 0.80 to 0.99) for the WBLT was good.

The WBLT can be measured using the maximum distance of the big toe from a perpendicular wall, (Bennell et al., 1998; Collins et al., 2004; Gilbreath et al., 2014; Marrón-Gómez et al., 2015; Vicenzino, Branjerdporn, Teys, & Jordan, 2006), goniometer (Johanson et al., 2008), and inclinometer (Bennell et al., 1998). The big toe to wall WBLT is a reliable measure of dorsiflexion, the foot is placed towards the wall, and the participant lunges the knee and touches the wall, the foot is then moved further from the wall, and the lunge is repeated until the participant cannot move the foot further back while still maintaining knee contact with the wall, and the heel with the ground (Bennell et al., 1998; Vicenzino et al., 2006). The WBLT with goniometry measures the maximum dorsiflexion range of a lunge, using a goniometer with the arms applied in line with the fibular head and the fifth metatarsal (Johanson et al., 2008). Dorsiflexion measurements using goniometry are considered unreliable (Gatt & Chockalingam, 2011). When the WBLT is measured using an inclinometer, the participant performs a lunge (as describe for the WBLT), the inclinometer is placed on the tibia, and the measurement calculated is the angle between the tibia and the horizontal floor (Bennell et al., 1998). The WBLT with inclinometer has been found to be a reliable measure (ICC = 0.97, 95% CI 0.90 to 0.99) of active weight-bearing dorsiflexion.
1.9 Quantifying soft tissue sliding

Fascial and tendon sliding and deformation can be visualised using ultrasound imagining (USI) (Van Doesburg et al., 2012; Yoshii et al., 2009). The two forms of USI available to quantify fascia and tendon sliding and deformation are elastography (Langevin, Fox, et al., 2011; Luomala et al., 2014), and speckle tracking (Van Doesburg et al., 2012; Yoshii et al., 2009). Elastography USI allows for the examination of changes in tissue due to mechanical strain (Luomala et al., 2014). Pre- and post- mechanical loading echo signal sets are compared to quantify mechanical strain (Luomala et al., 2014).

Tissue speckle tracking uses frame-by-frame tracking of acoustic signals (speckles) in the sonogram to track tissue movement (Van Doesburg et al., 2012; Yoshii et al., 2009). Tissue speckle tracking is an in vivo, non-invasive measure that does not require ionising radiation (Dilley et al., 2001). Tissue speckle tracking has been used to analyse movement in several different tissues including cardiac muscle (ventricular function) (Helle-Valle et al., 2005; Notomi et al., 2005; Pirat, McCulloch, & Zoghbi, 2006), nerve excursion (Dilley, Greening, Lynn, Leary, & Morris, 2001; Erel et al., 2003), and tendon excursion (Davies, 2014; Korstanje, Selles, Stam, Hovius, & Bosch, 2009, 2010; Yoshii et al., 2011; Yoshii et al., 2009), including AT excursion (Davies, 2014; Slane & Thelen, 2015).

1.9.1 Frame-by-frame cross-correlation algorithm

Frame-by-frame cross-correlation algorithms have been shown to be reliable at measuring the excursion of nerves in the limbs (Carroll, Yau, Rome, & Hing, 2012; Coppieters, Hough, & Dilley, 2009; Dilley et al., 2001; Ellis, Hing, Dilley, & McNair, 2008; Ridehalgh, Moore, & Hough, 2012) and fascia (Chen, Tsubota, Aoki, Echigo, & Han, 2009; Griefahn, Oehlmann, Zalpour, & von Piekartz, 2016; Edel Kelly, 2011). Investigations have been made into tendon excursion (Chen et al., 2009; Edel Kelly, 2011) but a review of the literature could only locate one study investigating the reliability of this method in measuring tendon excursion (Davies, 2014).

Davies (2014) examined the reliability of AT and crural fascia excursion using the frame-by-frame cross-correlation algorithm of Dilley et al. (2001). In the study by Davies (2014), participants (n=10, mean ± SD age=34.7 ± 18.9 years) underwent passive and active ankle dorsiflexion and plantar flexion while using high resolution, B-mode USI. Longitudinal AT
and crural fascia excursion was quantified using a frame-by-frame cross-correlation algorithm. Davies (2014) found that variance arises because of the operator and the differences in scanning between measures and the differences in tissue movement between measures making this unreliable for extraction for crural fascia excursion (ICC=0.56, 95%CI = -0.11 – 0.88). However, using the correlation descriptors described by Hopkins (2000), the reliability of extracting AT excursion was ‘very large’ (ICC=0.86, 95%CI = 0.53 – 0.96). Ultrasound imaging used to quantify AT excursion intra-session and inter-session reliability was ‘very large’ for active range (ICC=0.89, 95%CI= 0.57-0.97; ICC =0.80, 95%CI = 0.19-0.95), ‘nearly perfect’ for passive range intra-session reliability (ICC =0.96, 95%CI = 0.84-0.99) and ‘very large’ for passive range inter-session reliability (ICC = 0.88, 95%CI= 0.53-0.97). Based on these findings, tissue speckle tracking in conjunction with a frame-by-frame cross-correlation algorithm appears to be a non-invasive and reliable method to investigate AT excursion.

1.10 Factors that may affect fascia and AT excursion

Variances in AT excursion can occur due to age (Couppe et al., 2009; Slane & Thelen, 2015; Thorpe, Udeze, Birch, Clegg, & Screen, 2013), and gender (Kubo, Kanehisa, & Fukunaga, 2003; Onambélé, Burgess, & Pearson, 2007). It is theorised that increasing age may affect the tendons sliding ability thereby minimising tendon excursion potentially due to age associated changes in plantarflexion load sharing, or a decrease in fascial sliding (Couppe et al., 2009; Slane & Thelen, 2015; Thorpe et al., 2013). Greater non-uniform displacement, which is associated with greater tendon displacement, was observed in young adults (24.1 ± 1.4years) when compared with middle-aged adults (49.0 ± 3.1years) (Slane & Thelen, 2015). Differences in viscoelastic tendon properties have also been observed between females and males (Kubo et al., 2003; Onambélé et al., 2007). Female AT, when compared to male AT, was observed to display lower hysteresis, lower stiffness, greater tendon elongation, and larger strain (Kubo et al., 2003). Greater tendon excursion in females than males has also been observed at the patella tendon (Onambélé et al., 2007). It should be noted that differences in sex and age do not refer to within participant comparison studies and therefore were not considered when designing the current study in Section II.
2. Part B – Critical Appraisal

The aim of this section was to undertake a detailed critical appraisal of studies reporting soft tissue techniques to the tendo-Achilles region for the purpose of influencing foot and ankle dorsiflexion. Specifically, the goal was to appraise methodological issues in these studies to inform the design of the experiment as described in Section II of this thesis. The study undertaken in this thesis investigates the effect of a myofascial technique on foot dorsiflexion and fascial sliding layers.

2.1 Literature search

A search of the following databases was performed: Academic Search Complete, AMED - The Allied and Complementary Medicine Database, CINAHL with Full Text, Google Scholar, MEDLINE with Full Text, ScienceDirect, and SPORTDiscus. The keywords used were combinations of the following: massage, ankle range of motion, ankle, and range. The principal search string was “ankle AND massage AND range”. Search results were screened by one reviewer (DSW) by inspecting the title and abstract within each database, and if considered relevant the full-text was saved for further consideration of eligibility.

2.2 Eligibility for appraisal

The inclusion criteria for appraisal were:

- participants were healthy adults,
- dorsiflexion was an outcome measure,
- studies were prospective,
- the intervention was a soft tissue technique (operationally defined as a non-invasive technique externally applied to the target area with the intention of affecting the soft tissues) targeting the tendo-Achilles region.

Studies were excluded if they were:

- a thesis,
- non-peer reviewed,
- non-English language,
• participants had current ankle injuries,
• if reliability for dorsiflexion measurement had not been established in a separate peer-reviewed article,
• if dorsiflexion was not an outcome measurement,
• the intervention was not directed at the tendo-Achilles region,
• if full-text was not available.

See Figure 1 for the PRISMA flow diagram of the search process.

Studies meeting the eligibility criteria were appraised by one reviewer (DSW) using the Downs and Black appraisal checklist (Downs & Black, 1998) (see Main Thesis Appendix B). The Downs and Black appraisal checklist has been widely used in healthcare as a tool for assessing the methodological quality of non-randomised and randomised studies. The appraisal checklist is a valid and reliable tool consisting of a total of 27 items used to evaluate studies on Reporting, External Validity, Internal Validity–Bias, Internal Validity–Confounding, and Power (Altman & Burton, 1999; Downs & Black, 1998; Saunders, Soomro, Buckingham, Jamtvedt, & Raina, 2003).
Records identified through Academic Search Complete; AMED - The Allied and Complementary Medicine Database; CINAHL with Full Text; MEDLINE with Full Text; ScienceDirect; SPORTDiscus with Full Text, Health Source: Nursing/Academic Edition database searching (n=32)

Additional source: Google Scholar (first 10 pages of search results) (n = 100)

Records after duplicates removed (n =110)

Records screened (n =20)

Records excluded (n =90)

Full-text articles excluded, with reasons:
Non-English (n=1)
Thesis (n=3)
Intervention location not directed at the tendo-Achilles region (n=3)
Dorsiflexion not an outcome measurement (n=2)
Unreliable measure of dorsiflexion (n=1)

Studies appraised using Downs and Black tool (n = 2)

Figure 1. PRISMA flow diagram
Two studies met the eligibility criteria and were subject to appraisal. Table 1 describes the methodological characteristics of each study. The Downs and Black scores for (Halperin et al., 2014) and (McKechnie et al., 2007) were 21/28 and 19/28 respectively (Table 2), this corresponds with a ‘strong’ and ‘moderate’ quality as described by Simpson, Reid, Ellis, and White (2015) (see Main Thesis Appendix C for the Categorisation of Quality Index Scores described by Simpson et al. (2015)).
<table>
<thead>
<tr>
<th>Aim</th>
<th>Design</th>
<th>Blinding</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcome Measures</th>
<th>Time</th>
<th>Results</th>
<th>Main finding</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halperin (2014)</td>
<td>RCT with CO</td>
<td>N</td>
<td>M=14 F=2</td>
<td>Physically active (2×30 minutes a week)</td>
<td>Ankle DF&lt;sup&gt;1,3&lt;/sup&gt; (WBLT)</td>
<td>1 min</td>
<td>Roller: pre-test 1 p=0.004 SS pre-test 1 p=0.004 pre-test 2 p=0.001 10 mins</td>
<td>Foam roller and SS showed statistically significant changes in DF immediately after the interventions when compared to pretest 1, and 10 mins after for Roller.</td>
<td>The study is not representative of the population due to the use of convenience sampling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>23 ± 4 22 ± 3</td>
<td>1) SS (3 x 30s) 2) Roller. (3 x 30 rep)</td>
<td>Own control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McKechnie et al (2007)</td>
<td>RCT with CO</td>
<td>N&lt;sup&gt;2&lt;/sup&gt;</td>
<td>M=11 F=8</td>
<td>Physically active (regular team sports)</td>
<td>PNWB ankle DF&lt;sup&gt;2,4&lt;/sup&gt; (One trial)</td>
<td>Immediate</td>
<td>p=?? R foot. Pettrissage d=0.64&lt;sup&gt;5&lt;/sup&gt; Tapotement d=0.62 L foot Pettrissage d=0.48 Tapotement d=0.34</td>
<td>Both types of massage had an effect on DF although the effect was not reported as significant.</td>
<td>DF was only measured once per test increasing the magnitude of error. Due to the use of convenience sampling the study is not representative of the population.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21 ± 2.25</td>
<td>1) Pettrissage Massage 2) Tapotement Massage 3) Control</td>
<td>Own control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: RCT = Randomised control trial; CO = cross-over; N=mo; Roller.= self-massage with a foam roller; SS=static stretching; DF=dorsiflexion; WBLT = weight-bearing lunge test; PNWB=passive non-weight-bearing; R=right; L=left; d=effect size
1 The authors reported investigating ankle DF but with WBLT as the outcome measure whole foot dorsiflexion was being measured.
2 Other outcome measures were reported but as not included in the table as DF was the focus.
3 An attempt at blinding participants to the intervention, however due to the sporting population being recruited it is likely that participants may have previous experience of the intervention
4 The authors reported investigating ankle DF however there is no mention of controlling for subtalar pronation in the description of data. It is probable that foot DF is truly outcome measure whole foot dorsiflexion is being measured.
5 The reporting of P-values was confusing and could not clearly be interpreted.
6 Effect size magnitudes established using Cohen’s effect size (Cohen, 1988)
Table 2. Results for Downs and Black appraisal checklist for the selected two studies.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reporting</td>
<td>9/11</td>
<td>8/11</td>
</tr>
<tr>
<td>External Validity</td>
<td>0/3</td>
<td>0/3</td>
</tr>
<tr>
<td>Internal Validity-Bias</td>
<td>4/7</td>
<td>4/7</td>
</tr>
<tr>
<td>Internal Validity-confounding (selection bias)</td>
<td>3/6</td>
<td>3/6</td>
</tr>
<tr>
<td>Power</td>
<td>1/1</td>
<td>0/1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21/28</strong></td>
<td><strong>20/28</strong></td>
</tr>
</tbody>
</table>

2.3.1 Reporting

Poor study reporting can generate bias in interpretation of the study by the reader as the information is not conveyed clearly or is missing. For the category of Reporting, Halperin et al. (2014) and (McKechnie et al., 2007) both performed well, scoring 9/11, and 7/11 respectively. Both studies included clear descriptions of the objectives of the study, outcome measures, and the interventions. McKechnie et al. (2007) did not clearly describe the main findings causing confusing interpretations, and implied statistically significant change in left sided dorsiflexion when no statistically significant difference was reported in the results.

2.3.2 External Validity

Considering External Validity, both studies scored poorly (0/3, 0/3) mainly due to unclear reporting. Although the participants recruited may have been representative of the populations from which they were recruited, the ambiguity in reporting for both studies ensured that it was unable to be determined definitively.

The design of a hypothesis proving study (which these papers appear to be intended as the purpose of the papers), as distinct from a hypothesis generating study, requires that results be generalisable to a population. To achieve generalisability, sample selection needs to attempt to draw a random sample which is representative of the population to which the authors intend to generalize. Convenience sampling exposes the study to the
risk of being unable to be generalised to wider populations. However, studies that are designed for hypothesis generation may sacrifice external validity to investigate the potential of establishing the plausibility of a novel concept (Davidson and Goobie 2016). The generalisability of these studies are purposefully broad and limited. Better designed and performed studies are required to investigate the hypothesis more conclusively.

2.3.3 Internal Validity – Bias

Both studies could have improved in Internal Validity–Bias; (4/7, 4/7), with the main reason for the loss of points due to incomplete reporting, therefore ‘unable to determine’ was scored for both studies. Both studies had good intervention compliance with no drop outs, and the statistical analyses matched the outcome measures used. McKechnie et al. (2007) made an attempt to blind the participants to the intervention received. However, there are doubts about the success of blinding, as due to the sample of sports people, there is a distinct possibility that participants may have experienced massage prior to enrolment in the study, and based on previous experience, might be able to determine which intervention they were receiving.

Both studies failed to account for different times between sessions for participants, a factor that can decrease internal validity. Internal validity was also compromised in the study by McKechnie et al. (2007) with the use of the drop jump measure which was not reported to be valid and reliable and only that it had been utilised in a previous study. The implication of using measures that have not had reliability and validity established is that it is impossible to assess whether the measure is recording what it is intended to record and if it is recording it accurately. Future studies should include only valid and reliable outcome measures.

2.3.4 Internal Validity – Confounding

Neither study met the criteria for Internal Validity–Confounding (3/6, 3/6). Again unclear reporting made it difficult to interpret information, resulting in many items marked as ‘unable to determine’. The selection process for participants was poorly reported for both studies, neither of the studies reported any loss of participants and did not describe the number of participants recruited instead reported only the number of participants who participated in the studies. A CONSORT-style flow diagram which
shows the participant processes would be useful to show readers exactly where participants come from resulting in transparent reporting (Piaggio, Elbourne et al. 2012).

2.3.5 Statistical Power

One item was used to score statistical power as modified by Simpson et al. (2015) and Hartling, Brison, Crumley, Klassen, and Pickett (2004). If a power calculation was described 1 point was scored, but if the absence of power calculation was reported then a zero was scored. Halperin et al. (2014) scored 1 point on the Downs and Black, McKechnie et al. (2007) scored 0 points.

2.3 Discussion and summary

The main findings from this review relevant to the thesis are that reporting needs to be clear and free of ambiguity. Without a full account of the research process, the absence of information creates an opportunity for bias to arise because of difficulty in interpreting the work. Accurate reporting reduces bias and requires precise descriptions, especially regarding the objective of the study, outcome measures, and the interventions. Including blinding in a study decreases risk of bias; the researcher needs to ensure that blinding is occurring (Gøtzsche, 1996; Polit, 2011). McKechnie et al.’s (2007), attempt at blinding the participants to the intervention was ineffective in these two studies. Due to the recruitment of participants from a population that may potentially be aware of the interventions and the control, blinding is ineffective. Populations and intervention connections need to be considered when incorporating blinding to ensure correct implementation of blinding. The use of a CONSORT-style flow diagram is a transparent way to display the study process, accounts for all participants at all points of the study, and can improve study reporting (Moher et al., 2010). Also, both studies compromised external validity in their methods of participant selection and the use of a laboratory setting. The two studies investigated were hypothesis proving studies, however, studies that are hypothesis generating may compromise on external validity when investigating new areas.
3. **Summary and rationale for study**

Dorsiflexion is important for functional movement, and reduction in range can lead to negative health consequences. Soft tissue related dysfunction is one cause of reduced dorsiflexion range. Various manual therapy techniques around the ankle have been documented as increasing dorsiflexion range (Cleland, Mintken et al. 2013, Green 1989, Vaillant, Rouland et al. 2009, Kelly 1997, Mobarakeh and Hafidz 2015, Klumkool, Sintara et al. 2014, McKechnie, Young et al. 2007), although the outcome measures are mainly directed at range of motion. There has been little research directed at the effects of manual therapy techniques influencing soft tissue functions at the cellular level of soft-tissues at the ankle. The emergence of imaging techniques utilising USI may offer insight into soft tissue function, and recent investigation into the measurement of AT excursion has good reliability (Davies, 2014).

Several instrumented soft tissue techniques have been described in the literature (Borda & Selhorst, 2016; Griefahn et al., 2016; Halperin et al., 2014). A novel technique has been described using percussion of the soft tissues, and anecdotally it has been suggested that the technique can influence “sliding of the soft tissues” (Starrett, 2011). However, to date there appear to be no studies investigating this technique in any form. Therefore, the aim of this thesis was to conduct an exploratory investigation for the purpose of hypothesis generation on the effect of a novel percussive myofascial technique on tissue sliding of the AT and dorsiflexion range.
References


Hägglund, G., & Wagner, P. (2011). Spasticity of the gastrosoleus muscle is related to the development of reduced passive dorsiflexion of the ankle in children with cerebral


doi:http://dx.doi.org/10.1016/j.foot.2011.09.001


doi:http://dx.doi.org/10.1016/j.ptsp.2014.02.001


Section II: Manuscript

Note to readers: The presentation of this manuscript follows the general style of the *Journal of Bodywork and Movement Therapies* (see Guide for Authors here: http://goo.gl/Xbul4F). Because the presented manuscript is part of a thesis it does not comply with the following recommendations in the Guide for Authors: The abstract exceeds the recommended 150 word limit, and figures and tables are placed within the manuscript to enhance readability. Throughout the manuscript references to the thesis appendices are indicated by square brackets.
SHORT-TERM INFLUENCE OF A PERCUSSIVE SOFT-TISSUE TECHNIQUE ON ACTIVE WEIGHT-BEARING DORSIFLEXION AND ACHILLES TENDON EXCURSION: A CASE SERIES

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Abstract

Short-term influence of a percussive soft-tissue technique on active weight-bearing dorsiflexion and Achilles tendon excursion: A case series

**Background:** Restriction of lower limb dorsiflexion has been associated with poor musculoskeletal outcomes. Impairment to soft tissue sliding of the tendo-Achilles region is one possible cause of decreased dorsiflexion. Anecdotally, a novel percussive soft tissue technique has been used to increase tissue sliding and improve dorsiflexion range.

**Aim:** To explore the effects of a percussive soft tissue technique applied to the tendo-Achilles region of healthy participants with reduced dorsiflexion, as measured by pre-post changes in active weight-bearing dorsiflexion (ADF), and Achilles tendon (AT) excursion as measured by high-resolution, B-mode, real-time ultrasound imaging.

**Design:** Six n=1 case studies were undertaken using a pre-post repeated measures design for the purpose of hypothesis generation.

**Methods:** A novel percussive soft tissue technique was administered once on Day 1 and once on Day 4. Pre-post comparisons of ADF and AT excursion were made on Day 1, Day 4 and Day 8. Findings were interpreted using a minimal detectible change (MDC) established as 1.76 deg for ADF, and 0.64mm for AT excursion.

**Results:** Six healthy participants (M = 3, F = 3, mean age 27.2 ± 6.3 years, mean height 1.75 ± 1.1 m, median body weight = 75kg [range 62 to 98 kg]) with reduced ADF participated in the study. Mean change in ADF pre-post for Day 1 was 6.15 deg (d=0.81), pre-post for Day 4 was 3.10 deg (d=0.37), and between pre-intervention Day 1 and follow up Day 8 was 11.29deg (d=1.49). Between pre-intervention Day 1 and follow-up Day 8, 3 participants increased AT excursion, 2 participants decreased AT excursion, and change was unclear (<MDC) for 1 participant.

**Conclusions:** All participants showed improvement in ADF as a result of the intervention. Achilles tendon excursion was improved for some participants and not others. These findings provide evidence to support further research with more power to investigate the influence of the percussive soft tissue technique on AT excursion and ADF.

**Keywords:** Sliding surfaces mobility, manual therapy, Achilles tendon, dorsiflexion
1. INTRODUCTION


It has been suggested that manual therapy may improve the soft tissue sliding (Findley 2011). In recent years, several studies have demonstrated the effect of manual techniques on soft-tissue sliding in the lumbar region (Griefahn et al 2016). A suspected mechanism for reduced dorsiflexion is characterised by impaired sliding of the Achilles tendon (AT) thereby reducing tendon excursion. Until recently there have been few tools available to investigate the claims that reduced AT excursion is associated with reduced dorsiflexion. However, a recent study by Davies (2014) reported that ultrasound imaging (USI) with appropriate image processing software
can reliably quantify AT excursion. The weight-bearing lunge test (WBLT) is a reliable measure for ADF (Powden et al 2015). Starrett (2011) has described a novel percussive technique applied to the tendo-Achilles region that may improve the sliding surfaces of the tendo-Achilles soft tissues thereby increasing ADF. To date, there appear to be no studies investigating the efficacy of this technique. Therefore, the aim of this study was to explore the effects of a novel percussive soft tissue technique applied to the tendo- Achilles region of healthy participants with reduced dorsiflexion as measured by ADF and AT excursion using high-resolution, B-mode, real-time USI. It was hypothesized that improvement in ADF would be associated with an increase in AT excursion.
2. METHODS

2.1 DESIGN AND EXPERIMENTAL APPROACH TO THE PROBLEM

A series of n=1 case studies were undertaken using a pre-post repeated measures design for the purpose of hypothesis generation. A descriptive repeated-measures approach was used to investigate AT excursion and ADF. Although operationally defined as ADF, the range of motion includes the mobility of the ankle, the hindfoot and forefoot which is needed to achieve foot dorsiflexion. Dynamic real-time ultrasound imaging of a squat was used to investigate the sliding layers of the ankle following a soft tissue technique intervention, and WBLT was used to assess ADF. Where higher values of degrees are traditionally related with an increase in ADF range, in this paper the angle between the anterior shaft of the tibia to and the horizontal floor was measured to give ADF therefore lower values of degrees represent an increase in ADF range.

2.2 Participants and ethics

Participants were recruited from the Auckland region using convenience sampling, posters, and word of mouth. Participants were required to meet the following eligibility criteria: Inclusion criteria: (1) healthy individuals with no current medical condition or symptoms of disease; (2) aged between 20-55 years of age; (3) one or both lower limbs with greater than 65 deg ADF; and (4) perceived resistance to induced sliding by palpation of the soft-tissues (i.e. skin and subcutaneous tissue) over the AT, as examined by the primary researcher. Participants were excluded from the study if they had any previous history of ankle surgery, AT rupture or sprain, venous thromboembolism, calf warmth, tenderness, swelling, or erythema; acute calf pain; pitting oedema; manual therapy or medical treatment of the lower extremity for the duration of the time of the study, and/or; the presence of comorbidities including conditions of rheumatological,
neurological, orthopaedic, or metabolic nature.

The study was approved by the Unitec Research Ethics Committee (UREC 2015-1009). Verbal and written informed consent was gained from all participants.

2.3 Outcome measures

2.3.1 Weight-Bearing Lunge Test range of motion.

The WBLT, adapted from Konor et al (2012) was used to measure ADF. Each measure was repeated 5 times with the mean value of the 5 scores used, thereby decreasing the magnitude of error (Cejudo et al 2014). The WBLT has been shown to be a reliable measure of ADF (Konor et al 2012, Powden et al 2015).

2.3.2 Sliding excursion between Achilles tendon and subcutaneous fascia.

High-resolution, B-mode, real-time USI was used to study AT excursion and the subcutaneous fascia during the downward and then upward motion of a squat. A Philips iU22 (Philips Medical Systems Co., Eindhoven, The Netherlands) diagnostic ultrasound machine, with a L15-7io Linear Transducer was used. Due to the superficial location of the AT, a depth of 2 cm was chosen. Cine-loop recordings (3s duration, 102 frames per 3s) were captured at a frequency of 34Hz, commencing at the start of the squat to the down position, then again at the bottom of the squat to the standing position. All ultrasound imaging was performed by a qualified and experienced sonographer specialising in musculoskeletal ultrasound imaging. The sonographer was blinded to the technique application and the outcome measure results. Specialised software using a cross-correlation algorithm (Motion 6, Matlab, USA) was used to calculate AT excursion, and has been shown to be reliable in ultrasound imaging analysis (Dilley et al 2001; Davies 2014). Davies (2014), has demonstrated the MDC for active AT excursion
is 5mm, and passive AT excursion is 3mm.

### 2.4 Pilot work

#### 2.4.1 Development of ultrasound imaging scanning protocol.

Prior to data collection five sessions (total ~7hrs) were dedicated to developing scanning protocol as no protocol of ultrasound imaging during active squatting movement was available in the literature. To ensure the primary researcher was practiced and familiarised with the procedure, preliminary practice of 30 WBLT measurements was undertaken. To establish intra-rater reliability and determine measurement error, a convenience sample of 10 participants (M=5, F=5, mean age 27.8± 5.17 years, mean height 171.3 ± 4.24 cm, mean weight 70.9 ± 7.3 kg) was recruited. The intra-rater reliability for WLBT was ICC = 0.994 (95%CI 0.974 to 0.998). The standard error of measurement (SEM) was 0.64 degrees, and MDC was 1.76 degrees.

#### 2.4.2 Reliability for data extraction of tissue excursion

The primary researcher undertook ~ 20hr of practice data extraction using 3s cine-loops collected during pilot work. Intra-rater reliability of calculating AT excursion measures using a cross-correlation algorithm software (Motion 6, Matlab, USA) was then established. An assistant prepared 10 pairs of identical cine-loops, each identical pair was assigned an identification code known only to the assistant. The order of the cine-loops were randomised (http://www.random.org) and delivered to the primary researcher, who was blinded to the pairings. The primary researcher then extracted the AT excursion in relation to the subcutaneous fascia data from the cine-loops, the data was sent to the assistant who un-blinded, un-coded, and analysed the data. Intra-rater
reliability coefficients were ‘high’ to ‘nearly perfect’, see Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Intra ICC</th>
<th>95%CI</th>
<th>Descriptor</th>
<th>SEM (mm)</th>
<th>MDC (mm)</th>
</tr>
</thead>
<tbody>
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<td>AT</td>
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<td>‘very high’</td>
<td>0.20</td>
<td>0.56</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>0.95</td>
<td>0.85 - 0.99</td>
<td>‘nearly perfect’</td>
<td>0.13</td>
<td>0.35</td>
</tr>
<tr>
<td>Relative movement</td>
<td>0.63</td>
<td>0.11 – 0.88</td>
<td>‘high’</td>
<td>0.23</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Notes: AT = Achilles tendon; ICC = Intraclass correlation coefficient; CI = confidence interval; SEM = Standard error of measurement; MDC = Minimal detectable change; n=6; Descriptors for magnitudes of correlation based on Hopkins (2002).

2.5 Intervention

The intervention was a novel percussive soft tissue technique as described by Starrett (2011). The intended aim of the technique was to minimise the sliding surface dysfunction between the tendon and the skin, to increase ADF. Figure 1 illustrates the application of the technique and is described in terms of the TIDier checklist (Hoffmann, Glasziou et al 2014) [see Main Thesis Appendix D for TIDier checklist]. (See Supplementary Material for an audio-visual clip of the technique application.).

The intervention was delivered by a post graduate osteopathy student, with 2 years clinical experience. The practitioner underwent 1 hour training in delivery of the technique, and undertook 1 week of self-directed practice prior to the data collection. The intervention was delivered face-to-face, to each participant individually. The intervention was delivered in a clinical laboratory, special features included an electronic plinth, and a curtained off area. The frequency of
the intervention was once on Day 1 and once on Day 4, and took approximately 60 s to deliver.
Figure 1 Application of the percussive soft tissue technique.

(Panel A) The start position, the participant lay prone with the practitioner standing at the foot of the table, the knee was passively held in a flexed position. The AOI was held in full dorsiflexion by fixing the foot under the practitioners’ costal margin, thereby creating tension in the posterior tissues of the leg.

(Panel B) The lacrosse ball was held as demonstrated in Panel B. The opposite hand was used to percuss against the lacrosse ball using the palm.

(Panel C) The lacrosse ball was placed against the intervention point, tension was created with the contact of the lacrosse ball to “take up the slack” of the soft tissues beneath the intervention point. The practitioner held the ball tightly against the intervention point with one hand while the other hand percussed the lacrosse ball against the intervention point with an anteroposterior force. Each intervention point was percussed three times, then using the foot as a leaver the ankle was passively moved through full dorsiflexion to full plantarflexion. The cycle was repeated four times in total for the intervention.
2.6 Procedures

Data collection was scheduled over an eight-day period, with three sessions each separated by four nights (see Figure 2).

Figure 2. Timeline of events in the same order as they occurred: Day 1, the participant preformed the warm-up exercises, the dependent variables were measured in the order of WBLT, squat with ultrasound imaging, then application of the intervention. Immediately following the intervention, the dependent variables were measured in order of squat with USI, then WBLT. These procedures were repeated on Day 4, then again on Day 8 excluding the intervention and the second lot of dependent variable measurements.

2.6.1 Measurement session (Day 1 and Day 4).

Identification of the ankle of interest (AOI) occurred at the time of enrolment in the study, the side with the greatest limitation in ADF was assigned as the AOI. The intervention points were identified and marked with ink on the skin overlying the affected sites of AOI by the primary researcher (Figure 3).
Figure 3. Identification and marking of the intervention points: (Panel A) Marking position. The participant lay prone on the treatment table with their feet overhanging the end of the plinth. Using palpation, the primary researcher identified the insertion of the AT into the calcaneus. The yellow lines indicate the medial and lateral border of the AT; (Panel B) A full set of intervention points on the participant. The points were marked with a vivid pen on the medial and lateral border of the AT just proximal to the insertion of the AT. Four more points on each side were marked going proximally from the last mark following the border of the AT, each separated approximately by two of the primary researcher finger width. Adjustments in the distance between the vertical points were made according to the length of the AT.

Each participant undertook a standard warm-up under supervision of the primary researcher in a room separate from the clinical laboratory. The exercises, in order, were: (1) calf stretches, 20 repetitions; (2) double leg heel rise, 20 repetitions; (3) active full dorsiflexion to plantarflexion movement in a non-weight-bearing position, 20 repetitions; (5) full squat, 5 repetitions.

The AOI ADF was measured by the primary researcher using a WBLT and digital inclinometer (Baseline Evaluation Instruments, Model 12-1057, Fabrication Enterprises Inc, NY) (Figure 4). A successful trial was defined as maintenance of participant’s heel in contact with the ground during the full range of motion. Five successful trials were performed with the mean value of the five used for data analysis.
**Figure 4.** Weight-bearing lunge test.

(Panel A) Start position, the participant stood with feet shoulder width apart and facing forward, the foot of the AOI was placed forward facing a wall. The primary researcher maintained a light contact over the medial and lateral aspect of the calcaneus to monitor heel contact with the ground throughout the movement (inserted);

(Panel B) The participant was directed to “lunge the front knee as close to the wall” as they could get “without lifting the heel off the ground” while maintaining a forward facing posture. The front knee was requested to track over the second toe to limit subtalar pronation and give a standardised movement (Munteanu, Strawhorn et al 2009). End range of ADF was recorded when the participant could go no further without the heel breaking contact with the ground;

(Panel C) Alignment of digital inclinometer: Once reached, the end of range ADF was held and the inclinometer, which had been zeroed prior to the measurement, was placed vertically at the inferior aspect of the tibial tuberosity, along the anterior tibial crest maintaining a tight and contestant contact with the leg. Active dorsiflexion was measured in reference to the angle of the tibia relative to the ground. The primary researcher pushed ‘hold’, saving the angle reading, and recorded the measurement.
After warming up, each participant walked approximately 5 m to the clinical laboratory. The scanning point was identified by the sonographer (Figure 5). Ultrasound imaging of the posterior leg was performed while the participant performed a full squat (Figure 6). Due to the requirements of the data extraction software, cine-loops were limited to 3s duration. Therefore, the participants were required to perform the descending motion of the squat in 3 s, hold the squat for 2 s, and then perform the up phase of the squat in 3s. Pre-recorded instructions were played to cue the participant to achieve standardised duration of squat movements. The verbal cue was “3, 2, 1, go, 1, 2, stop, ready, go, 1, 2, stop” using a cadence of 1 word per second. The participants began the movement at ‘go’ and reached the bottom of the squat at ‘Stop’. During the ‘ready’ phase the participant waited at the bottom of the squat to allow for processing to allow for new recordings of the cine-loop. At the second ‘go’ the participant returned to the vertical position with the movement complete at ‘stop’. The primary researcher provided verbal feedback during and after each repetition to ensure the whole movement was performed within 3 s [see Main Thesis Appendix E for instructions given during squats]. Each participant undertook multiple repetitions until 5 sets of cine-loops of sufficient quality had been collected (see .6.1 Selection of cine-loops.).
Figure 5. Identification of the scanning point: (Panel A) ultrasound image of the calcaneus. The participant stood with feet shoulder width apart, and the transducer in the transverse plane, the calcaneus was identified; (Panel B) Ultrasound image of soleus muscular tendinous junction. The transducer was then moved superiorly along the AT until the soleus muscular tendinous junction was visualised, the skin was marked with ink at the height of the muscular tendinous junction at the inferior aspect of the transducer. (Panel C) The transducer was then moved superiorly along the AT until the medial gastrocnemius muscular tendinous junction was visualised, the skin at the inferior aspect of the transducer was then marked with ink; (Panel D) The scanning point. A line made from joining the two muscular tendinous junction points was bisected midway and marked as the scanning point. Throughout the scanning, the transducer was sufficiently applied with ultrasound transmission gel. Orientation of ultrasound images: left hand side is cephalad; right hand side is caudad; top of image is superior; and bottom of image is deep. Notes: MTJ = muscular tendinous junction; AT= Achilles tendon.
Figure 6. Squat with ultrasound imaging applied to the posterior leg:

(Panel A) Squat start position. The participant stood facing a treatment table, feet placed shoulder width apart, facing forward and parallel, and arms shoulder width apart holding onto the table. The sonographer held the transducer to the scanning point in the longitudinal plane.

(Panel B) Mid squat, the participant was requested to lower their hip crease to the ground posterior to their knees in a continuous motion. The participant was requested to track their knees over their second toe, thus compensatory subtalar pronation was minimised (Munteanu, Strawhorn et al 2009).

(Panel C) ‘Down position’ of the squat, was achieved when participant could descend no further into the squat. The participant was directed to hold the ‘down position’ for 2 s before ascending to the upright position.

(Panel D) The upright position, the participant stands with knees loosely extended, head facing forward, feet parallel and facing forward, and hands approximately shoulder width apart and holding onto the table.
The sonographer then left a curtained off area and the practitioner entered the room to deliver the intervention, see Figure 1. The practitioner was blinded to the purpose of the study, the outcome measures, and outcome measure results.

Once the intervention was delivered, the practitioner left the room, and the sonographer returned. The dependent variables were measured (ADF and AT excursion), the sonographer left a curtained off area when not required.

2.7 Data extraction and statistical analysis

2.7.1 Selection of cine-loops.

Five scans were taken of the movement of standing to a down squat during data collection. The three cine-loops with the highest quality meeting the following criteria were selected for analysis: clear pixilation with no dark spots of the subcutaneous tissue and AT consistently for the duration of the cine-loop; consistent speed of the AT throughout the cine-loop; the smooth motion of the tissues.; AT movement occurs mainly in the horizontal plane with little vertical movement, and, clear cessation of AT movement by the completion of the cine-loop. Fifteen cine-loops per participant were analysed, resulting in analysis of 90 cine-loops in total.

2.7.2 Cross-correlation algorithm for measurement of tissue excursion.

For each cine-loop (duration 3 s, capture rate 34 Hz), AviBmp (Avi4Bmp, version 2.4 Bottomap Software) was used to convert the cine-loop into 102 individual bitmap frames. The scale of pixels per millimetre (pixels/mm) was then calculated by uploading a single frame to ImageJ (version 1.46, National Institute of Health, USA) and calibrated using the scale marker present on the image. For all cine-loops analysed, the scale was 23.6 pixels/mm.
Motion 6 was used to perform the cross-correlation image analysis. Parameters for analysis were set as: start frame 1, end frame 99, vertical tracking 1, vertical pixel shift -2 and +2, horizontal pixel shift +2 -5 and +20; and, Background (0) or Tissue of Interest (1), Tissue of Interest was selected with the AT, and subcutaneous tissue for Background. Careful consideration was made to ensure the region of interest was maintained within the target tissues [see Main Thesis Appendix F for the considerations to maintain tissue type during data extraction]. Finally, the background tissue was subtracted from total area, and the horizontal subtracted from the hypotenuse.

2.8 Statistical Analysis

The small sample size precluded analysis using inferential statistics, therefore Cohen’s effect sizes (Cohen 1988) (d) were calculated to represent the magnitude of change in ADF and AT excursion between time points. The magnitudes of Cohen’s d were interpreted as ‘trivial’ (d <0.20), ‘small’ (0.20 ≤ d < 0.50), or ‘moderate’ (0.50 ≤ d < 0.80), and ‘large’ (d ≥ 0.80) (Cohen 1992).
3. **RESULTS**
Six healthy participants (M = 3, F = 3, mean age 27.2 ± 6.3 years, mean height 1.75 ± 1.1 m, median body weight = 75kg [range 62 to 98 kg]) met the exclusion and inclusion criteria and were enrolled into the study (Figure 7).

![Participant Flow Diagram](image)

**Figure 7.** CONSORT style participant flow diagram
3.1 Differences in active weight-bearing dorsiflexion between time points.

Figure 8 illustrates differences in ADF between time points. On Day 1, the difference between pre-intervention and immediately post-intervention for ADF was 6.15 deg ($d = \text{‘large’}$). Between Day 1 post-intervention and Day 4 pre-intervention, there was a difference of 1.79 deg ($d = \text{‘small’}$) indicating minimal change between sessions.

Between Day 4 pre- and post- intervention there was a difference of 3.10 deg ($d = \text{‘small’}$) indicating minimal immediate change. Between Day 4 post-intervention and Day 8 Follow-up, there was a difference of 0.25 deg ($d = \text{‘trivial’}$), again the ‘trivial’ effect size indicating minimal change between sessions. Overall, between Day 1 pre-intervention and Day 8 Follow-up, there was a difference of 11.29 deg ($d = \text{‘large’}$).

![Figure 8. Histogram showing effect size and mean ADF between time points. Horizontal shaded bands represent range of values less than the minimal detectable change (MDC ± 1.76 deg). The range shown here is the vertical measurement from the tibial tuberosity relative to the horizontal floor. A decrease in the mean ROM represents an increase in ADF range. Note: $d =$ effect size; ROM= range of motion.](image-url)
3.2 Differences in Achilles tendon excursion between time points.

Figure 9 displays the differences in AT excursion during active movement (from standing to full squat), between pre-intervention and immediately post-intervention, over an 8-day period. Table 2 displays the frequency of participants demonstrating AT excursion change in relation to MDC. On Day 1, the difference in AT excursion between pre- and post-intervention showed 1 participant had decreased AT excursion, while the difference in AT excursion for 3 participants was unclear as the MDC did not exceed, and 2 participants demonstrated increased AT excursion.

Considering the difference in AT excursion between Day 1 post-intervention and Day 4 pre-intervention, 2 participants had decreased AT excursion, 3 participants’ results were unclear as AT excursion did not exceed the MDC, and 1 participant had increased AT excursion.

On Day 4, the difference in AT excursion between pre- and post-intervention was unclear for all participants (n = 6) as the AT excursion MDC did was not exceeded.

Between Day 4 post-intervention and Day 8 follow-up, the difference in AT excursion showed 3 participants had unclear results as AT excursion did not exceed the MDC, and 3 participants had increased AT excursion.

Between Day 1 pre-intervention and Day 8 follow-up, the difference in AT excursion showed decreased AT excursion in 1 participant, 2 participants results were unclear as AT excursion did not exceed the MDC, and 3 participants had increased AT excursion.
Figure 9. Plot showing AT excursion from standing to full squat pre- and post-intervention over an 8 day period.
Table 2. Table to shows categorisation of Achilles tendon excursion changes in relation to minimal detectable change.

<table>
<thead>
<tr>
<th></th>
<th>Change exceeded MDC and associated with decrease in AT excursion</th>
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<tr>
<td>Day 1 Pre – Post</td>
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<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Day 1 Post – Day 4 Pre</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Day 4 Pre – Post</td>
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<td>0</td>
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<td>3</td>
</tr>
<tr>
<td>Day 1 Pre – Day 8 Follow-up</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Notes: AT = Achilles tendon; MDC = minimal detectable change. MDC was ±0.64mm. Figures in each cell represent the number of participants demonstrating AT excursion changes in relation to minimal detectible change.
3.3 Interaction between change in Achilles tendon excursion and active weight-bearing dorsiflexion

Figure 10 shows the interaction between change in Achilles tendon excursion and ADF. On Day 1, of the 5 participants that showed an increase in range, 3 had a change of AT excursion exceeding the MDC, of those 3 participants, 2 participants had increased AT excursion, and 1 participant had decreased AT excursion (Figure 10, Panel A).

On Day 4, of the 4 participants that showed increase in ADF, none showed a change in AT excursion, as no participant exceeded the MDC for AT excursion (Figure 10, Panel B).

Between Day 1 pre-intervention and Day 8 Follow-up, of the 6 participants that exhibited increase in ADF, 5 participants exceed the MDC displaying change in AT excursion. Of those 5 participants, 3 participants increased AT excursion and 2 participants decreased AT excursion (Figure 10, Panel C).
Figure 10. Mean change in participant ADF and Achilles tendon excursion over time. The shaded region represents values that do not exceed the minimal detectible change (MDC). The horizontal shaded area represents ADF (MDC = 1.76 deg), the vertical shaded area represents AT excursion (MDC = 0.64mm). (A) Day 1, change between post and pre-intervention. (B) Day 4, change between post and pre intervention. (C) Change between Day 8 follow up and Day 1 pre-intervention. Abbreviations: AT Excursion = Achilles tendon excursion; ADF = active weight-bearing dorsiflexion; AT MDC =Achilles tendon excursion minimal detectable change; ADF MDC =active weight-bearing dorsiflexion minimal detectable change.
4. DISCUSSION

The aim of this study was to explore the influence of a novel percussive soft-tissue technique applied to the tendo-Achilles region in people with reduced ADF and AT excursion. It was anticipated that improvement in ADF range would be matched by increase AT excursion post-intervention. However, although there was an increase in ADF range for all participants (n = 6) both immediately after the intervention, and for 4 days, a commensurate change in AT excursion was observed in just 3 of the 6 participants.

The mismatch between change in ADF and AT excursion for some participants, and not for others, could be partially explained by increases in excursion occurring in parts of the AT that were not scanned in this study. The scanning point in this study was just a small section of the AT; the midway between the soleus and medial gastrocnemius muscular tendinous junction was chosen as the scanning point as it could be consistently identified between scans and contact between the transducer and the scanning point could be maintained throughout the squat. In some cases, the scanning point may not have matched the point of application for the percussive technique, as the majority of the intervention points were distal to the scanning point therefore movement at the scanning point may not fully reflect changes in excursion due to the intervention. Only one scanning site was used due to the time intensive nature of processing the cine-loops and the difficulty producing quality scans in active movement.

Achilles-tendon excursion is known to occur in all three axis (Obit et al 2014), and it is therefore possible that changes in movement occurred in axis of the AT not visible during the scan. Rotation and reorganisation of fibres of the AT under load have been
reported, for example, an investigation into deformation of the AT in isometric plantarflexion found greater transverse deformation at the mid-portion of the AT when compared to distal and proximal sites (Obst et al 2014). In the present study, only total longitudinal tendon excursion was measured, while measures of transverse displacement were not possible using the methods available. Thus, changes in tendon excursion that may have occurred in directions other than the longitudinal axis may not have been detected. Three-dimensional imaging of the AT is possible (Obst et al 2014), but is currently only available in image static conditions (Farris et al 2013, Lichtwark et al 2013, Obst et al 2014).

Unlike the present study which included two intervention sessions and measurements across 8 days, Griefahn et al (2016) measured change in soft-tissue sliding after a single session performing only one post-treatment measurement at 10 min post intervention. In the present study, both immediate, and effects up to 8 days post-intervention were explored.

The delayed effects of increased tissue stiffness and tissue matrix hydration, of fascia in mice have been observed 30 min post fascial stretch compared with immediately post intervention (Schleip et al 2012). The potential for delayed effects in changes to fascia were not directly assessed either here, or by Griefahn et al (2016). Given that delayed effects have been described, changes observed in ADF and AT excursion here may not represent the full extent of post-intervention changes occurring, and a longer period of post-intervention follow-up, for example 5, 15, 30, 60 min may be useful.

4.1 Findings in context of the wider literature

To date, it appears there are no other directly comparable studies reporting changes in AT excursion following application of soft-tissue techniques. However, one
recent investigation reports the effect of a different myofascial techniques on the sliding of soft-tissue interfaces (Griefahn et al 2016). Griefahn et al (2016) investigated the effect of foam rolling on the sliding of thoracolumbar fascia in a three-group randomised control trial involving 38 physically active participants (F= 25, M= 13; age mean ±SD = 23.34 ± 2.58). The participants were divided into either foam roll (n= 13), placebo (n=12), or control group (n= 13), where they received one of the three interventions: the self- applied foam roll to the posterior trunk, light self-foam rolling to the trunk (gentle with no pain), or no treatment. Outcome measures were thoracolumbar fascia mobility, lumbar flexion, and mechanosensivity of the dorsal spine muscles. Changes in sliding of the thoracolumbar fascia were quantified using USI and the same cross-correlation algorithm (Dilley et al (2001)) used in the present study. Griefahn et al (2016) found the foam roll group significantly improved thoracolumbar fascia mobility (p <0.001, $d = 0.76$), with an average of 1.79mm increase in excursion observed. Changes in the placebo and control group were not statistically significant, $p = 0.40$ for placebo, and $p= 0.86$ for control group. No significant change was observed in lumbar flexion and mechanosensivity measures for any group. There are two main points of comparison between Griefahn et al (2016) and the present study: Firstly, both studies used active movements when assessing soft tissue sliding. Similar to Griefahn et al (2016), the present study used active movement to assess soft-tissue sliding. The use of active movements is important in order to be representative daily function (Whitting et al 2013). Secondly, the magnitude of immediate pre-post intervention effect was similar between studies. Griefahn et al (2016) observed a ‘moderate’ ($d= 0.76$) effect size, in the present study the pre-post effect size was of a similar magnitude for Day 1 magnitude ($d= ‘moderate’$), in contrast, the effect size for Day 4 was ‘small’.
The mechanism resulting in the decreased scale of effect sizes for ADF after the initial intervention is unknown, it may be related to a maximum improvement in the sliding layers at the intervention point. Further study is necessary to investigate this further.

Although a range of instrumented myofascial techniques have been described including foam rollers (Halperin et al 2014, Griefahn et al 2016), compression bands (Starrett & Cordoza 2013, Borda and Selhorst 2016), and Graston (Heinecke et al 2014), it appears there is only one peer reviewed article documenting application of a lacrosse ball as a form of instrumented soft tissue technique applied at the tendo-Achilles region (Borda & Selhorst 2016). In a clinical case study investigating change in range, Borda & Selhorst (2016) describe using a lacrosse ball technique directed at the AT, however, in the technique described by Borda & Selhorst (2016), the participant was treated with a combination of lacrosse ball massage and “compression tack flossing”, and did not attempt to measure changes in tissue excursion.

4.2 Internal validity

Given the near absence of previous studies investigating changes in AT excursion and ADF range following soft-tissue technique, this study was designed as an exploratory study, with extensive pilot work undertaken to develop procedures. For example, there appear to be no other described protocols for assessment of AT in standing during active movement and therefore this protocol needed development prior to commencing data collection. A total of ~7hrs across five sessions were undertaken by the investigators developing the scanning protocol to achieve satisfactory image quality. Scanning while a participant is actively moving is technically challenging, the AT is small, just 14.4 ± 1.4 mm across in males and 13.3 ± 1.0 mm in females (Mello et al 2006), and an L15-7io Linear Transducer with a small cross-section was used. One
experienced sonographer (S.A) performed all scanning in this study, thus controlling for inter-rater differences in protocol or technique. Even though the sonographer was experienced, it was technically challenging to achieve the scan while maintaining contact of the transducer over the scanning point. Not every trial was of acceptable quality, in some participants, 10% of the overall proportion of trials were rejected and had to be repeated. Additional measurement trials might introduce a possible treatment effect; however, most of the rejected trials occurred pre-intervention thereby mitigating possible treatment effect associated with repetitions. Further, as recommended by Gabin (2008) and Hanson et al (2015), the design included extensive warm up prior to data collection to ensure a ‘stable’ state of the soft-tissues.

4.2.1 Scanning while undertaking a squat

Although scanning of the AT during active movements has previously been investigated, it appears that previous studies have used non-weight-bearing movements (Pearson et al 2013, Davies 2014). A strength of this study was the use of functional weight-bearing movement to assess the sliding layers of the tendo-Achilles region. Using a weight-bearing and functional measure more closely resembles the excursion of the AT during activities of daily living (walking, running, jumping) compared to unloaded positions (Whitting et al 2013).

4.2.2 Performance of the WBLT

A rigorous approach to the performance of the WBLT was undertaken, and the observed reliability and associated measurement error is similar in magnitude to others (Powden et al 2015). Several controls to decrease bias in outcome measurement were undertaken. Firstly, when performing the WBLT, participants were not permitted to stabilise themselves by holding onto anything, potentially resulting in limited full ADF
range due to participants not having assistance with balance. Secondly, participants were also required to position their feet facing forward so that there was consistent foot positioning between measures. Dorsiflexion can increase by up to 10 deg depending on subtalar position (Tiberio et al 1989, Woodburn 1991), and there was no attempt to position the foot into a ‘subtalar neutral’ position, the foot position was standardised to maintain a reliable measure of ADF (Tiberio et al 1989, Woodburn 1991). Similarly, the positioning of the squat performed during scanning was also standardised.

4.2.3 Achilles tendon excursion

Achilles tendon excursion was measured relative to the subcutaneous fascia. Potentially the intervention may have affected the sliding ability of the subcutaneous fascia with adjacent tissue increasing movement of the subcutaneous fascia. Therefore, the magnitude for AT excursion is probably a conservative estimate of the true effect in cases where the subcutaneous fascia may have also increased sliding following the intervention. The limitations of the measurement approach preclude being able to distinguish changes in excursion between these two tissues.

4.2.4 Weight-bearing lunge test vs. extended knee position

Testing ADF with the knee extended engages the effect of both the gastrocnemius and soleus muscles on ADF (Ekstrand et al 1982, Munteanu, Strawhorn et al 2009). However, to avoid this, here the WBLT was performed in a flexed knee position.

4.3 Limitations

Several limitations are apparent in the design of this study. Firstly, as an exploratory study a small number of participants were recruited. However, a sample of 6 participants was adequate for the purpose of hypothesis generation and development of measurement protocol. The data extraction for AT excursion was time intensive, with
90 scans taking approximately 9 hours to extract and process. Other assessment
algorithms are available (Lee et al 2008, Arndt et al 2012, Pearson et al 2013) and may
be less time intensive. In the scope of this study, the extensive time involved in the
analysis limited participant numbers. Considering the interesting findings, further
investigation is needed, and an increase in funding to improve resources available for
data processing, or alternatively, the use of more automated measurement of excursion
may enable larger samples in future studies.

Secondly, extracting data from active movements was technically challenging as the
USI cine-loops needed to have a smooth linear motion of the AT, and this was
challenging to achieve as the participant is controlling the movement and the
sonographer has to dynamically adapt to the changing angles of the scanning point
throughout the movement of the squat. Even with extensive practice, this skill can be
challenging.

Thirdly, it has been theorised that deformation of the AT differs at different areas of the
tendon creating various points of increased compression and stress (Obst et al 2014).
When selecting the scanning point for the study presented, areas of high movement
were considered throughout the development of the scanning process but were rejected
as it was too difficult to produce high-quality cine-loops that could be processed
through the software (Motion 6, Matlab, USA). Specifically, access to a scanning point
for which transducer contact could be maintained throughout the movement of the squat
was difficult. An area of high AT displacement could not be used as a scanning point,
instead an area on comparatively less displacement was selected to enable sufficient
transducer contact throughout the full range of active functional movement.

Finally, due to technical limitations of the software used to extract AT excursion, only
the superficial half of the AT was assessed. To maintain the region of interest within
the AT, only the superficial half could be assessed due to the vertical movement that occurred in the cine-loops from active movement. Arndt et al (2012) investigated healthy tendons (n=9) during passive dorsiflexion and found differences in displacement between deep, middle and superficial parts of the AT. Arndt et al (2012) reported that in all participants, there was greater displacement in the deep layer than in the middle and superficial layers. Greater deformation has also been observed using USI in conjunction with elastography technique in the deeper layers of the AT than the superficial layer (Chimenti et al 2015).

This study was designed to investigate changes in ADF following application of a novel percussive soft tissue technique and undertake a preliminary exploration of soft-tissue sliding as one possible mechanism. As such, the findings of this study are not intended to directly inform clinical practice.

4.5 Suggestions for further research

Further work should include establishing normative data for soft tissue excursion measures, and comparing the influence of a range of soft-tissue techniques applied to the tendo-Achilles region in people with soft-tissue dysfunction. On the basis of the findings here, a larger study employing a randomised design with control group, with a greater number of time points is needed to further investigate mechanisms, and to assess generalisability of the effect.

4.6 Conclusion

In summary, this study demonstrates that a percussive soft tissue technique applied to the tendo-Achilles region has the potential to increase ADF and influence AT excursion. However further research, such as a larger, randomised controlled trial is needed in order to fully examine the effect of this intervention.
Supplementary Material

S1 Supplementary video of percussive soft tissue technique.

File name: Soft tissue percussion technique.

Available from: https://youtu.be/vnQ7sNEQ8ek
References


http://dx.doi.org/10.1016/j jbmt.2016.05.011


http://dx.doi.org/10.1016/j jbmt.2015.12.004


extended is reliable. Journal of Science and Medicine in Sport, 12(1), 54-59.


Section III: Appendices
Appendix A: Summary table of soft tissue techniques to improve dorsiflexion
<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Aims (relating to DF)</th>
<th>Study design</th>
<th>Blinding</th>
<th>Participants (n)</th>
<th>Gender (n)</th>
<th>Age (y) (mean±SD)</th>
<th>Symptomatic Treatment</th>
<th>Comparison</th>
<th>Type of dorsiflexion</th>
<th>Outcome measure/s/ Measurement tools</th>
<th>Time</th>
<th>Results</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vicenzino et al. (2006)</td>
<td>Evaluate the effect of WB and NWB MWM techniques of the talocrural joint DF</td>
<td>RCT CO</td>
<td>Y</td>
<td>16</td>
<td>F=8 M=8</td>
<td>19.8 ± 2.3 Y</td>
<td>WB MWM (4 x4 rep)</td>
<td>Own control</td>
<td>AWBDF</td>
<td>DF (WBLT)</td>
<td>Immediately</td>
<td>WB MWM d= 0.4, NWB MWM d= 0.3</td>
<td>WBLT</td>
</tr>
<tr>
<td>Reid et al. (2007)</td>
<td>Evaluate the effect of a ankle joint MWM on DF</td>
<td>R CT CO</td>
<td>Y</td>
<td>23</td>
<td>F=15 M=8</td>
<td>25.6 ± 9 Y</td>
<td>WB MWM (2x 10 rep)</td>
<td>Own control</td>
<td>AWBDF</td>
<td>DF (WBLT )</td>
<td>Immediately</td>
<td>WB MWM p=0.019</td>
<td>WBLT</td>
</tr>
<tr>
<td>Beazell et al. (2012)</td>
<td>Evaluate the effect of proximal or distal tib-fib joint manip. on ankle DF</td>
<td>R CT</td>
<td>Y</td>
<td>43</td>
<td>F=3 M=7</td>
<td>25.6 ± 7.6 Y</td>
<td>Prox. tib-fib joint manip.</td>
<td>Control group</td>
<td>AWBDF</td>
<td>DF (WBLT )</td>
<td>Immediately</td>
<td>Across time P=.82</td>
<td>WBLT</td>
</tr>
<tr>
<td>Cruz-Diaz, et al. (2015).</td>
<td>Evaluate the effect of mob.of the ankle jnt.</td>
<td>RCT</td>
<td>Y</td>
<td>90</td>
<td>F=7 M=7</td>
<td>19 -44 Y</td>
<td>ankle joint mob.</td>
<td>Control group</td>
<td>DF</td>
<td>immediately 6month</td>
<td></td>
<td>WBLT</td>
<td></td>
</tr>
<tr>
<td>Marrón-Gómez, Rodriguez-Fernández et al. (2015)</td>
<td>To compare the effect of MWM &amp; HVLA to the ankle on DF</td>
<td>R CT</td>
<td>Y</td>
<td>52</td>
<td>F = 21 M=31</td>
<td>20.7± 3.4 Y</td>
<td>WB MWM (1 x 10 reps)</td>
<td>Placebo group</td>
<td>AWBDF</td>
<td>DF (WBLT)</td>
<td>Immediately, 10 min, 24 h 48 h</td>
<td>WB MWM d=0.63 HVLA d=0.44</td>
<td>Placebo</td>
</tr>
<tr>
<td>Study (Year)</td>
<td>Aims</td>
<td>Study design</td>
<td>Blinding</td>
<td>participants</td>
<td>Gender (n)</td>
<td>Age (y) (mean±SD)</td>
<td>Symptomatic Treatment</td>
<td>Comparison</td>
<td>Type of dorsiflexion</td>
<td>Outcome measures/Measurement tools</td>
<td>Follow up</td>
<td>Results</td>
<td>Main findings</td>
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<tr>
<td>Hoch et al. (2011)</td>
<td>Examine the effects of a single joint mobil on DF of ank of pp with CAI</td>
<td>RCT</td>
<td>N</td>
<td>20</td>
<td>F=11 M=9</td>
<td>23.4 ±5.4 years</td>
<td>CAL</td>
<td>joint mobil. (2 x 2min )</td>
<td>Control group</td>
<td>AWBDF</td>
<td>DF (WBLT)</td>
<td>immediately</td>
<td>jnt mob. p&lt;0.01</td>
</tr>
<tr>
<td>Hoch et al., (2012)</td>
<td>Examine the effects of 2wk AP joint mobil interv of an k on DF of pp with CAI</td>
<td>Prospective cohort design</td>
<td>N</td>
<td>12</td>
<td>F=6 M=6</td>
<td>27.4±4.3</td>
<td>CAL</td>
<td>AP joint mobil (2 x 2min ) (6 x over 2wk)</td>
<td>Own control</td>
<td>AWBDF</td>
<td>DF (WBLT)</td>
<td>Immediately</td>
<td>24-48hrs 1wk</td>
</tr>
<tr>
<td>de Souza, Venturini et al. (2008)</td>
<td>Determine the correlation b/w force and displacement during AP joint mobil of ank on DF</td>
<td>Exploratory, methodological study</td>
<td>N</td>
<td>25</td>
<td>F=15 M=10</td>
<td>25.08 ± 3.01</td>
<td>N</td>
<td>AP joint mobil of ank</td>
<td>Own control (other limb was control)</td>
<td>ANWBDF</td>
<td>DF</td>
<td>Immediately</td>
<td>jnt mob. p=0.35</td>
</tr>
<tr>
<td>Gilbreath et al. (2014)</td>
<td>Within-subject repeated measures design with a single cohort</td>
<td>Within-subject repeated measures design with a single cohort</td>
<td>N</td>
<td>11</td>
<td>F=6 M=5</td>
<td>21.5 ± 2.2</td>
<td>CAL</td>
<td>TC MWM (3ses over 1wk)</td>
<td>Own control</td>
<td>AWBDF</td>
<td>DF (WBLT)</td>
<td>Immediately</td>
<td>Post final ses 24-48 hr</td>
</tr>
<tr>
<td>Fryer et al. (2002)</td>
<td>To investigate whether 1 HVLA to the T/C joint impacts DF</td>
<td>RCT</td>
<td>Y</td>
<td>41</td>
<td>F=26 M=15</td>
<td>18-40, (mean age 22).</td>
<td>N</td>
<td>T/C HVLA (1 x1rep)</td>
<td>CG</td>
<td>PNWDF</td>
<td>Passive DF</td>
<td>Immediately</td>
<td>T/C HVLA Compared with CG p = .000</td>
</tr>
<tr>
<td>Collins et al. (2004)</td>
<td>Investigate how MWM DF &amp; pain following LAS</td>
<td>RCT</td>
<td>Y</td>
<td>16</td>
<td>F=8 M=8</td>
<td>28.25±9.33 grade II LAS</td>
<td>WB MWM (3sets x10rep)</td>
<td>CG</td>
<td>MWM</td>
<td>AWRFD</td>
<td>DF (WBLT)</td>
<td>Immediately</td>
<td>MWM p = 0.013 Placebo p = 0.202 CG p = 0.208</td>
</tr>
<tr>
<td>Green et al. (2001)</td>
<td>Compare the effect of an AP T/C mob on the + RICE protocol with the effect of the RICE protocol alone on pain , DF, &amp; gait</td>
<td>RCT</td>
<td>Y</td>
<td>41</td>
<td>F= M=</td>
<td>acute AIS</td>
<td>AP T/C mob +RICE</td>
<td>CG</td>
<td>PNWDF</td>
<td>DF (Lidcombe template)</td>
<td>Immediately</td>
<td>AP T/C mob +RICE p&lt;0.01</td>
<td>No significant change observed in DF</td>
</tr>
<tr>
<td>Study (Year)</td>
<td>Aims</td>
<td>Study design</td>
<td>Blinding</td>
<td>participants</td>
<td>Gender (n)</td>
<td>Age (y) (mean±SD)</td>
<td>Symptomatic Treatment</td>
<td>Comparative Treatment</td>
<td>Type of dorsiflexion</td>
<td>Outcome measure/s/ Measurement tools</td>
<td>Follow up</td>
<td>Results</td>
<td>Main findings</td>
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<tr>
<td>Pellow et al. (2001)</td>
<td>Determine the efficacy of adjusting the ankle in symptomatic pop</td>
<td>comparative</td>
<td>Y</td>
<td>30</td>
<td>F=11 M=19</td>
<td>24.9</td>
<td>AIS (grade I &amp; grade II)</td>
<td>MSA</td>
<td>Placebo Group</td>
<td>PNWBDF</td>
<td>DF (prone)</td>
<td>Immediately 1mo</td>
<td>Placebo &amp; DF T1 p= 0.603 Placebo &amp; DF T2 p= 0.050 Placebo &amp; DF 1mo p=0.001</td>
</tr>
<tr>
<td>Andersen et al. (2003)</td>
<td>To determine the effects of an HVLA to the T/C joint in a LAS pop on ankle ROM</td>
<td>RCT</td>
<td>Y</td>
<td>52</td>
<td>F=29 M=23</td>
<td>22</td>
<td>LAS</td>
<td>T/C HVLA (1 xrep)</td>
<td>CG</td>
<td>PNWDF</td>
<td>DF (Supine)</td>
<td>Immediate</td>
<td>T/C HVLA p= 0.707</td>
</tr>
</tbody>
</table>

Notes: AWBDF=active weight-bearing dorsiflexion; ANWBDF=active non-weight-bearing dorsiflexion; PNWBDF=passive non-weight-bearing dorsiflexion; CO=cross-over; d=day; d=Cohen’s effect size; NWB=non-weight-bearing; WB=weight-bearing; MWM=movement with mobilisation; rep=repetition; RCO=randomised cross-over; mo=month; manip=manipulation; tib-fib=tibiofibular; T/E=time effect; AP=anteroposterior; ank.=ankle; b/w=between; T/C=talocrural; ses=session; CG=control group; LAS=lateral ankle sprain; Y=yes; N=no; RICE=rest, ice, compress, elevate; jnt=sjoint; pp=participant; prox.=proximal; dist.=distal; mob=mobilisation; HVLA=high velocity low amplitude thrust; T=treatment; intvn=intervention; AIS=ankle inversion sprain; MSA=mortise separation adjustment; PDF=passive dorsiflexion
Appendix B: Results for Downs and Black quality appraisal checklist
### Results for Downs and Black checklist

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1. Is the hypothesis/aim/objective of the study clearly described?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2. Are the main outcomes to be measured clearly described in the Introduction or Methods section?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3. Are the characteristics of the patients included in the study clearly described?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4. Are the interventions of interest clearly described?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5. Are the distributions of principal confounders in each group of subjects to be compared clearly described?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6. Are the main findings of the study clearly described?</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7. Does the study provide estimates of the random variability in the data for the main outcomes?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8. Have all important adverse events that may be a consequence of the intervention been reported?</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Have the characteristics of patients lost to follow-up been described?</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10. Have actual probability values been reported (e.g. 0.035 rather than &lt;0.05) for the main outcomes except where the probability value is less than 0.001?</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**External validity**
<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited?</td>
<td>0</td>
</tr>
<tr>
<td>12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited?</td>
<td>0</td>
</tr>
<tr>
<td>13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?</td>
<td>0</td>
</tr>
</tbody>
</table>

**Internal validity – bias**

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Was an attempt made to blind study subjects to the intervention they have received?</td>
<td>1</td>
</tr>
<tr>
<td>15. Was an attempt made to blind those measuring the main outcomes of the intervention?</td>
<td>0</td>
</tr>
<tr>
<td>16. If any of the results of the study were based on “data dredging”, was this made clear?</td>
<td>1</td>
</tr>
<tr>
<td>17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?</td>
<td>1</td>
</tr>
<tr>
<td>18. Were the statistical tests used to assess the main outcomes appropriate?</td>
<td>1</td>
</tr>
<tr>
<td>19. Was compliance with the intervention/s reliable?</td>
<td>0</td>
</tr>
<tr>
<td>20. Were the main outcome measures used accurate (valid and reliable)?</td>
<td>0</td>
</tr>
</tbody>
</table>

**Internal validity – confounding (selection bias)**

101
21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?

22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?

23. Were study subjects randomised to intervention groups?

24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?

25. Was there an adequate adjustment for confounding in the analyses from which the main findings were drawn?

26. Were losses of patients to follow-up taken into account?

Power

27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.
Appendix C: Categorisation of Quality Index Scores described by Simpson et al. (2015).

<table>
<thead>
<tr>
<th>Total Modified Downs and Black checklist Score (/28)</th>
<th>Percentage</th>
<th>Quality Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 +</td>
<td>75%+</td>
<td>Strong</td>
</tr>
<tr>
<td>14-20</td>
<td>50-74%</td>
<td>Moderate</td>
</tr>
<tr>
<td>7-13</td>
<td>25-49%</td>
<td>Limited</td>
</tr>
<tr>
<td>&lt;7</td>
<td>&lt;25%</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Appendix D: TIDier checklist
The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

<table>
<thead>
<tr>
<th>Item number</th>
<th>Item</th>
<th>Where located **</th>
<th>Other † (details)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRIEF NAME</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Provide the name or a phrase that describes the intervention.</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Describe any rationale, theory, or goal of the elements essential to the intervention.</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.</td>
<td>69-70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHO PROVIDED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WHERE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.</td>
<td>69</td>
<td></td>
</tr>
</tbody>
</table>

WHEN and HOW MUCH
8. **Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.** TAILORING

9. **If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.** MODIFICATIONS

10. † **If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).** HOW WELL

11. **Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.** N/A

12. † **Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.** N/A

<table>
<thead>
<tr>
<th><strong>Authors</strong> use N/A if an item is not applicable for the intervention being described. Reviewers – use '?' if information about the element is not reported/not sufficiently reported.</th>
</tr>
</thead>
</table>

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).

† If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see BMJ 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a randomised trial is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of Item 5 of the CONSORT 2010 Statement. When a clinical trial protocol is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of Item 11 of the SPIRIT 2013 Statement (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).
Appendix E Instructions given during squats
• Do you feel like you have reached the bottom of the squat?
• Can you go further?
• Slow the squat down
• Speed up the squat at the end
Appendix F: Considerations to maintain tissue type during data extraction
The region of interest was selected and defined as three adjacent, similar sized boxes containing only the AT. The results were viewed, and the velocity graph was assessed for any dropouts. Then, a movie representing the visual activity of Motion 6 was reviewed. The 3s movie showed the original cine-loop with three overlapping boxes representing cross correlation image analysis. The Blue box represented the region of interest, the Yellow box signified the average movement in the region, and the White box represented the average movement of all of the regions. The movie was reviewed to ensure all boxes stayed within the region of interest, or the cause of vertical dropout if identified in the results. The presence of any of the boxes straying into other tissue, or vertical dropout without reason, led to a reanalysis of the cine-loop.
Appendix G: Ethics Approval Letter
22.10.15

Dear Demelza,

Your file number for this application: 2015-1009

Title: A prospective case series of the immediate and long term effects of a myofascial technique on the sliding surface movement of the Achilles tendon excursion as observed using ultrasound imaging.

Your application for amendments to be allowed to be made to the above ethics application has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 14.10.15
Finish date: 24.4.16

Please note that:

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

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

You may now commence your research according to the protocols approved by UREC.

We wish you every success with your project.

Yours sincerely,

[Signature]

Sara Donaghey
Deputy Chair, UREC

cc: James Hutchinson
Cynthia Almeida
Appendix H: Participant Information Sheet
PARTICIPANT INFORMATION SHEET

My name is Demelza Scott-Weekly (DSW). I am currently enrolled in the Master of Osteopathy degree at Unitec New Zealand. I’m seeking your help in meeting the requirements of a research project which forms a substantial part of this degree.

What is the project about? We are investigating how a myofascial technique (a particular form of soft tissue massage) applied to the calf may change ankle flexibility.

What will I be required to do? You will be asked to attend three 30-minute sessions over the space of 8 days (we will schedule appointments with you every second day) at Clinic 41. You’ll need to wear loose fitting clothing so that your legs are visible from the knees down.

What will happen at each session?

At each session the researcher (DSW) will gather some flexibility measures of your ankle and record some measures using an ultrasound image of your leg muscles. You will then have the myofascial technique applied to the back of your calf and the measures will then be repeated. During the single leg squat, a video recording of your lower limb will be made – the video will not include your face.

The myofascial technique involves mild compression of your calf tendon and muscle and may feel slightly uncomfortable but not painful. If you experience any pain we’ll stop or modify the technique. The myofascial technique will be applied by a registered osteopath.

If I change my mind about participating can I withdraw?

Yes, you are free to withdraw from the research at any time up to and including data collection, and may withdraw all of your data from the study at any point up until 5pm on the next business day following the completion of your final data collection point.

Can I get a copy of the research findings?

Yes, if you’d like a plain language summary of the research findings please let us know by email: dcscottweekly@gmail.com

Is the information I give confidential?


We will ensure that the information you have given is kept confidential. Raw data collected during the study will be anonymised and will be stored securely so that only the principal researcher and research supervisors can access it. Raw copies of the data will be stored for five years following the study and will then be destroyed.

**How do I give consent?**

This information will be repeated to you before the commencement of the study with an opportunity for you to clear any doubts or concerns. Both verbal and written consent will be gained from you and it is taken as an indication that you consent to participate in this study.

**Who do I contact with questions or concerns?**

If you have any queries about the research, you may contact one of us at any time:

Primary researcher:

Demelza Scott-Weekly

Department of Community and Health Services (Osteopathy)

Tel: 022 674 0683

Email: dcscottweekly@gmail.com

Principal Supervisor:

Rob Moran

Department of Community and Health Services (Osteopathy)

Tel: 09 815 4321 ext 8197

Email: rmoran@unitec.ac.nz

**UREC REGISTRATION NUMBER: 2015-1009**

This study has been approved by the UNITEC Research Ethics Committee from 4.5.15 to 4.5.16. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix I: Participant Consent Form
Participant Consent Form

**Research Project Title:** A prospective case series of the immediate and long term effects of a myofascial technique on the sliding surface movement of the Achilles tendon excursion as observed using ultrasound imaging

I have had the research project explained to me and I have read and understand the information sheet given to me.

I have had an opportunity to ask questions and have had them answered. I understand that neither my name nor the name of my organisation will be used in any public reports, and that I may withdraw from the research at any time up to and including data collection, and may withdraw all of your data from the study at any point up until 5pm on the next business day following the completion of your final data collection point.

I understand that all the information and data gathered from me is confidential and the only persons that have access to the data gathered are the researcher and their supervisors.

I understand that there will be a video recorded of me preforming a single leg squat, but that it will not show my face.

I also understand that all the information and video recordings will be stored in a locked secure cabinet for 5 years that only the researcher and her supervisors have access to.

I understand that I can see the finished research document if I write a written request to dcscottweekly@gmail.com.

I have had time to consider everything and I give my consent to be a part of this project.

Participant Name: …………………………………………………………………….......

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

Project Researcher: ……………………………. Date: ……………………………

**UREC REGISTRATION NUMBER: 2015-1009**

This study has been approved by the UNITEC Research Ethics Committee from 4.5.15 to 4.5.16. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Full name of author: Danielle Scott-Weekly

Full title of thesis/dissertation/research project: Short-term influence of a percussive soft-tissue technique on active weight-bearing dorsiflexion in Achilles tendon excursion: A case series

Department of: Osteopathy

Degree: Master

Year of presentation: 2016

EITHER:

(1) I agree to my thesis/dissertation/research project being lodged in the Unitec Library (including being available for inter-library loan), provided that due acknowledgement of its use is made. I consent to copies being made in accordance with the Copyright Act 1994.

I agree that a digital copy may be kept by the Library and uploaded to the institutional repository and be viewable worldwide.

OR:

(2) I wish to apply for my thesis/dissertation/research project to be embargoed for a limited period as per Academic Policy 12 Conduct of Student Research, Guideline 12/8.

Reason for embargo: _________________________________________________________________

Supervisor Approval: ________________________________________________________________

Dean, Research Approval: __________________________________________________________

Embargo Time Period: ______________________________________________________________

Signature of author: ________________________________________________________________

Date: 24/8/16