Immediate Effect of Two Myofascial Interventions on Navicular position, Great Toe Extension and Balance Measures in Asymptomatic Subjects with Pronation – Placebo Controlled

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I, Jeff Puttergill, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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DEDICATION

I dedicate this work to my loving parents, Greg and Julie for their patience and support, without it, I would not be the man I am today.

ARBITRATUS NUNQUAM CALAMITUS AUSPEX.

I thank God for the blessings and friendships I have received along the way.

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ABSTRACT

Background:

Myofascial therapies are widely researched with regards to their effects on pain, disability and range of motion. The benefits of such therapies are attributed to the mechanical changes that myofascial therapies are proposed to have on the fascial and myofascial structures. Breakthrough imaging and laboratory techniques, have allowed the in vivo study of these structures, resulting in new hypotheses regarding the roles that connective tissues might play in proprioception.

Objectives:

The purpose of this investigation was to assess the effects of two myofascial therapies, in terms of immediate changes in navicular pronation, great toe extension measurements and balance tests, as indicated by the postural stability (eyes open and closed) and limits of stability tests. Pre-, post-intervention analysis was used to determine if there were significant changes between the groups.

Aim:

The myofascial interventions aimed to reduce myofascial restriction and adhesions, within the plantar and crural fasciae's of individuals with bilateral pronation.

Methods:

The study recruited 45 subjects with bilateral pronation (2 or more degrees) and randomly allocated them into a placebo ultrasound, ischaemic compression or myofascial release group. Each subject underwent a case history, physical examination, foot, ankle and knee regional examinations, as well as screened for contraindications. A blinded assistant examiner helped measured and record the baseline measurements for navicular position and great toe extension, using a standard two arm goniometer. The researcher then tested participants for postural stability (eyes open, eyes closed) and limits of stability, on the Biosway Portable Balance System. Subjects were then examined and treated bilaterally, for myofascial restrictions in the foot, lower leg and ankle, related or unrelated to the pronation

present. Pre- and post-intervention measurements were recorded within a 20 minute window immediately before and after the relevant intervention.

Statistical analysis:

Repeated measures ANOVA testing was used to compare the rate of change (between pre- and post-intervention measurements) amongst the three groups, and a *p*-value <0.05 was considered statistically significant. Post hoc Bonferroni adjusted tests were done to compare all pair wise groups, as well as identify trends between groups.

Results and Discussion:

The data showed that both myofascial groups, significantly improved in postural stability (eyes closed) overall, post hoc testing showed the ischaemic compression group (p=0.004) and myofascial release group (*p*=0.031), compared to changes in the placebo ultrasound group.The overall changes were predominantly found in the anterior-posterior axes, with significant improvements in ischaemic compression (*p*=0.007) and myofascial release group (*p*=0.053) axes compared to placebo.

For the other outcome variables, statistically significant treatment effects were not consistant bilaterally between the groups. Significant (*p*=0.051) time*group differences for changes in right navicular position. Post hoc testing revealed a borderline significant (*p*=0.056) improvement in pronation for the myofascial release group in comparison to the ischaemic compression group, which on average got worse. With regards to passive non-weight bearing great toe extension left, significant (*p*=0.067) improvements for the ischaemic compression group were shown compared to placebo, although this was not consistent for all the great toe extension tests. A borderline significant (*p*=0.059) time*group effect for postural stability (eyes open) medial-lateral test was obtained. Post hoc Bonferroni adjusted testing showed a non-significant (*p*=0.063) correlation between the myofascial release group and placebo ultrasound group.

Conclusion:

The results of this study, rejects the Null hypothesis for changes in balance measurements and suggests that both myofascial interventions had a significant positive outcome for

postural stability, compared to placebo. The postural stability (eyes closed) test gave an indication of positive or negative changes in centre of pressure displacement, about the centre of gravity. It is noted that the sham ultrasound, used as a placebo intervention may have produced a treatment effect and is therefore not a reliable placebo measure for this type of investigation.

Key words

Myofascial therapy, pronation, great toe extension, postural stability, limits of stability

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DEFINITIONS

Acute: A phase or period of time, from the initial event up to four weeks. Usually describes a traumatic event or period of heightened symptoms.

Axial Skeleton/System: The skeletal anatomy related to the head, neck, spine, rib cage and sacrum.

Base of Support: The limits to which a subject can orientate their centre of pressure, before having to step.

Baseline: The initial, pre-intervention measurement or mean

Balance Testing: Postural stability (eyes open and closed) as well as limits of stability tests used in the present investigation.

Bilateral: This refers to either both limbs or both sides.

Biotensegrity: The model used to explain the functional mechanics of an organism in terms of compressive and tensional elements.

Body Mass Index (BMI): A calculation using the height and weight of an individual. BMI is generally used to gauge the level of obesity and risk of disease. This is calculated using the following formula:

BMI = (weight.kg)/(height.m)^2

Congenital: Disease or deformity, present at child birth.

Calcaneal Valgus: The presentation of the calcaneus where there is concavity in the achilles tendon to the lateral direction. The inferior part of the calcaneus is more lateral than the superior part.

Central Nervous System: The neurons in the spine, brainstem and brain.

Centre of Gravity: The reference point on the force platform which is thought to be point at which a body's centre of pressure is in the most neutral position, relative to the forces of gravity acting on the body.

Centre of Pressure: The resultant point of pressure, a body exerts onto the ground. This is calculated from pressure sensors located on a force platform.

Chronic: A phase or period of time, after the acute setting. This phase is prolonged and has no definitive end point.

Crural Fascia: The connective tissue and myofascia associated with the posterior leg region.

Distal: The relation of a part or parts, being closer to the edges or periphery.

Dorsum: The superior, non-weight bearing surface of the foot.

Extracellular Matrix (ECM): The space between the cells of the body, consisting of collagen, elastic fibres, as well as ground substance and non-collagenous link proteins.

Extrinsic Muscles: Muscles not originating from the area of reference or relevant joint.

Fascial Net: The tensional system which connects every cell of the body.

Fascia: The physical architecture of cellular connection in the human body.

Forefoot Abduction: The movement of the forefoot from medial to lateral in the horizontal plane.

Gait: The different phases and biomechanics involved in walking. Gait is usually explained with regards to a cycle, between steps on the same foot.

Great Toe: The largest and most medial of the phalanges

Ground Reaction Force: The resultant force, which opposes the weight and gravitational accelerations of a body on the ground.

Ground Substance: The semi fluid viscous substance, bathing the fibres in the ECM. The ground substance consists of glycosaminoglycans, proteoglycans and binds to water

Histological Study: The study of biology at very high resolutions, in order to view cells and tissue with regards to their physical appearance

Inter-Class Coefficient: Indicates how reliable a variable or test is with regards to inter- or intra-rater reliability.

Ischaemic Compression: Also referred to as pressure release. Described as the technique used in the present investigation whereby a static compressive type pressureis used to treat myofascial restrictions.

Lamellae/s: A sheet of parallel or undulating collagen fibres, usually arranged in many layers, varying in direction.

Mean: A calculation of the average value within a defined group of values.

Mechanoreceptors: Specialized nerve endings or proprioceptors which include encapsulated and unencapsulated nerve endings, capable of receiving and transmitting different forms of mechanical stimuli to the central nervous system.

Medial Arch: This is the bridge formed between the bones of the foot, from the first metatarsal head to the talus and calcaneus.

Myofascial Therapies: Forms of manual therapies which generally involve the slow working of the soft tissues of the body, including muscles and connective tissue.

Myofascial Release: The techniques used in the present investigation, where a slow, deep tangential force is applied to the areas of myofascial restriction.

Navicular Position: The relative position of the navicular in degrees in relation to the achillies tendon and first metatarsal head. The measurement of the navicular position indicates the amount of pronation or supination present at the navicular.

Neuropathy: Neurological dysfunction, disorder of disease affecting balance or proprioception.

Neurophysiological: The reflex and uncontrolled regulation of the body, in relation to its neurons.

Nomenclature: This is the explanation, classifications and current definitions for a topic or term.

Outcome Measures: Pre- and post-intervention measurements of navicular position, great toe extension, postural stability (eyes open and closed), as well as limits of stability.

Postural Equilibrium: A balanced state of forces acting on a body in response to postural sway and stability.

Plantar: The surface of the foot which is in contact with the ground.

Plantar Fascia: The connective tissue sheets bridging the arches of the feet and supporting the plantar foot muscles.

Power: Indicates the strength of the investigation in being able to reject or accept a hypothesis.

Pressure Release: This is used synonymous with ischaemic compression to describe the myofascia technique where pressure is used to change specific outcomes.

Proprioception: The conscious and subconscious ability of the body to receive and transmit sensory stimuli, from specialized afferent nerve fibres to the central nervous. The central nervous system then uses this data to elicit the appropriate motor responses, via efferent motor nerves, to the muscle fibres for contraction or relaxation.

Proprioceptor: Specialized nerve endings used for proprioception, gathering and transmitting sensory stimuli to the central nervous system for processing.

Pronation: The presentation of a foot posture in which the medial longitudinal arch has dropped, leg is internally rotated and the calcaneus has moved laterally. Pronation is usually measured in terms of navicular position and drop.

Prone: The position of a subject, where they are lying on their stomach.

Proximal: The relation of a part or parts, to being more central or at the origin.

Saggital Plane: A vertical plane (y-axis) in the anterior and posterior direction.

Sarcomere Contraction: The shortening of muscle fibres which results in muscle contraction, specific to the actin and myosin muscle fibres.

Stability Index: The resultant distance or deviation of a body's centre of pressure, from the proposed centre of gravity, over time.

Standard Deviation: Represents how far apart, on average, values within a group of values differ from each other. This is calculated by the following formula:

standard deviation^2 = (Sum of squares)/(n-1)

Substrate: The base parts, which together make up and represent the whole.

Supine: The position of a subject, where they are lying on their back.**Sway Index:** The average change in the centre of pressure trajectories of a body over time. Used to determine how unsteady a body is.

Tensegrity Structures: Structures involving tensional and compressive elements, which are constantly in equilibrium and distributing forces throughout the whole structure.

Unilateral: Indicating a single limb or side.

LIST OF ABBREVIATIONS

AP	Anterior-posterior
BMI	Body mass index
CNS	Central nervous system
DUT	Durban University of Technology
ECM	Extracellular Matrix
GTE	Great toe extension
ICC	Inter-class correlation coefficient
LS	Limits of stability
ML	Medial-lateral
NWB	Non weight bearing
PNF	Proprioceptive neuromuscular facilitation
PS	Postural stability
SMS	Short message service
WB	Weight bearing

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Myofascial therapies are generally hands on therapies involving the treatment and or manipulation of the soft tissues of the body. These therapies have been used by practitioners to treat myofascial pain, speed up healing and improve function, although the exact mechanisms by which this is achieved has been shown to be theoretical, anecdotal and controversial (Fernández-de-las-Peñas et al. 2006; Remvig 2008; Simmonds, Miller and Gemmell 2012). Included in these proposed mechanisms are possible changes is proprioception, immediately after the application of myofascial therapies (Schleip 2003a; b; Stecco et al. 2010a)

Fascia is the connective tissue of the body and is a target of many myofascial therapies. Histological evidence has shown that fascial tissues contain numerous mechanoreceptors, previously thought to be exclusive to the joint and muscle tissue (Scheip 2003a; Benjamin 2009; Stecco et al. 2010). Similarly, fascia was known for connecting the different parts of the body together and as such was thought to only provide mechanical support (Benjamin 2009). Renewed interest into the morphology, physiology and pathophysiology of fascia, has shed much light onto this previously overlooked structure (Schleip et al. 2006; Benjamin 2009; Liptan 2010; Stecco et a. 2011). As a result, leading researchers have theorised the roles that fascia plays in proprioception, but according to Simmonds, Miller and Gemmell (2012), the exact mechanism by which this is achieved is still controversial (Schleip 2003a; b; Van der Wal 2009; Stecco et al. 2010a).

Proprioception describes the process and neural pathways by which sensory input, received by specialised nerve endings, is conveyed to the spinal cord and central nervous system (CNS) for processing (Lephart and Fu 2000: xxii; Van der Wal 2009). The CNS makes use of this sensory information to elicit and coordinate appropriate motor responses, for example: moving an arm or balancing on one foot (Lephart and Fu 2000: xxii; Van der Wal 2009). The specialised nerve endings that are able to sense changes in mechanical stimuli are called

mechanoreceptors (Schleip 2003a; Stecco et al. 2010a). The mechanoreceptors are classically known to be situated in joints and muscles (Van der Wal 2009).

This research tests the more recent evidence regarding the immediate effect that myofascial therapies may have on proprioception (Schleip 2003a; Stecco et al. 2010a). Although numerous studies exist with regards to the effect of myofascial therapies on pain and range of motion, there are no studies to date which demonstrated the immediate effects of myofascial therapies on proprioception (Fernandes-des-las-penas et al. 2006; Ercole et al. 2010; Trampas et al. 2010; Castro-Sanchez et al. 2011; Arun, Joginder and Sheetal et al. 2014). In the present study, the foot, lower leg and ankle was chosen as areas of interest due to their unique functional characteristics and specializations for maintaining balance and postural stability (Huang et al. 1993; Kim and Voloshin, 1995; Cote et al. 2005; Wright, Ivanenko and Gurfinkel 2012).

1.2 AIMS AND OBJECTIVES

This study aimed to measure immediate changes in navicular position, great toe extension, postural stability (eyes open and closed) and limits of stability, after two types of myofascial interventions were delivered to participants with bilateral navicular pronation. The data was also compared to a placebo group.

Objective One:

> To determine the immediate effect that placebo ultrasound (Group A) had on navicular position, great toe extension, postural stability (eyes open and closed) and limits of stability.

Objective Two:

> To determine the immediate effect that ischaemic compression (Group B) had on navicular position, great toe extension, postural stability (eyes open and closed) and limits of stability.

Objective Three:

To determine the immediate effect that myofascial release (Group C) had on navicular position, great toe extension, postural stability (eyes open and closed) and limits of stability.

Objective Four:

To compare amongst the groups, any trend with regard to outcome measures between.

1.3 RATIONALE

The ability to stand and balance is as a result of sensory contributions from the visual, vestibular and somatosensory (mechanoreceptive) systems (Lephart and Fu 2000: 37, Horak 2006, Clifford and Holder-Powell 2010). Mechanoreceptors are the specialized neurons which make up the somatosensory contribution to balance, relaying this mechanosensitive information to the CNS for processing (Lephart and Fu 2000: 37-42). Van der Wal (2009) acknowledges the presence of these mechanoreceptors in fascial tissue as well as in the joints and myofascial tissue. Schleip et al. (2013: 81, 82), goes on to explain that these mechanoreceptors are the substrate for proprioception, providing the necessary information to sense the position, location, orientation and movement of the body and its parts. Recent evidence suggests that fascia plays a role in proprioception as these mechonoreceptors have been found in these tissues (Schleip 2003a; Stecco et al. 2010a; Simmonds, Miller and Gemmell 2012).

The muscle fascia or myofascia is continuous throughout the fascial body, distributing muscle contraction force along these fascial connections (Purslow 2008; Benjamin 2009; Schleip et al. 2013: 5). Over time, fibrous deposition in response to inflammation can result in limited extensibility of the myofascia, and these are called myofascial restrictions (Shah and Bhalara 2012). The response of myofascial tissue to myofascial therapies are explained by several mechanisms, some are mechanical and others neurophysiological in nature (Barnes 1997; Schleip 2003a; b).

Previous mechanisms were thought to be purely mechanical in nature, due the fibrous adhesions between myofascial structures, restricting the ability of the different layers to glide freely past one another (Shah and Bhalara, 2012). In short, the mechanical interventions aim to break up fibrous tissue adhesions; either through sliding collagenous tissues past each other in response to stretch; by loosening the cross-links between the collagen fibres or by inducing micro-failure of the collagen fibres (Threlkeld 1992; Barnes 1997). The mechanical mechanisms generally involve breaking adhesions that have formed between the different layers of fascial and myofascial tissues. Other mechanical mechanisms include changing the viscosity of extracellular ground substance (in which the fascia is embedded) from gel to solvent, thus changing the mechanical properties of the fascia in question, by altering it's viscoelastic properties (Rolf 1977). These effects have a bearing on range of motion and physical function. The presence of mechanoreceptors if fascia has since brought about a neurophysiological model by which fascia may influence proprioception.

The proposed neurophysiological model has been adapted by many leading authors (Schleip 2003a; Chaudhry et al. 2007; Hammer 2007: 20-22). These authors propose that through the stimulation of mechanoreceptors (located in fascial and myofascial tissues), immediate changes in tissue extensibility occur (Hammer 2007: 20). Schleip (2003a; b) theorises that, mechanoreceptor stimulation in the application of myofascial therapies, alters the muscle's motor tone (via gamma motor stimulation). This change in motor tone is suggested to explain the tangible sensation of immediate tissue release, reported by practitioners (Schleip 2003a; b; Hammer 2007: 22). For the present study, all of the proposed mechanisms will be regarded as true and thus may have a possible effect on outcome measures (Simmonds Miller and Gemmell 2012).

The long term effects of myofascial therapies on balance and postural stability have been investigated by Castro-Sanchez et al. (2011), and revealed no significant results with regards to balance measures. A possible reason for this could be that treatments focussed on the myofascia (muscle fascia) of the head, neck and back, in participants with fibromyalgia (a disorder characterised by widespread deposition of fibrous tissue in the body). The feet have been shown to be spacialised for balance and control of posture (Wright, Ivanenko and and Gurfinkel 2012). The specialised functional anatomy in the feet as well as the presense mechanoreceptors, relay mechanoreceptive information about forces acting on the feet to the

CNS (Benjamin 2009). No studies have investigated the effects of myofascial therapies in the foot, lower leg and ankle.

Relevant to this study, the medial arch, plantar and crural fascia as well as myofascia, are integral components of the somatosensory system, for achieving balance and postural equilibrium (Hicks 1954; Dananberg 1993a; Kim and Voloshin 1995; Loram, Maganaris and Lakie 2005; Cheng et al. 2007; Cheng et al. 2008; Wright, Ivanenko and Gurfinkel 2012). Cote et al. (2005) studied the effects of different foot types (pronated, neutral, supinated) on postural stability and limits of stability measurements. The authors concluded that postural stability was affected by foot type and that the reasons for these findings appeared to be due to the structural differences associated with the different foot types (Cote et al. 2005). For this reason the degree of navicular pronation was recorded before and after the relevant intervention for possible changes.

As a result of abnormal (sustained) pronation, the foot abducts, the medial longitudinal arch drops in response and lengthens relative to the calcaneus, causing increased tension in the plantar fascia (Hicks 1954, Donatelli 1987; Dananberg 1993a; b). These biomechanical and tensional relationships are suggested to restrict the extension range of motion at the first metatarsophalangeal joint or great toe, although this has not been conclusively proven (Dananberg 1993a; b; Kaufman et al. 1999; Durrant 2009). The great toe extension has been studied with regards to balance in many different scenarios, in part, due to its functional relationships with the plantar fascia (Kappel-Bargas et al. 1998; Nawoczenski, Braumhauer and Umberger 1999; Cheng et al. 2007; Durrant and Chockalingam 2009; Ku et al. 2012). For reasons mentioned above, great toe extension was included as a variable for the present study.

It is important to note that the present study did not investigate the exact mechanisms behind possible changes in outcome measures, nor did the investigation try to identify the primary mechanisms involved in each type of myofascial therapy administered.

1.4 HYPOTHESEIS

A Null hypothesis was set, when comparing the time*group effect for significant change ($p \leq 0.05$). In respect of the objectives:

Null hypothesis one: there would be no statistically significant pre/post changes in outcome measures for the placebo ultrasound group.

Null hypothesis two: There would be no statistically significant pre/post changes in outcome measures for the ischaemic compression group.

Null hypothesis three: There would be no statistically significant pre/post changes in outcome measures for the myofascial release group.

Null hypothesis four: When comparing the time*group interactions between the groups, this would yield no statistically significant differences.

Null hypothesis five: When comparing the results, there would be no trend seen in outcome measures, amongst the groups.

1.5 ASSUMPTIONS

- As per screening methods and inclusion into the study, participants were asymptomatic with regards to active pain in the foot, lower leg and ankle.
- The random allocation and recording of goniometry was done according to the set procedure, outlined in the methodology.
- It is assumed that the assistant examiner took and recorded the goniometric measurements accurately and was blinded as to which intervention the participant received.
- The detuned ultrasound had no therapeutic effect.
- The researcher treated all possible myofascial restrictions in the foot, lower leg and ankle.

1.6 LIMITATIONS

- The sample size was limited to 15 per group. This is consistent with the literature when investigating similar variables (Cote et al. 2005; Arun, Joginder and Sheetal 2014).
- The principal researcher helped position the participant and was not blinded in the recording of the goniometric measurements as two examiners were needed in some cases.
- All participants potentially differed in their presentation of myofascial restrictions affecting the variability of treatments, between the participants.

1.7 OUTLINE OF CHAPTERS

Chapter One introduces the topic and main themes in this study, providing the rationale, aims and objectives as well as highlighting the assumptions and limitations of the study. Chapter Two identifies the previous misconceptions regarding connective tissue as well as discussing the evidence and proposed roles that fascia plays in proprioception and myofascial therapies. This chapter identifies the functional relationships of the distal lower limb in maintaining posture and also describes how abnormal foot biomechanics may influence these functional relationships. Chapter Three details the sampling, research protocols and procedures involved in conducting this research. The interventions, measurement tools and different tests are explained in this chapter. Chapter Four summarizes the results by order of significance. Chapter Five discusses these results and possible explanations for the outcomes of chapter four. Chapter Six draws conclusions and makes recommendations for future studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Recent evidence has changed the way researchers and practitioners view connective tissue and its related tissues in the body (Van der Wal 2009; Stecco et al. 2010a). This has stimulated new research and theories, with regards to the function and roles that fascia plays in the body (Schleip 2003a; b)

This literature review will discuss recent evidence linking fascia to proprioception as well as the mechanisms by which myofascial therapies are used to treat myofascial restrictions (Schleip 2003b; Simmonds, Miller and Gemmell 2012). Evidence brought into this chapter helps in building a rationale as to how myofascial therapies may influence navicular pronation, great toe extension and balance testing (postural stability with eyes open and closed as well as limits of stability tests).

Functional characteristics of the foot, lower leg and ankle are detailed and explained with regards to their contributions to maintaining posture and balance (Wright, Ivanenko and Gurfinkel 2012).

2.2 UNDERSTANDING FASCIA

Schleip, Jager and Klingler (2012) reviewed the origins of the English term ‘fascia’, along with terms used for referring to connective tissue in other languages. The authors highlight that previous definitions, in some cases were controversial, partly due to language and country of study (Schleip, Jager and Klingler 2012). The authors define fascia as “the fibrous collagenous part of a body wide tensional force transmission system” (Schleip, Jager and Klingler 2012: 500).

After the first Fascial Research Congress, fascia was defined as “the soft tissue component of the connective tissue system that permeates the human body”. More recent definitions include the fibrous sheets and layers along with the local densifications like ligaments and tendons. Softer connective tissues like the superficial fascia and the intramuscular layers of the endomysium also fall under these definitions (Schleip, Jager and Klingler 2012: 500). The above authors agree that fascial tissues commonly blend with one another, which is important for understanding how these tissues function interdependently in the body (Kalin and Hirsch 1987; Findley and Schleip 2007; Stecco et al. 2010a).

Thomas Findley, having been involved in fascial research for the past 30 years, noticed a spike in the number of studies relating to this structure (Grimm 2007). Findley played an integral part in the inception of the 2007 Fascia Research Congress, which seated health care professionals from mainstream medicine as well as alternative health care, including chiropractors and rolfers (deep tissue manipulators). Such practitioners’ targeted fascia when treating their patients, attributing the stretching and manipulation of these tissues to the improvements they had previously seen in their clients (Grimm 2007). According to Grimm (2007), practitioners admitted that they did not have sufficient evidence or data to support the benefits of myofascial treatment and it was at this event, practitioners and researchers discussed and reviewed the different nomenclatures (definitions and classifications) of fascia (Schleip, Jager and Klingler 2012).

Huijing and Langevin (2009) point out that it is now acknowledged that ligaments and tendons commonly blend with fascia and that when treating these tissues, it is nearly impossible to isolate a particular fascial tissue (Langevin and Huijing 2009). This is of particular relevance to the present investigation, due to the fact that when treating myofascial restrictions in the foot, lower leg and ankle, exclusively effecting the myofascial structures is most likely impossible (Benjamin 2009).

2.2.1 Fascia Superficialis (Outermost layer)

The skin, comprising of the epidermis and dermis, surrounds the entire body and protects it from the external world. Deep to this is an enveloping layer of dense areolar connective tissue and fat, which is referred to as the fascia superficialis (Langevin and Huijing 2009).

The fibres within this layer are arranged in a loose, irregular lattice pattern allowing for great mobility in all the directions (Shah et al. 2012). Iatridis et al. (2003), further showed that when applying tension to the skin in one direction, the response is linear and viscoelastic, as it returned to its original position after the tension was removed (Iatridis et al. 2003; Schleip et al. 2013: 21). Any palpatory differences in skin mobility can help interested parties identify areas of myofascial restriction (Manheim 2008: 7; Shah and Bhalara 2012).

2.2.2 Deep Fascia: Lower Leg (Innermost Layer)

Structurally, the skin is anchored to the deep fascia via cutaneous ligaments (Nash et al. 2004). These cutaneous ligaments are widespread and at varying tensions throughout the body, resisting numerous types of forces, including the gravitational influences on the skin (Nash et al. 2004).

Benjamin (2009) explains that the continuity and interconnectivity of fascia is from the skin and fascia superfiscialis, into the deep fascia, finally investing into the periosteum and bone. An example of this continuity is shown in the connection between the crural and plantar fascia (Shaw et al., 2008). The crural fascia and the achillies tendon insert into the calcaneus posteriorly and after investigation, these insertional fibres have been shown to be continuous with those of the plantar fascia of the foot (Wood Jones 1944; Snow et al. 1995; Shaw et al. 2008). This occurs as a result of load bearing over time, during walking and running, where these layers eventually fuse together and may appear as two separate entities (Milz et al. 2002; Langevin 2006; Schleip et al. 2013: 31).

The functional connection between the crural and plantar fasciaes (explained at length in Section) provides the rational for treating the myofascial restrictions within the plantar fascia as well as crural fascia.

2.2.3 Microscopic Anatomy

2.2.3.1 Fibres and Fibrous Bundles

There are generally three types of fibres found within fascia, collagen, reticular and elastic, each contributing to its biomechanical properties (Meyer et al. 2007). Collagen provides tensile strength when fascia is placed under stretch. Reticulin is a type of collagen, but is classified as a separate type of fibre. These fibres surround fat cells, separating them into lobules, as well as connecting the dermis to the underlying deep fascia (Meyer et al. 2007). Elastic fibres contain mostly mature elastin, forming a continuous network, concerned with stretching and the elastic recoil of the fascia. The elastic fibres are predominantly found in the loose connective tissue (Meyer et al. 2007; Schleip et al. 2013: 22).

These fibres are arranged in fibrous bundles, which are made up of two or three layers of parallel collagen fibres. In adjacent layers the fibres are arranged in parallel, generally vary in their orientation by 78 degrees on the x and y plane, in order to provide strength and support in multiple directions (Benetazzo et al. 2011; Stecco et al. 2011). Adjacent layers are usually separated by a thin layer of loose connective tissue allowing the layers to move and function independently (Schleip et al. 2013: 34). This loose connective tissue cushions the connective tissues and allows for the deep fascial structures to glide past each other. The loose connective tissue stores water and ions for the surrounding substances and is capable of accumulating different degradation products (Schleip et al. 2013: 34).

According to Schleip et al. (2013: 34), changes in the concentrations and contents of these substances (water, ions and degradation products) have potential to interfere with the gliding mechanisms between adjacent fascial layers.

2.2.3.2 Extracellular matrix (ECM)/Ground substance

The extracellular matrix is located between and around the collagen fibres, comprising of a semi fluid viscous substance called the ground substance (Schleip et al. 2013: 166). Water is bound to the glycosaminoglycans and proteoglycans found within the ground substance, allowing for frictionless movement between the fibres (Rolf 1977).

If there is a loss of ground substance, the collagen fibres develop pathological cross-links and move closer together. These cross-links reduce the ability of the fibres to glide freely and move independently thus influencing tissue extensibility and potentially range of motion measurements in the present investigation (Schleip et al. 2013: 165-170).

2.2.3.3 Retinacula

Ankle retinacula will later be described in relation to the roles they may play in proprioception (Stecco et al. 2010a). Microscopic evaluations of the retinacula reveal that the collagen fibre bundles, display a slight undulating (wavey) arrangement (Schleip et al. 2013: 33).

Classically, retinacula were thought to act like pulleys keeping tendons flush with the bones beneath them (Stecco et al. 2011). Recent studies into the ankle retinacula has shown that they appear more as reinforcements of the deep fascia, not separate from them (Abu-Hijleh and Harris, 2007; Stecco et al. 2010a; b). In contrast to the other deep fascia, retinacula display more densely packed fibre bundles with less loose connective tissue (Stecco et al. 2010a). This finding does not support a pulley system as this system would be advantaged by more loose connective tissue to facilitate frictionless gliding (Benjamin 2009).

The retinacula function to stabilize the deep fascia and tendons around joints and bony prominences (Schleip et al. 2013: 33).

2.2.3.4 Myofascia

Located within the deep fascia is the muscle fascia or myofascia (Benjamin 2009). Microscopic anatomy of myofacia classifies it as irregular, dense, connective tissue with the function of enveloping muscles (Benjamin 2009). More recently, muscle fascia has been shown to be essential in the transmission of the forces (generated by sarcomere contraction), to broader myofascial connections, as well as through the muscle tendon (Purslow 2008; Benjamin 2009; Vander Wal 2009). Classically muscles were thought to transmit forces exclusively through tendons (Van der Wal 2009).

2.2.3.5 Fibroblasts

Fibroblasts are the dominant cell type in the deep fascia (Schleip, Klingler and Lehmann-Horn 2006). In an article by Chiquet (1999) the author explains that through mechanical loading, fibroblasts are stimulated to turn on and turn off genes controlling the regulation of the extracellular matrix. This was shown to occur within very short time periods (24 to 48 hours) in response to the mechanical stretch and relaxation (Chiquet 1999). That being said these effects have not been sown to occur in the immediate time frame with relevance to the present investigation.

Chiquet (1999) demonstrates how chronic mechanical stress can influence the expression of genes regulating the extracellular matrix (deposition and remodeling of the fibres in ECM) (Chiquet 1999; Stecco et al. 2010a). Over time, the fibrotic and fibrinolytic gene expression leads to altered tissue structure and possibly a change in function. Liptan (2010) supports this in his study linking fascia to the eitiology of fibromyalgia, characterized by gross fibrous deposition. A study by Jones et al. (2011), showed that fibromyalgic patients had deficits in postural control and balance testing.

These findings by Chiquet (1999) are of particular relevance, as participants in the present study have chronic pronation stress. The chronic stress is suggested to cause fibrous deposition and restrictions in the myofascia, as a result (Donatelli 1987).

2.2.4 Gross Fascial Anatomy: Lower Leg

The gross anatomy of the deep fascia consists of many lamellae (layers) of connective tissue, which can be separated from the fascia superficialis and underlying muscle fascia (Schleip et al. 2013: 31). There is a near uninterrupted plane of gliding between the deep fascia and muscle fascia, thanks to the loose areolar connective tissue which appears as a pliable, gel-like gelatinous substance, laden with fibroblasts, collagen and elastic fibres (Schleip et al. 2013: 31).

The deep fascia also functions to compartmentalize groups of muscles and transmit forces between these compartments and their associated bony attachments (Benjamin 2009). These compartments are also referred to as osteofascial compartments (Benjamin 2009).

The deep fascia is surrounded by an aponeurosis, which is invested (shares connection) by the epimysium, perimysium, endomysium (fascia covering and investing the muscle) as well as the osteofascial compartments (Stecco et al. 2008).

2.2.5 Structural Mechanics of Fascia

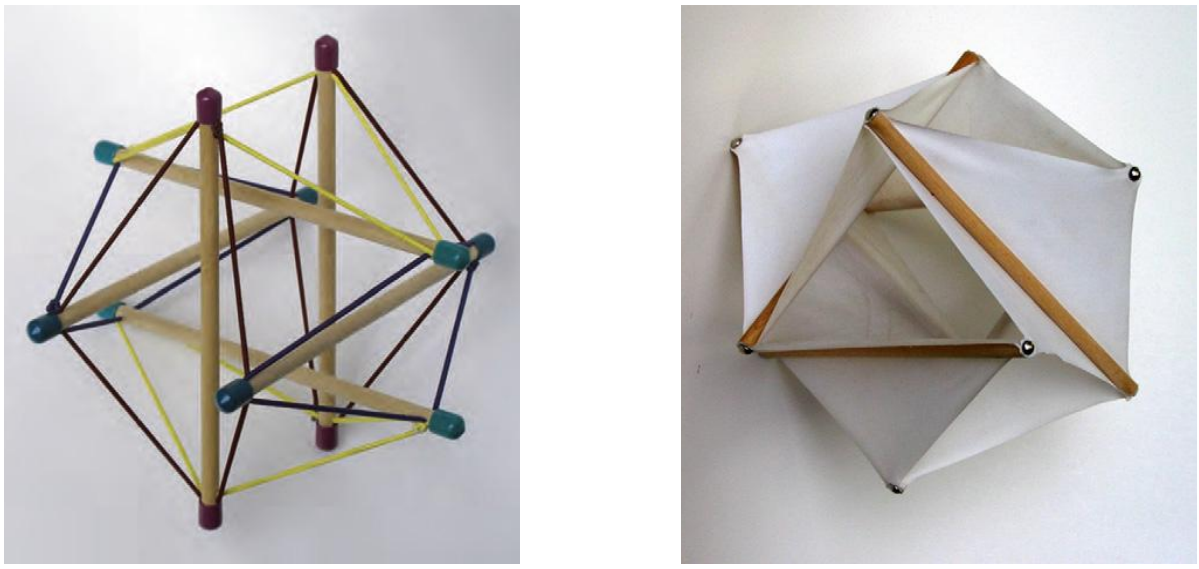
A biotensegrity model has been proposed to explain the mechanics of fascial tissues (Schleip et al. 2013: 137). Biotensegrity is based on tensegrity structures which are principally composed of compressive elements and tensional elements. Together these elements exist co-dependently and are under constant tension (Schleip, Jager and Klingler 2012).

The term biotensegrity refers to how tensegrity elements are applied to and model the structural mechanics of biological organisms (Fuller and Applewhite 1975; Schleip et al. 2013: 137). This model can be used to represent the functioning of structural elements within organisms, from viruses to vertebrates (Levin and Martin 2012). This model is in contrast to previous concepts, that the skeleton is the frame from which the soft tissues are draped. In applying the biotensegrity model to humans, the body is viewed as an integrated fascial net which houses bony compressive elements within the tensioned fascial elements (Levin and Martin 2012). In this way, during erect bipedal stance and locomotion, the body is able to resist gravity with very little effort as the structure is already under tension allowing for efficient leverage, with minimal effort (Levin and Martin 2012).

In mechanically loading these structures, the tensional elements constantly distribute the tensional stress across all the tensional elements in the system (Schleip, Jager and Klingler 2012). The forces occurring within all tensegrity and biotensegritis structures are equal to zero (compressive and tensional), at a given time. This interdependence and functional interconnectivity of the tensional elements are of vital importance for understanding how the architecture of fascia is thought to be related to proprioception (Van der Wal 2009).

Figure 2.1 illustrates two examples of simple tensegrity structures (icosahedrons). The model on the left uses elastic bands to represent tensional elements and on the right, elastic sheeting is used to model the tensile elements (Schleip, Jager and Klingler 2012: 499). Although the two examples below are simple tensegrity structures, they provide insight into

how a biotensegrity model may be applied to the different types of tissues within the human body.



(Schleip, Jager and Klingler 2012: 499)

Figure 2.1 Simple tensegrity structures, using different tensional elements

2.2.6 The Biotensegrity Model, Applied to Growth and Development

Wolff's law recognises that over time, bone will stiffen in response to compression stress (Prendergast and Huiskes 1995). In Levin and Martin (2012), the authors support this model and go on to state that it must be the fascia with its enmeshed bony stiffeners that evolve and adapt to physical and functional demands (Levin and Martin 2012; Schleip et al. 2013: 137).

According to Blechschmidt and Gasser (2012), all connective tissue elements originate from the mesenchymal cells. The authors postulate that it is the loading history of a tissue which influences its specialization into; strong bands; loose areolar tissue; planar sheets or other fibre arrangements (Blechschmidt and Gasser 2012). For example when the mesenchymal tissue is resisting local compression, cartilage and bone is formed. Conversely, when this tissue is required to resist tensional loads, collagen fibres are embedded within the semi-fluid ground substance and fascial structures are formed (Schleip, Jager and Klingler 2012).

A clinical example of the processes mentioned above, can be related to the iliotibial band, regarded as one of the strongest bands in the body. In wheelchair patients this structure is thin and soft to palpation, however in professional horseback riders this band is dense and strong on palpation. Additionally in horseback riders, there is often bony expression on the medial side of the thigh called riders bone (Bowen 1924). Riders bone is also called cavalry bone, developed from the chronic stress at the adductor muscle attachment site, through chronic horse riding (Schleip, Jager and Klingler 2012).

2.3 MYOFASCIAL EXPANSIONS AND INTERCONNECTIVITY

The fascia associated with muscle fibres, is related to the functioning, of these structures (Purslow 2008).

With reference to fascia, Wood Jones (1944), a very influential anatomist, first coined the term 'ectoskeleton'. This was to build the idea that fascia could serve as a significant site for muscle attachment (Wood Jones 1944). Benjamin (2009) supports the view that fascia is a 'soft tissue skeleton', which reinforces and compliments the osseous skeleton. The author further explains that the force generated by skeletal muscle fibres, is not only transmitted to

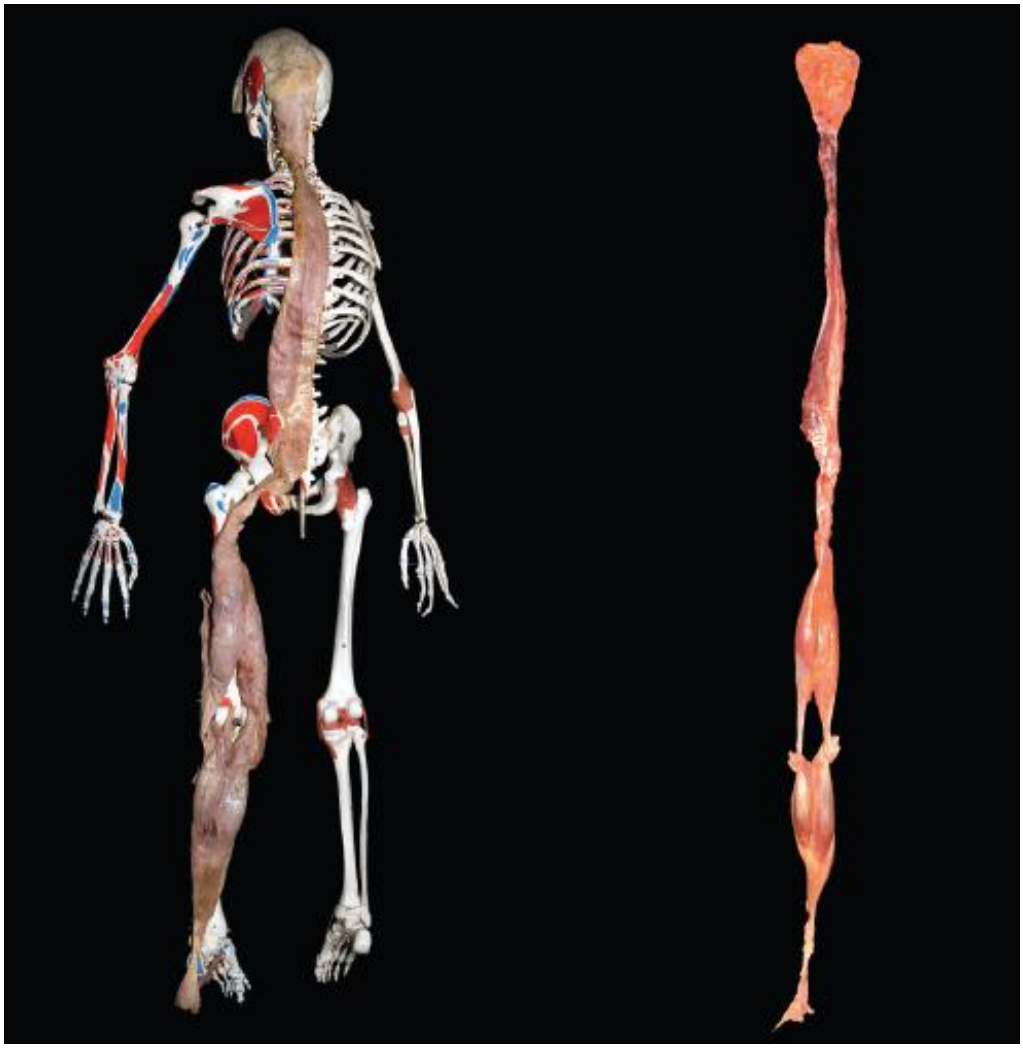
the tendon directly, but also to other connective tissue elements. These elements lie both inside and outside the skeletal muscle (Huijing et al. 2003; 2007; Benjamin 2009).

Schleip et al. (2013: 117) builds on this stating that at sites of great tensional stress, like tendon insertions, myofascial expansions exist (Huijing 2003; 2007). These myofascial expansions serve to distribute tensional loads within and from the muscle fascia, over a broader attachment site that is not limited to bone. The author explains that these myofascial expansions may function to stabilize tendons and reduce the concentrated stress at the tendon attachment or enthesis (Schleip et al. 2013: 117-121).

Kalin and Hirsch (1987) support this and found that in the human foot, only eight out of the sixty nine interossei muscles studied, had attachments that were limited to bone. The authors used dissecting room cadavers to obtain their findings and in the vast majority of cases, the muscles had extensive attachments to ligaments and fascia. According to Kalin and Hirsch (1987), these myofascial connections are theorized to help functionally link the muscles together, in order to promote their contraction as a co-ordinated unit.

Another study done by Huijing, Maas and Baan (2003), revealed that in the anterior crural compartment of rats, muscle tendon force transmission accounted for only 70% of the total force and the other 30% was through myofascial expansions. Although this study was done on rats, the margins are too significant to ignore, giving insight into how this interconnectivity may be involved in the overall functioning of the limbs (Huijing 1999; Huijing, Maas and Baan 2003; Stecco et al. 2011). These ideas have led to many depictions of how mechanical force is transmitted along the myofascia (Schleip et al. 2013:131-136).

Some of the most well know work was done by Myers (2011), where the author dissected out whole chains of muscles, modeling their roles in the human body (Myers 2011). *Figure 2.2* illustrates the physical connection of the myofascia and myofascial expansions, as demonstrated by dissecting methods and presents physical evidence of the interconnectivity discussed in the present section.



(adapted by Myers 2011: 72)

Figure 2.2 Fascial interconnectivity as shown by the whole-part dissection of the superficial back line

Specific patterns and lines of forces can be strengthened by fibroblast gene expression (in response to mechanical stimuli), through the deposition of fibres and ground substance (Chiquet 1999; do Carmo et al. 2008). The evidence above suggests that myofascial restrictions may also develop in myofascial expansions and as a result, mechanically addressing these restrictions, could have bearing on the lines of force transmission, effecting function (Shah and Bhalara 2012; Schleip et al. 2013: 33).

In the present study, the treatment of myofascial restrictions was not limited to the muscle fascia, as all possible fascial structures (including myofascial expansions) may have been restricted and thus treated (Barnes 1997, Myers 2011; Shah and Bhalara 2012).

2.4 MYOFASCIAL RESTRICTIONS

Practitioners use manual palpation to examine participants for restricted movements as well as to identify areas of myofascial adhesion and restriction (Akeson et al. 1977; 1987).

During prolonged postural stress or in response to trauma (acute or chronic), inflammation is a physiological response to such an event (Wynn 2008). As a result, the fascia in question undergoes protective changes at a histological, physiological and biomechanical level (Wynn 2008). The result is the deposition of fibrous colloid commonly referred to as scar tissue or fibrous cross-links. If this process is left untreated (as in immobility) or if the inflammation persists, fibrous adhesions develop as a result (Barnes 1997; Wynn 2008). These adhesions cause restrictions in the gliding potential of the fascia and this is suggested to then restrict range of motion (Carano and Siciliani 19996; Shah and Bhalara 2012). As such, structures which were able to function separately are now bonded together, impairing their ability to function independently (Shah and Bhalara (2012).

In order to detect myofascial restrictions, the researcher used different forms of palpation to assess the fascia. Range of motion testing and as well as direct palpation was used to identify these areas. According to Manheim (2008: 7) it is very difficult to objectively measure and observe myofascial restrictions in vivo. This is because palpation is a subjective measurement, not easily quantified by objective means.

For the purposes of this study, myofascial restrictions will refer to the palpated sensation where the fascia in question has limited extensibility or has a shortened resting length, preventing optimal contraction and relaxation of the myofascia (Manheim 2008: 7; Shah and Bhalara 2012). The researcher aimed to reduce the myofascial restriction using techniques outlined in the methodology section.

2.5 PROPRIOCEPTION

According to Lephart and Fu (2000; xvii) Sherrington (1906), who described the proprioceptive system as: “the afferent information from proprioceptors that contributes to conscious sensations, total posture and segmental posture”. The combination of somatosensory (mechanoreceptive), visual and vestibular (labyrinthine) information supplies the CNS with continual feedback, regarding the environment and the mechanical forces within the body, allowing the central nervous system to initiate smooth and coordinated movements (Barker et al. 1974; Lephart and Fu 2000: 23; Van der Wal 2009).

2.5.1 The Substrate for Proprioception

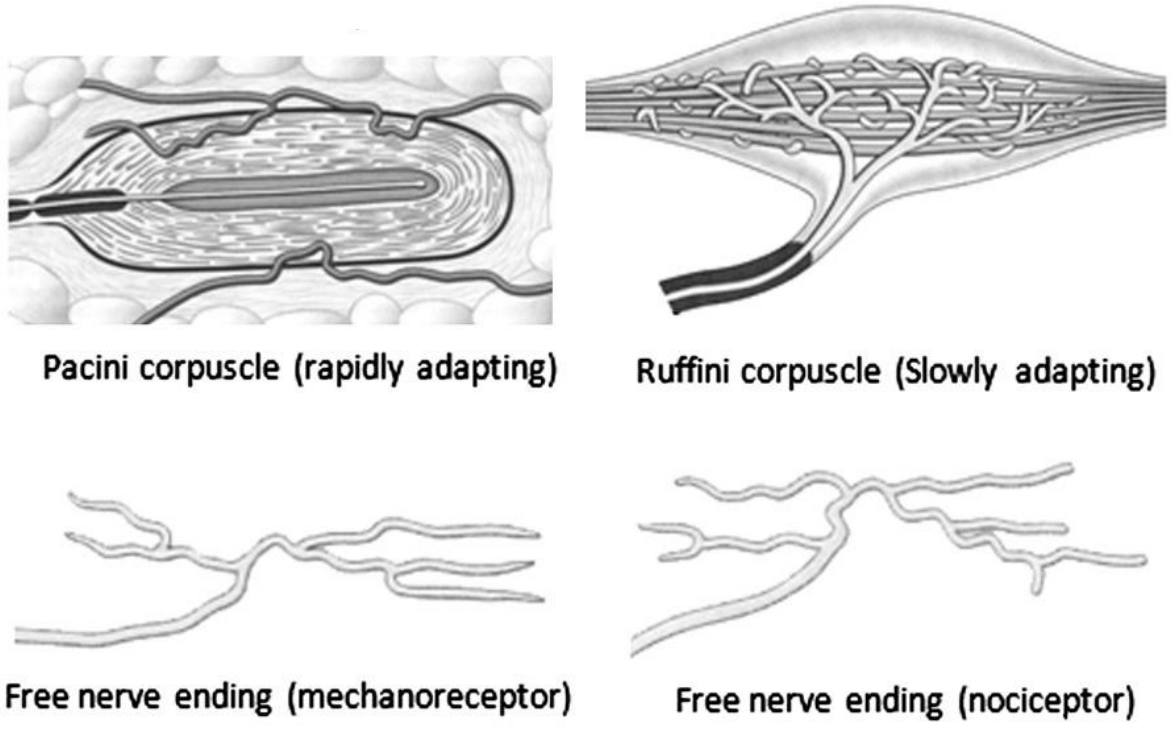
Mechanoreceptors are sensitive to different mechanical stimuli and make up the somatosensory contribution to proprioception and balance (Benjamin 2009; Schleip et al. 2013: 84).

The different mechanoreceptors are classified according to their microscopic structure, physiological feature and associated afferent nerve fibre (Freeman and Wyke 1967a; b). Mechanoreceptors have classically been reported to occur in muscles and joints, known as muscle receptors and joint receptors respectively (Schleip 2003a; b). That being said, as evident in this section mechanoreceptors have also been found in the connective tissues of the body (Stecco et al. 2010a; Simmons, Miller and Gemmell 2012). Two important types of muscle receptors are muscle spindles and Golgi tendon organs, found in tendons, aponeurosis and muscle fascia (Barker 1974). The joint receptors are situated in joint capsules and their related structures, including reinforcing ligaments (Schleip et al. 2013: 84). The Golgi tendon organs and Ruffini receptors possess similar physiological features

and are named according to the site in which they are found (Mitchell and Schmidt 1997: 623-658).

According to Van der Wal (2009) and Schleip et al. (2013: 77, 78), there are also free nerve endings, widespread throughout the body. The free nerve endings are known to be involved in the generation of pain, as well as possibly fulfilling a proprioceptive role. Morphological evidence for proprioceptors located within fascial tissue now exists (Stecco et al. 2009; Stecco et al. 2010a; b). Although this link to proprioception has been made, explanations and evidence on the exact mechanisms are inconclusive (Langevin 2006; Simmonds, Miller and Gemmell 2012).

Figure 2.3 provides an illustration of the different types of mechanoreceptors in accordance with their physiological appearance.



(adapted from Simmonds, Miller and Gemmell, 2012: 3)

Figure 2.3 Different mechanoreceptors found in the body

2.5.2 Evidence Linking Fascia to Proprioception

Van der Wal (2009) points out that in almost thirty five years of anatomical study, the set procedure was to dissect out the fascia, exposing the more defined tissues such as muscles and tendons for viewing. The author highlights that with advances in research tools and the in vivo study of human anatomy at high resolutions, connective tissue has now been considered in forming new hypotheses in relation to the functioning of the body as well as in pathology (Schleip 2003a; b; Bouché and Johnson, 2007; Cheng et al. 2008; Murley, Menz and Landorf, 2009; Liptan 2010). Van der Wal (2009) suggests that only if the architecture of the fasciae in question (embedded with mechanoreceptors), is related to the muscular or skeletal elements, could the fasciae in question provide the necessary proprioceptive information (Stecco et al., 2010a; Van der Wal 2009).

Mechanoreceptive information is derived not only from the skin, muscles, joint surfaces and joint structures, but also the fascia as suggested in this section (Mitchell and Schmidt, 1997: 623-658; Stecco et al. 2010a; Schleip et al. 2013: 81). Free nerve endings, Ruffini and Pacinian corpuscles have been found in the thoracolumbar fascia, bicipital aponeurosis as well as the ankle retinacula in the lower limb (Stecco et al. 2008; Benjamin 2009; Stecco et al. 2010a).

In Stecco et al. (2010a; b), the authors suggest that the ankle retinacula function as regional specializations and densifications of the deep fascia as opposed to separate entities. Stecco et al. (2010a) studied three amputated legs as well as another 24 ankle retinacula. All three of the amputated legs had a ten month history of immobilisation, of which two had a history of diabetes. The 24 retinacula were obtained from 12 cadavers. The authors analyzed the histological and gross morphological appearance of the specimens. The ankle retinacula were inseparable from the deep fascia, appearing as strong fibrous bundles with a criss-cross type of arrangement (Stecco et al. 2010a). Further analysis revealed that all three amputated specimens had extensive fibrous attachments to the deep fascia and bone, making it impossible to isolate the retinacula. Additional fibrotic bundles were also found in some cadaveric specimens. Stecco et al. (2010a) concluded that there was a strong correlation between the mechanical functioning of the tissues and structural composition (appearance of additional fibrous bundles) of the connective tissues (Stecco et al. 2010a).

The laboratory analysis of the ankle retinacula in Stecco et al. (2010a) noted the existance of mechanoreceptors presented within all of the ankle retinacula. These specialized neurons are suggested to be the necessary substrate for proprioception (Stecco et al. 2010a). This contradicts the previous understanding that ankle retinacula only served a mechanical and structural function. In explanation, Validot et al. (1984) mentions an example of inversion of the ankle joint, causes the peroneal retinacula to be tensioned. This would cause reflex contraction of the peroneal muscles (Schleip et al. 2013: 32). The ankle retinacula were not targeted, but could have been indirectly treated in this study and effect proprioception (Stecco et al. 2010a).

In the present study, the researchers stimulated and attempted to change the structure of the myofascial restrictions (Schleip 2003a). According to the biotensegrity model and as a result of this structural change, the entire structure in question is suggested to accommodate. The changes in load bearing and load distribution relationships in the foot, lower led and ankle are linked to posture and proprioception (Schleip, Jager and Klingler 2012).

2.6 PROPOSED MECHANISMS OF MYOFASCIAL THERAPIES

According to Shah and Bharala (2012), myofascia and related connective tissues have been the target of many myofascial therapies. Numerous studies have shown that when participants are treated pain, disability and range of motion have all been measures which have improved (Barnes 1997 Fernandes-des-las-penas et al. 2006; Castro-Sanchez et al. 2011; Macdonald et al. 2013; Trampas et al. 2010; Arun, Joginder and Sheetal 2014).

These treatment outcome measures have traditionally been thought to improve as a result of reducing the myofascial restrictions in the tissues, by modifying the mechanical characteristics and fibrosis after injury and chronic stress (Ercole et al. 2010). The rationale behind this belief, involves the mechanical interactions of the fibrous deposition and myofascial adhesions (fibrous cross-links), as they impair the extensibility of the myofasciae in question (Shah and Bhalara 2012). Another argument is that such restrictions are due to dysfunctions in sensorimotor regulation and that by stimulating mechanoreceptors within fascia, this will have an effect on the associated muscle tone in the area treated (Schleip

2003a; b; Stecco et al. 2009; Van der Wal 2009). This in turn is thought to improve palpable restrictions within in the myofascia.

This debate, led to a paper by Trager, Guadagno-Hammond and Turnley Walker (1987). These authors noticed that myofascial restrictions disappeared after anaesthetic was administered to their patients. The consequence of the observations in Trager, Guadagno-Hammond and Turnley Walker (1987) was further investigation, represented by leading researchers, from both the mechanical and sensorimotor hypotheses. The result of which, indicated that passive arm elevation and ankle dorsiflexion improved, after anaesthetic was administered. This suggests that the perceived mechanical restriction may be somewhat due to a neurophysiological mechanism (Schleip et al. 2013: 77, 78). Cottingham (1985) was first to outline a neurologically orientated model explaining the effect of myofascial therapies. This neurophysiological model presented by Cottingham (1985), has been further expanded on by many leading authors, building the foundation for research into the proprioceptive roles of fascia and manual therapies (Chaitow and DeLany 2003: 44, 45; Schleip 2003a; b; Hammer 2007: 20-22).

It is important to note that the piezoelectric effect is another mechanism proposed by some authors, but will not be discussed in this dissertation. This is due to the length of time required for possible changes to occur, as well as the evidence regarding this explanation is still controversial amongst the literature (Schleip 2003a; Langevin 2006; Simmonds, Miller and Gemmell 2012). The proposed mechanisms are divided into mechanical and neurophysiological mechanisms below.

2.6.1 Mechanical Model

The forces involved stretching or stressing tissues are brought about by applying mechanical pressure or force. More common myofascial therapies in this group include instrument assisted myofascial release like grasten and foam rolling, as well as deep tissue work such as in structural integration (Simmonds, Miller and Gemmell 2012; Macdonald et al. 2013). The heat generated as a result of the mechanical pressure is also used to achieve therapeutic effects (Simmonds, Miller and Gemmell 2012).

All the therapies aim to break up adhesions between the fasciaes, resulting in immediate and sometimes permanent alteration of the tissue structure (Barnes 1997). These therapies claim to have an effect on the density, tonus, viscosity or arrangement of fascia, through mechanical means (Cantu and Grodin 1992; Threlkeld 1992; Rolf 1977; Schleip 2003a).

Simmonds, Miller and Gemmell (2012) briefly summarize these outcomes in relation to mechanical effect, below:

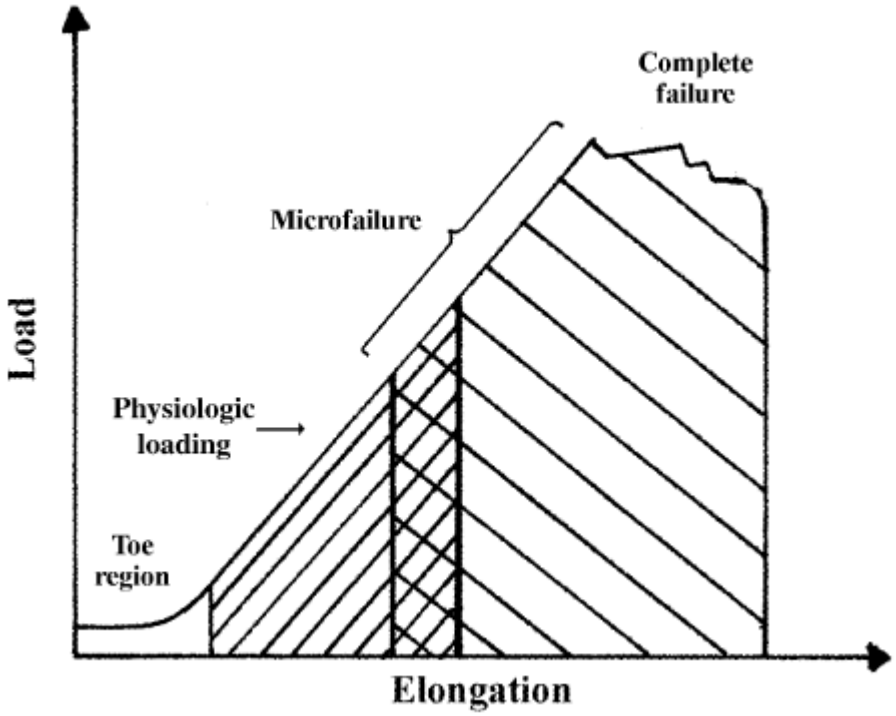
- Some techniques use slow stretching which results in the collagen fibres sliding past each other, in areas of restriction, reducing the crimping of the fibrous bundles and increasing the tissues extensibility.

- Some therapies intend to loosen the cross-links between the collagen fibres, using frictions and other more aggressive therapies like ‘grip and rip’ as well as instrumented assisted release.

- Some therapies are thought to deform the collagen fibres through a phenomenon known as creep. This process occurs when the tissue is stretched past the elastic barrier, for a length of time, permanently altering its structure and thus length.

- Some therapies intend to induce micro-failure of the collagen fibres. This is particularly relevant in the case of instrument assisted fascia release, where there is deliberate damage to the tissue, inciting an inflammatory response. This is thought to speed up the healing process.

Figure 2.4 illustrates the mechanical response of fascial tissue to increasing mechanical loads and stress over time.



(Schleip 2003a: 3)

Figure 2.4 Load and deformation of fascia in myofascial therapies

Included in the mechanical hypotheses is the ‘gel to sol’ model proposed by Rolf (1997). This mechanism involves changing the mechanical characteristics of the ground substance in which the fibres are embedded. Rolf (1997) explains that connective tissue is a viscoelastic substance and by applying heat or mechanical pressure, the ground substance can be changed from a dense gel, to a more fluid solvent state. This change in the viscosity is theorized to improve the gliding potential of the fascial sheets (Rolf 1997; Schleip 2003a). This proposed ‘gel to sol’ effect was shown to occur after long term mechanical stress applications in a study by Twomey and Taylor (1982).

According to Schleip (2003a), myofascial therapies applied for less than one and a half minutes are too short to produce the above mentioned ‘gel to sol’ effects. Additionally, the problem of reversibility occurs, where the ground substance is said to return to a gel state within minutes (Schleip 2003a)

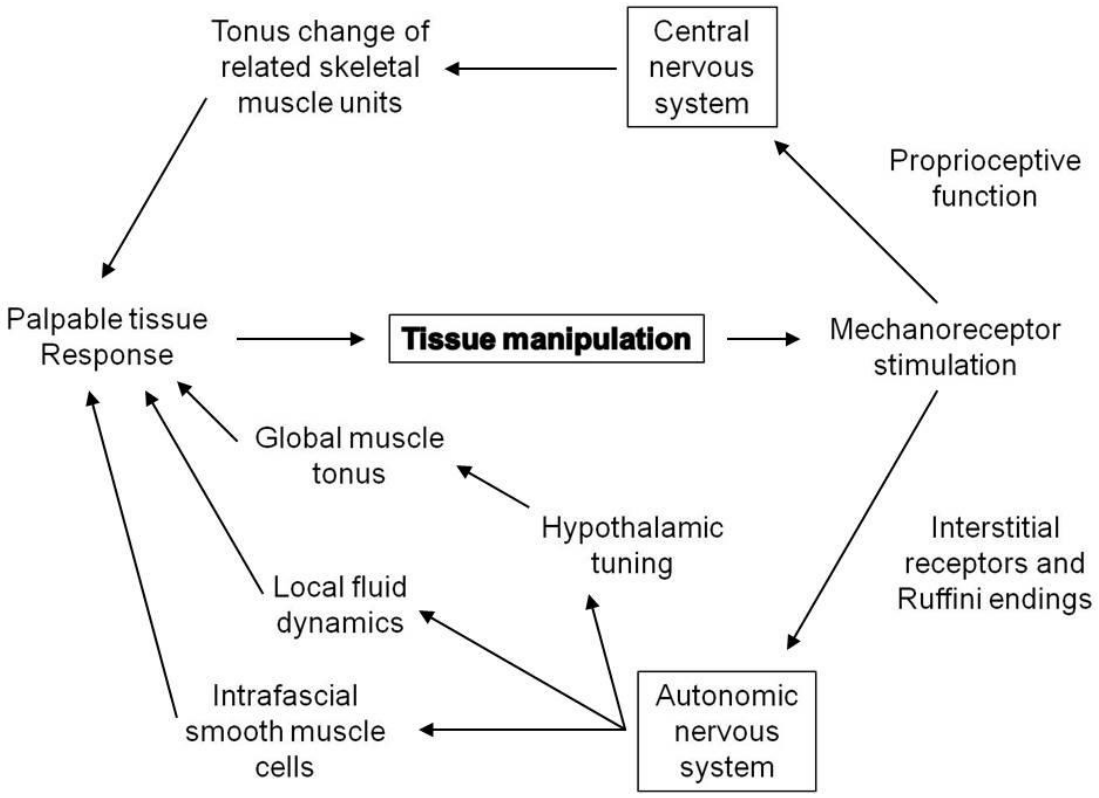
2.6.2 Neurophysiological Model

The palpable tissue changes, reported immediately after the application of myofascial therapies, cannot be explained by mechanical mechanisms alone (Schleip 2003a). The forces generated in the application of myofascial therapies have been shown to be too low to cause micro failure of the collagen, barring very thin or loose areolar tissue, such as in nasal fascia (Barnes 1997; Chaudhry et al. 2007; Simmonds, Miller and Gemmell 2012). The permanent deformation of dense connective tissues has also been shown to require long periods of application and a significant force (Currier and Nelson 1992). According to Threlkeld (1992), this deformation in the collagen fibres requires a forceful stretch, three to eight percent of fibre elongation. This will result in tearing, inflammation and other side effects (Schleip 2003a). Permanent deformation without tearing will take approximately one to one and a half hours, to get a one to one and a half percent fibre elongation (Threlkeld 1992). For these reasons, a purely mechanical explanation for immediate tissue release has raised debate (Schleip 2003a; b).

Some therapies included in the neurophysiological model include massage and connective tissue massage; myofascial release; neuromuscular techniques; structural integration and trigger point therapy (Simmonds, Miller and Gemmell 2012).

According to Hammer (2007: 22), the neurophysiological response to connective tissue loading occurs via the stimulation of the different types of mechanoreceptors. Pacinian receptors seem to be involved in high velocity thrusts. High velocity thrusts will not be discussed in the present study (Schleip 2003a). Ruffini receptors appear to be mostly stimulated by myofascial therapies through slow, deep pressure techniques, associated with a tangential force or stretch (Hammer 2007: 22). Schleip (2003a) notes that it is a common finding that these types of therapies have a relaxing effect on the associated fasciae, as well as the whole organism.

Figure 2.5 represents the different neurophysiological effects of mechanically stimulating the mechanoreceptors. The effects have been divided into stimulation of the central and autonomic nervous systems.



(adapted from Hammer 2007: 22).

Figure 2.5 Proposed neurophysiological effects of myofascial therapies

As it is impossible to exclusively stimulate only one type of mechanoreceptor, *Table 2.1* represents the known effects of stimulating the different types of mechanoreceptors in the body.

Table 2.1. Known effects of stimulating the different mechanoreceptors

Preferred location of receptor	Responds to:	Known result of stimulation
Golgi: Type Ib		
Myotendinous junctions, Attachment areas of aponeurosis, ligaments of peripheral joints and joint capsules.	Golgi tendon organ – muscular contraction. Other Golgi receptors – strong stretch only.	Decreased tone in related striated motor fibres
Pacini and Paciniform: Type II		
Myotendinous junctions, deep capsular layers, spinal ligaments and investing muscular tissues.	Rapid pressure changes and vibrations.	Used for proprioceptive feedback in movement control.
Ruffini: Type II		
Ligaments of peripheral joints, dura mater, outer capsular layers and other tissues associated with regular stretching.	Like Pacini, but also to sustained pressure. Especially responsive to tangential forces (lateral stretch).	Inhibition of sympathetic activity.
Interstitial: Type III and IV		
Most abundant receptor type, found almost everywhere, even within bones. Highest density within the periosteum.	Rapid as well as sustained pressure changes. 50% are high threshold and 50% low threshold units.	Changes in vasodialation and plasma extra-vasation.

(adapted by Schleip 2003a: 5).

In Simmonds, Miller and Gemmell (2012) the authors conclude that the beneficial effects derived from myofascial therapies, are probably due to contributions from both mechanical and neurophysiological mechanisms. The authors present a testable framework for the role of fascia in myofascial therapies and highlight the need for in vivo study into these mechanisms and their contributions (Simmonds, Miller and Gemmell 2012). Although the present study tested the immediate effects of myofascial therapies on proprioception and other outcomes, specific contributions as well as the exact mechanisms were not the aim. The present study merely explored if there were significant effects between the two myofascial groups, compared to a placebo.

2.6.3 Evidence for the Effect of Myofascial Therapies

In an article by Ercole et al. (2010), the authors review the literature in search of the time it takes to modify the palpatory sensation of fibrosis, present in the fascia. Forty participants suffering with acute or chronic mechanical low back pain were recruited. Depending on palpation, the application of the fascial manipulation technique (in the form of elbow release), was delivered bilaterally or unilaterally. Using a verbal numeric scale the participants were asked to report on the pain every 30 seconds. The results of the study showed that, on average, it took approximately 3.24 minutes to reduce the pain to about 50% of its baseline measurement. According to Ercole et al. (2010), these times correlated with the palpated tissue release reported by the practitioner. This investigation suggested that it is possible to modify pain and more importantly fibrosis in the immediate setting. The article by Ercole et al. (2010) supplies evidence for the immediate effect of myofascial therapies, with reference to pain.

Fernandes-des-las-penas et al. (2006) investigated the immediate effect of ischaemic compression and transverse frictions on the tenderness of active and latent myofascial trigger points in participants with mechanical neck pain. The pressure pain threshold showed significant improvement (p=0.03) as well as significant decrease in the visual analogue scores (p=0.04), within each group. There were no differences found between the groups and the results of this study showed that both types of myofascial therapies were equally as effective in reducing tenderness in myofascial trigger points (Fernandes-des-las-penas et al. 2006). Schleip et al. (2013: 300), points out that the involvement of fascia in the structural anatomy of muscles, suggests that some fascial orientated therapies are indicated in the treatment of myofascial trigger points. This has also been previously suggested by other authors (Grobi and Dommerholt 1997). Fernandes-des-las-penas et al. (2006) further showed that ischaemic compression and frictions are equally effective in treating pain.

In a recent article by Arun, Joginder and Sheetal (2014), the authors compared myofascial release and pressure release (synonomous with ischaemic compression) on pain and ankle range of motion. Thirty participants with an active soleus myofascial trigger point were treated, after which pain rating (using a numeric rating scale) as well as ankle dorsiflexion (using a goniometer) improved significantly in both groups. There was no difference between the groups and the authors concluded that both therapies were an effective treatment option for soleus myofascial trigger points (Arun, Joginder and Sheetal 2014). It is unclear whether

the reduction in pain was due to an increase in range of motion or if this increase in motion was secondary to a reduction in pain. Arun, Joginder and Sheetal (2014) provided evidence that in the treatment of soleus trigger points, pain as well as range of motion improved with both pressure release and myofascial release.

Smith and Fryer (2008), used stretching in combination with muscle energy techniques (group one - 3 second stretching interval, group two - 30 seconds stretching interval) to treated the hamstrings and knee range of motion was measured. Participants were treated twice, one week apart. Pre- and post-intervention measurements were done with significant changes and significant (p<0.01) were noticed. Post hoc testing showed that the significant differences were noticed in the immediate time frame (pre- and post-intervention) and were not different between the groups (Smith and Fryer 2008). This study suggests that myofascial therapies have a significant, post-intervention effect in terms of increasing range of motion in the knee for both short and long periods of treatment and stretching.

In Trampas et al. (2010), the authors investigated the immediate effect of modified proprioceptive neuromuscular facilitation (PNF) stretching versus PNF stretching combined with clinical massage, on latent hamstring myofascial trigger points. Thirty active males between 19 and 24 years of age volunteered for the study. Knee range of motion, stretch perception, pressure pain threshold and subjective pain thresholds were all measured post intervention and at 10 and 30 minutes after the relevant intervention. Results showed significant (p=0.05) changes in the combined group, with the pain intensity scores being lower than that of the stretching alone. Both groups improved compared to the control. These results suggest that in the treatment of latent trigger points, range of motion and pain scores improved significantly when treated with PNF stretching as well as combined with clinical massage (Trampas et al. 2010).

In a recent but small study, Macdonald et al. (2013) recruited eleven healthy males to investigate the immediate effects of self myofascial release to the quadriceps (using a foam roller). The participants were tested for maximum voluntary contraction force, evoked force and activation as well as knee joint range of motion. Readings were taken before, two minutes and ten minutes after the two conditions. One condition preformed self myofascial release and the other condition had no self myofascial release. The results showed that the self myofascial release group had a significant increase (p<0.001) in knee range of motion of ten degrees and eight degrees at two and ten minutes respectively, post intervention. The

authors concluded that self myofascial release was an effective treatment and significantly increased knee joint range of motion (Macdonald et al., 2013). Although a small sample size was used, Macdonald et al. (2013) demonstrated that myofascial release in the form of a foam roller could immediately improve range of motion in healthy asymptomatic participants.

In reviewing these studies, both ischaemic compression as well as myofascial release, have been effective at improving range of motion, reducing dysfunction as well as treating pain, in selected individuals.

With regards to the effect of myofascial therapies on balance and postural control, Castro-Sanchez et al. (2011) investigated the effect of multiple myofascial release treatments, on postural stability in fibromyalgic participants (a disease characterised by generalised fibrous colloid deposition). The investigation treated the myofascia of the axial skeleton, from the head to the lumbar spine, over twenty sessions. The study resulted in significant improvements in pain and disability but did not have any significant change in postural stability (Castro-Sanchez et al. 2011). This non-significant outcome may have been due to the area in which the treatment was delivered. To the best knowledge of this researcher, no study has investigated the immediate effects of myofascial therapies on balance measures, when treating the foot, lower leg and ankle. These areas have been shown to be specialized for the control of posture (Wright, Ivanenko and Gurfinkel 2012).

2.6.4 Ischaemic Compression and Myofascial Release

Ischaemic compression is often referred to as pressure release and is used to areas of myofascial dysfunction due the proposed effects outlined in Section 2.6 (Travell and Simons 1992: 3, 9). This therapy is traditionally used to treat active and latent myofascial trigger points (Simons 1987; Fernandes-des-las-penas et al. 2006). With regards to the present study, an ischaemic compression group was included due to the static nature of its application, in order to compare to the more dynamic myofascial release group (Arun, Joginder and Sheetal 2014).

For the purposes of this study ischaemic compression was used to treat areas of myofascial restriction (Donatelli 1987; Travell and Simons 1992: 3). Participants were asymptomatic with

regards to active pain; however it was interesting to note that areas of myofascial restriction were also areas of latent tenderness.

According to Manheim (2008: 8), the generic term ‘myofascial release’, is commonly used by researchers to describe any form of soft tissue work. This definition is supported by Simmons, Miller and Gemmell (2012), who suggest that there is much overlap between different myofascial techniques. The present study will define myofascial release as the dynamic techniques used, in which a slow, deep pressure is applied tangentially onto the skin, in areas of myofascial restriction, with the aim of reducing the restriction and improving function (Shah and Bhalara 2012; Hammer 2007: 20-22; Schleip 2003a; b)

Treatments in the myofascial release group differed from the ischaemic compression group, in the total area of application as well the nature of mechanical stimulation, in their application (Hammer 2007: 22). That being said, myofascial release has been shown to be comparable to ischaemic compression, in terms of increasing range of motion in the ankle after treating the soleus in selected individuals (Arun, Joginder and Sheetal 2014).

In the treatment of the myofascial restrictions, the tibialis anterior myofacia was avoided, due the proposed inhibitory (relaxing) effects of the myfascial therapies (Schleip 2003a; Hammer 2007: 20-22). This muscle is integral in supporting the medial longitudinal arch and has been shown to be over active in pronated participants compared to a control (Murley, Menz and Landorf 2009). For this reason, if the muscle tone was inhibited, the result may increase the navicular pronation and negatively influencing the biomechanics in pronated participants.

2.7 POSTURAL ANATOMY

The foot and ankle are made up of numerous specialised bones which function interdependently, in transmitting and distributing ground reaction forces (Wright, Ivanenko and Gurfinkel 2012). These ground reaction forces are the resultant accelerations and forces of the body, resisted by the Earth’s surface (Clifford and Holder-Powell 2010). In order to understand how these forces are transmitted through the feet, the bony anatomy of the foot, lower leg and ankle, are orientated according to Moore and Dalley (2006).

2.7.1 The Tibia and Fibula

The lower leg is made up of the tibia medially and the fibula more laterally. The tibia is the second largest bone in the body and articulates with the femur superiorly and the talus inferiorly. Each end provides a large surface area for articulation and weight transfer (Moore and Dalley 2006: 566). The distal end of the tibia has a bony prominence medially called the medial malleolus (Moore and Dalley 2006: 567).

The fibula is fixed to the tibia (unlike the radius and ulna in the forearm) by a tibiofibular interosseus membrane (Moore and Dalley 2006: 568). The fibula is not directly involved in weight bearing and mainly serves as a point for muscle attachment, in the leg (Moore and Dalley 2006: 568).The distal end of the fibula is enlarged inferiorly and laterally to form the lateral malleolus. The lateral malleolus together with the medial malleolus bridge the talus, forming the ankle mortise, which provides attachment for the ligaments that help stabilize the mortise joint (Moore and Dalley 2006: 568).

2.7.2 The Foot and Ankle

2.7.2.1 Hindfoot:Talus and Calcaneus

The talus is a sesamoid bone having no muscular attachments as most of its surface is covered with articular cartilage. Superiorly, the talus articulates with the leg bones on a structure called the trochlea of the talus or talar dome. The talus receives weight from the tibia and divides it between the calcaneus in the hindfoot and the navicular in the midfoot (Moore and Dalley 2006: 570).

During standing, the majority of the body's weight is transmitted through the calcaneus into the ground. For this reason the calcaneus is the largest and strongest bone in the foot (Moore and Dalley 2006: 570). The talus articulates with the anterior two thirds of the superior surface of the calcaneus, while the cuboid (mentioned below) articulates with the anterior surface of the calcaneus. An oblique ridge exists on the lateral surface of the calcaneus, anchoring part of the ankle retinacula (Stecco et al. 2010a). In pronation, the peronial muscles are an area of interest for the development of myofascial restrictions as

they are chronically shortened as a result of foot abduction (Donatelli 1985; 1987; Murley, Menz and Landorf 2009).

The calcaneal tuberosity is a massive weight bearing prominence on the posterior part of the calcaneus. This tuberosity has anterior, medial and lateral tubercles, of which only the medial tubercle is in contact with the ground during standing. The medial tubercle is also the proximal attachment point for the plantar fascia (Moore and Dalley 2006: 570).

2.7.2.2 Midfoot: Navicular, Cuboid and Cuneiforms

The navicular is a flattened, boat shaped bone, wedged between the talus posteriorly and three cuneiforms anteriorly (Moore and Dalley 2006: 570). The navicular tuberosity is projected inferiorly from the medial surface of the navicular and is a point of reference in determining the navicular position, or degree of pronation (Sporndly-Nees et al. 2011). The navicular tuberosity is an important site for muscle attachment (tibialis anterior) as the medial longitudinal arch of the foot does not rest on the ground. The navicular plays an integral part in the structure and function of the medial longitudinal arch, as discussed later in Section 2.8 (Moore and Dalley 2006: 571).

Cubical in shape and located most laterally in the distal row tarsal bones, lies the cuboid bone. The cuboid articulates with the last two metatarsals anteriorly (Moore and Dalley 2006: 571). Donatelli (1985) gives insight into how the cuboid and fibularis longus muscle are involved in establishing a pulley system. This pulley system enables the extrinsic muscles of the foot to function more efficiently, in order to set up a rigid lever from which to stand and push off (Donatelli 1985; Durrant and Chockalingam 2009).

There are three cuneiform bones, medial, intermediate and lateral cuneiforms (Moore and Dalley 2006: 571). The cuneiforms articulate with the navicular posteriorly and with each corresponding metatarsal anteriorly. The lateral cuneiform also has articulations with the cuboid laterally (Moore and Dalley 2006: 571).

2.7.2.3 Forefoot: Metatarsals and Phalanges

Five metatarsal bones, numbered from medial to lateral make up the forefoot (Moore and Dalley 2006: 572). Each metatarsal base, articulates with the cuneiforms and cuboid proximally (Moore and Dalley 2006: 572). Distal to each metatarsal head, lies a proximal phalanx, articulating with its corresponding metatarsal (Moore and Dalley,2006: 572). Medial and lateral sesamoid bones are embedded in the tendons passing along the plantar surface of the great toe. These sesamoid bones play an important role in supporting the medial longitudinal arch due to their plantar fascial insertion, explained in Section 2.8.2 (Hicks 1954).

The second to fifth metatarsals have three phalanges, proximal, middle and distal phalanges while the great toe only has a proximal and distal phalanx (Moore and Dalley 2006: 572). Proximal to distal, each phalanx has a base, shaft and head (Moore and Dalley 2006: 572).

2.8 FUNCTIONAL ANATOMY OF THE FOOT AND ANKLE

2.8.1 The Arches of the Foot

Tarsal and metatarsal bones in the foot are arranged in longitudinal and transverse arches (Hicks 1954). These arrangements bridge and distribute forces throughout the plantar surface of the foot (Dananberg 1993a; b). The arches allow the foot to absorb shock during locomotion and help in maintaining balance (Wright, Ivanenko and Gurfinkel 2012).

The arches of the foot are defined as follows:

- Medial longitudinal arch: This arch is made up of the calcaneus, talus, navicular, three cuneiforms and first three metatarsals. The talar head is the keystone of this arch (Moore and Dalley 2006: 710).
- Lateral longitudinal arch: Flatter than the medial longitudinal arch, resting on the ground during standing and is made up of the calcaneus, cuboid and lateral two metatarsals (Moore and Dalley 2006: 710).

- Transverse arch: This arch is formed by the cuboid, cuneiforms and bases of the metatarsals. The longitudinal arches serve as pillars to house the transverse arch. The tibialis posterior and fibularis longus tendons cross underneath the foot, attaching to numerous osseus structures, respectively these muscles maintain the transverse arch medially and laterally (Moore and Dalley 2006: 710).

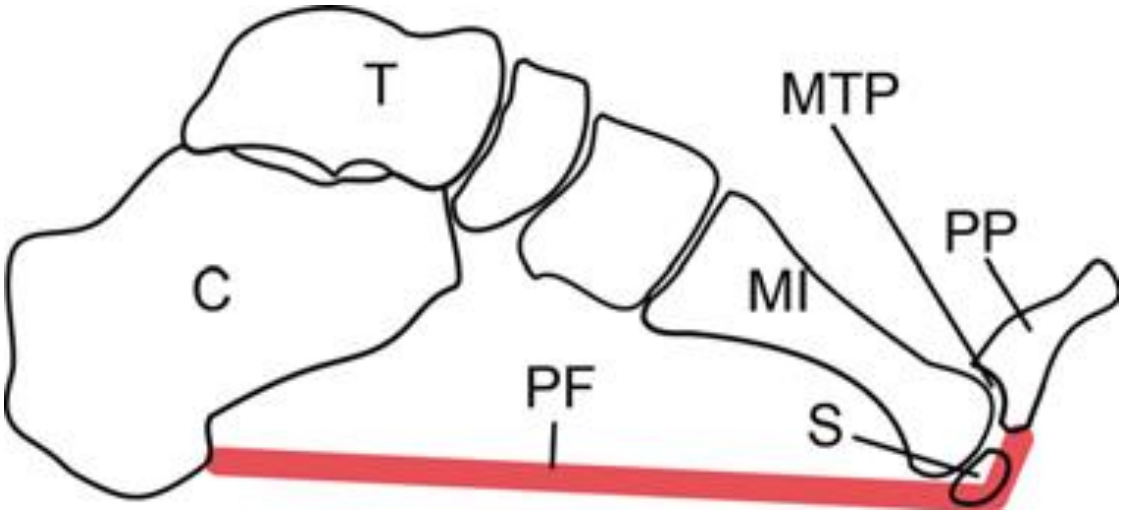
2.8.2 The Windlass Effect

In order to understand the functional anatomy and specialized characteristics of the foot, many authors refer to the windlass mechanism, to explain these relationships (Benjamin 2009).

Hicks (1954), was the first to describe and explain the beam action of the metatarsals and the tensile strength of the plantar fascia, as they work together to maintain the arches of the foot. Many authors refer to this as the windlass effect (Hicks 1953; 1954; Dananberg 1993a; b; Donatelli 1985; Durrant 2009). Key to this understanding the relationships above is the distal insertion of the plantar fascia is into two sesamoid bones at the head of the first metatarsal (Moore and Dalley 2006: 572). Hicks (1954) explains that when the toes are extended, the plantar fascia is wound around the metatarsal heads (due to its insertion into the sesamoid bones and great toe), resulting in shortening of the plantar fascia relative to the first metatarsal head and calcaneus. The author demonstrates that with this relative shortening of the plantar fascia, there is a need for the metatarsal head and medial longitudinal arch to move in a downward direction, in response. During standing, the downward movement of the metatarsal head increases the plantar pressure in the foot, distributing force axially along the metatarsals and arches (Hicks 1954; Dananberg 1993a; b; Donatelli 1987, Durrant and Chockalingam 2009).

This mechanism has been previously compared to the stringing of a bow (Dananberg 1993a). By tensioning a bowstring, an increase in the bow arch and rigidity results (Hicks 1954; Root, Orien and Weed 1977; Bojsen-Mdkr and LamOreux 1979; Dananberg 1993a; b; Benjamin 2009, Durrant and Chockalingam 2009).

Figure 2.6 has been adapted by Benjamin (2009) and represents the windlass effect occurring with great toe extension, proposed by Hicks (1954).



T – talus; C –calcaneous; MI – first metatarsal; MTP – metatarsophalangeal joint; PP – proximal phalanx; S – sesamoid; PF- plantar fascia (Benjamin 2009: 13)

Figure 2.6 The windlass effect.

2.8.3 Properties of the Plantar and Crural Fascia

In order to understand the anatomical and relationships mentioned above, attachments and relationships of the plantar and crural fascia (fascia associated with the leg), first needs to be discussed.

The plantar fascia consists of connective tissue sheets, attaching proximally to the medial process of the calcaneal tuberosity (Benjamin 2009). These sheets continue distally and divide into five bands which insert into the five digits (Benjamin 2009). Due to the predominantly medial attachment of the plantar fascia into the calcaneus, supination of the foot, results in tightening and stiffening of the plantar fascia (Kim and Voloshin 1995; Barthold 2001). The increase in tensile stress as a result of supination, further adds to supporting the arches in the foot (Kim and Voloshin 1995; Benjamin 2009). The plantar fascia also functions to cover, protect and support the intrinsic muscles of the foot according to Benjamin (2009).

In an article by Shaw et al. (2008), the connection between the plantar fascia and the achilles tendon is explained. The author goes on to mention that at birth, these two structures are

interconnected. With aging and over many years of mechanical stress and fibrous deposition, these extensions become fused at the calcaneal tuberosity (Shaw et al. 2008).

Cheng et al. (2008) developed a foot model to understand the connection between the windlass mechanism and the achillies tendon. The results showed that dorsiflexion of the ankle increased the strain in the planter fascia, especially the fascia extending to the great toe. The study found that by tensioning the achilles, the strain in the plantar fascia was to a lesser degree in the toes located more laterally, with the strain increasing the most in the great toe (Cheng et al. 2008). Stecco et al. (2009) and Natali, Pavan and Stecco (2010) have explained the mechanical response of this tissue to stress, indicating that this fasciae is hyperelastic and fibre reinforced, allowing it to accommodate to the large forces involved in posture and locomotion.

2.8.4 Normal Foot Function and the Windlass

In addition to supination of the foot, short and long plantar ligaments, along with the calcaneonavicular ligament (spring ligament), have also been shown to assist in the passive maintenance of the medial longitudinal arch (Donatelli 1985).

Donatelli (1985) adds that the dynamic aspects of foot function depends on and work in conjunction with the static mechanisms and points out the functional contribution of the plantar fascia and related structures, in stabilizing the medial arch. A few years later, Huang et al. (1993), investigated this and studied the contribution of the above mentioned structures to foot function. The authors used fresh frozen cadaveric specimens to investigate the structures involved in longitudinal arch integrity. The specimens were sectioned 20cm proximal to the distal tibia and all skin and the subcutaneous tissue was removed. The researchers applied different loads (230, 460 and 690 Newton) to the sole of the foot and then sequentially sectioned the plantar fascia, plantar ligaments and then spring ligament. All sequences of sectioning were tested and arch height was recorded at each stage. The results showed that arch height dropped after each sectioning, with the most relative contribution to arch integrity, coming from the plantar fascia, followed by the plantar ligaments and lastly the spring ligament (Huang et al. 1993).

2.8.5 Result of Abnormal Foot Biomechanics

Pronation and supination in the foot allows for the attenuation of ground reaction forces, by modifying the foot posture (Donatelli 1985). According to Donatelli (1987) explaining abnormal foot postures, the hypermobility in pronation or hypomobility in supination, results in the reduced ability of the foot to absorb shock, convert torque, adapt to different terrains and act as a rigid lever during push off. Over time, abnormal biomechanical loading in the foot, leads to chronic strain in the relevant skeletal, fascial and myofascial structures (Donatelli 1987). This chronic strain causes structural changes (fibrous deposition) in the connective tissue, effecting joint mobility (Jahss 1982; Root, Orien and Weed 1977; Donatelli 1987; Bouche and Johnson 2007). This is in addition to compensational changes in muscle function and biomechanics (Donatelli 1987; Dananberg 1993a; b, Murley, Menz and Landorf 2009; Stecco et al. 2010a).

2.8.5.1 Supination

Although supination is not a criteria for inclusion in the present study, it is important to understand the biomechanical changes, present in supinated individuals as they apply to abnormal foot function. According to Donatelli (1987), supination of the foot occurs in three scenarios or classifications.

I. The first classification is a pes cavus foot, demonstrating a fixed plantarflexed forefoot during weight bearing, with the calcaneus in neutral. The plantarflexed forefoot must not be confused with a pronated forefoot.

II. The second classification is a pes caco varus foot. In this type there is fixed plantarflexion of the first ray and the calcaneus is inverted, displaying a calcaneal varus during weight bearing. Root, Orien and Weed (1977) define forefoot valgus as eversion of the forefoot on the hindfoot, when the subtalar joint is placed in a neutral position. In compensation for the forefoot valgus, inversion of the calcaneus occurs during weight bearing. A forefoot valgus and/or a fixed plantarflexed first ray are the most common intrinsic deformities resulting in an abnormal supination of the calcaneus (Donatelli 1987).

III. The third classification of supination is the pes equinovarus, which demonstrates a fixed, plantarflexed forefoot and rearfoot. There is also no compensation demonstrated during weight bearing for this type.

During gait, participants with excessive supination remain supinated throughout the stance phase. Normally the foot would be in neutral at heel strike and begin pronating immediately, whereas supinators pronate late in stance phase (Donatelli 1987). According to Root, Orien and Weed (1977), late pronation in the push-off phase of gait, results in greater trauma and stress in the foot (Donatelli (1987).

2.8.5.2 Pronation

In his article Donatelli (1987) discusses the aetiology of abnormal pronation in relation to the foot, with regards to congenital, developmental and intrinsic or extrinsic factors. Only the resultant biomechanical changes with reference to pronation will be discussed below (Donatelli 1985; 1987).

The alignment of the calcaneus, talus, cuboid and navicular undergo changes, in compensation to pronation (Donatelli (1987). According to Donatelli (1987), the tibia, talus and calcaneus move simultaneously due to their structural and functional connection. In abnormal pronation the tibia, in combination with the talus, moves anterior and medially which results in internal rotation of these two structures (increasing the strain on the medial longitudinal arch). The internal rotation is superior to the calcaneus, causing its inferior surface of the foot to be positioned more laterally (forefoot abduction). This lateral movement of the calcaneus, and convex appearance of the achilles is called calcaneal valgus (Root, Orien and Weed 1977; Ramig et al. 1980; Donatelli 1987). According to Mann and Hagy (1980), the calcaneal valgus occurs as the calcaneus is subluxing (talocalcaneal incongruency) underneath the talus (Donatelli 1987). During excessive pronation, the height of the calcaneus is reduced relative to the ground (as a result of the tilt), which in turn causes the navicular and cuboid move away from each other, lowering of the medial and lateral longitudinal arches respectively Donatelli (1987). According to (Mann and Hagy 1980) this can be demonstrated on weight bearing x-rays of the foot.

In summary, the calcaneal valgus causes the navicular tuberosity to bulge medially, the forefoot is abducted onto the hindfoot and a reduction in the height of the medial longitudinal arch is observed (Mann 1980; Ramig et al. 1980; Hutton and Dhanendran 1981; Harradine and Bevan 2000; Dananberg 1993a; Durrant 2009).

In abnormal pronation, the excessive movements of these joints along with the accompanied myofascial compensations, lead to chronic joint stress and the development of adhesions within the myofascia and related structures (Harradine and Bevan 2000; Bouché and Johnson 2007; Wynn 2008; Shah and Bhalara 2012). Although no studies have shown the exact patterns of these adhesions, the evidence above provides a sufficient rationale, for the development of myofascial restrictions in the plantar and crural fasciaes, for participants with pronation.

2.8.6 Navicular Position

The navicular position test is a useful test to determine the degree of pronation or supination, present at the navicular (Sporndly-Nees et al. 2011). This test has shown to be highly reliable with a high inter-class coefficient (ICC) in both the intra-rater (ICC - 0.94) and inter-rater (ICC - 0.91) reliability (Sporndly-Nees et al. 2011).

According to Sporndly-Nees et al. (2011), the reliability of the navicular position test is greater than that of the navicular drop test and Feiss line measurements, used to measure pronation. The navicular position test accounts for a variation in foot size, which is a limitation reported in the literature with regards to the navicular drop test and Feiss line measurements. In a study establishing the reliability of the navicular position test, physiotherapy students were used as examiners in comparison to experienced physiotherapists. The results showed that both groups had a high inter-class coefficient as indicated above (Sporndly-Nees et al. 2011).

The measurement of navicular position by Sporndly-Nees et al. (2011) is suggested to be more reliable in detecting changes in the degree of pronation.

2.9 CONTROL OF POSTURE

The feet are specialized, for the roles they play in gait and maintaining posture and balance (Erdemir and Piazza 2004). In erect bipedat stance, the central nervous system relies on visual, vestibular and somatosensory (mechanosensory) inputs, in order to elicit the appropriate motor responses for balance (Horak 2006; Wright, Ivanenko and Gurfinkel 2012).

The visual contribution to balance provides information regarding the orientation of the eyes and head, in relation to the external environment (Clifford and Holder-Powell 2010). The vestibular apparatus gathers information with regards to gravitational, linear and angular accelerations of the head, in relation to inertial space (Horak et al. 1994; Lephart and Fu 2000: 37-39; Clifford and Holder-Powell 2010).

According to Lephart and Fu (2000: 38) the vestibular information is said to have a minor contribution to balance when the visual and somatosensory systems are working accurately. The present study focused on the somatosensory contributions of the foot, lower leg and anke to balance (and thus proprioception), by investigating if two different types of myofascial therapies had any immediate effect on mechanical (myofascial adhesions) and neurophysiological (mechanoreceptors) factors involved in balance (Simmonds, Miller and Gemmell 2012).

The postural stability (eyes closed) measure, removed the visual component and as a result, increase the dependency on the somatosensory and vestibular systems (Horak et al. 1994; Cote et al. 2005).

2.9.1 Postural Equilibrium and Postural Sway

According to Horak (1987; 2006), standing humans are constantly in an unstable equilibrium or balance, with the force of gravity on the body, continuously being opposed and counteracted. Balance and postural equilibrium are interchangeable terms according to Lephart and Fu (2000: 37). That being said, balance is usually referred to in terms of maintaining the centre of gravity within the body's base of support (Lephart and Fu 2000: 37). Postural equilibrium is generally used when describing the balanced state of forces and moments acting on the body's centre of mass (Lephart and Fu 2000: 37). Balance and

postural equilibrium can be assessed in terms of fluctuations in a participant's centre of pressure, using a force platform (Biosway Portable Balance System: Operation manual. No Date; Horak 1987; 2006; Clifford and Holder-Powell 2010).

The centre of pressure is classically described as the point at which the resultant ground reaction forces, aim to counteract the gravity acceleration forces on the body and its supports (Rougier 2009). Recorded changes in centre of pressure trajectories over time, provides the necessary data to calculate postural stability and amount of sway (Biosway Portable Balance System: Operation manual. No Date). This calculation of postural sway is used in many scenarios to determine how unsteady a body is (Clifford and Holder-Powell 2010). Postural sway or Sway index measures the ability of the participant, to control their centre of pressure, with the least amount (fluctuation) of sway possible (Clifford and Holder-Powell 2010). The somatosensory system is integral for achieving this as it provides continuous feedback with regards to the mechanical forces within the body (Rougier 2009).

The somatosensory system forms part of the proprioceptive system, but this term is more specific to the mechanorecpetors, relating to the control of posture (Lephart and Fu 2000: 39, Rougier 2009).

2.9.2 Postural Strategies

The body's centre of gravity is located above the lower extremities including the feet, ankles, knees and hips. Motions about any one of these joints are controlled by at least one pair of muscles working in opposition (Loram, Maganaris and Lakie 2005; Wright, Ivanenko and Gurfinkel 2012). During disturbed balance or imbalance, movement strategies involving the lower extremity coordinate the centre of pressure back to a balanced position (Lephart and Fu 2000: 41). Ankle, hip and stepping strategies act as effective mechanisms in repositioning the centre of gravity over the base of support. It must be mentioned that the stepping strategy will not be discussed as it only occurs when the centre of pressure exceeds the limit of stability in the prevention of falls (Lephart and Fu 2000: 42).

2.9.2.1 Ankle Strategy

The ankle strategy involves rotating the body about the ankle joints. The soleus, gastrocnemius and tibialis anterior muscles work in close relation to produce rapid plantarflexion and dorsiflexion moments respectively (Loram, Maganaris and Lakie 2005). In anterior sway, the gastrocnemius contracts to increase the plantar pressure, thus resisting anterior sway. Conversely the tibialis anterior contracts to increase ankle dorsiflexion and thus reduces the posterior sway (Lephart and Fu 2000: 42).

Rougier (2009) highlights that plantar pressure variations alone are controlled by anterior-posterior sway, which is of interest in the present as the areas treated influence plantar pressure, as demonstrated by Cheng et al. (2008).

2.9.2.2 Hip Strategy

The hip strategy involves loading and unloading the leg or hips to achieve modifications in medial-lateral sway (Rougier 2009). This mechanism is most effective when the centre of pressure is located near the limits of stability perimeter (Lephart and Fu 2000: 42).

Rougier (2009) showed that sway in the medial-lateral directions, is primarily controlled by the hip strategy but also has minor contributions from plantar pressure variations in each foot (Lephart and Fu 2000: 42; Rougier 2009). According to Rougier (2009), the resultant centre of pressure analysis needs to be broken down into medial-lateral as well as anterior-posterior axes.

2.9.3 Measuring Balance in Erect Bipedal Stance

Neural information is relayed and processed at incredibly high speeds in the body (Loram et al. 2005) Thus a highly specific and reliable measurement tool is required to record balance measures. A force platform was selected due to the objectivity and high sensitivity to forces and fluctuation thereof (Biosway Portable Balance System: Operation manual. No Date)

The Biosway Portable Balance System in *Figure 2.7* is a reliable tool to record the clinical test of sensory integration and balance (Biodex Portable Balance System: Operation manual.

No date). This test is made up of six different testing conditions which challenges how well the participant integrates their senses (visual, vestibular and somatosensory) with regards to balance. The interclass coefficient of the clinical test of sensory integration and balance was 0.81, which is considered acceptable, according to the Biosway Portable Balance System: Operation manual (No Date).

(Biosway portable balance system: Operation manual. No Date)

Figure 2.7 The Biosway Portable Balance System

A force platform (like the one used by the Biosway Portable Balance Platform) collects pressure readings from four pressure sensors, located at each corner of the force platform.

Using this data, the changes in centre of pressure can be calculated over a specific time period (Horak 1987; 2006; Clifford and Holder-Powell 2010). When the resultant centre of pressure is calculated for a participant, it is compared to the proposed centre of gravity and this is referred to as the Stability Index (Biodex Portable Balance System: Operation manual.

No date). The information used to calculate the Stability Index can also be used to calculate the standard deviation of Stability Index, called the Sway Index (Biodex Portable Balance System: Operation manual. No date). The Stability Index and Sway Index are described below:

- Stability Index: This is described as the average position of the centre of pressure from the proposed centre of gravity. This score is a calculation of the average distance of the resultant centre of pressure from the centre of gravity (Biodex Portable Balance System: Operation manual. No date).

- Sway Index: The Stability Index does not represent how much the participant has swayed, although the standard deviation of the Stability index does. The higher the Sway index, the more unsteady the participant was during the test (Biodex Portable Balance System: Operation manual. No date).

2.9.4 Foot Type and Balance

Balance in erect bipedal stance, is maintained in a closed kinetic chain, therefore any diminished afferent feedback (proprioception) or deficiencies in strength and mechanical stability, along the kinetic chain may have an effect on balance (Guskiewicz and Perrin 1996).

Cote et al. (2005) investigated single limb postural stability (eyes open and eyes closed) and limits of stability in 48 individuals. Participants were divided into equal groups of pronated, neutral and supinated feet (with a navicular drop of greater than 10mm, 5-9mm and less than 4mm respectively). The results showed that the Stability Index was greater in pronators than in supinators but neither group was significantly different from neutral foot types. Limits of stability revealed that pronators generally reached further in the anterior and anterior-medial directions with supinators reaching further in posterior and posterior lateral directions. According to Cote et al. (2005) during single limb stance, postural stability is affected by foot type, in static postural stability (eyes open and eyes closed) as well as dynamic conditions, using the limits of stability tests. There were no statistically significant differences between the groups (Cote et al. 2005).

This evidence suggests that postural stability and limits of stability are affected by pronation to some degree although the exact mechanisms behind these results are inconclusive (Cote et al. 2005).

2.9.5 Great Toe Extension

Researchers have investigated the great toe in many different scenarios. This is due to its importance in load bearing and how its structure is related to normal functioning of the windlass mechanism and maintaining longitudinal arch integrity (Nawoczenski et al. 1999; Nolan and Kerrigan 2004; Van Gheluwe et al. 2006; Cheng et al. 2007; Ku et al. 2012).

In the measurement of great toe extension, Hopson, McPoil and Cornwall (1995) compared the inter-rater reliability and validity of four great toe extension measures. Twenty healthy participants, between the ages of 21 and 43, were recruited and evaluated for four types of static great toe extension measures. Dynamic great toe extension was determined by video analysis during gait. The results showed that all four measures were reliable and that all measures of great toe extension exceeded the degree needed, during gait, when compared to the dynamic measure. The authors aimed to validate a particular measure, but noted that although all the measures of great toe extension were shown to be reliable, they should not be considered as interchangeable (Hopson, Mcpoil and Cornwall 1995). For this reason all of the great toe extension measurements were selected for the present study

Table 2.2 reflects the mean and standard deviations of the different great toe extension measurements in healthy participants with normal biomechanics in Hopson, McPoil and Cornwall (1995).

Table 2.2 Reliability and standard deviation for great toe extension measurements

Technique	Mean	Standard deviation	Range	ICC	Standard error
Passive non-weight bearing great toe extension	95.9	9.7	89-116.7	0.951	1.26
Active non-weight bearing great toe extension	85	10.7	66-99.3	0.906	1.38
Partial weight bearing great toe extension	100.4	6.	90-107.3	0.948	0.80
Weight bearing great toe extension at step length	109.6	11.1	92-142.3	0.976	1.44

Mean - in degrees, ICC – interclass correlation coefficient (adapted from Hopson, McPoil and Cornwall, 1995: 202).

Great toe extension was chosen as a variable due to its anatomical and functional relationships with the plantar fascia and medial longitudinal arch, in relation to the windlass effect (Durrant 2009). This gave an indication of the extensibility of the plantar fascia (in relation to the calcaneus and the great toe) under different weight bearing conditions (Hopson, McPoil and Cornwall 1995; Van Gheluwe et al. 2006; Durrant 2009).

2.10 THE PRESENT INVESTIGATION

The present study investigated the immediate effects that two myofascial therapies had on outcome measures in terms of function, compared to a placebo control group. Balance testing, with regards to postural stability (eyes open and closed) and limits of stability, indicated any changes amongst the groups in relation to proprioceptive ability. The study also compared bilateral changes (if any) in navicular pronation and great toe extension measurements to asses if the groups had any significant changes in alignment and range of motion, related to the medial arch.

CHAPTER THREE

METHODOLOGY

3.1 RESEARCH DESIGN

This was a prospective, quantitative, pre/post-test experimental investigation, comparing two myofascial intervention groups, to a placebo control. All participants had asymptomatic navicular pronation bilaterally. The study design was approved by the Faculty of Health Sciences Research Committee.

The Institutional Research Ethics Committee (IREC) approved that the research protocol satisfying the ethical requirements set out by the IREC and the Durban University of Technology (DUT).

IREC Reference Number: REC20/14

3.2 SAMPLE

A sample size of 45 participants were recruited from the greater Durban area in the Ethekweni district of Kwazulu Natal.

The participants were randomly allocated according to Section 3.5 into one of three intervention groups. Fifteen participants per group is consistent with the literature (Cote et al. 2005, Arun, Joginder and Sheetal 2014; Esterhuizen 2015).

3.3 CRITERIA FOR INCLUSION

Gender, ethnicity and occupation were not criteria for inclusion and age was limited, due to the possible contribution of joint degeneration to altered position sense.

3.3.1 Inclusion Criteria:

- Participants had to be between the ages of 18-35 (Hageman, Leibowitz and Blanke 1995; Fernandes-des-las-penas et al. 2006; Arun, Joginder and Sheetal 2014)
- Participants had to have navicular pronation of two degrees or greater in both feet as indicated by the navicular position test.

3.3.2 Exclusion Criteria:

- Participants were excluded if they were symptomatic with regards to pain in the foot, lower leg and ankle.
- Participants who had congenital, traumatic or surgical deformities in the foot, lower leg or ankle, other than bilateral pronation.
- Participants were excluded if they suffered from peripheral neuropathy or neurological dysfunction effecting balance or proprioception, were exclusions.
- Females were excluded if they were pregnant, as this effects ligament laxity.
- Participants were excluded if they suffered from any local or systemic disease, that contraindicates soft tissue therapy (varicose veins, oedema due to cardiac insufficiency, infection, thrombosis, cellulitis).
- Participants were excluded if they received chiropractic treatment within two weeks prior to being recruited.

3.4 RECRUITING

Participants were recruited through advertising in the form of posters, pamphlets and by word of mouth (Appendix A). The pamphlets were emailed to chairpersons of sporting and recreational clubs for the onward distribution to their members, once permission was obtained from the relevant person/s (Appendix B). Pamphlets were also placed on notice

boards of local libraries, shopping centres and other areas of communal gathering, after gaining the relevant permission (Appendix B).

Once a potential recruit had responded by phone or short message service (SMS), the researcher returned the call and telephonically interviewed the recruit to determine if the he or she would possibly meet the inclusion criteria for the study. The telephonic interview involved a list of questions which the researcher asked during the telephonic interview (Appendix C). Refer to *Table 3.1* for the list of questions used to recruit participants over the phone.

Table 3.1 Questions and required answers of the telephonic interview

	Questions	Required Answers
1	Would you be willing to answer a few questions about yourself regarding foot function and well-being?	YES
2	Are you between the ages of 18 and 35 years?	YES
3	While standing, do your arches drop?	YES
4	Have you ever been told you have flat feet?	YES
5	Do you currently have any pain in your foot or ankle?	NO
6	Have you had significant trauma or surgery to the foot or ankle?	NO
7	Do you have any altered sensation in the foot or ankle?	NO
8	Do you take medication for any chronic diseases?	NO
9	Would you be willing to attend a consultation at the DUT Chiropractic Clinic, to determine if you will be able to participate in this study?	YES

(Appendix C)

The researcher recorded and kept in confidence all results of the telephonic interview. After the recruit gave the required answers, an appointment was scheduled at the DUT Chiropractic Day Clinic. No appointment was booked if the researcher received answers that excluded him or her from the study. If the recruit was unsure of their answers, an appointment was scheduled in order to determine their eligibility. The researcher informed

potential recruits to bring their identification document or drivers licence to the consultation to verify their age.

Active recruitment, that is, word of mouth was done on the DUT campus. The researcher placed A3 advertising boards (Appendix A) next to a measurement station, which included two standing platforms, used to measure the navicular position. The advertising boards (Appendix A) assisted the researcher in explaining to interested recruits what the measurement entailed. Potential recruits were notified that research was currently being conducted at the DUT Chiropractic Day Clinic. The researcher tested interested recruits for navicular position, through the navicular position test. This test is non-invasive and measures the navicular position using a goniometer and tippex marker (Sporndly-Nees et al. 2011). The navicular position test was shown to have a high intra- and inter-tester reliability (Sporndly-Nees et al. 2011). Two or more degrees of navicular pronation indicated possible recruitment into the study.

3.5 RESEARCH PROTOCOL

1. Permission was gained to undertake research at the DUT Chiropractic Day Clinic (Appendix L).

   Interested parties were then interviewed telephonically. If eligible, an appointment was scheduled at the DUT Chiropractic Day Clinic.

   Upon arrival at the appointment each person was given a Letter of Information and an Informed Consent Form to read and sign (Appendix D, 2D). These forms provided the person with a detailed explanation of what the research entailed and what was expected of them as participants. These people were made aware that once accepted into the study, they could withdraw at any point in time.

2. Participants then underwent a case history (Appendix E), physical examination (Appendix F), knee regional (Appendix G), foot and ankle regional (Appendix H) examinations.

   The researcher palpated and made the relevant foot markings on both feet, in all participants.

The researcher then screened for inclusion and exclusion criteria.

3. The participant received general instruction with regards to test requirements and relevant explanations according to the Biosway Portable Balance System: Operation manual (No Date)

   At this point the researcher used the Biosway Portable Balance Platform to familiarize the participant with the postural stability and limits of stability tests by conducting one test trial. The results were not saved.

4. Participants were randomly allocated into one of the three intervention groups (group one: placebo ultrasound, group two: ischaemic compression, group three: myofascial release) by a designated sample allocator (Appendix N). The allocator drew a folded number from one to forty five out of an envelope, corresponded to a number on the random allocation table (Appendix O). This indicated the group allocation. The allocator then wrote the name and surname of the participant alongside the relevant number on the random allocation table for record purposes. The participants height and weight was measured at the DUT Chiropractic Day Clinic.

5. Any relevant information with regards to the examination forms (Appendices E-H) was entered into the SOAPE note (Appendix I). Thereafter the relevant clinician on duty at the DUT Chiropractic Day Clinic reviewed the findings before signing off the documentation.

6. Before the commencement of the study, two senior chiropractic interns were selected as assistant examiners, and trained to perform the navicular position test and great toe extension measurements using a standard two arm goniometer (Hopson, McPoil and Cornwall 1995; Sporndly-Nees et al. 2011). The researcher and supervisor signed off the Assistant Examiner Training Form (Appendix K), once the researcher felt his assistant examiners were competent in the recording of navicular position and great toe extension measurements.

   The relevant assistant examiner was blinded as to which intervention the participants received.

   Two people were needed to record the goniometric measurments, therefore the researcher helped position the participant and the assistant examiner performed the

measurement and entered the data into the Data Sheet, using a pen (Appendix J). If an error was made on the Data Sheet, a line was drawn through the error and the assistant examiner placed their signature next to the error.

Goniometric measurements were done according to Section 3.8 in the methodology

The researcher operated the Biosway Portable Balance System for balance testing according to Section 3.10 in the methodology. The results were saved after each test.

7. The pre-intervention data was recorded in the following order for goniometry first: navicular position; passive non-weight bearing great toe extension; active non-weight bearing great toe extension; partial weight bearing great toe extension; weight bearing great toe extension at step length.

   Balance testing commenced immediately after in the following order: postural stability (eyes open); postural stability (eyes closed); limits of stability.

8. Immediately after the pre-intervention data was collected, the researcher delivered the relevant intervention bilaterally, to myofascial restrictions in the foot, lower leg and ankle.

9. The post-intervention data was immediately following the relevant intervention. The assistant examiner placed their signature at the bottom of the data sheet once it was completed (Appendix J).

3.5.1 Blinding of Assistant Examiners

Two examiners were chosen in accordance with Appendix K, due to the availability of the assistant examiners.

The assistant examiner was blinded as to which intervention the participant received. The principal researcher helped position the patient while the assistant examiner performed each test with the two arm goniometer. The assistant examiner recorded the results into Appendix J (data sheet) and signed at the bottom of the data sheet.

3.6 INTERVENTIONS

All interventions (including the placebo ultrasound) were delivered to palpated myofascial restrictions in the foot, lower leg and ankle. Areas of myofascial restriction correlated with biomechanical and postural compensations in the participants with bilateral navicular pronation.

It must be noted that in the treatment of the myofascial restrictions, myofascia associated with the tibialis anterior and tibialis posterior were avoided. This is due to the integral part that these muscles play in supporting the medial longitudinal arch and a subsequent reduction in the motor tone of these muscles, was thought to worsen the navicular pronation (Donatelli 1985; 1987; Dananberg 1993a; b; Schleip 2003a; b; Murley, Menz and Landorf 2009)

3.6.1 Group A: Placebo Ultrasound

This group received placebo ultrasound bilaterally to myofascial restrictions in the foot, lower leg and ankle.

- In delivering the placebo ultrasound therapy, procedure was followed according to Kitchen and Bazin (1996: 254-261) with the exception of the therapeutic effect. This was achieved by setting the intensity to zero.
- The participant was positioned supine on the plinth and asked to raise both knees to 90 degrees.
- The machine was switched on and after placebo settings were entered, the ultrasound gel was applied to areas of myofascial restriction.
- The head of the ultrasound was moved in a circular pattern, to spread the gel over the foot, lower leg and ankle for fifteen minutes per leg. The sole of the foot was not treated in this group.
- The participant was wiped clean at the end of the procedure.

3.6.2 Group B: Ischaemic Compression

This group received ischaemic compression bilaterally to myofascial restrictions in the foot, lower leg and ankle. Ischaemic compression, also referred to as pressure release was applied according to Travell and Simons (1992: 398-540).

- Reinforced thumb pressure was applied as close to the pain threshold as possible for the participant. The pressure was held at multiple points of myofascial restriction for up to a minute or until the participant reported that the discomfort had disappeared (Travell and Simons 1999: 126-146).

- The areas of myofascial restriction were placed under static passive stretch during periods of reinforced thumb pressure. In the case of myofascial restrictions in the gastrocnemius and soleus, the foot was held in passive dorsiflexion, while the participant lay prone and reinforced thumb pressure was applied (Travell and Simons 1992: 397-422, 427-456).

- Myofascial restrictions in the peroneals were treated with the patient side lying and the participant's foot was passively inverted. Reinforced thumb pressure was applied to points of myofascial restriction (Travell and Simons 1992: 370-394, 473-498).

- The plantar fascia was treated with the participant supine while the researcher held the foot with both hands, moving it into a dorsiflexed position. The researcher used his thumbs to apply pressure to points of restriction in the plantar fascia (Travell and Simons 1992: 500-518, 522-538).

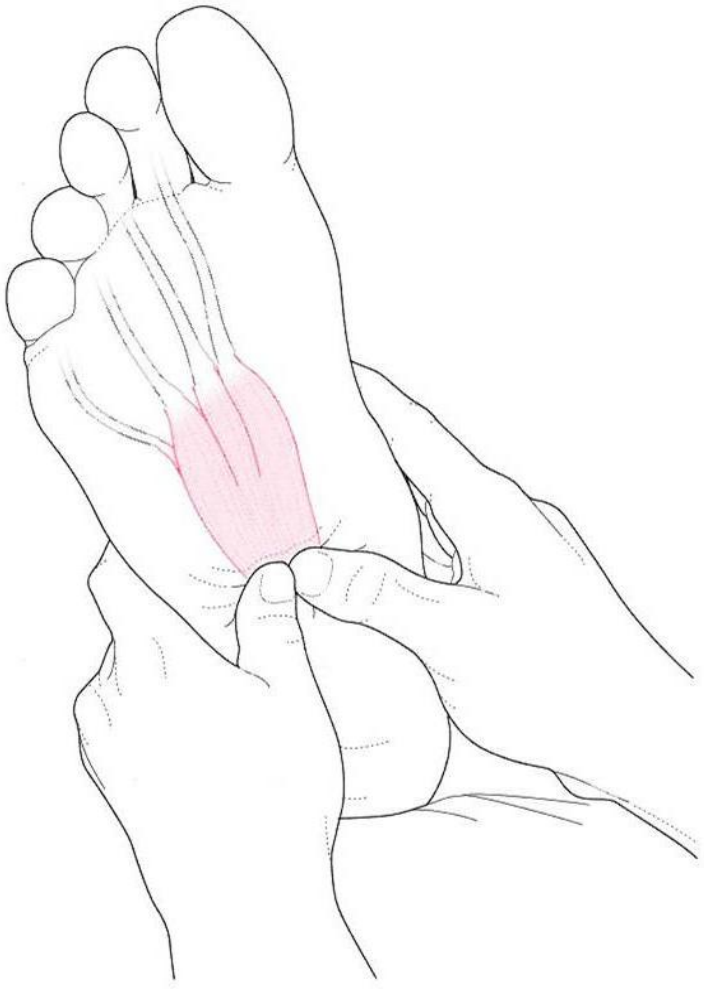
3.6.3 Group C: Myofascial Release

This group received myofascial release bilaterally to myofascial restrictions in the foot, lower leg and ankle.

- The myofascial release was applied according to Chaitow and DeLany (2002; 497-567). These neuromuscular techniques illustrated in Figure 3.1; 3.2; 3.3 and 3.4, were applied at slow, deep pressures, tangentially along the entire length of the restricted mofascia (Hammer 2007: 20-22).

- These techniques were delivered at a bearable threshold for 15 minutes on each leg or until no further tightness or restrictions were palpated.

- *Figure 3.1* demonstrates myofascial release in the sole of the foot. This Neuromuscular technique addressed the plantar fascia and intrinsic muscles, along the plantar aspect of the foot. Participant was supine and the researcher placed both thumbs on the medial aspect of the calcaneus. The researcher delivered slow, deep strokes through the plantar fascia in the direction of the digits. The strokes are repeated along the medial and lateral columns of the foot.



(Chaitow and DeLany, 2002: 563-566)

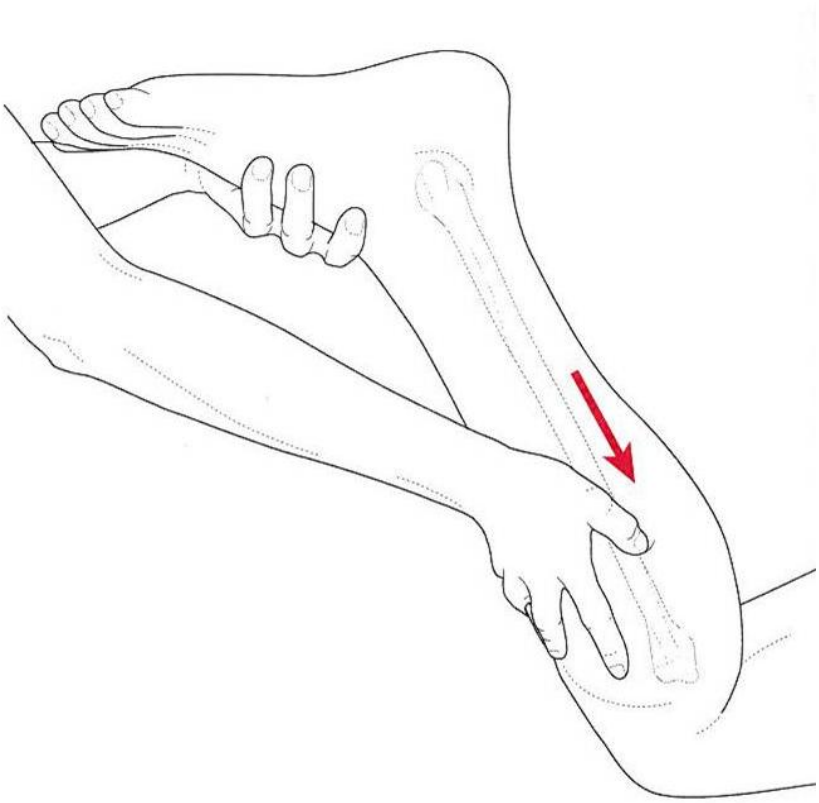
Figure 3.1 Release of the intrinsic muscles and plantar fascia of the foot

- *Figure 3.2* demonstrates myofascial release of the ankle and achilles. This neuromuscular technique addressed myofascial restrictions in the achillies, calcaneus and ankle region. The participant lay prone and the researcher stood at the base of the bed.Thumbs were placed on both sides of the calcaneus and slow deep strokes were applied through the calcaneus into the achilles tendon. Simultaneously the researcher increased dorsiflexion in the ankle.

(Chaitow and DeLany, 2002: 538)

Figure 3.2 Release of the calcaneus and achilles

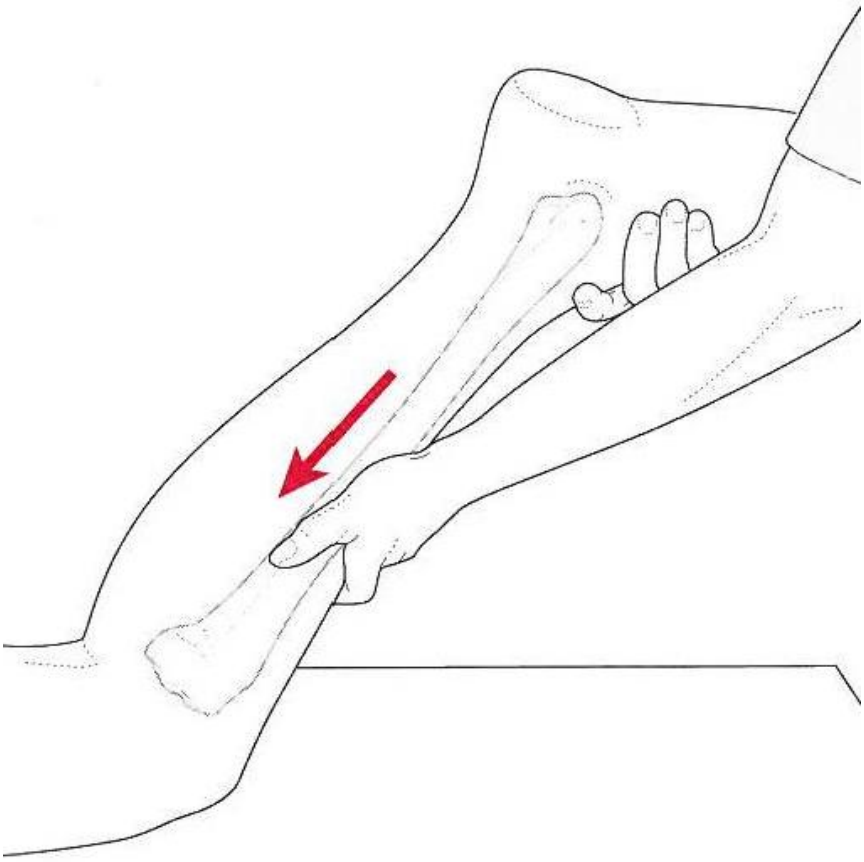
- *Figure 3.3* demonstrates the myofascial release of the posterior lateral crural fascia. This neuromuscular technique was used to treat myofascial restrictions in the posterior lateral crural fascia. The participant's knee was passively flexed up to 90 degrees and the researchers hands were placed onto the posterior shaft of the fibula. The thumb pointed in the direction of the knee. Restrictions in the peroneal muscles, lateral head of gastrocnemius and lateral belly of the soleus were treated using this technique. The strokes were applied at slow, deep pressures and the researcher was careful not to put pressure onto the peroneal nerve. It is again noted that the thumb does not move onto the anterior aspect of the fibula as the tibialis anterior was avoided in the treatment of the lower leg.



(Chaitow and DeLany, 2002: 544, 545)

Figure 3.3 Release of the posterior lateral fibula

- *Figure 3.4* demonstrates myofascial release of the posterior medial crural fascia. This neuromuscular technique was used to treatment myofascial restrictions along the posterior medial crural fascia. The strokes were applied in the same manner as for the posterior lateral crural fascia. In this technique the medial head of gastrocnemius and medial belly of soleus addressed. The tibialis posterior was avoided in the treatment of the posterior medial crural fascia.



(Chaitow and DeLany, 2002: 544, 545)

Figure 3.4 Release of the posterior medial tibia

3.7 MEASUREMENTS

3.7.1 Tools

1. The researcher used a massage table with adjustable height settings for participants to lie and sit on, for goniometric measurements.
2. The researcher used a tippex marker and red permanent marker to make the relevant markings on the participant's feet.
3. The assistant examiner used a standard two-arm goniometer, to perform the measurements.
4. Two level standing platforms of equal height, aided in the recording of the goniometric measurements. This was because the arms of the goniometer would be obstructed by the floor, during these measurements.
5. A wooden pole was made available to participants who felt unstable, during the goniometric measurements.
6. A standard spirit level was used to measure the participant's step length, as indicated by the weight bearing great toe extension at step length measurement.
7. The Biosway Portable Balance Platform, was used to test postural stability (eyes open and closed) and limits of stability tests.

3.7.2 Foot Markings

As indicated in the Research Protocol, participants were marked by the researcher prior to being examined by the assistant examiner (Hopson, McPoil and Cornwall 1995; Sporndly-Nees et al. 2011). The markings were made as small and as precise as possible, using a tippex marker, on the following anatomical landmarks, as indicated by *Figure 3.5*.

A. Great toe interphalangeal joint: A mark was made on the most medial point of the distal interphalangeal joint.

B. First metatarsal head: The most medial point on the distal head of the first metatarsophalangeal joint.

C. First metatarsal base: The most medial and prominent point on the base of the first metatarsal was marked.

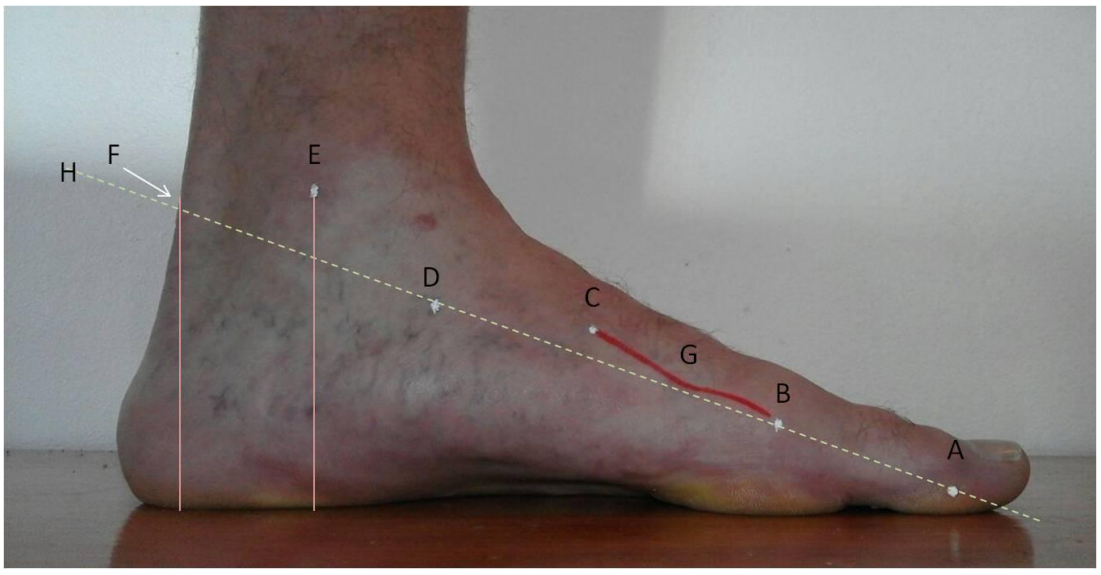
D. Navicular tuberosity: Medial prominence, inferior to the medial malleolus and anterior to the talus was marked.

E. Medial malleolus: The medial malleolus was marked at its most distal point.

F. Achillies tendon: The height from the standing platform up to the mark made on the medial malleolus was measured using the goniometer. A mark was then made on the achillies tendon, parallel to and at the same height as the one on the medial malleolus.

G. The red permanent marker was used to draw a straight line connecting the mark made on the base and head of the first metatarsal using the goniometer.

H. Imaginary neutral line



(adapted from Hopson, McPoil and Cornwall 1995; Sporndly-Nees et al. 2011)

Figure 3.5 Foot markings used to measure goniometry

3.8 GONIOMETRY:

3.8.1 Navicular Position Test

The navicular position was recorded bilaterally, first left followed by the right foot.

For the navicular position test, the participant stood with the relevant foot being measured posterior and along the medial edge of one raised platform (in order to remove the obstruction of the floor for the goniometer). The contralateral foot was placed comfortably placed anterior and on the other raised platform, shoulder width apart. The heel of the anterior foot was positioned in line with the tip of the posterior foot's great toe. The participant was allowed to make use of a pole to balance if he or she felt unstable (Sporndly-Nees et al. 2011).

The assistant examiner measured the navicular position by placing the axis of the goniometer onto the mark made on the navicular tuberosity. One arm of the goniometer was placed over the mark made on the first metatarsal head and the second arm was taken to the mark made on the achilles tendon (Sporndly-Nees et al. 2011). The assistant examiner then entered the recording into the Data Sheet (Appendix J) and placed their signature at the bottom of the page, after pre- and post-intervention measurements.

A positive degree indicated supination as the navicular moved above the imaginary line made between the first metatarsal head and the mark on the achilles tendon. Conversely, pronation was where the navicular moved below this point and was indicated by a negative degree on the goniometer (Sporndly-Nees et al. 2011).

3.8.2) Great Toe Extension

All measurements of great toe extension were done bilaterally, first left then followed by the right foot.

Great toe extension was measured relative to the first metatarsal and the great toe (Hopson, McPoil and Cornwall (1995). Patient positioning and recording of the four great toe extension measurements, according to Hopson, McPoil and Cornwall (1995) are as follows:

3.8.2.1) Passive Non-Weight Bearing Great Toe Extension

This test required the participants to lie supine on a massage table, with their feet over the edge of the table. The researcher placed the relevant foot into sublatar neutral by applying dorsiflexion pressure to the fourth and fifth metatarsal heads. The researcher then passively dorsiflexed the hallux maximally, while the assistant examiner recorded the great toe extension.

The assistant examiner performed the measurement by placing the axis of the goniometer on the mark made on the first metatarsal head. One arm of the goniometer was placed onto the mark made on the base of the first metatarsal, with the second arm moved to the mark on the distal interphalangeal joint. The angle was then recorded into data sheet by the assistant examiner (Hopson, McPoil and Cornwall 1995).

3.8.2.2) Active Non-Weight Bearing Great Toe Extension

The participant remained in the same position as for passive non-weight bearing great toe extension. The researcher placed the relevant foot into subtalar neutral and asked the participant to hold the foot in that position, after which the researcher removed his hand. The researcher extended the great toe to the point where the first metatarsal head had begun to move in a plantar direction.

The assistant examiner then placed the axis of the goniometer in line with the dorsum (top surface) of the foot, opposite the mark made on the first metatarsal head. The arms of the goniometer then measured extension relative to the dorsum of the first metatarsal and great toe. The angle was then recorded into data sheet by the assistant examiner (Hopson, McPoil and Cornwall 1995).

3.8.2.3) Partial Weight Bearing Great Toe Extension

The researcher asked the participant to sit on the edge of the massage table (adjusted for height) and to place each foot on a raised level platform (shoulder width apart and on the

medial edge of the platforms), so that their knees were bent at 90 degrees. The relevant foot examined, was then positioned (more posteriorly) so that the great toe was in line with the heel of the contralateral (opposite) foot.

The researcher asked the participant to maximally raise the heel of the foot examined (posterior foot) up to a point where the entire great toe was still in remained on the platform. If the examiners noticed that the first metatarsal head lifted off the platform, the participant was asked to repeat the movement.

The assistant examiner then recorded the great toe extension, by placing the axis of the goniometer on the marking made on the head of the first metatarsal. The arms of the goniometer measured great toe extension relative to the line and mark made along the shaft and base of the first metatarsal, with the other arm on the mark made at the distal interphalangeal joint. The angle was then recorded into data sheet by the assistant examiner (Hopson, McPoil and Cornwall 1995).

3.8.2.4) Weight Bearing Great Toe Extension at Step Length

In order to measure the step length, the participant was asked to walk at a normal pace across the room. The researcher asked the participant to halt, at a point where both feet were in contact with the floor. The participant remained in this position and the researcher used a spirit level to measure the distance between the heel anteriorly and great toe posteriorly. This distance recorded onto the data sheet, next to the ‘‘Weight bearing at step length’’ block (Appendix J). The step length could then be reproduced when examining the contralateral foot, as well as for the post-intervention measurements.

The two raised platforms were spaced according to the participant’s step length, using the spirit level. The participant stood with the relevant foot examined posterior and the researcher positioned the foot onto the medial edge of the raised platform so that the great toe was at the most anterior point on the platform. The heel of the contralateral (front) foot was spaced at shoulder width and onto the posterior (back) edge of the front platform. A pole was made available to the participant if they felt unsteady

The participant was then instructed to maximally raise their heel up to a point where the entire great toe remained in contact with the floor, as for the partial weight bearing great toe extension.

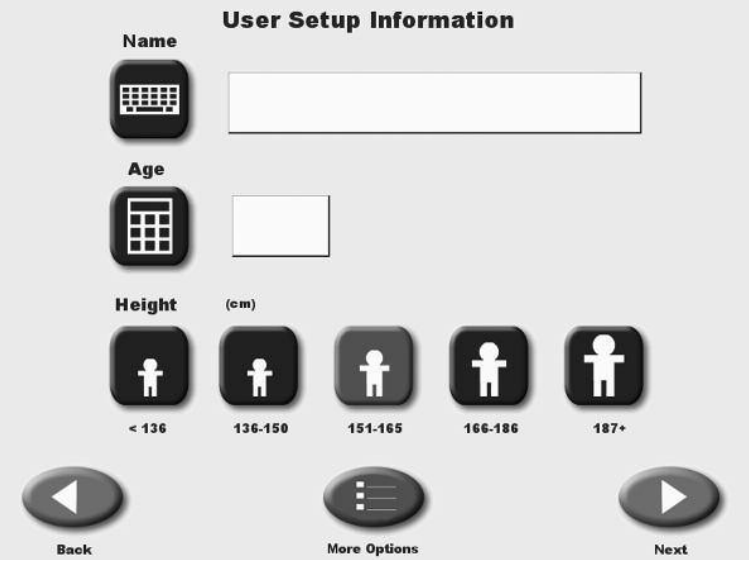
The assistant examiner then recorded the great toe extension, by placing the axis of the goniometer on the marking made on the head of the first metatarsal. The arms of the goniometer measured great toe extension relative to the line and mark made along the shaft and base of the first metatarsal, with the other arm on the mark made at the distal interphalangeal joint. The angle was then recorded into data sheet by the assistant examiner (Hopson, McPoil and Cornwall 1995).

3.9) BIOSWAY PORTABLE BALANCE SYSTEM

3.9.1) General Instruction and Set Environment

As indicated in the Research Protocol, participants were trained to perform postural stability tests (eyes open and eyes closed) and the limits of stability test, after the physical examination, in order to familiarise him or her with the balance testing.

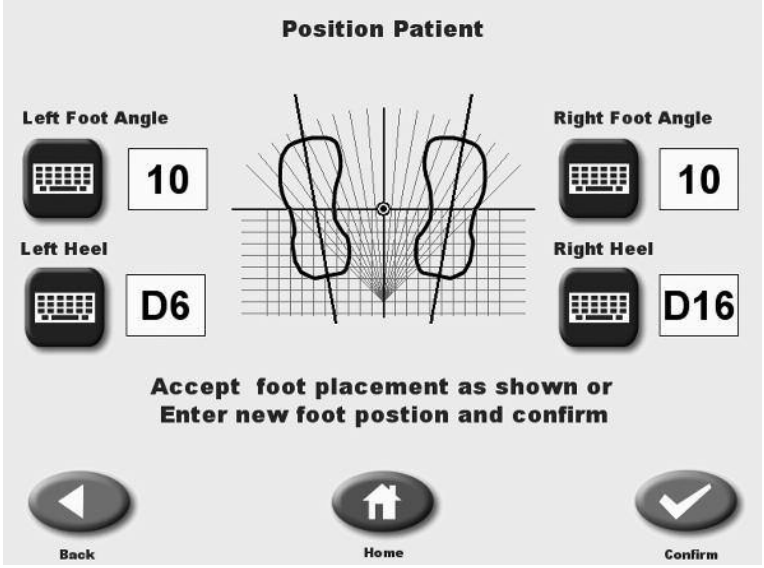
- Environmental conditions, instruction and set procedure and was carried out by the researcher as indicated in the Biosway Portable Balance System: Operation manual (No Date).
- Temperature was set to 23 degrees Celsius.
- The participant was bare foot.
- The Biosway Portable Balance System was turned on and levelled according to on screen prompting.
- The participant's details and parameters, *Figure 3.6*, were entered into the monitor.



(Biosway Portable Balance System: Operation manual. No Date)

Figure 3.6 Participant parameters

- Thereafter the participant was asked to stand at the recommended foot positioning, *Figure 3.7*, with equal pressure on each foot, as indicated by the Biosway Portable Balance System's monitor.
- After the participant was positioned onto the Biosway Portable Balance Platform, he or she was told not to shift their feet during the testing. If the participant did shift their feet, the test was stopped and repeated again using the recommended foot positioning.
- Participants were told to keep their arms at their sides.
- The monitor was adjusted to eye level and kept at the same position for all the tests.
- The relevant test was selected and carried out according to the instruction displayed on the monitor and in the Biosway Portable Balance System: Operation manual (No Date).
- The balance training was done in the following order: postural stability test (eyes open); postural stability test (eyes closed); limits of stability test.
- For each of the balance tests the participants were given three, 20 second trials, after which an average score was automatically calculated, but was not saved.



Biosway Portable Balance System: Operation manual. No Date)

Figure 3.7 Recommended foot positioning

3.10 BALANCE TESTING:

All balance tests required the participant to stand in erect bipedal stance (Biosway Portable Balance System. No date).

All tests required the participants to remain in the recommended foot positioning (Biosway Portable Balance System. No date).

All balance testing required the participants to perform each test for 20 seconds over three trails. The average score with regards to the three trials was calculated by the Biosway Portable Balance System (Biosway Portable Balance System: Operation manual. No date).

The participant was asked to do their best for both the pre-intervention and post-intervention testing.

3.10.1) Postural Stability Test (Eyes Open)

This test evaluated how well the participant could control their centre of pressure with regards to the proposed centre of gravity (indicted on the Biosway Portable Balance Systems's monitor). The monitor gave a visual reference point, for any changes in centre of pressure (Biosway Portable Balance System: Operation manual. No Date; Le Clair and Riach 1996; Clifford and Holder-Powell 2010).

- The postural stability test (eyes open) required the participant to position their centre of pressure (shown as a moving dot on the Biosway Portable Balance Systems's monitor) in the centre of the target displayed on the monitor. The participants was asked to keep as steady as possible, while maintaining this position for 20 seconds.
- This was done for another two trials, after which the results were saved and the next test was selected.

3.8.2) Postural Stability Test (Eyes Closed)

This test was performed with the participant in the same position as for the postural stability test, barring that the participant's vision was removed, using a blindfold provided (Biosway Portable Balance System, No Date). The blindfold eliminated the vision and as a result the participant did not have a reference point indicating where their centre of pressure was. This eliminated the variables associated with the monitor and increased the participants reliance on their own perceived centre of gravity (Biosway Portable Balance System, No Date). This test challenged the participants to use mechanoreceptive information from the body as well as from the inner ear (vestibular information) to control their centre of pressure (Cote et al. 2005; Clifford and Holder-Powell 2010).

Participants were told that during this test they had to stand with as little sway possible in a natural and comfortable position where they felt that they were not swaying from front to back or from left to right.

- The postural stability test (eyes closed) required the participant to stand in a relaxed and neutral position for each for 20 seconds (Biosway Portable Balance System: Operation manual. No Date)
- This was done for another two trials, after which the results were saved and the next test was selected.

3.8.3) Limits of Stability Test

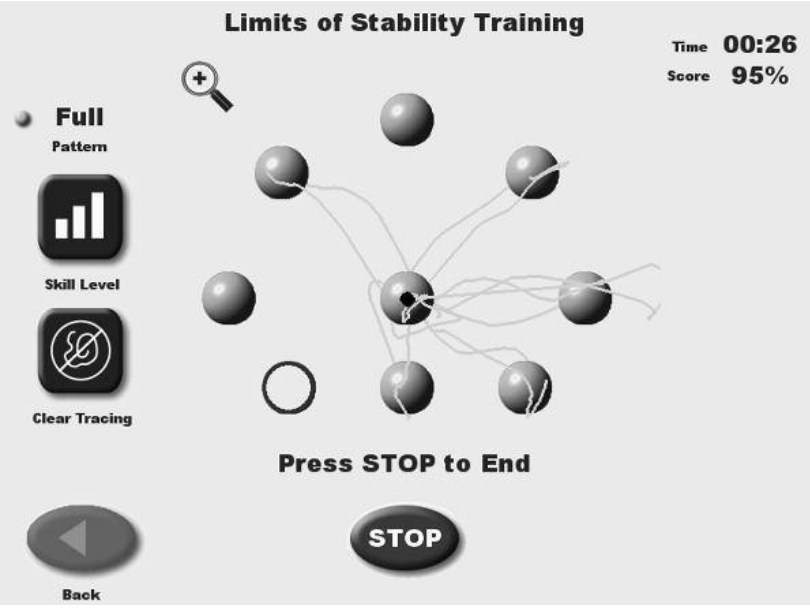
The limits of stability testing required the participant to shift their centre of pressure (as seen on the monitor) in multiple directions (indicated on the monitor), within their base of support. The limits of stability test allowed for a dynamic measure of erect balance, challenging the ability of the participant to control their centre of pressure in reaching the different points (Biosway Portable Balance System: Operation manual. No Date; McCollum and Leen 1989; Clark and Rose 2001).

The tests recorded how fast the participant could complete the test, as well as how much the centre of pressure deviated in each direction. In calculating this, the Stability Index was used to assess the average distance that the participant's centre of pressure deviated, during each

direction. The deviation was calculated with reference to an imaginary line, between the centre dot (proposed centre of gravity) and each of the eight limits on the monitor (Biosway Portable Balance System: Operation manual. No Date). Refer to *Figure 3.8* for an illustrated example.

- Before beginning the test, the participant was reminded to position their centre of pressure in the centre dot (indicated on the monitor). After the test commenced and the centre dot stopped flashing, one of the eight limits would flash (at random) and the participant then manoeuvred their centre of pressure to reach the flashing dot. Once the participant reached the flashing dot, it stopped flashing and the centre dot begun to flash again. The participant manoeuvred back to the centre dot and this process was repeated for all the eight directions. The dots flashed in a different sequence for each of the trials.

- As for postural stability testing, the participant undertook three trials for limits of stability and the average score between the three measures was automatically calculated and then saved. The limits of stability test gave a score in percent for all of the eight directions as well as overall.



(Biosway Portable Balance System: Operation manual. No Date)

Figure 3.8 Limits of stability test

3.9 STATISTICAL ANALYSIS

IBM SPSS version 23 was used to analyze the data and a $p \leq 0.05$ was considered as statistically significant. Repeated measures ANOVA testing was used to compare the rate of change pre- and post-intervention, between the three groups.

Baseline data is represented on profile plots for each result, in order to identify trends between the groups.

The time*group effect was calculated using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. In the time*group calculation time refers to the difference between the pre- and post-intervention data. These measures indicated whether there were significant differences between the groups for immediate change.

In the event of the time*group effect being significant, post hoc Bonferroni adjusted tests were done to compare all pair wise groups. These multiple group comparisons helped establish how significant the time*group effects were, between the different groups. The means for pre- and post-intervention data was graphically represented. The graphically represented trends in average change helped determine the clinical significance of the post hoc Benferroni adjusted tests.

For each participant the resultant left and right navicular change in pronation was calculated and combined. This was also done for the four great toe extension measurements. The means for change between the groups was then calculated. This data was then used to determine if there were significant differences between the groups.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

All participants were assessed bilaterally and this produced a large amount of data. The raw pre-intervention and post-intervention data has been attached in Appendix P. The results after comparing this data have been summarized into tables of significance at the start of each set of variables.

Graphs depicting the profile plots were generated to illustrate the time*group effect in addition to identifying trends for the rates of change between the groups. Post hoc Benferroni adjusted tests were only included where there were significant or borderline time*group effects.

The mean weight, mean height and mean Body mass index (BMI) were calculated and presented in the Raw Dataset (Appendix P). Placebo ultrasound group had a mean weight of 59.7kg, mean height of 1.64m and a mean BMI of 21.9: Ischaemic compression group had a mean weight of 64kg, mean height of 1.67m and mean BMI of 23.2: Myofascial release group had a mean weight of 72kg, mean height of 1.64m and a mean BMI of 26.8. Variations in BMI exist, as these were not inclusions for the present study.

4.2 NAVICULAR POSITION TEST

Results for both the navicular position tests are summarized in *Table 4.1* below in terms of Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. There were significant (p=0.051) time*group effects for the right navicular position. Post hoc Bonferroni adjusted tests revealed that the myofascial release group had a significant (p=0.056) change in right pronation, compared to the ischaemic group.

Table 4.1 Overall significance of the time*group effect for navicular position measurements

Measurement Left	*p*-value	Measurement Right	*p*-value
Navicular position	**0.574**	**Navicular position**	**0.051**
There was no significant time*group effect, therefore there was no significant pre/post change between the groups. Although all groups started at roughly the same baseline measurement. The ischaemic compression group increased in pronation over time while the myofascial release group showed a reduction in pronation over time. The ultrasound group stayed the same.		There was a significant treatment effect. Post hoc Bonferroni testing showed significant (p=0.056) differences between the ischeamic compression group and myofascial release groups.	

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. *p*-value < 0.05 was considered significant

4.2.1 Left Navicular Position

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for revealed no significant (p=0.574) time*group effect for left navicular pronation. *Figure 4.1* represents pilot plots for the average means between the groups.

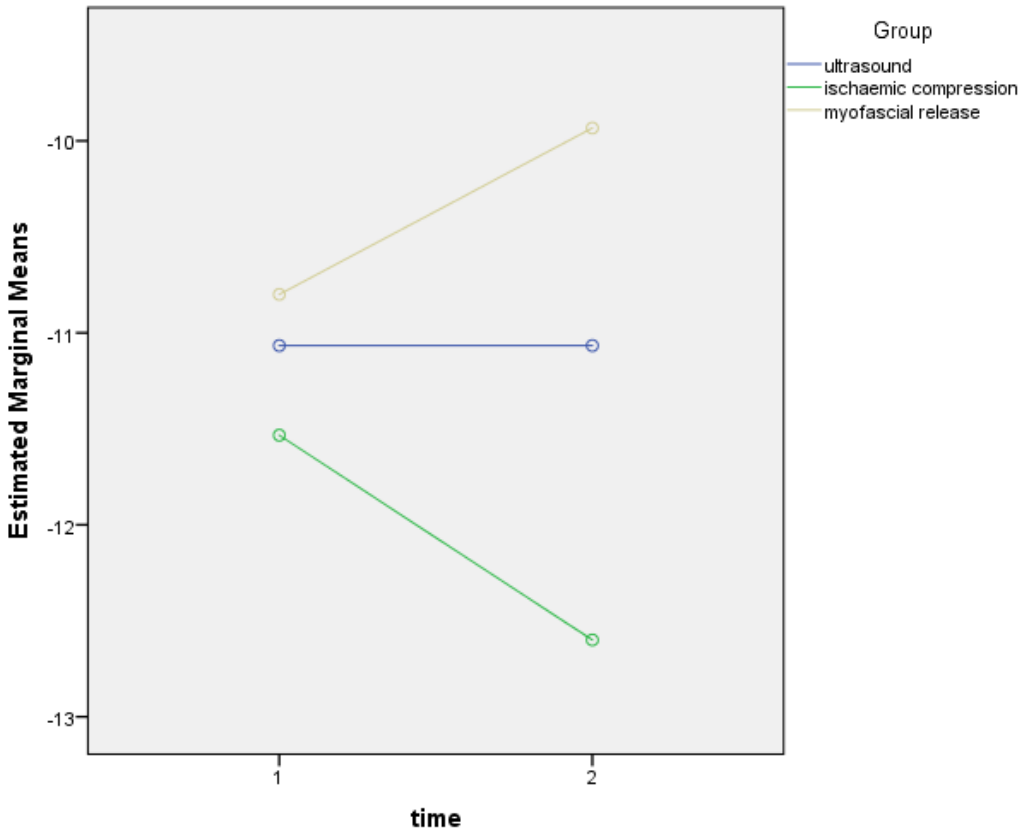


Figure 4.1 Time*group effect for left navicular position

4.2.2 Right Navicular Position

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for revealed no significant (p=0.051) time*group effect for right navicular pronation. *Figure 4.2* represents pilot plots for the average means between the groups.

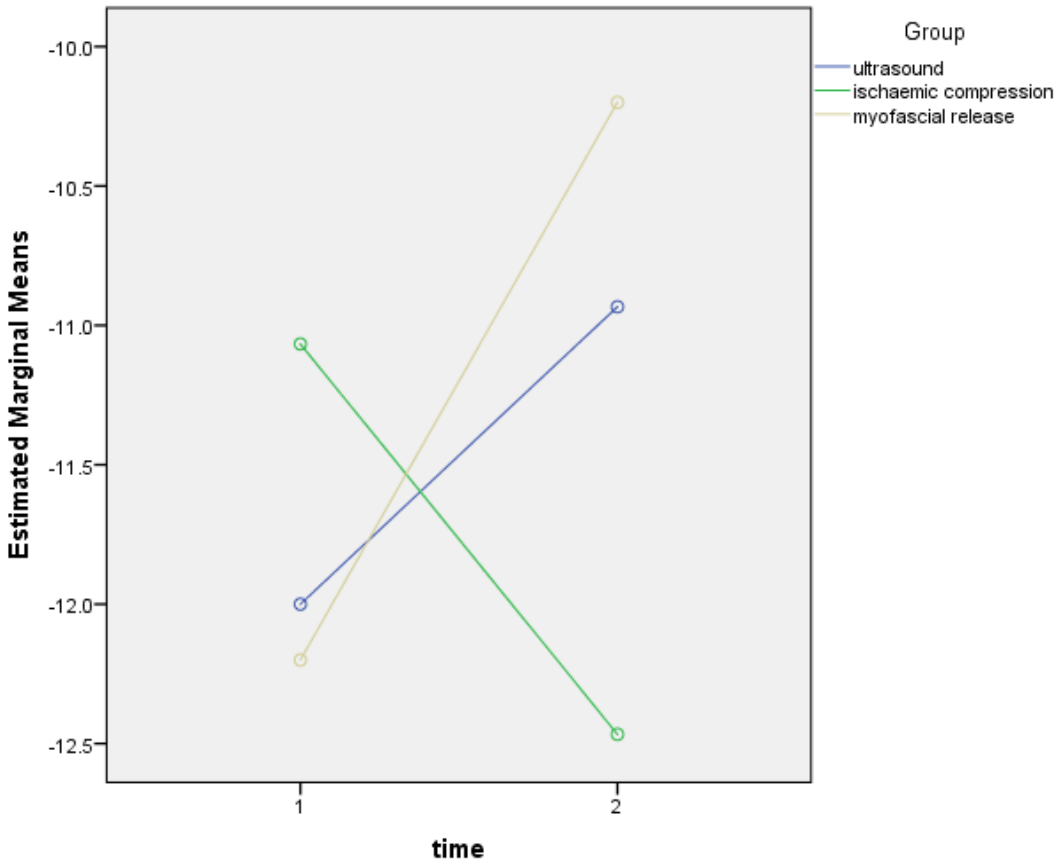


Figure 4.2 Time*group effect for right navicular position

Table 4.2 indicated that there were borderline significant (*p*=0.056) differences between the improvements seen in the myofascial release group and worsening pronation in ischaemic compression group, for right navicular position.

Table 4.2 Multiple group comparisons for right navicular position

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	2.467	1.390	.250	-1.00	5.93
	Group C	-.933	1.390	1.000	-4.40	2.53
Group B	Group A	-2.467	1.390	.250	-5.93	1.00
	Group C	-3.400	1.390	.056	-6.87	.07
Group C	Group A	.933	1.390	1.000	-2.53	4.40
	Group B	3.400	1.390	.056	-.07	6.87

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.3 GREAT TOE EXTENSION MEASUREMENTS

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for all of the great toe extension measurements are summarized in *Table 4.3*. There was a significant (p=0.048) time*group effect for left passive non-weight bearing great toe extension. Post hoc Bonferroni adjusted testing showed non-significant (p=0.067) differences between the ischaemic compression group and placebo ultrasound group.

Table 4.3 Overall significance of the time*group effect for great toe extension measurements

Measurement: Left	***p*-value**	**Measurement: Right**	***p*-value**
Passive NWB GTE	**0.048**	**Passive NWB GTE**	**0.982**
Significant treatment effect. Post hoc Bonferroni testing showed non-significant (p=0.067) differences between the ischaemic compression group and the placebo ultrasound group.		No significant treatment effect.	
Active NWB GTE	**0.433**	**Active NWB GTE**	**0.222**
No significant treatment effect.		No significant treatment effect.	
Partial WB GTE	**0.091**	**Partial WB GTE**	**0.069**
No significant treatment effect.		Borderline non-significant treatment effect.	
WB GTE at step length	**0.162**	**WB GTE at step length**	**0.435**
No significant treatment effect.		No significant treatment effect.	

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. p-value < 0.05 was considered significant. NWB – non-weight bearing, WB – weight bearing, GTE – great toe extension

4.3.1 Left Passive Non-Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed a significant (p=0.048) time*group effect for left passive non-weight bearing great toe extension. *Figure 4.3* represents pilot plots for the average means between the groups.

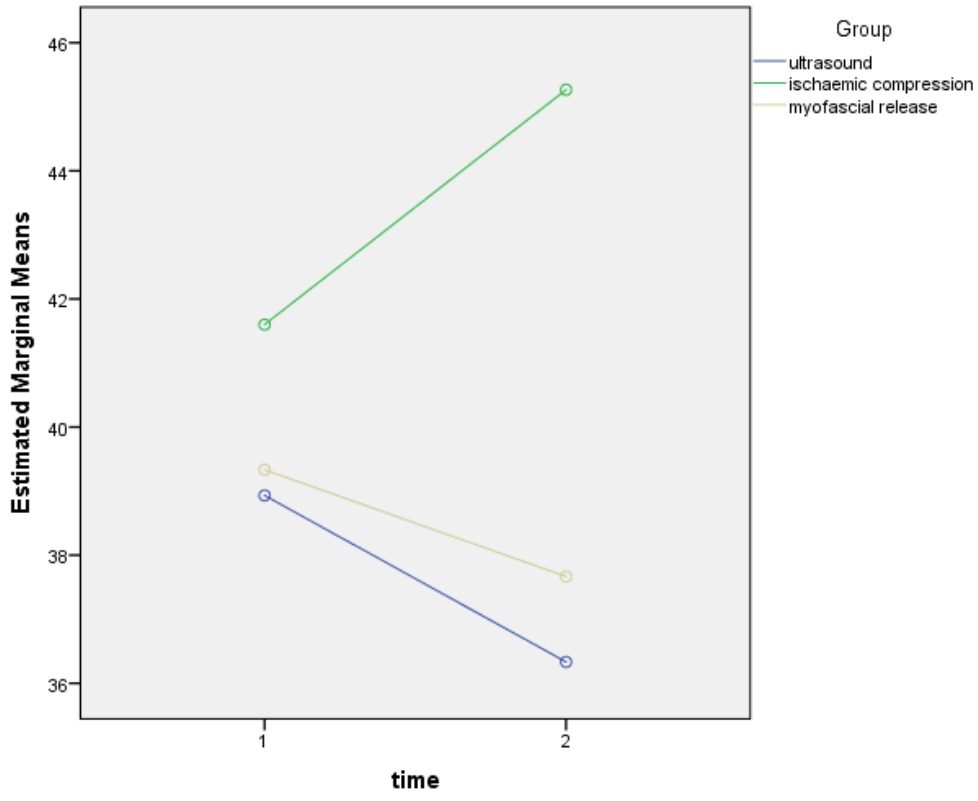


Figure 4.3 Time*group effect for left passive non-weight bearing great toe extension

Table 4.4 reveals that post hoc Bonferroni adjusted testing found borderline non-significant (p=0.067) differences between the increased great toe extension for the ischaemic compression group and reduced great toe extension in the placebo ultrasound group.

Table 4.4 Multiple group comparisons for left passive non-weight bearing great toe extension

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	-6.267	2.641	.067	-12.85	.32
	Group C	-.933	2.641	1.000	-7.52	5.65
Group B	Group A	6.267	2.641	.067	-.32	12.85
	Group C	5.333	2.641	.149	-1.25	11.92
Group C	Group A	.933	2.641	1.000	-5.65	7.52
	Group B	-5.333	2.641	.149	-11.92	1.25

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.3.2 Left Active Non-Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.433) time*group effect for left active non-weight bearing great toe extension. *Figure 4.4* represents pilot plots for the average means between the groups.

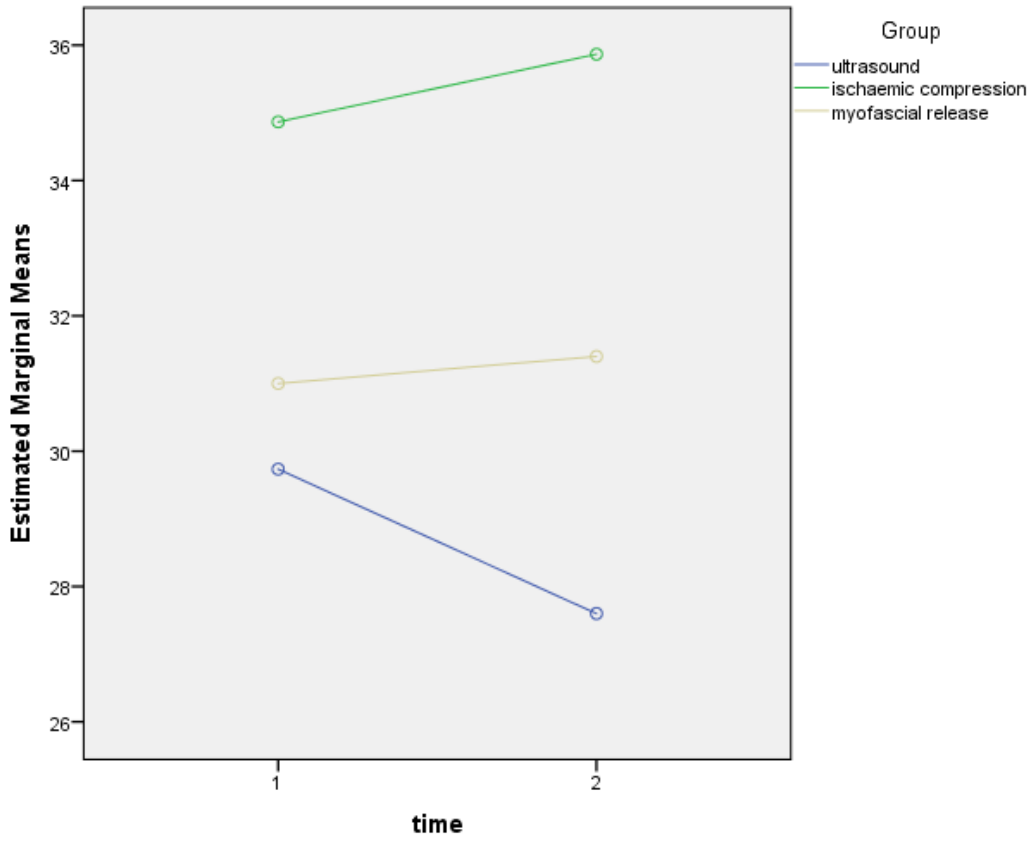


Figure 4.4 Time*group effect for left active non-weight bearing great toe extension

4.3.3 Left Partial Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.091) time*group effect for left partial weight bearing great toe extension. *Figure 4.5* represents pilot plots for the average means between the groups.

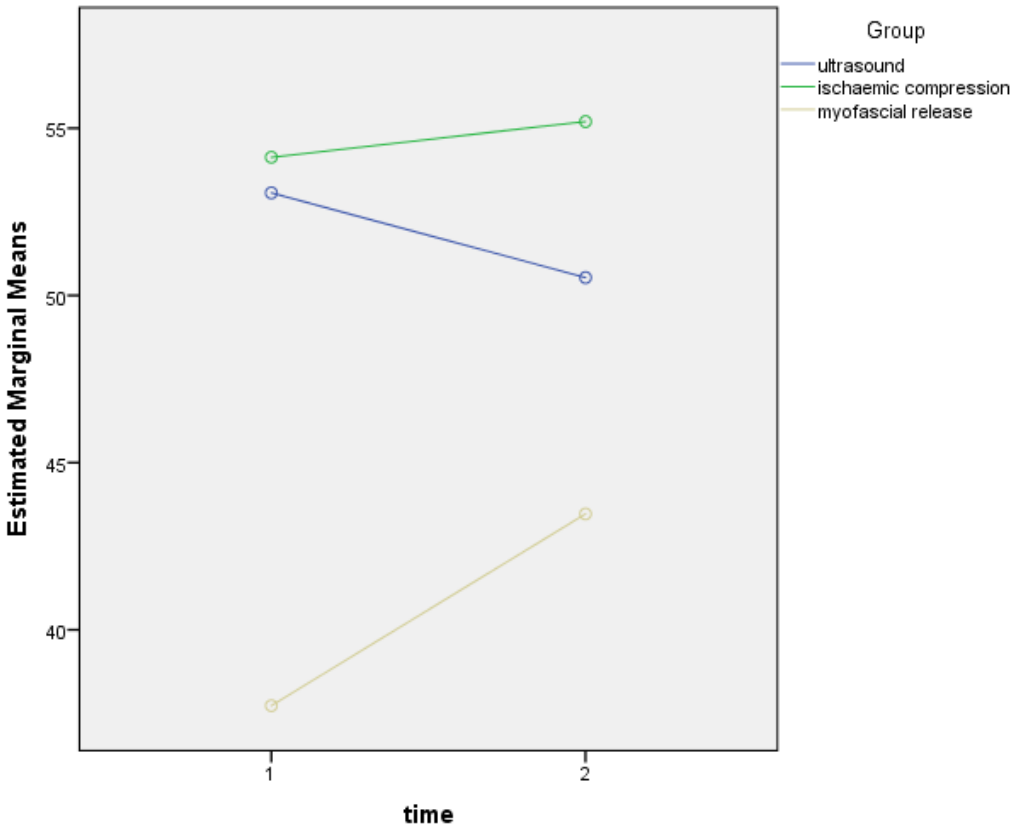


Figure 4.5 Time*group effect for left partial weight bearing great toe extension

4.3.4 Left Weight Bearing Great Toe Extension at Step Length

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.162) time*group effect for left weight bearing great toe extension at step length. *Figure 4.6* represents pilot plots for the average means between the groups.

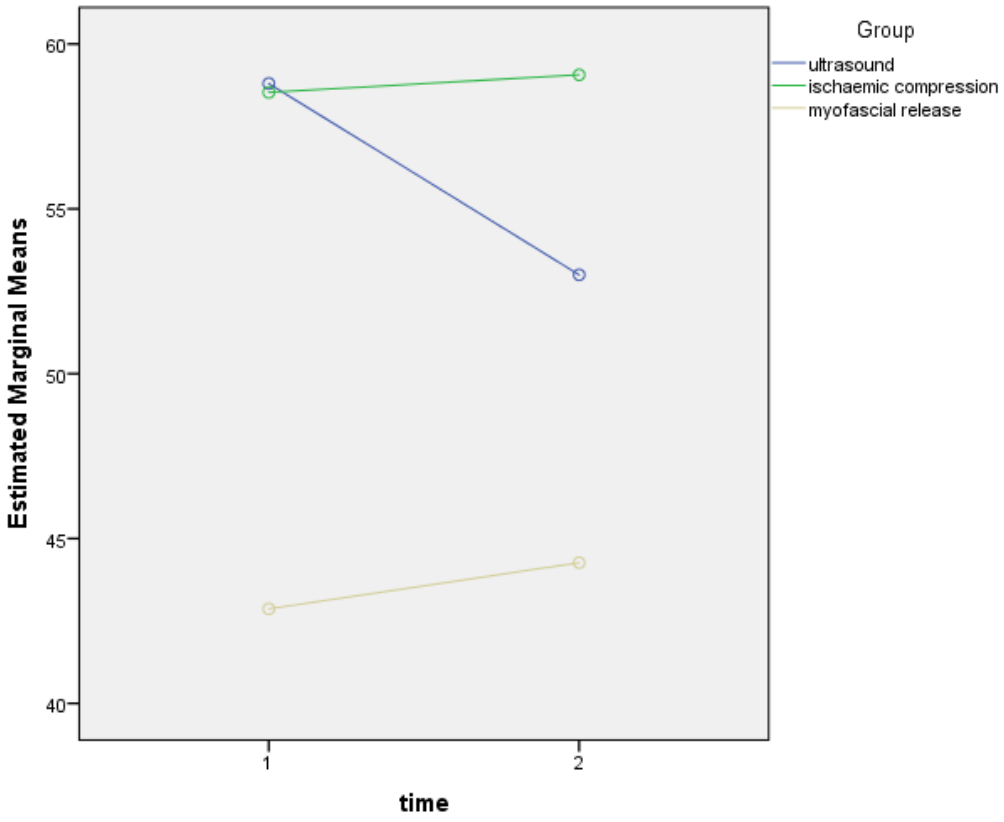


Figure 4.6 Time*group effect for left weight bearing great toe extension at step length

4.3.5 Right Passive Non-Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.982) time*group effect for right passive non-weight bearing great toe extension. *Figure 4.7* represents pilot plots for the average means between the groups.

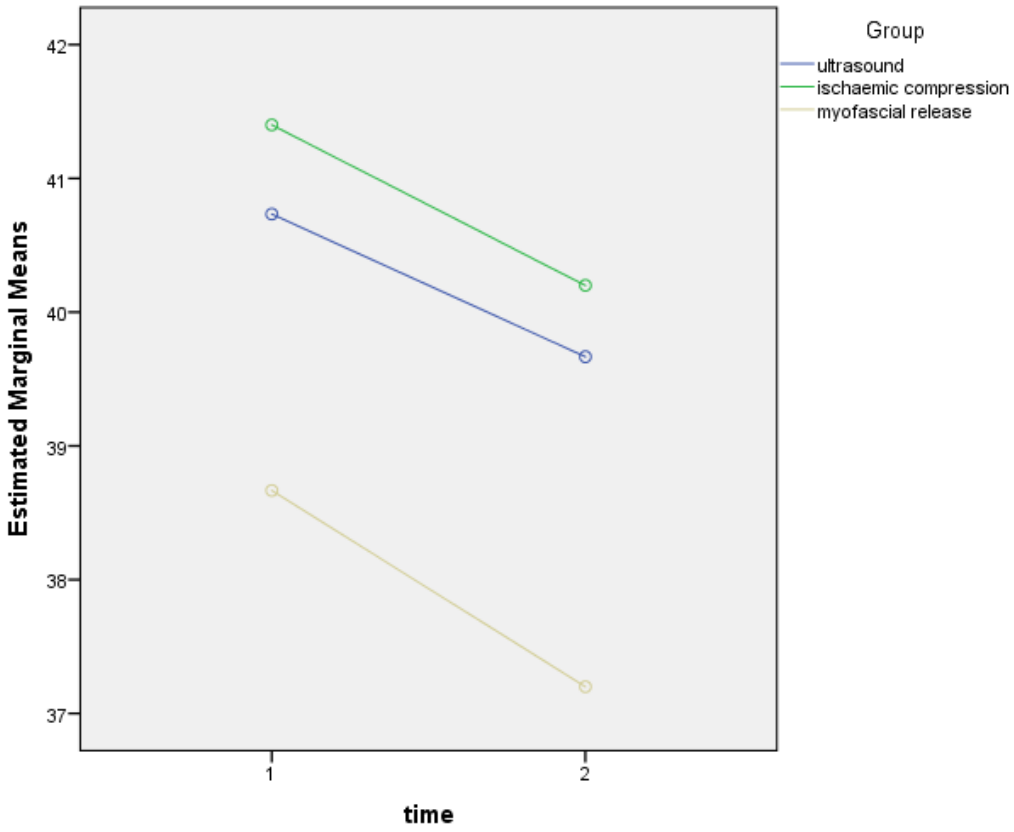


Figure 4.7 Time*group effect for right passive non-weight bearing great toe extension

4.3.6 Right Active Non-Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.222) time*group effect for right active non-weight bearing great toe extension. *Figure 4.8* represents pilot plots for the average means between the groups.

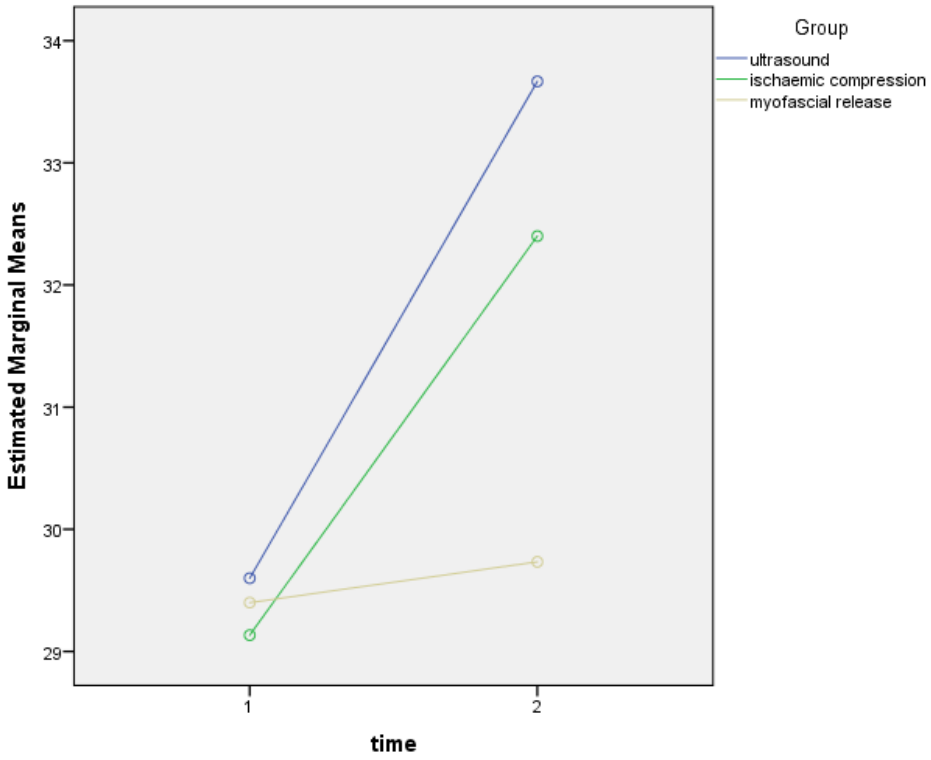


Figure 4.8 Time*group effect for right active non-weight bearing great toe extension

4.3.7 Right Partial Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed borderline non-significant (p=0.069) time*group effect for right partial weight bearing great toe extension. *Figure 4.8* represents pilot plots for the average means between the groups.

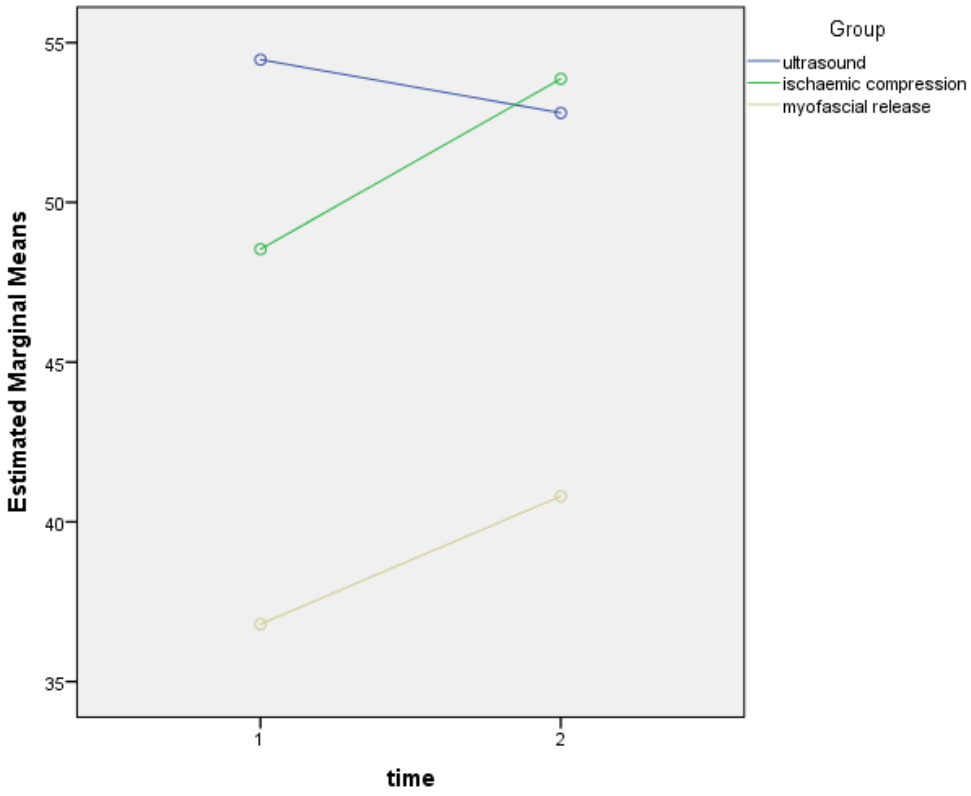


Figure 4.9 Time*group effect for right partial weight bearing great toe extension

In *Table 4.5* post hoc Bonferroni adjusted testing showed non-significant (*p*=0.090) differences in increased range of motion, between the ischaemic compression group and the placebo ultrasound group.

4.5 Multiple group comparisons for right partial weight bearing great toe extension

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	-7.000	3.113	.090	-14.76	.76
	Group C	-5.667	3.113	.228	-13.43	2.10
Group B	Group A	7.000	3.113	.090	-.76	14.76
	Group C	1.333	3.113	1.000	-6.43	9.10
Group C	Group A	5.667	3.113	.228	-2.10	13.43
	Group B	-1.333	3.113	1.000	-9.10	6.43

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.3.8 Right Weight Bearing Great Toe Extension at Step Length

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing revealed non-significant (p=0.435) time*group effect for right weight bearing great toe extension at step length. *Figure 4.9* represents pilot plots for the average means between the groups.

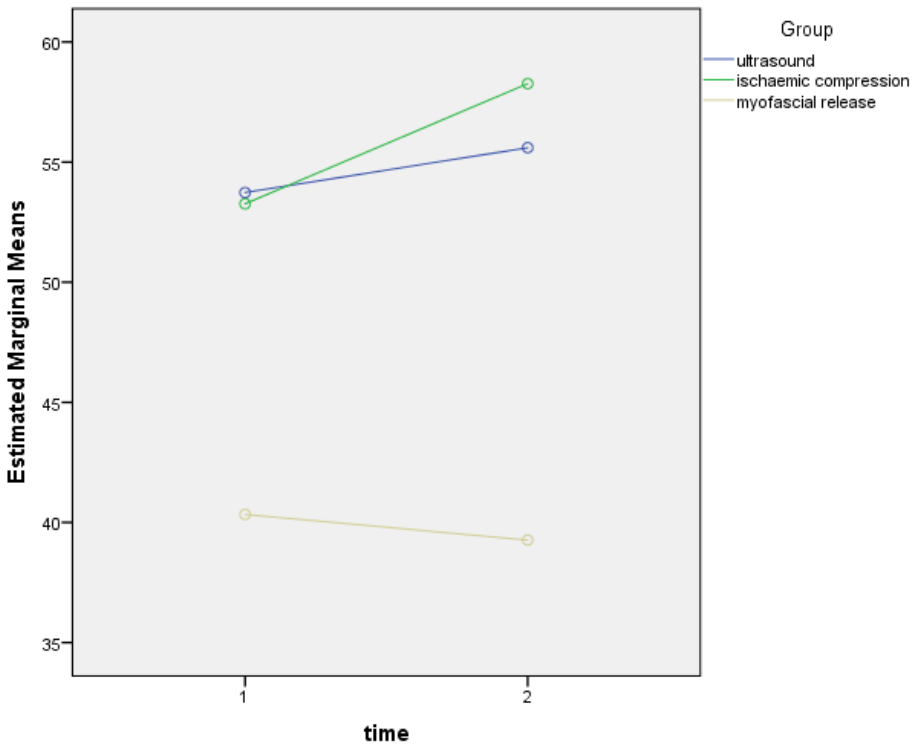


Figure 4.10 Time*group effect for right weight bearing great toe extension at step length

4.4 COMBINED LEFT AND RIGHT CHANGE

The data used for *Table 4.6* below, represents the mean change (average left change plus right change for each participant) and the standard deviation, between the groups.

Table 4.6 Combined means and standard deviation for participants in each of the intervention groups

Combined (L + R) Measure		Placebo ultrasound	Ischaemic compression	Myofascial release
Navicular position	Mean	1.1	-2.5	2.9
	Standard deviation	5.0	8.1	5.2
Passive NWB GTE	Mean	-3.7	2.5	-3.1
	Standard deviation	6.3	12.6	8.6
Active NWB GTE	Mean	1.9	4.3	.7
	Standard deviation	9.4	9.4	9.5
Partial WB GTE	Mean	-4.2	6.4	9.7
	Standard deviation	11.7	13.6	18.3
WB GTE at step length	Mean	-3.9	5.5	.3
	Standard deviation	19.6	14.1	14.3

WB, weight bearing; NWB, non-weight bearing; GTE, great toe extension.

4.4.1 Combined Navicular Position

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.071) time*group effects for combined navicular position. *Figure 4.10* graphically represents the average means for changes between the different groups.

4.4.2 Combined Passive Non-Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.161) time*group effects for combined passive non-weight bearing great toe extension. *Figure 4.10* graphically represents the average means for changes between the different groups.

4.4.3 Combined Active Non-Weight Bearing Great Toe Extension

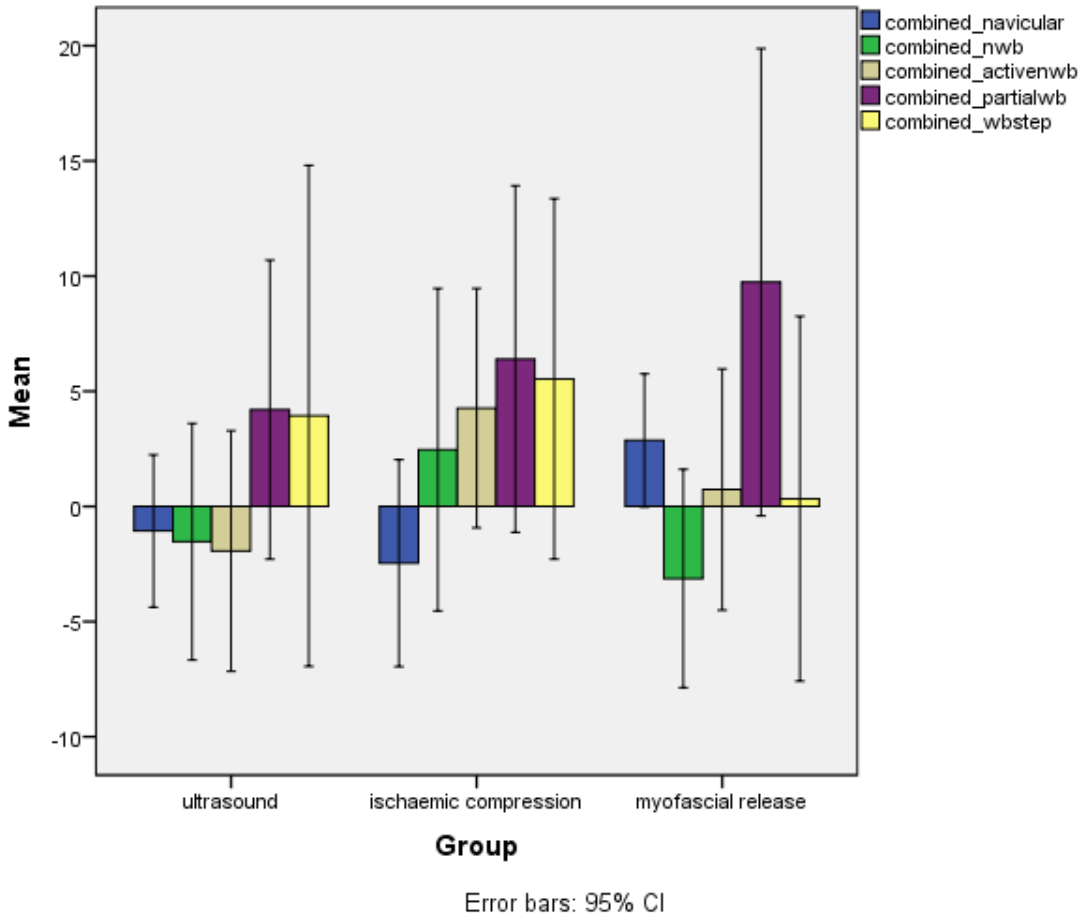
Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.584) time*group effects for combined passive non-weight bearing great toe extension. *Figure 4.10* graphically represents the average means for changes between the different groups.

4.4.4 Combined Partial Weight Bearing Great Toe Extension

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed significant (p=0.035) time*group effects for combined partial weight bearing great toe extension. Post hoc Bonferroni adjusted testing revealed significant (p=0.041) differences between the myofascial release group and the placebo ultrasound group. *Figure 4.10* graphically represents the average means for changes between the different groups.

3.4.5 Combined Weight Bearing Great Toe Extension at Step Length

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.035) time*group effect for combined weight bearing great toe extension at step length. *Figure 4.10* graphically represents the average means for changes between the different groups.



CI – Confidence interval

Figure 4.11 Combined mean changes for goniometry between the intervention groups

Table 4.7 represents significance of the time*group effect between the combined measures, where the combined partial weight bearing great toe extension was significant (p=0.035).

Table 4.7 Repeated measures ANOVA for the combined goniometric measurements

Measurement		Sum of squares	df	Mean square	F	*p*-value
Combined navicular change	Between Groups	220.844	2	110.422	2.813	**.071**
	Within Groups	1648.400	42	39.248		
	Total	1869.244	44			
Combined passive NWB GTE change	Between Groups	346.311	2	173.156	1.905	**.161**
	Within Groups	3816.800	42	90.876		
	Total	4163.111	44			
Combined active NWB GTE change	Between Groups	96.844	2	48.422	.545	**.584**
	Within Groups	3732.800	42	88.876		
	Total	3829.644	44			
Combined partial WB GTE change	Between Groups	1588.044	2	794.022	3.624	**.035**
	Within Groups	9202.933	42	219.117		
	Total	10790.978	44			
Combined WB GTE at step length	Between Groups	674.311	2	337.156	1.280	**.289**
	Within Groups	11062.000	42	263.381		
	Total	11736.311	44			

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. *p*-value < 0.05 was considered significant. NWB – non-weight bearing, WB – weight bearing, GTE – great toe extension

Table 4.8 Post hoc Bonferroni adjusted testing revealed significant (p=0.041) differences between the increases in combined great toe extension for the myofascial release group and the placebo ultrasound group.

Table 4.8 Multiple group comparisons for the combined partial weight bearing great toe extension

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	-10.60000	5.40515	0.170	-24.0786	2.8786
	Group C	-13.93333*	5.40515	0.041	-27.4120	-.4547
Group B	Group A	10.60000	5.40515	0.170	-2.8786	24.0786
	Group C	-3.33333	5.40515	1.000	-16.8120	10.1453
Group C	Group A	13.93333*	5.40515	0.041	.4547	27.4120
	Group B	3.33333	5.40515	1.000	-10.1453	16.8120

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.5 Postural Stability (Eyes Open)

Results for time*group effects are represented in *Table 4.9*. Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for postural stability (eyes open) showed a borderline significant (p=0.059) time*group. Post hoc Bonferroni adjusted testing revealed no significant (p=0.063) time*group effect between the myofascial release group and the placebo ultrasound group.

Table 4.9 Overall significance of postural stability (eyes open) in terms of the Stability Index and Sway Index

Axes	Stability		Sway	
	Significance	***p*-value**	**Significance**	***p*-value**
PSO overall	No significant treatment effect.	0.542	No significant treatment effect.	0.217
PSO - AP	No significant treatment effect.	0.567	No significant treatment effect.	0.460
PSO - ML	No significant treatment effect.	0.462	Borderline significant treatment effect. Post hoc Bonferroni adjusted testing show non-significant (p=0.063) differences between the myofascial release group and the placebo ultrasound group.	**0.059**

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing. p-value < 0.05 was considered significant. PSO, postural stability (eyes open); AP, anterior-posterior; ML, medial-lateral

4.5.1 Postural Stability (Eyes Open) Overall

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.542) time*group effects for postural stability (eyes open) overall. *Figure 4.12* represents pilot plots for the average means between the groups.

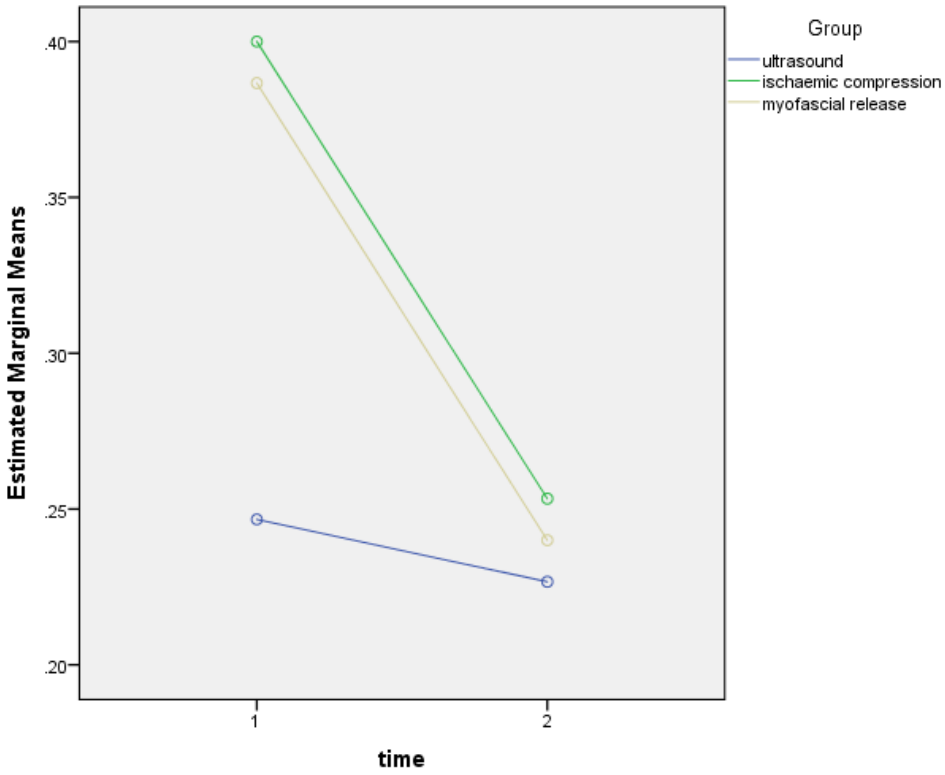


Figure 4.12 Time*group effect for the Stability Index in the postural stability (eyes open) overall

4.5.2 Postural Stability (Eyes Open) Anterior-Posterior

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.567) time*group effects for postural stability (eyes open) anterior-posterior. *Figure 4.12* represents pilot plots for the average means between the groups.

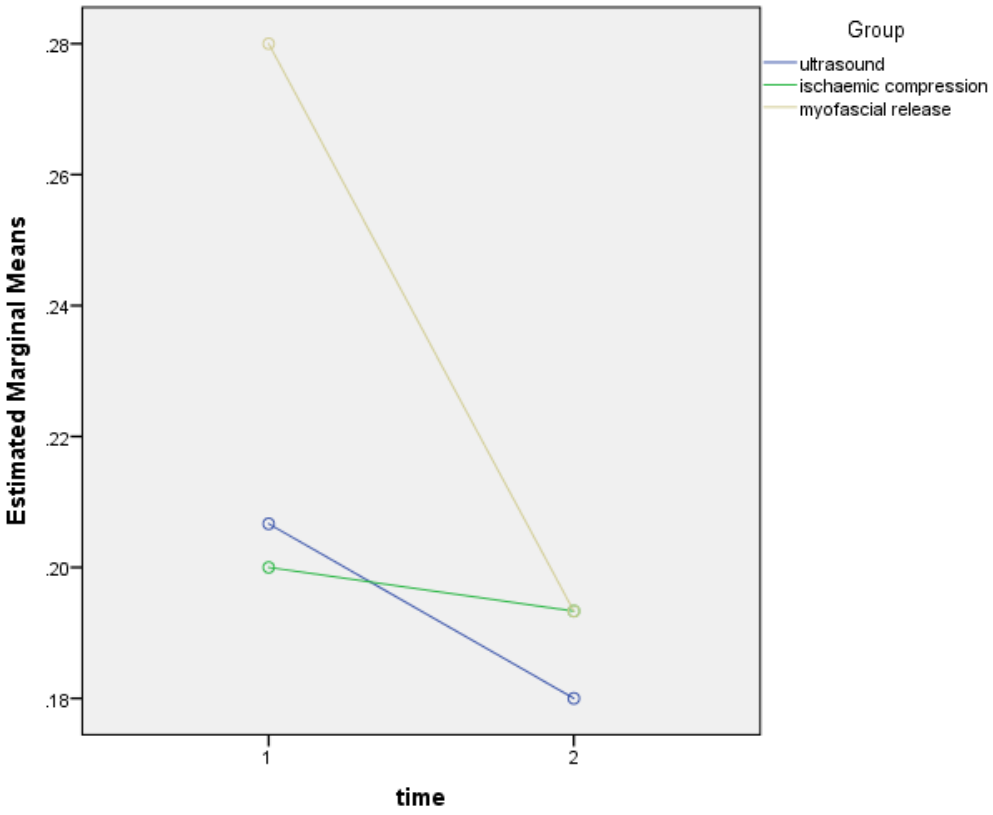


Figure 4.13 Time*group effect for the Stability Index in the postural stability (eyes open) anterior-posterior

4.5.3 Postural Stability (Eyes Open) Medial-Lateral

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.462) time*group effects for postural stability (eyes open) medial-lateral *Figure 4.14* represents pilot plots for the average means between the groups.

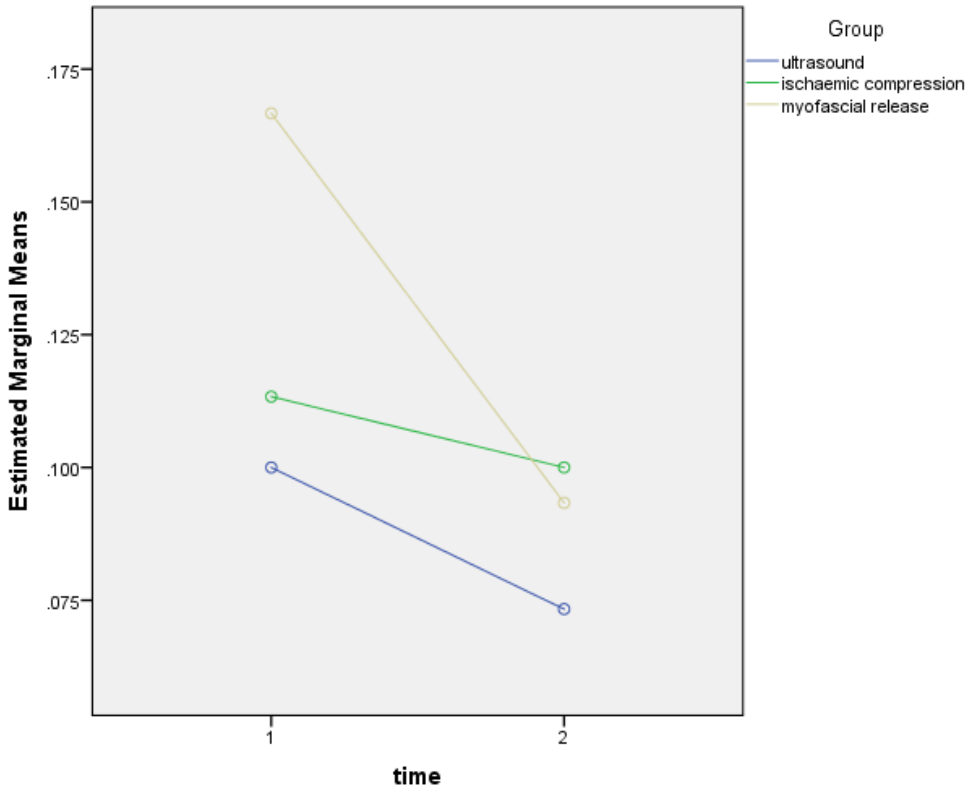


Figure 4.14 Time*group effect for the Stability Index in the postural stability (eyes open) medial-lateral

4.5.4 Postural Sway (Eyes Open) Overall

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.217) time*group effects for postural sway (eyes open) overall. *Figure 4.15* represents pilot plots for the average means between the groups.

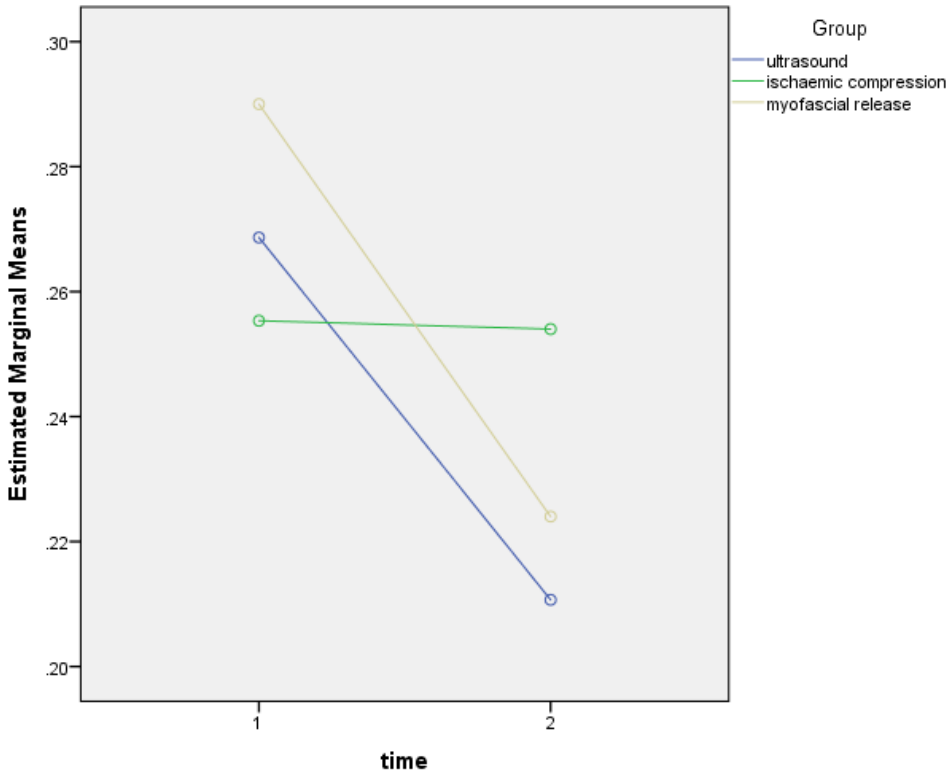


Figure 4.15 Time*group effect for the Sway Index in the postural sway (eyes open) overall

4.5.5 Postural Sway (Eyes Open) Anterior-Posterior

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed no significant (p=0.460) time*group effects for postural sway (eyes open) anterior-posterior. *Figure 4.16* represents pilot plots for the average means between the groups.

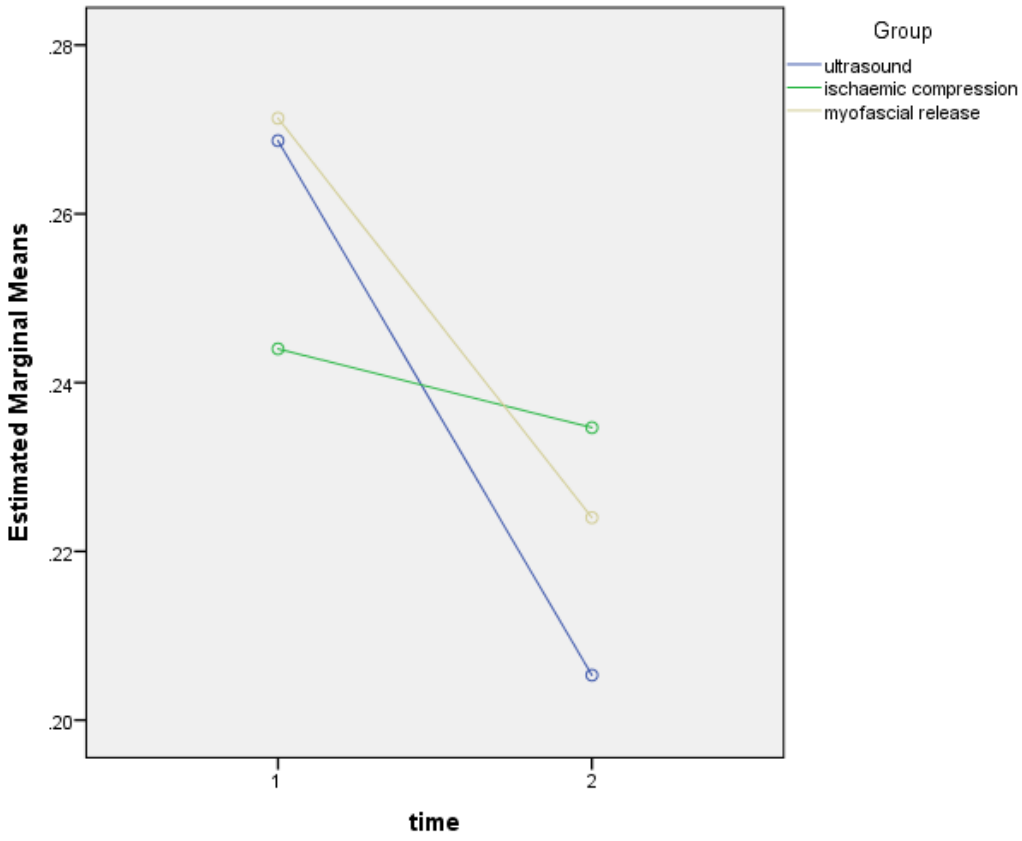


Figure 4.16 Time*group effect for the Sway Index in the postural sway (eyes open) anterior-posterior

4.5.6 Postural Sway (Eyes Open) Medial-Lateral

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a borderline significant (p=0.059) time*group effect for postural sway (eyes open) medial-lateral. *Figure 4.17* represents pilot plots for the average means between the groups.

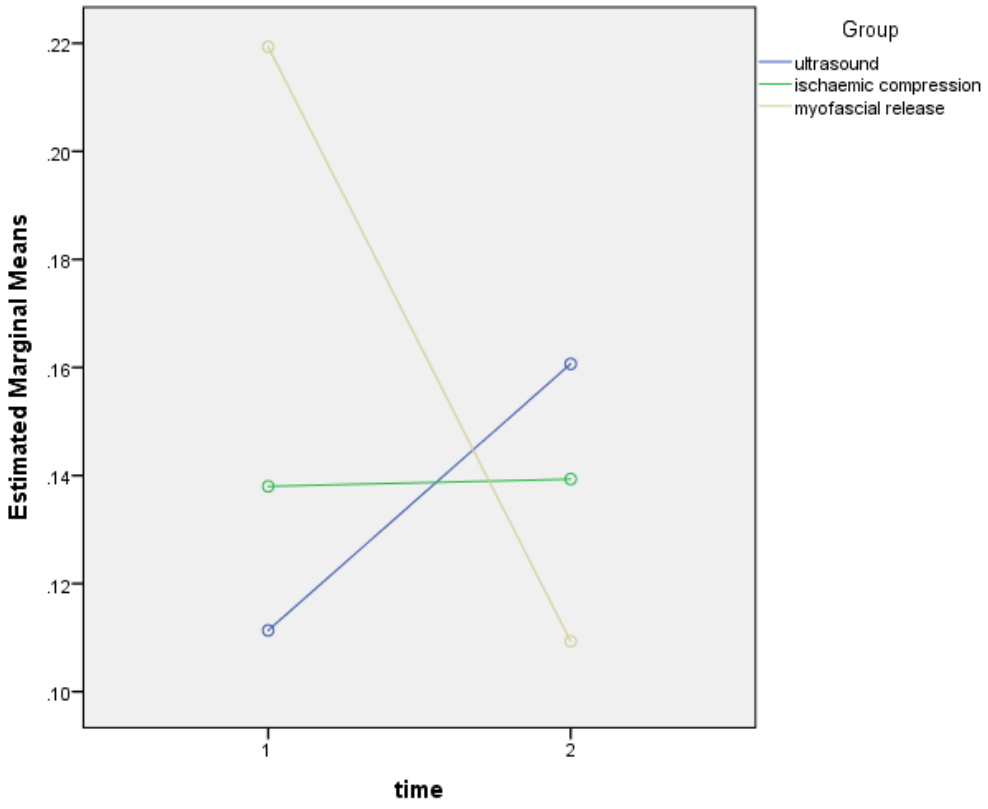


Figure 4.17 Time*group effect for the Sway Index in the postural sway (eyes open) medial-lateral

Table 4.10 shows Post hoc Bonferroni adjusted testing had a borderline non-significant (*p*=0.063) difference between the decreased range of motion in the myofascial release group.and the increased range of motion in the placebo ultrasound group.

Table 4.10 Multiple group comparisons for postural sway (eyes open) medial-lateral axis

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	.04800	.06649	1.000	-.1178	.2138
	Group C	.15933	.06649	.063	-.0065	.3251
Group B	Group A	-.04800	.06649	1.000	-.2138	.1178
	Group C	.11133	.06649	.304	-.0545	.2771
Group C	Group A	-.15933	.06649	.063	-.3251	.0065
	Group B	-.11133	.06649	.304	-.2771	.0545

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.6 Postural Stability (Eyes Closed)

Results for Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for postural stability (eyes closed) are summarized in *Table 4.11.* There were significant time*group effects for the postural stability (eyes closed) overall (p=0.003) and postural stability (eyes closed) anterior-posterior (p=0.006).

Post hoc Bonferroni adjusted testing showed significant differences for ischaemic compression (p=0.004) and myofascial release (p=0.031) groups when comparing to the placebo ultrasound group. For postural stability (eyes closed) anterior-posterior significant differences were again between the ischaemic compression (p=0.007) and myofascial release (p=0.053) groups when comparing to the placebo ultrasound group.

Table 4.11 Overall significance of postural stability (eyes closed) in terms of the Stability Index and Sway Index

Axes	Stability Index		Sway Index	
	Significance	***p*-value**	**Significance**	***p*-value**
PSC Overall	Significant treatment effect. Post hoc Bonferroni adjusted testing showed significant differences between both the ischaemic compression group (*p*=0.004) and myofascial release group (*p*=0.031), in comparason to the placebo ultrasound group.	0.003	No significant treatment effect	0.152
PSC – AP	Significant treatment effect. Post hoc Bonferroni adjusted testing revealed significant differences between both the ischaemic compression group (*p*=0.007) and myofascial release group (*p*=0.053) in comparison to the placebo ultrasound group.	0.006	No significant treatment effect	0.269
PSC - ML	No significant treatment effect	0.272	No significant treatment effect	0.775

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root measures. p-value < 0.05 was considered significant. PSO, postural stability (eyes open); AP, anterior-posterior; ML, medial-lateral

4.6.1 Postural Stability (Eyes Closed) Overall

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed significant (p=0.003) time*group effects for postural stability (eyes closed) overall. *Figure 4.18* represents pilot plots for the average means between the groups.

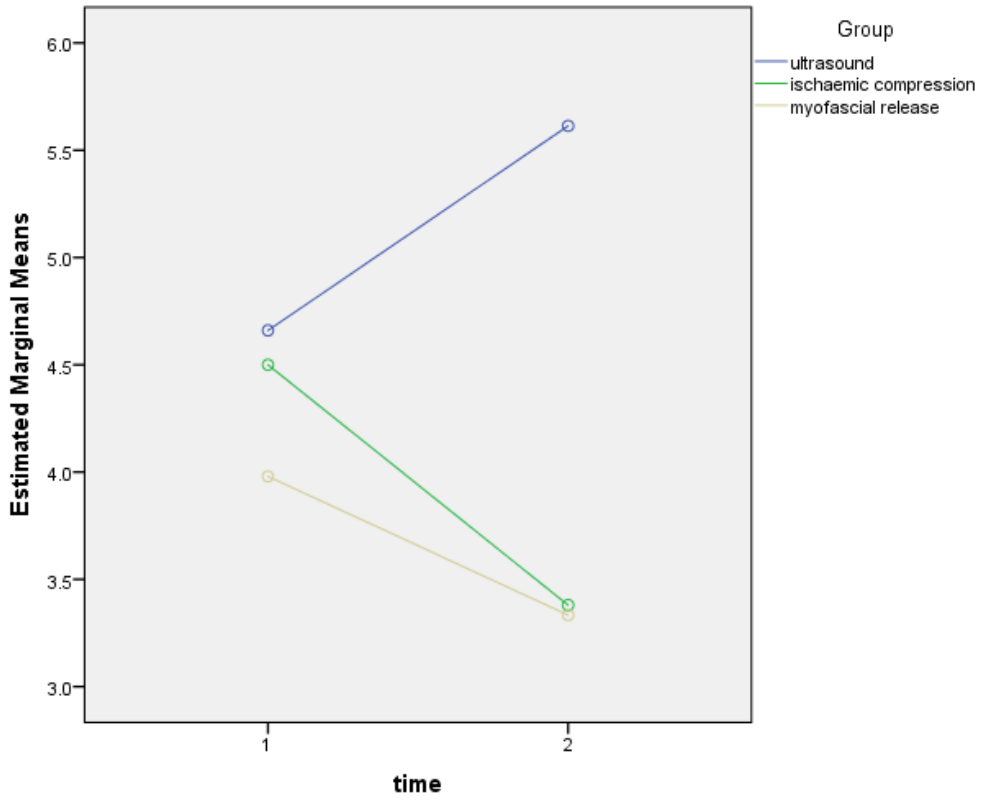


Figure 4.18 Time*group effect for the Stability Index in the postural stability (eyes closed) overall

Table 4.12 shows significant differences for post hoc Bonferroni adjusted testing between the ischaemic compression group (p=0.004) and myofascial release group (p=0.031), when comparing to the placebo ultrasound group. Both myofascial groups improved and the placebo group got worse on average.

Table 4.12 Multiple group comparisons for postural stability (eyes closed) overall

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	2.0733*	.5952	.004	.589	3.558
	Group C	1.6000*	.5952	.031	.116	3.084
Group B	Group A	-2.0733*	.5952	.004	-3.558	-.589
	Group C	-.4733	.5952	1.000	-1.958	1.011
Group C	Group A	-1.6000*	.5952	.031	-3.084	-.116
	Group B	.4733	.5952	1.000	-1.011	1.958

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.6.2 Postural Stability (Eyes Closed) Anterior-Posterior

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed significant (p=0.006) time*group effects for postural stability (eyes closed) anterior-posterior: the placebo ultrasound group increased (more sway) in the overall Stability Index. *Figure 4.19* represents pilot plots for the average means between the groups.

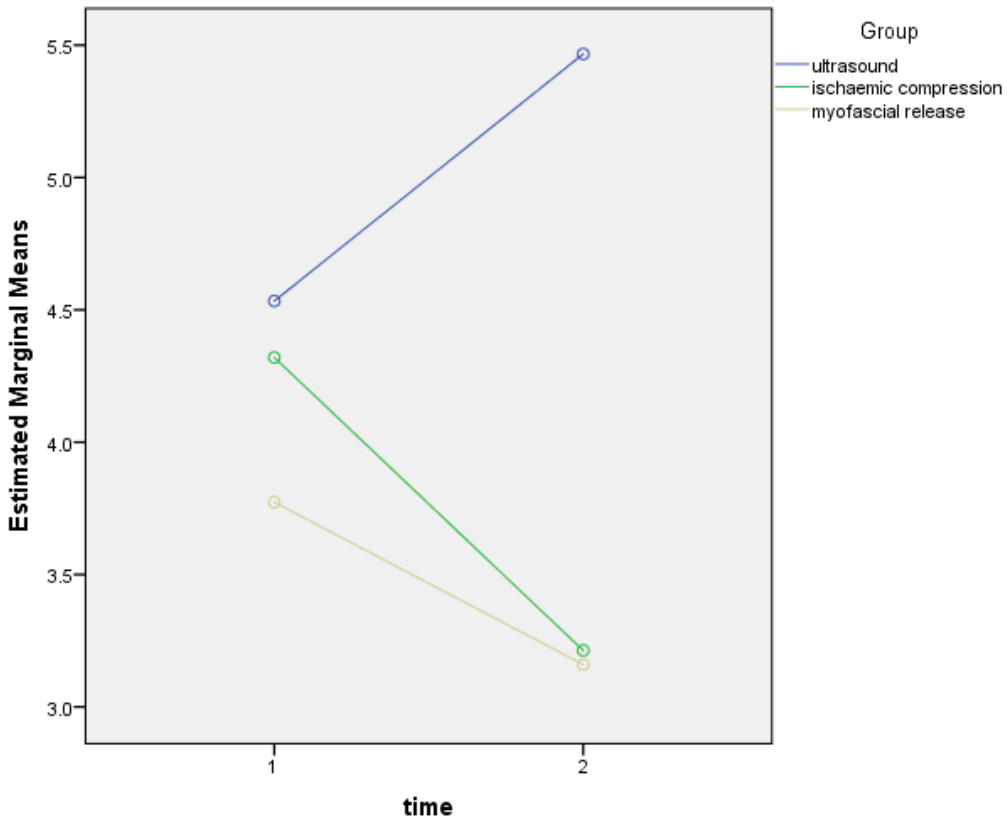


Figure 4.19 Time*group effect for the Stability Index in the postural stability (eyes closed) anterior-posterior

Table 4.13 shows significant differences in post hoc Bonferroni adjusted testing in the ischaemic compression (*p*=0.007) and myofascial release groups (p=0.053), when compared to the placebo ultrasound group. Both myofascial groups improved and the placebo group worsened.

Table 4.13 Multiple group comparisons for postural stability (eyes closed) anterior-posterior

Group Comparisons		Mean difference	Standard error	*p*-value	Lower bound CI	Upper bound CI
Group A	Group B	2.0400*	.6254	.007	.480	3.600
	Group C	1.5467	.6254	.053	-.013	3.106
Group B	Group A	-2.0400*	.6254	.007	-3.600	-.480
	Group C	-.4933	.6254	1.000	-2.053	1.066
Group C	Group A	-1.5467	.6254	.053	-3.106	.013
	Group B	.4933	.6254	1.000	-1.066	2.053

Post hoc Bonferroni adjusted tests, p-value < 0.05 was considered significant. Group A – placebo ultrasound, Group B – ischaemic compression, Group C – myofascial release, CI – confidence interval

4.6.3 Postural Stability (Eyes Closed) Medial-Lateral

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.272) time*group effect for postural stability (eyes open) medial-lateral. *Figure 4.20* represents pilot plots for the average means between the groups.

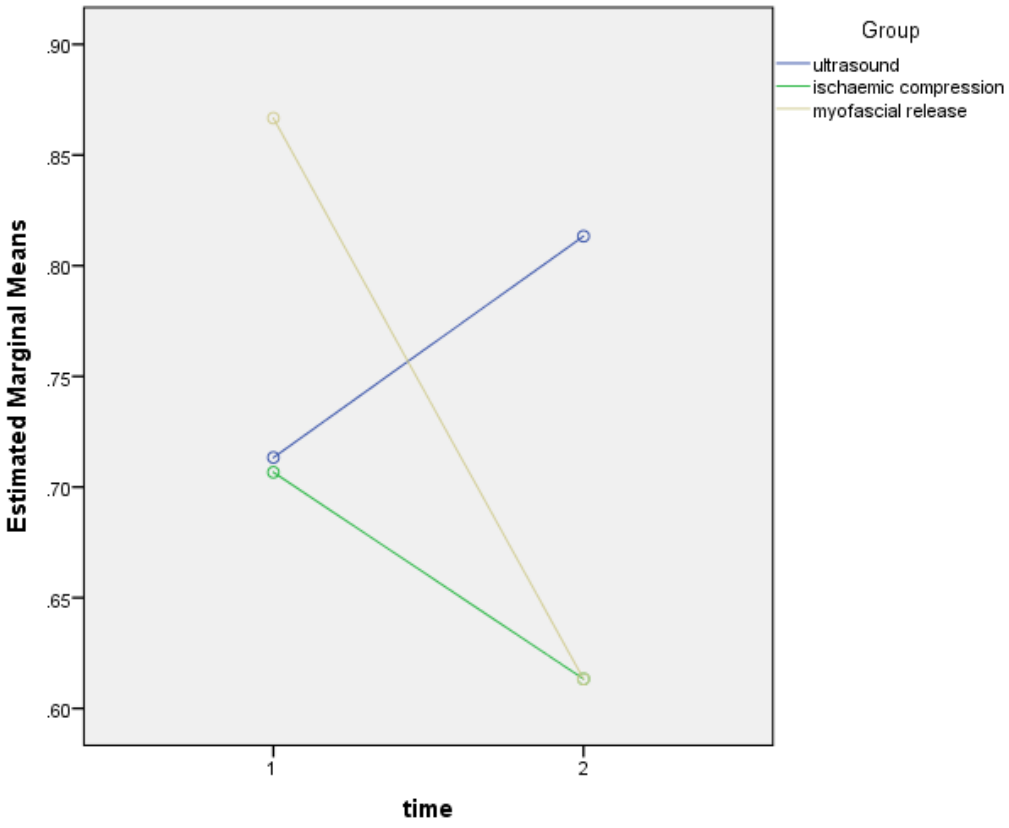


Figure 4.20 Time*group effect for the Stability Index in the postural stability (eyes closed) medial-lateral

4.6.4 Postural Sway (Eyes Closed) Overall

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.152) time*group effect for postural sway (eyes open) overall. *Figure 4.21* represents pilot plots for the average means between the groups.

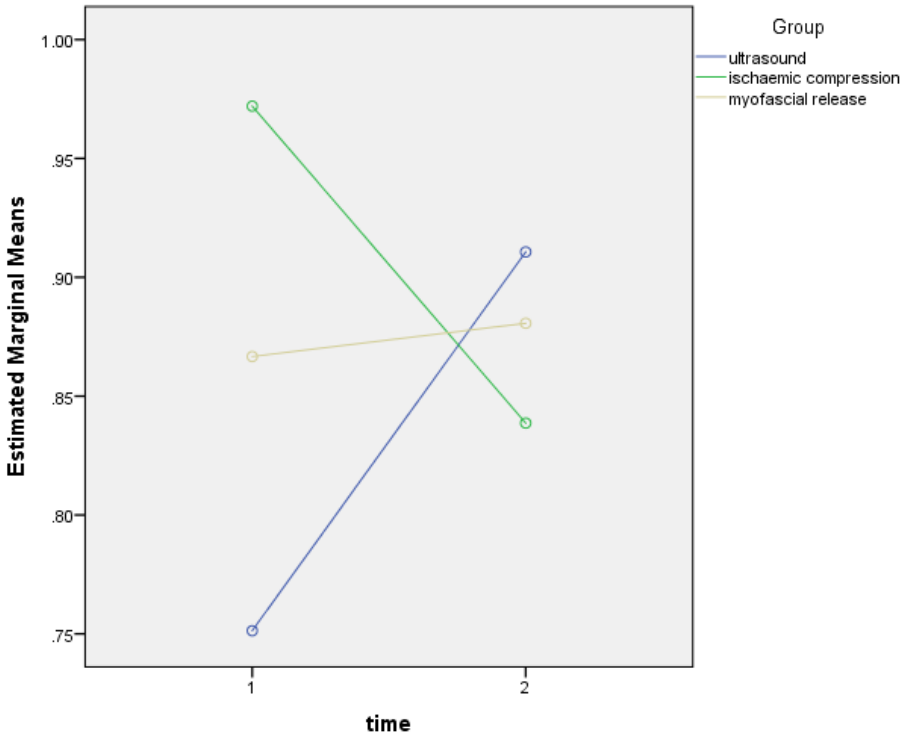


Figure 4.21 Time*group effect for the Sway Index in the postural sway (eyes closed) overall

4.6.5 Postural Sway (Eyes Closed) Anterior-Posterior

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.269) time*group effect for postural sway (eyes open) anterior-posterior. *Figure 4.22* represents pilot plots for the average means between the groups.

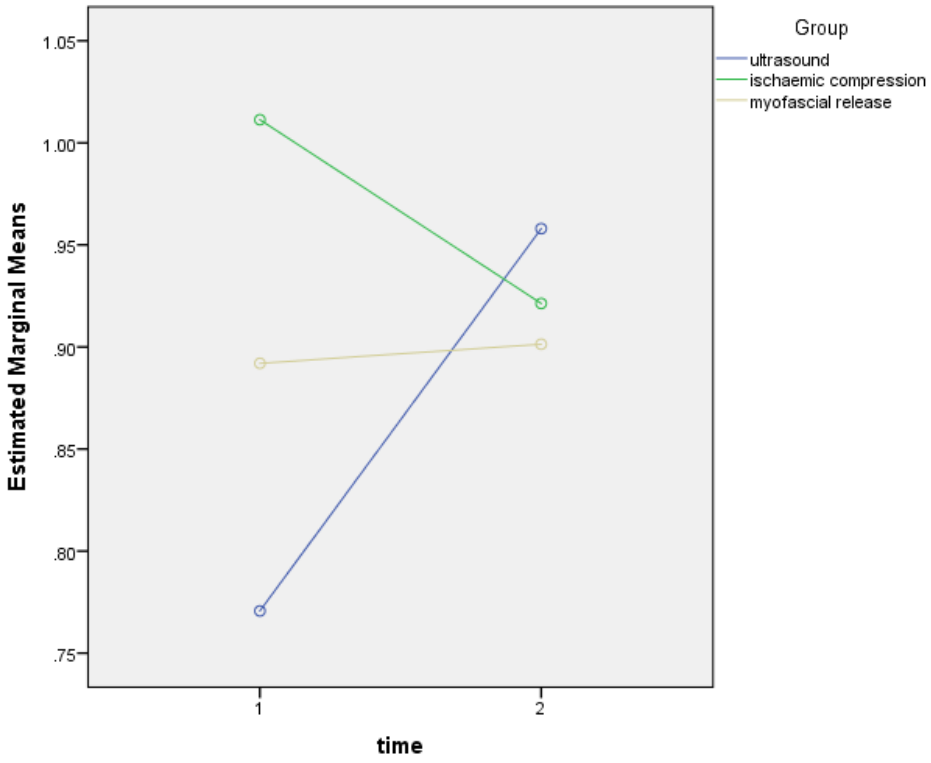


Figure 4.22 Time*group effect for the Sway Index in the postural sway (eyes closed) anterior-posterior

4.6.6 Postural Sway (Eyes Closed) Medial-Lateral

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.775) time*group effect for postural sway (eyes open) medial-lateral. *Figure 4.23* represents pilot plots for the average means between the groups.

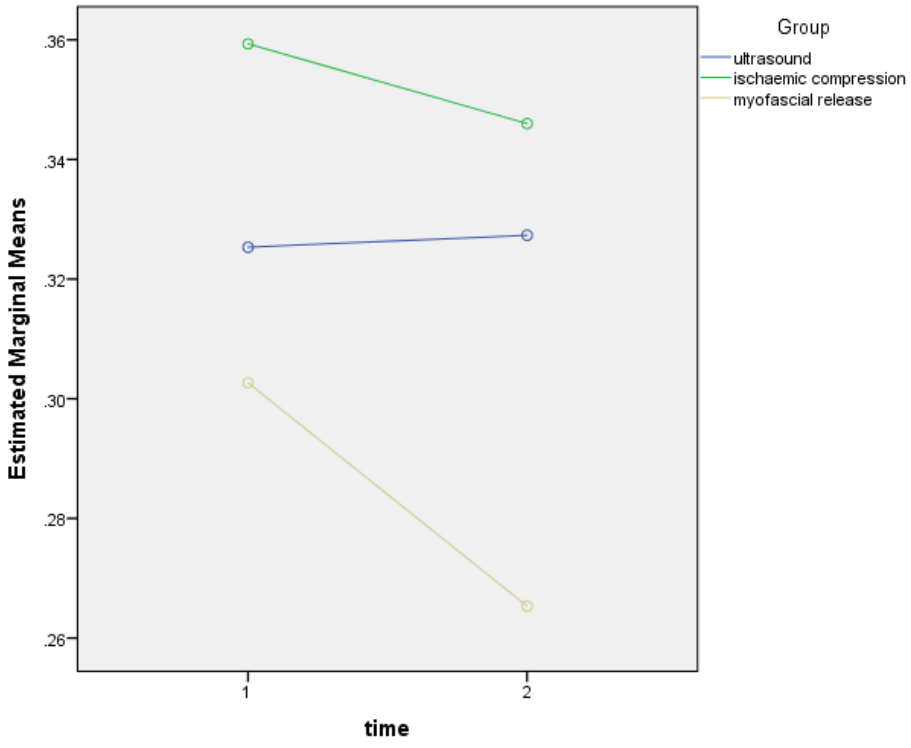


Figure 4.23 Time*group effect for the Sway Index in the postural sway (eyes closed) medial-lateral

4.7 LIMITS OF STABILITY

Results Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing for postural stability (eyes closed) are summarized in *Table 4.14.* There were no significant time*group effects for limits of stability tests.

Table 4.14 Overall significance of the limits of stability in terms of the Stability Index

Axes	Significance	*p*-value
Overall	No significant treatment effect	0.622
Front	No significant treatment effect	0.598
Back	No significant treatment effect	0.369
Left	No significant treatment effect	0.961
Right	No significant treatment effect	0.820
Front left	No significant treatment effect	0.077
Front right	No significant treatment effect	0.413
Back left	No significant treatment effect	0.715
Back right	No significant treatment effect	0.293

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root measures. p-value < 0.05 was considered significant.

4.7.1 Overall Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.622) time*group effect for overall limits of stability. *Figure 4.24* represents pilot plots for the average means between the groups.

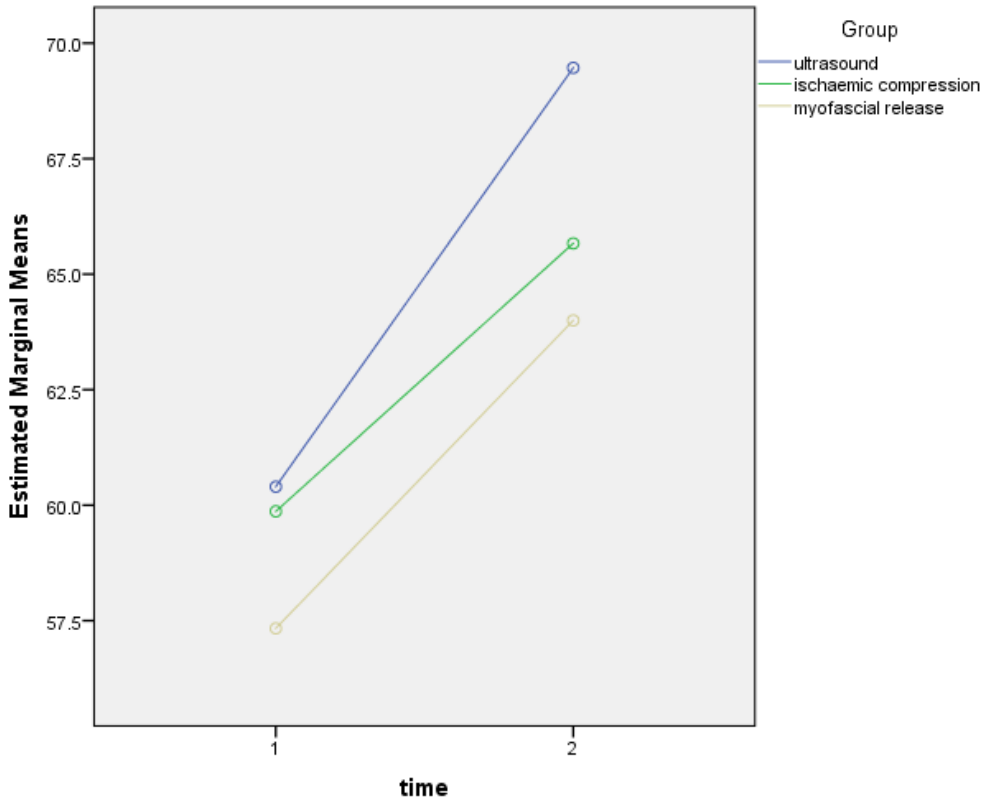


Figure 4.24 Time*group effect for the Stability Index in the overall limits of stability

4.7.2 Front Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.598) time*group effect for overall limits of stability. *Figure 4.25* represents pilot plots for the average means between the groups.

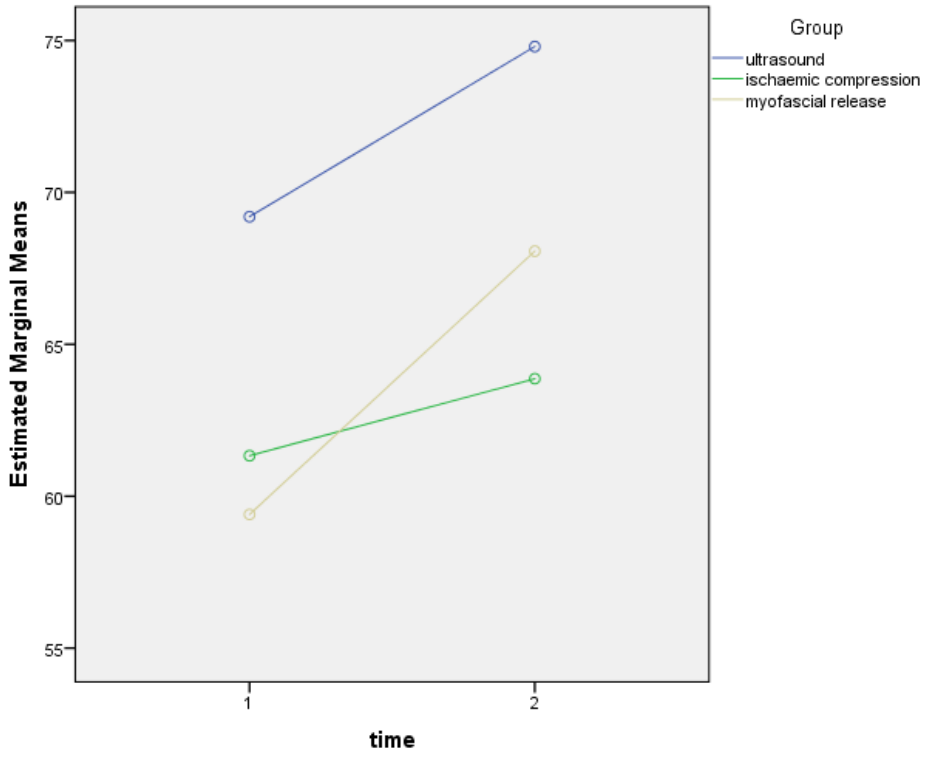


Figure 4.25 Time*group effect for the Stability Index in the front limits of stability

4.7.3 Back Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.369) time*group effect for overall limits of stability. *Figure 4.26* represents pilot plots for the average means between the groups.

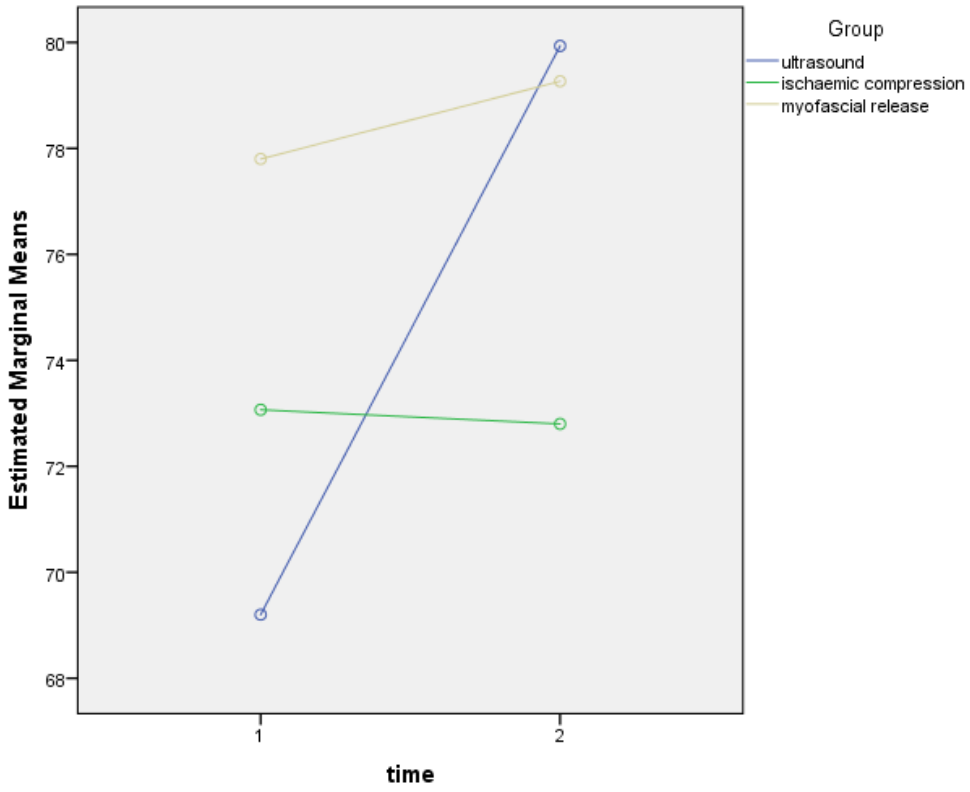


Figure 4.26 Time*group effect for the Stability Index in the back limits of stability

4.7.4 Left Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.961) time*group effect for overall limits of stability. *Figure 4.27* represents pilot plots for the average means between the groups.

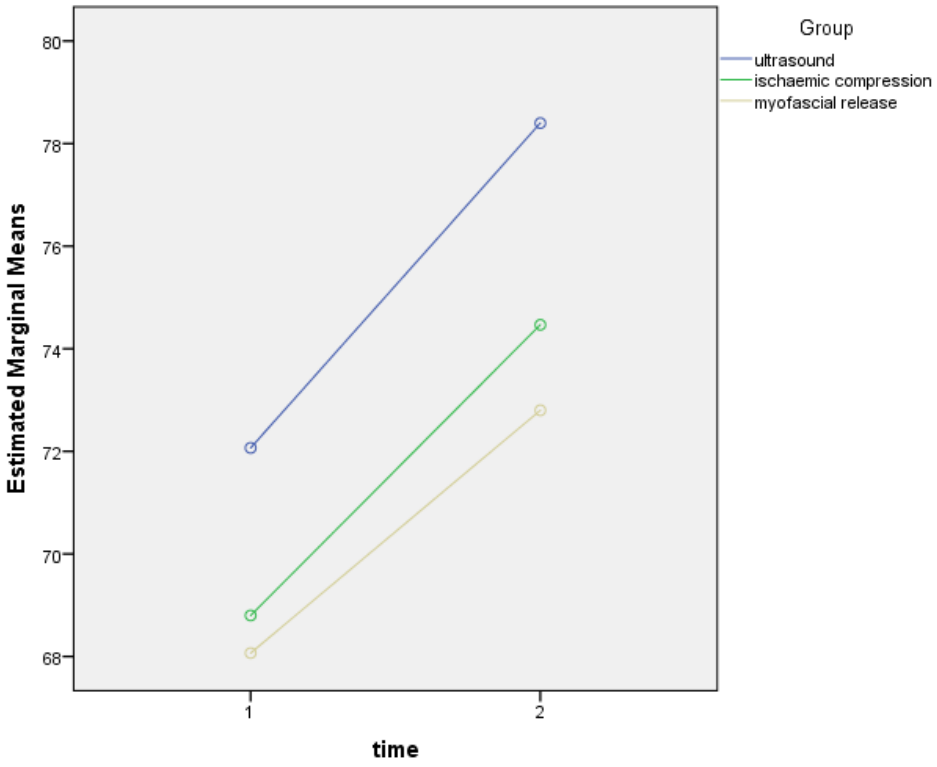


Figure 4.27 Time*group effect for the Stability Index in the left limits of stability

4.7.5 Right Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.820) time*group effect for overall limits of stability. *Figure 4.28* represents pilot plots for the average means between the groups.

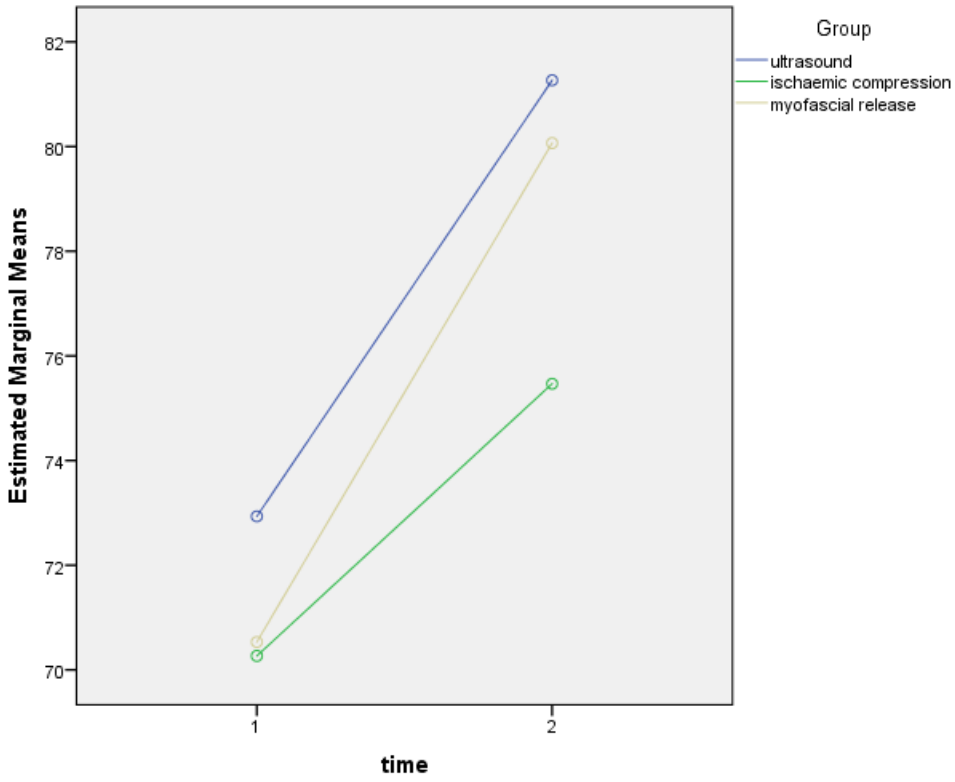


Figure 4.28 Time*group effect for the Stability Index in the right limits of stability

4.7.7 Front Left Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.077) time*group effect for overall limits of stability. *Figure 4.29* represents pilot plots for the average means between the groups.

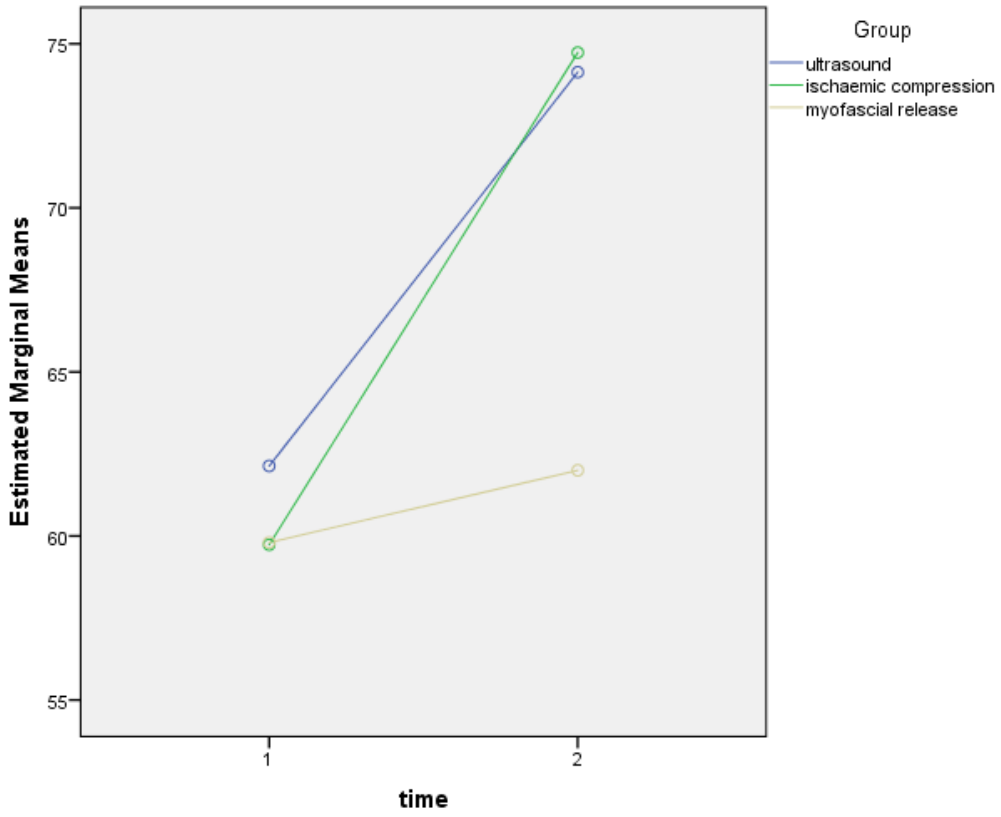


Figure 4.29 Time*group effect for the Stability Index in the front left limits of stability

4.7.8 Front Right Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.413) time*group effect for overall limits of stability. *Figure 4.30* represents pilot plots for the average means between the groups.

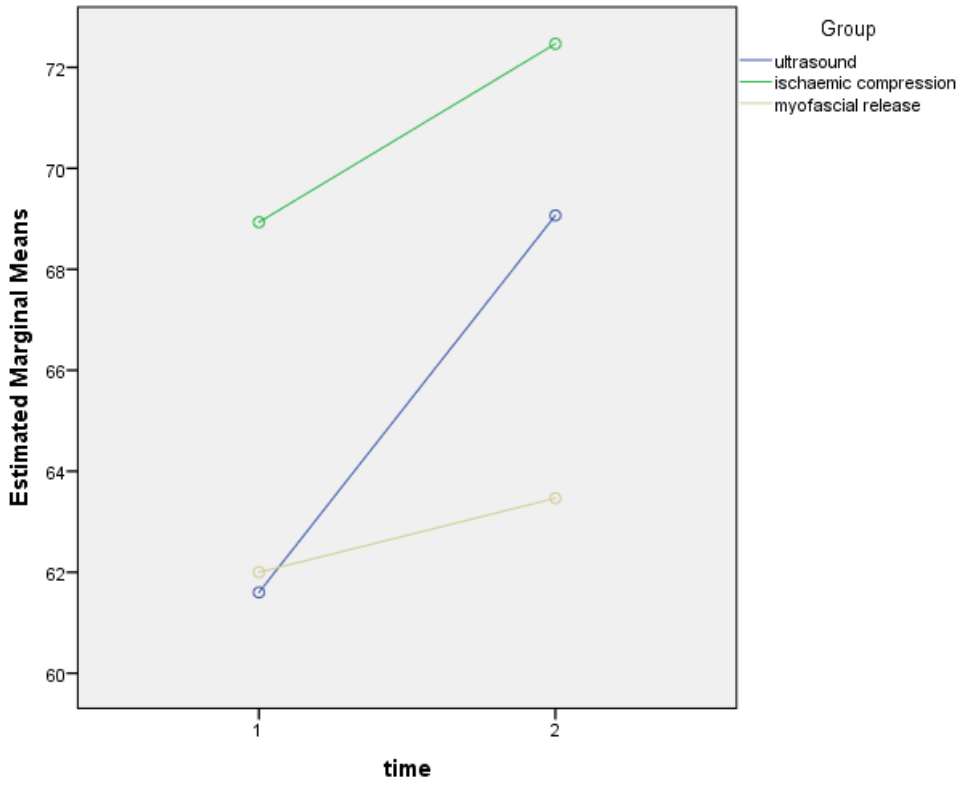


Figure 4.30 Time*group effect for the Stability Index in the front right limits of stability

4.7.9 Back Left Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.715) time*group effect for overall limits of stability. *Figure 4.31* represents pilot plots for the average means between the groups.

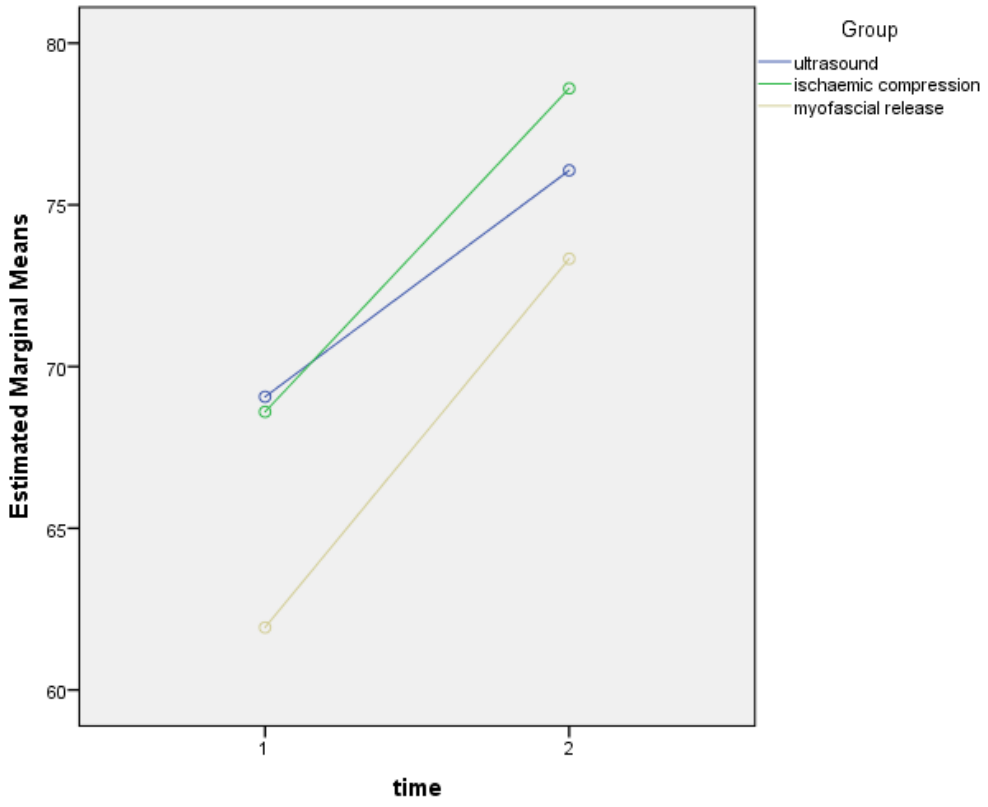


Figure 4.31 Time*group effect for the Stability Index in the back left limits of stability

4.7.10 Back Right Limits of Stability

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root testing showed a non significant (p=0.293) time*group effect for overall limits of stability. *Figure 4.32* represents pilot plots for the average means between the groups.

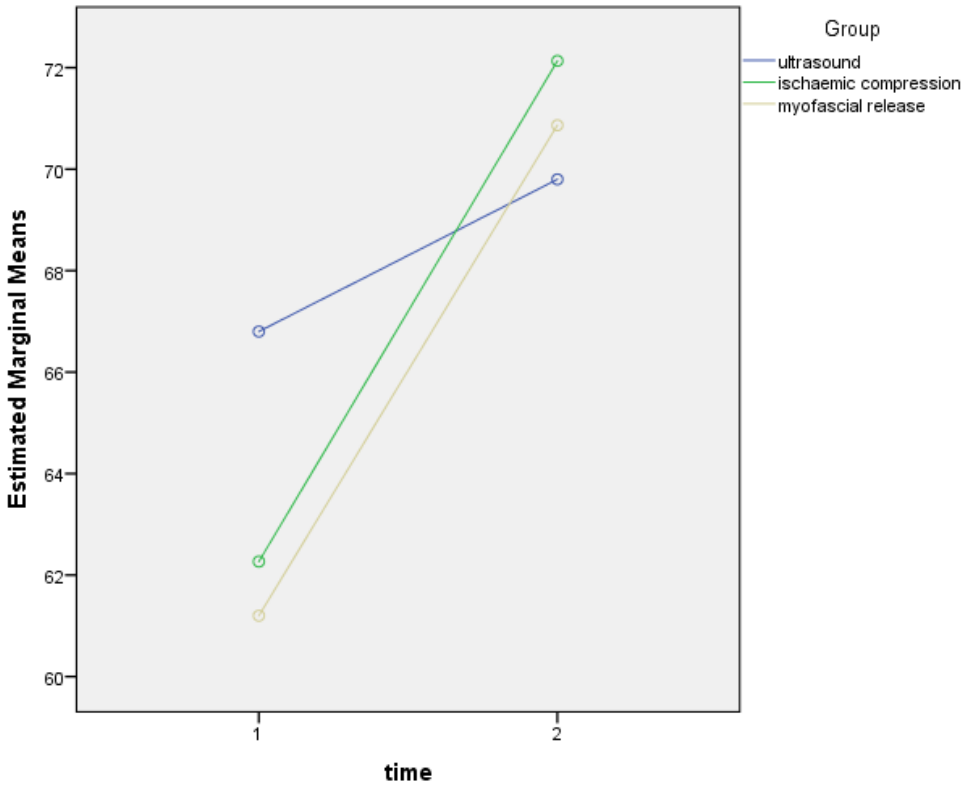


Figure 4.32 Time*group effect for the Stability Index in the back right limits of stability

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

The results of the study are discussed below in terms of the results shown in Chapter 4. The outcomes for the goniometric measurements for left and right outcomes are related to the combined results. Results of postural stability (eyes open) and postural stability (eyes closed) are discussed with regards to the Stability Index and Sway Index separately. Results for limits of stability are discussed in terms of the Stability Index.

Baseline and post-intervention means were presented graphically on pilot plots. There were no comparisons for means between the groups. Standardized baseline means were not set as inclusion criteria and varied amongst the groups. Only the amount of change between baseline and post-intervention were analysed in order to accept or reject the null hypothesis for immediate time*group effects between the groups.

5.1.1 Parameters

Pyykko, Jantti and Aalto (1990) demonstrated that elderly participants had reduced stability. According to Hageman, Leibowitz and Blanke (1995) these results were again shown in the eldery; however participants between the ages of 18 and 35 were shown no have no correlation with reduced balance and stability. Participants in the present investigation were between 18 and 35 years (Hageman, Leibowitz and Blanke 1995).

The parameters between the groups showed that the mean BMI for the placebo ultrasound group (21.9) and the ischaemic compression group (23.2), were within normal limits (<25). The mean BMI for the myofascial release group (26.8) indicated that this group was overweight (>25) on average (Vorona et al. 2005)

The literature is inconclusive as to the exact effect that body weight has on balance measures, but according to Hue et al. (2007) there is a strong correlation. The author

recruited participants with a mean age of 40.5 years, mean height of 1.75m and mean BMI of 35.2. For the present study the mean parameters were different to those used by Hue et al. and thus cannot be discussed with regards to the outcome measures (2007). No evidence exists to suggest that participants with increased BMI, are effected differently by manual therapy with regards to outcome measurements, post intervention.

5.2 NAVICULAR PRONATION

Navicular pronation was shown to have significant (p=0.051) time*group effect for right navicular pronation. Post hoc testing revealed a borderline significant (p=0.056) improvement in pronation for the the myofascial release group in comparison to the ischaemic compression group, which on average got worse. Refer back to *Figure 4.2.*

Before discussing the results for navicular position, mention must be made of Gardin et al. (2013), who hypothesized that after inducing fatigue in the ankle inverters, there may be an effect on navicular drop. The authors failed to show any significant effect with regards to navicular drop, but this may have bearing in the present study. In the present investigation, participants were tested for postural stability as well as limits of stability which challenged the stability of the foot and ankle complex. These tests have been shown to rely on the tibialis anterior muscle (aiding in medial longitudinal arch stability) as well as posterior crural muscles, for achieving balance (Loram, Maganaris and Lakie 2005). There was a possibility that the pre-intervention balance testing might have induced fatigue in the muscles responsible for supporting the medial longitudinal arch. It is also noted that balance testing was done after goniometric measurements.

Results for the placebo ultrasound group remained the same with regards to the changes in mean left navicular pronation. In the right, the mean navicular pronation decreased. These effects were not significant. The decrease in mean right navicular pronation was not shown in the combined analysis, as the combined analysis showed a non-significant mean increase in navicular pronation. Mean left and right changes for the groups do not take into account the clinical effect for each individual. It is suggested that this might explain the conflicting results between the mean improvement in right navicular pronation and the combined mean increase in navicular position, for the placebo ultrasound group.

The myofascial release group on the other hand improvement with regards to changes in the mean navicular position, bilaterally. The results of the combined left and right change for navicular pronation, supports the mean changes for the average left and right means. Shah and Bhalara (2012) suggest that myofascial restrictions hold the skeleton in asymmetrical alignment, which has bearing on function and posture. In the case of myofascial release therapy which targets these mechanical restrictions, it is suggested that this could have contributed to the significant treatment effects between the two myofascial groups.

The ischaemic compression group on the other hand had mean increases in pronation, bilaterally, although this effect was not significant, it was again evident in the combined change. Possible reasons for the negative result in this group, could be that the ischaemic compression group did produce a significant enough mechanical effect on the myofascial restrictions, compared to the myofascial release group (Shah and Bhalara 2012). The increase in pronation could also be explained by tonus changes (as a result of stimulating the mechanoreceptors) in the muscles supporting the medial longitudinal arch (Schleip 2003a; b). These explanations are mentioned with caution, as the aim of the present study was not to investigate the mechanisms for effecting outcome measures.

5.3 GREAT TOE EXTENSION

The mean passive non-weight bearing great toe extension left, improved significantly (p=0.048) with regards to the time*group effect seen in *Figure 2.3.* This effect was greatest when comparing the increased great toe extension for ischaemic compression group (p=0.067), compared to the average reduction in great toe extension for the placebo ultrasound group. There was also a borderline non-significant (p=0.069) time*group effect in the partial weight bearing great toe extension right. Post hoc testing failed to show any significant differences (p=0.090) between the ischaemic compression and placebo ultrasound groups

The significant (p=0.048) and borderline non-significant (p=0.069) differences in great toe extension, revealed that the significance was most different between the ischaemic compression group and placebo ultrasound group in both cases. Interestingly the combined partial weight bearing great toe extension showed that the time*group effect was also significant (p=0.035). Post hoc testing showed that these differences were again between the ischaemic compression and placebo ultrasound groups.

Dananberg (1993a; b) suggests that the great toe has limited extension in many cases, due to the compensatory changes in the windlass mechanism. In the case of the ischaemic compression group that the stimulation of the mechanoreceptors could have resulted in a change in the compensatory mechanisms (and biomechanical changes) presented by Dananberg (1993a; b) and Donatelli (1987) (Schleip 2003a; b).

In identifying trends with regards to combined great toe extension change, the ischaemic compression group was the only group which consistently improved with regards to all the great toe extension measurements. No other trends were noticed.

In terms of identifying clinical significance, Hopson, McPoil and Cornwall (1995) investigated the great toe extension range of motion in healthy, preselected participants with normal hip, knee and ankle ranges of motion. The authors demonstrated that for the great toe extension measurements, the mean ranges of motion between all of the measurements were between 85 and 109 degrees. The results cannot be compared for significance with this study as participants in the present study had bilateral pronation and were not screened for the above mentioned normative measurements. It is interesting to note that for the present study, great toe extension means for participants with bilateral pronation were between 29 and below 60 degrees. The literature is inconclusive with regards to the exact presentation of how pronation may affect great toe extension (Donatelli 1987; Durrant 2009).

Comparing the results for any clinical significance proved challenging, as literature with regards to participants with bilateral pronation is very limited. The present study could only draw from other studies investigating the immediate effects of myofascial therapies on range of motion in the knee and ankle respectively (Smith and Fryer 2008; Arun, Joginder and Sheetal 2014).

Smith and Fryer (2008), used stretching in combination with muscle energy techniques and had significant changes ($p<0.01$) in knee range of motion. Comparable changes ($p<0.001$) were noticed by Arun, Joginder and Sheetal (2014), after treating the soleus for changes in ankle range of motion. The significant time*group changes ($p=0.048$) for passive non-weight bearing great toe extension left, in the present study was not comparable to the studies mentioned above.

5.4 POSTURAL STABILITY AND SWAY

In assessing changes in the Stability Index, significant treatment effects for both myofascial groups were noticed in postural stability (eyes closed) with regards to overall ($p=0.003$) and anterior-posterior ($p=0.006$) axes. These changes were not seen for the postural stability (eyes open) test.

Both the ischaemic compression group and myofascial release group demonstrated significant differences, when compared to the placebo ultrasound group. For overall stability the time*group correlation was significant (p=0.004 and p=0.031) for the ischaemic compression group and myofascial release groups respectively. The time*group comparisons for anterior-posterior stability indicated that the ischaemic compression group (p=0.007) had greater significance than the myofascial release group (p=0.053), compared to the placebo ultrasound group. This was the case for both the overall and anteriorposterior axes. The ischaemic compression and myofascial release groups had no significant differences when compared to each other, in any of the post hoc testing.

For the Sway Index, there was a borderline significant (p=0.059) time*group effect for the postural stability (eyes open) medial-lateral test. Post hoc Bonferroni adjusted testing showed no significant (p=0.063) correlation with the myofascial release group and placebo ultrasound group.

In the literature, authors suggest that by eliminating the visual system, there is an increase in the reliance on somatosensory and vestibular contributions to balance (Lephart and Fu 2000: 38, Horak et al. 1994; Clifford and Holder-Powell 2010). These effects are also suggested by Cote et al. (2005) who demonstrated significant (p<0.001) differences in the Stability Index for eyes open and closed measures between participants with different foot types.

After analyzing the data for the postural stability (eyes closed) the improvement in centre of pressure scores, indicated by the Stability index, was predominantly in the anterior-posterior axis (*Figure 4.18 and 4.19*). This is supported by Rougier (2008) who suggests that anterior-posterior sway is predominantly controlled by plantar pressure variations. The present study hoped to mechanically and neurophysiologically alter variations in plantar pressure by increasing freedom of movement in the plantar fascia, ankle, achilles and crural fascia, as outlined in the methodology.

The significant time*group effects mentioned above are suggested to be due to the mechanical and neurophysiological mechanisms involved in both types of myofascial therapies (Simmonds, Miller and Gemmell 2012). To the best knowledge of the researcher, no other studies have investigated the immediate effects of myofascial therapies on postural stability, thus the clinical significance of the results need further testing.

In terms of postural sway, there was a borderline non-significant (p=0.059) change in the postural stability (eyes open) medial-lateral Sway Index.. The borderline non-significant effect with regards to the Sway Index was most different between the Myofascial release and placebo ultrasound groups (p=0.063).

A trend was noticed when comparing the results for postural stability (eyes open). Although not statistically significant, the downward slopes of the graphs in *Figure 5.1* indicated that on average all groups had improvements in the Stability and Sway Index for the postural stability (eyes open) tests. It is thought that the learning error between test and retest measurements accounted for these small but uniform improvements across almost all the groups. The learning error is influenced by performing the test more skillfully, after each measurement.

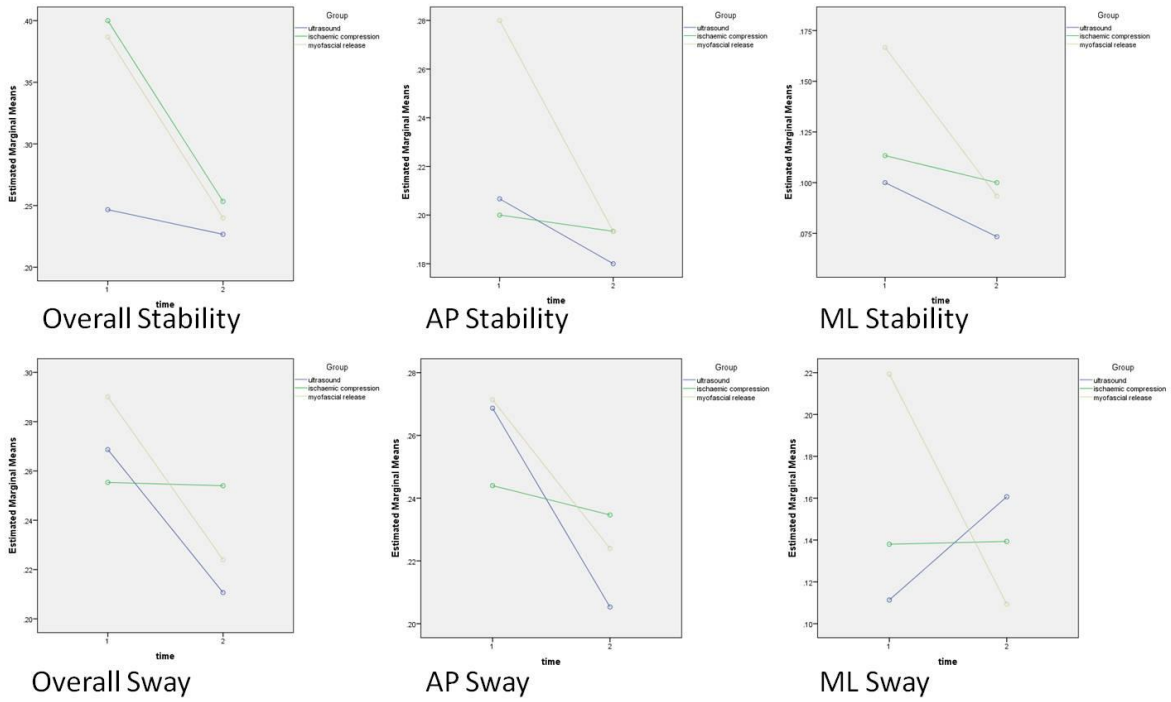


Figure 5.1 Postural Stability Test (Eyes Open). The y-axis represents the mean Stability Index and Sway Index scores, for the groups

5.5 LIMITS OF STABILITY

There were no statistically significant time*group correlations in the limits of stability test.

The measure in limits of stability is calculated using the mean deviation of the Stability Index, from the relevant axis and dot. This calculation differs to other studies, where the limits of stability are defined as the maximal distance from the centre of gravity with regards to the multiple directions (Cote et al. 2005).

The present study tested the limits of stability tests and used a set distance about the centre of gravity (Biosway Portable Balance System: Operation manual. No Date). The participants may not have been challenged enough with regards to individual end ranges or limits. This might be a reason for the non-significant changes between the groups, for limits of stability.

In identifying a trend, all groups seemed to improve, post intervention. As illustrated in *Figure 5.2* there was an upward slant for almost all the directions and groups with regards the Stability Index. This trend could possibly be explained by the learning error, after participants performed the limits of stability test at the pre-intervention measurement.

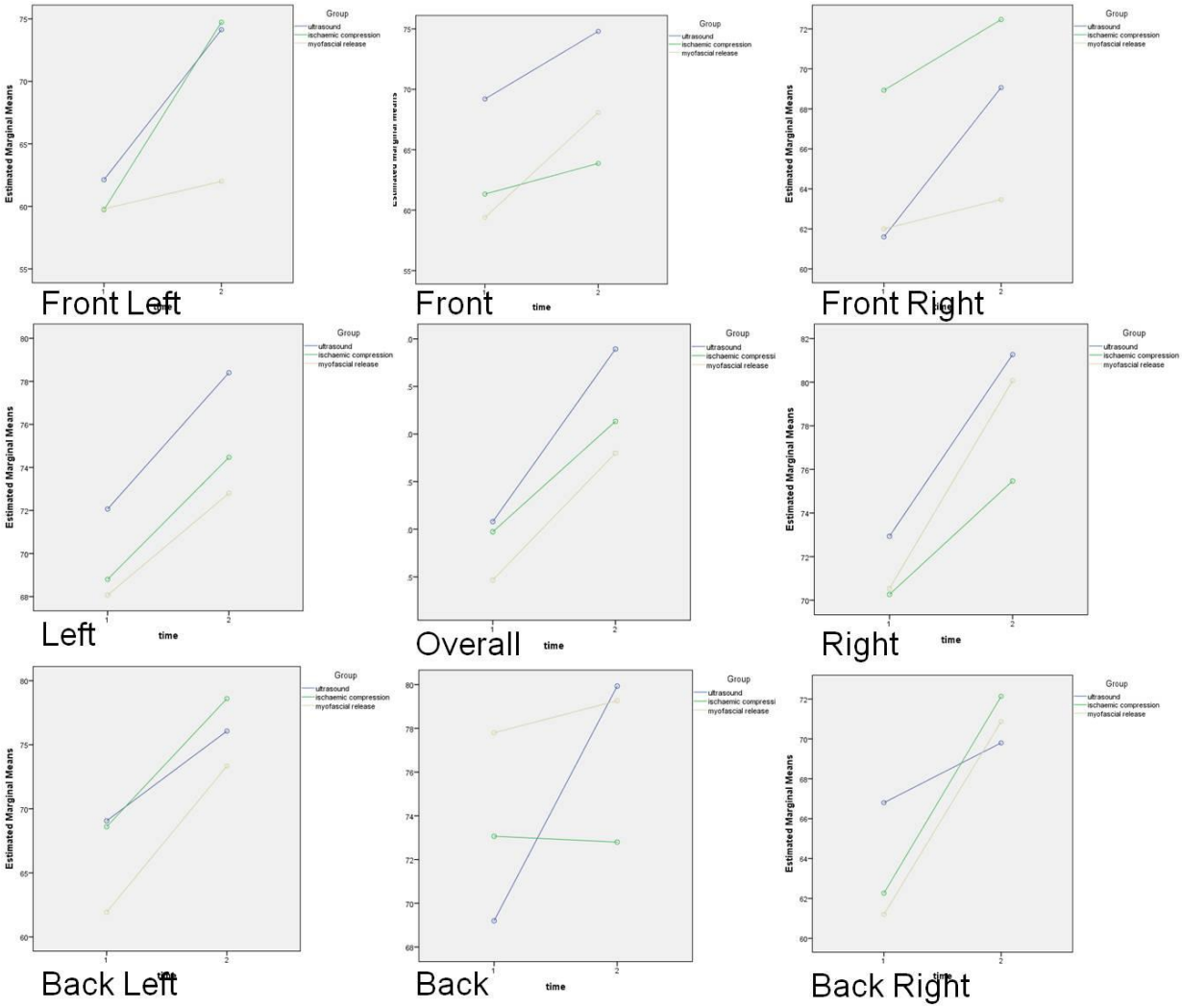


Figure 5.2 Limits of stability for overall and multiple axes, for the groups

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The conclusions drawn from the results have been explained in terms of the either accepting or rejecting the Null hypotheses in Section 1.4.

6.2 NAVICULAR POSITION

6.2.1 Conclusion for Navicular Position

This researcher accepts the Null hypothesis that states there would be no significant changes in navicular pronation, when comparing the groups. This is due to the fact that there were no statistically significant time*group changes between the groups; however it was interesting to note that the myofascial release group seemed to improve the navicular pronation, but the ischaemic compression seemed to worsen navicular pronation.

6.2.2 Recommendations for Assessing the Navicular Position

1. The participants included into this study, were required to have a minimum degree of navicular pronation, greater or equal to two degrees. It is recommended that future studies include participants with roughly the same degree of navicular pronation, defining an upper as well as lower limit, in order to limit variability and presentation of the navicular position and related myofascial restrictions.
2. It is also recommended that future studies should limit factors which may induce fatigue of the muscles associated with supporting the medial longitudinal arch.
3. Future studies need to focus on the differences between treating participants with bilateral pronation and unilateral pronation.

6.3 Great Toe Extension

6.3.1 Conclusion for Great Toe Extension

The researcher partially rejected the Null hypothesis in terms of showing non-significant changes in great toe extension, between the groups for great toe extension. The reason for this is due to the significant (p=0.048) and borderline (p=0.069) time*group effect for passive non-weight bearing great toe extension left and partial weight bearing great toe extension right respectively. In combined partial weight bearing great toe extension, the time*group revealed statistically significant (p=0.035) changes. Post hoc testing showed that all the significant results with regards to the above were between the placebo ultrasound group and the ischaemic compression group.

The Null hypothesis was partially rejected, as the significant results were not across all of the great toe extension measurements.

6.3.2 Recommendations for Great Toe Extension

1. Great toe extension was not investigated with regards to gait. This has been investigated in previous studies and it is recommended that future research might gain, by assessing changes in great toe extension with regards to a more dynamic measurement.

2. Future studies should attempt to use more objective means for the measurement of great toe extension. This is due to examiner and human error

3. Future studies need to investigate the exact relationships between great toe extension and pronation, this is controversial within the literature.

6.4 BALANCE TESTING

6.4.1 Conclusions for Balance Testing

The researcher concludes by rejecting the Null hypothesis in terms of showing non-significant changes in the time*group effect, between the groups for balance testing. Although not evident in the postural stability (eyes open) and limits of stability tests, both myofascial therapies had significant time*group effects for the postural stability (eyes closed) in bilaterally pronated participants when compared with the placebo group. The evidence presented, supports the hypothesis made by many leading authors with regards to possible effects of myofascial therapies on proprioception, in terms of balance testing.

6.4.2 Recommendations for Assessing Balance using the Biosway Portable Balance System

1. It is recommended that future studies should not use ultrasound as a placebo in comparing the effects of myofascial therapies. This is due to the possible stimulating effects onto the skin and thus on the mechanoreceptors

2. Future studies need to use other, more reliable tests, for evaluating the immediate effect that myofascial therapies may have on limits of stability. The Biosway Portable Balance Platform did not test limits of stability in terms of displacement, rather in terms of the stability index. Future studies should investigate if there was any immediate change in the displacement of limits from the centre.

3. Future studies are recommended to investigate the effect of myofascial therapies on balance testing in neutral, asymptomatic participants.

4. It is recommended that future studies combine different forms of myofascial therapies, in order to assess if there are significant differences in balance.

5. Future studies need to investigate the effect of delivering a unilateral treatment, as opposed to bilateral treatments, for changes in balance.

6. Future studies are recommended to assess post-intervention changes in balance measures between groups of obese and normal individuals, in order to explore the possible relationships.

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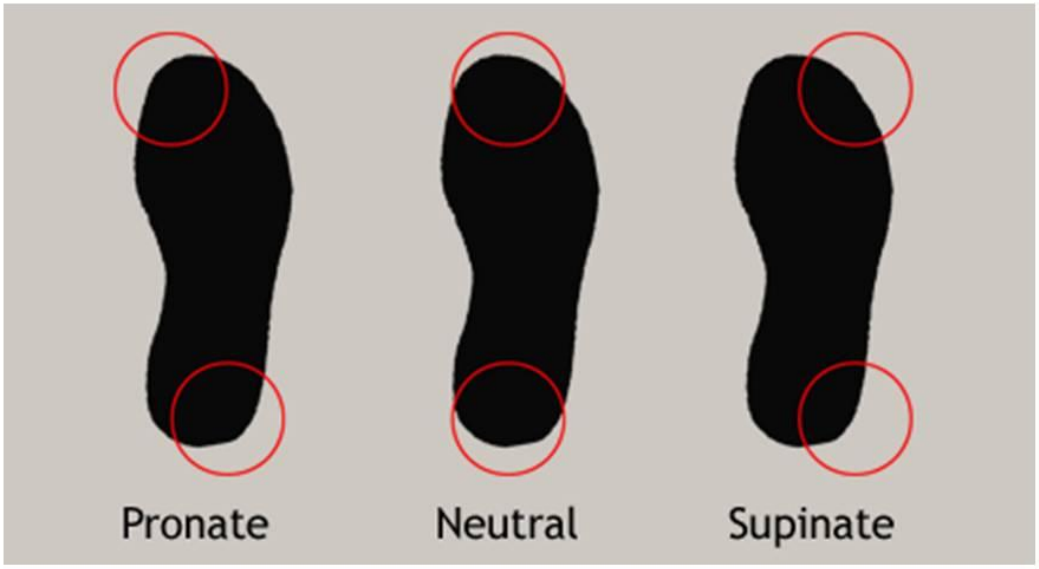
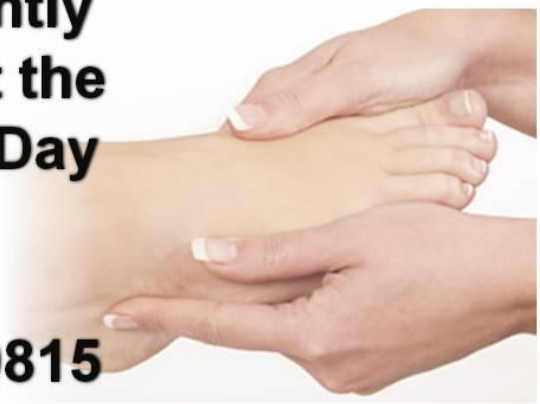
Appendix A

Have you heard of Pronation ?



Find out your foot type

Research is currently been conducted at the DUT Chiropractic Day Clinic



Contact: 082 851 9815 for more information

Appendix B

Request for Permission to Advertise

Chiropractic Day Clinic
Durban University of Technology
P.O.Box 1334
Durban
4000
Name of Company: _____

Dear Sir/Mam,

I am a masters chiropractic student (student #: 208204352) at the Durban University of Technology in South Africa. In order for us to complete and graduate we need to complete a comprehensive thesis (research study) that is supported and supervised by dedicate professionals, at the department of Chiropractic and Durban University of Technology.

My research project is an investigation into the possible effects of two different myofascial (muscle and connective tissue) therapies on foot type and balance. I require participants to have flat feet, dropped arches or pronated feet. It is for this reason I am attempting to recruit participants from various outlets, including your own.

In order to recruit such individuals, I require permission for any one of the following to take place

- Distribute of pamphlets through which potential participants can contact me and make an appointment.
- Setting up a station in order to measure an individual's foot type, at the interest of the individual.
- Put up a poster explaining the different foot types and the nature of the test.

I, Jeff Puttergill herewith kindly request for permission to advertise my research study within on your premises.

Kind Regards,

Jeff Puttergill Sign:_____

Permission Granted: **Yes** **No** **(*please circle*)**

I, _____, hereby give permission for Jeff Puttergill to advertise his research study within/on/at our premises, signed at _____(place)

Sign:_____ **Date:**_____

Appendix C

Answers to the Telephonic Interview:

Name: _____

Contact number: _____

Encircle given answer below:

Telephonic Interview		
Question?		Answer Required
1	Would you be willing to answer a few questions about yourself regarding foot function and well-being?	YES
2	Are you between the ages of 18 and 35 years?	YES
3	While standing, do your arches drop?	YES
4	Have you ever been told you have flat feet?	YES
5	Do you currently have any pain in your foot or ankle?	NO
6	Have you had significant trauma or surgery to the foot or ankle?	NO
7	Do you have any altered sensation in the foot or ankle?	NO
8	Do you take medication for any chronic diseases?	NO
9	Would you be willing to attend a consultation at the DUT Chiropractic Clinic, to determine if you will be able to participate in this study?	YES

Consultation date: _____

Time: _____

Appendix D

Letter of information

Title of Research Study:

Immediate effect of two myofascial interventions on balance and great toe range of motion measurements in subjects with pronated feet - Placebo controlled

Principal investigator: Jeff Puttergill – 082 851 9815

Co-Investigators: Dr HM Kretzmann (M.Dip Chiropractic)

Dear Participant

Welcome to my research project, below is some information regarding the nature of my research and issues pertaining to you.

Introduction and Purpose of the Study:

This study will investigate the effects of three different interventions to the lower limb. Once included you may fall into 1 of the 3 groups receiving 1.Placebo intervention, 2.Ischaemic compression or 3.Myofascial release. The theory behind these interventions is that they have all been shown to reduce myofascial adhesion or points of stickiness between the layers of muscles and thus increase the tissues range of motion or movement. Upon selection you will be randomly placed into one of these groups.

We will be examining your feet for alignment as well as movement of the big toe. We will also test your balance using a force platform. Your balance results will be available to you during the examination.

Outline of the procedures:

Letter of information and informed consent is signed and granted.

Case history and examination forms will be completed and signed off by the supervising clinician. At this point you will be notified whether you may participate in this study.

You will then be randomly allocated into one of the 3 groups.

You will undergo measurements before and after the treatment.

Risks/Discomforts and Benefits

The treatment is safe and is unlikely to cause any adverse effects. However, you may feel transient stiffness or discomfort after treatment as is evident with many manual therapies. This should resolve without further complication to you. However, should the discomfort persist for longer than three days, please report this to me and I can take the appropriate action. The treatment aims to increase range of motion of the myofascia and thus have an effect of balance and stability

Reason(s) why the participant may withdraw or be withdrawn from the study:

In the event that the participant does not meet the inclusion criteria or infringes on the exclusion criteria of the study, the participant will be withdrawn. Your participation in this study is voluntary and refusal to participate will not result in any adverse consequences. You are free to withdraw from the study at any time.

Remuneration:

You will not be awarded any remuneration for taking part in this study.

Cost of study:

Your participation in this research is free of charge, but should the participant wants further treatment upon completion of the study, a normal consultation fee/ rate will apply.

Confidentiality:

Your personal information will remain confidential by the use of a coding system for data analysis and reporting and kept in the Chiropractic Day Clinic for 15 years, after which it will be shredded. All the results will be made available in the Durban University of Technology library in the form of a dissertation, but no personal information will be melted.

Should there be a research related injury:

The D.U.T Clinic Protocol will be followed and the injury would also need to be reported to the Health Research and Ethics Committee, so please ensure that you advise me of any such problems.

Persons to contact in the event of any Problems or Queries:

Research: Mr Jeff Puttergill	Tel: 031 373 2205
Supervisor: Dr HM Kretzmann (M.Dip Chiropractic)	Tel: 031 373 2205
IREC Research Administrator (IREC)	Tel: 031 373 2900

Consent

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Jeff Puttergill, about the nature, conduct, risks and benefits of this study – Research Ethics Clearance Number _____.
- I have also received, read and understood the above written information (Participant letter of information) regarding this study.
- I am aware that the result of this study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in this study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Participant name (print) .....

Participant signature ..... Date.....

I, Jeff Puttergill, herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Researcher's name (print) .....

Researcher's signature .....Date.....

Witness name (print) .....

Witness signature .....Date.....

Appendix D

Incwadiyemininingwane

IsihlokosoCwaningo

Uphenyo olubheka imiphumela yama-myofascial intervention amabili kwisikalo se balance nezinga lokunyakaza kukabhozo kubantu abanezinyawo ezi-pronated, loluphenyo lubizwangokuthi lu placebo controlled.

Ophethe ucwaningo: Jeff Puttergill

Umsizi Wakhe: Dr HM Kretzmann (M.dip Chiropractic)

Ngiyakwamukela kwi research project yami.

Isingeniso nenhloso yoCwaningo:

Lolucwaningo luzobelubheka imiphumela yama intervention amathathu ahlukile emlenzeni.Mese usungenisiwekungenzeka ufakwe kweyodwa I group kulawawomathathu. 1) eyokuqala izothola I placebo intervention 2) eyesibili izothola I Ischaemic compression 3) eyesithathu izothola I myofascial release. Ngokocwaningo olubhaliwekuthiwa lama intervention ayasiza ukuqaqa noma ukwehlisa izinga lokunamathelana kwamamaseli ukuze akwazi ukusebenza kahle. Uma sewukhethiwe, uzobeusufakwa kweyodwa yalamagroup.

Kuzobe kuhlaziywa umehluko wokunyakaza kabhozo, kuphindwe kubhekwe izinga lokubhalansa kwakhokwi force plate.Imiphumela yakho, ungakwazi ukuthi uyicele mese kuqedwe uphenyo uma uyidinga.

I outline yama procedure:

i. Incwadi yemininingwane, neyesivumelwano iyasayinwa.
ii. Amaform e-case history, nophenyo oluncane lomzimba azogcwaliswa asayinwe udokotela osizayo. Uzobesewaziswa ukuthi uyavumeleka yini ukudlala indima kulolucwaningo.
iii. Uzofakwa kweyodwa yama group amathathu
iv. Uzokalwa ngaphambi kokuthi uthole I treatment, uphindeukalwe emuvakokube usuyitholile I treatment.

Ongakuzuza Nama-risk:

I treatment iphephile, futhi mancane amathuba okuthi kuvele izinkinga. Kungenzeka uzweubuhlungu beskhashana emuva kokuthola i-treatment, lokhu kuyinto ejwayelekile kuwowonke ama-Manual therapies. Kodwa uma kuqhubeka kumele wazise lo ophethe ucwaningo u-Jeff. Inhloso ye treatment ukwehlisa I stiffness kumamasela ukuze asebenze kahle assize nakwibalansi nokusekela.

Ukukhishwa nokuzikhipha kwi study:

Uma umuntu engazigcwalisi izidingo zokuthi angeniswe kwi study ngeke avunyelwe ukudlala indima kulestudy. Awuphoqelekile ukuthi uqhubeke uma usuqalile, futhi awuzu jeziswa ngalokho. Uvumelekile ukushiya nanoma inini.

Ukunxephezelwa:

Awuzunxephezeliswa ngalutho ngokudlala kwakho indima kulolucwaningo.

Okwezimali:

Ngeke uze ukhokhiswemali ukudlala indima kulolucwaningo ,kodwa uma ufuna ukuqhubeka ne treatment sesiphelile I study uzobe usukhokhiswa I consultation fee ejwayelekile.

Okuzofihlakala:

Imininingwane yakho ngeke ivele kubantu bomphakathi, kuzobe kusetshenziswa I coding system ukuthi kuhlaziywe imiphumela imininigwane nemiphumela, kuzobekwa e Chiropractic Day Clinic iminyaka engu 15, emvakwalokho amaphepha ayobe esedatshulwa, alahlwe. Yonke imiphume layocwaningo izobe itholakala e Library Yase Durban University of Technology, kodwa imininigwane efana njengegama nesbongo angeke kuvele.

Uma ulimala:

Kuzolandelwa I DUT clinic Protocol, futhi kuyomele kubikelwe i Health Reasearch and Ethics Committee.Siyacela uqinise ukuthiki uyamazisa ngokushesha uma kuvela izinkinga ezifana nale.

Abantu ongabathinta uma unenkinga noma unemibuzo:

Ophethe Ucwaningo: Mr Jeff Puttergill	Tel: 0313732205
Asebenza ngaphansi kwakhe: Dr HM Kretzmann	homerescue@telkomsa.net
IREC Research Administrator:	Tel: 0313732900

Isivumelwano

I Statmende sokuvuma ukudlala indima kulolucwaningo:

- Ngiyavuma ukuthi sengazisiwe ngokugcweleumphathi wocwaningo u Jeff Puttergill ngemininingwane, engingakuzuza, nokungangithikabeza kulonalolucwaningo.
- Sengitholile, ngafunda, ngaqonda lemininingwane mayelana nalolucwaningo.
- Ngiyavuma ukuthingiyazi ukuthi imiphumela yalolucwaningo: imininingwaneyami, igama, nesbongo, nosukulokuzalwa ne diagnosis kuzofakwa kwi computer . umasekwenziwa I report, ngeke livele igamalami nesbongo.
- Ngokwazi kwami ngezidingo zalolucwaningo, ngiyavuma ukuthi imininingwane ezokolekwa ngaso le study ingafakwa kwi system ye computer ifakwa uyena lo ophenyayo.
- Ngiyavuma futh iukuthi umasengingenile kulolucwaningo ngingayeka noma inini. Futhi ngalokho ngiyavuma ukuthi ngiyazi ukuthi ngeke ngixwaywe.
- Sengilitholile ithuba, ngeneliseka ngabuza nemibuzo eyanele. Sengiyavuma ukuthi ngazisiwe ngokwanele ,nangokugculisayo ukuthi ngidlaleindima kulolucwaningo.
- Ngiyaqonda ukuthi umakutholakala imiphumela emisha kule study ephathelene nami, ngizokwaziswa ngayo.

Igama:……

I signatur: ……..
UsukuNeskhathi:……

Mina u, Jeff Puttergill, ngiyavuma futhi ngiyaqinisekisa ukuthi umdlalindima usenolwazi olugcwele ngendlela esizosebenza ngayo kulolucwaningo.

Igamalakhe owenza ucwaningo:……..

Signature:…….Date……

Ufakazi: ……

Signature…….....Date……

yafakazi

Signature…….....Date……

APPENDIX E

CHIROPRACTIC DAY CLINIC CASE HISTORY

Patient: _____ Date: _____

File #: _____ Age: _____

Sex: _____ Occupation: _____

Student: _____ Signature _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature:

Case History:

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:

Reason for Conditional:

Signature: Date:

Conditions met in Visit No: Signed into PTT: Date:

Case Summary signed off: Date:

Student's Case History:

1. **Source of History:**

2. **Chief Complaint: (patient's own words):**

3. **Present Illness:**

	Complaint 1(principle complaint)	**Complaint 2 (additional or secondary complaint)**
Location Onset : Initial: Recent: Cause: Duration Frequency Pain (Character) Progression Aggravating Factors Relieving Factors Associated S & S Previous Occurrences Past Treatment Outcome:		

4. **Other Complaints:**

5. **Past Medical History:**

General Health Status

Childhood Illnesses

Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery

Hospitalizations

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication
Analgesics/week:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

APPENDIX F

PHYSICAL EXAMINATION: SENIOR

Patient Name: _____			**File no:** _____	**Date:** _____
Student:		**Signature:**		
VITALS:				
Pulse rate:			Respiratory rate:	
Blood pressure:	R	L	Medication if hypertensive:	
Temperature:			Height:	
Weight:	Any recent change?	Y / N	If Yes: How much gain/loss	Over what period

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		

SYSTEM SPECIFIC EXAMINATION:
CARDIOVASCULAR EXAMINATION
RESPIRATORY EXAMINATION
ABDOMINAL EXAMINATION
NEUROLOGICAL EXAMINATION
COMMENTS
Clinician: **Signature:**

FOOT AND ANKLE
REGIONAL EXAMINATION
APPENDIX G

Patient:_____ File no:_____ Date:_____

Student:_____ Signature:_____

Clinician:_____ Signature:_____

Observation
Gait analysis (antalgic limp, toe off, arch, foot alignment, tibial alignment).

_____

_____

Swelling_____
Heloma dura / molle_____
Skin_____
Nails_____
Shoes_____
Contours (Achilles tendon, bony prominences)_____

Active movements

Weight bearing:	**R**	**L**	***Non weight bearing:***	**R**	**L**
Plantar flexion			50°		
Dorsiflexion			20°		
Supination					
Pronation					
Toe dorsiflexion			40°(mtp)		
Toe plantar flexion			40° (mtp)		
		Big toe dorsiflexion (mtp) (65-70°)			
		Big toe plantar flexion (mtp) 45°			
		Toe abduction + adduction			
		5° first ray dorsiflexion			
		5° first ray plantar flexion			

Passive movement motion palpation (Passive ROM quality, ROM overpressure, joint play)	**R**	**L**		**R**	**L**
Ankle joint: *Plantarflexion*			Subtalar joint: *Varus*		
Dorsiflexion			*Valgus*		
Talocrural: *Long axis distraction*			Midtarsal:*A-P glide*		
First ray: *Dorsiflexion*			*P-A glide*		
Plantarflexion			*rotation*		
Circumduction of forefoot on fixed rearfoot			Intermetatarsal glide		
			Tarso metatarsal joints: *A-P*		
Interphalangeal joints: *L-A dist*			Metatarsophalangeal dorsiflexion (with associated plantar flexion of each toe		
A-P glide					
lat and med glide					
rotation					

Resisted Isometric movements	**R**	**L**		**R**	**L**
Knee flexion			Pronation (eversion)		
Plantar flexion			Toe extension (dorsiflexion)		
Dorsiflexion			Toe flexion (plantar flexion)		
Supination (inversion)					

Neurological	**R**	**L**
Dermatomes		
Myotomes		
Reflexes		
Balance/proprioception		

Special tests	**R**	**L**
Anterior drawer test		
Talar tilt		
Thompson test		
Homan sign		
Tinel's sign		
Test for rigid/flexible flatfoot		
Kleiger test (med. deltoid)		

Alignment	**R**	**L**
Heel to ground		
Feiss line		
Tibial torsion		
Heel to leg (subtalar neutral)		
Subtalar neutral position:		
Forefoot to heel (subtalar & Midtarsal neutral)		
First ray alignment		
Digital deformities		
Digital deformity flexible		

Palpation	**R**	**L**
Anteriorly		
Medial malleoli		
Med tarsal bones, tibial (post) artery		
Lat. malleolus, calcaneus, sinus tarsi, and cuboid bones		
Inferior tib/fib joint, tibia, mm of leg		
Anterior tibia, neck of talus, dorsalis pedis artery		
Posteriorly		
Calcaneus, Achilles tendon, Musculotendinous junction		
Plantarily		
Plantar muscles and fascia		
Sesamoids		

APPENDIX H

KNEE REGIONAL EXAMINATION

Patient:_____ File:_____ Date:_____

Student:_____ Signature:_____

Clinician:_____ Signature:_____

OBSERVATION (Standing, Seated and during gait cycle).

A. Anterior view

Genu Varum:_____
Genu Valgum:_____
Patellar position:_____
Tibial Torsion:_____
Skin:_____
Swelling:_____

B. Lateral view

Genu Recurvatum:_____
Patella Alta:_____
Patella Baja:_____
Skin:_____

C. Posterior view

Swelling:_____
Skin:_____

D. General

Movement symmetry:_____
Structures symmetry:_____

E. ACTIVE MOVEMENTS

Flexion (0 – 135º)_____
Extension (0 – 15º)_____
Medial Rotation (20 – 30º)_____
Lateral rotation (30 – 40º)_____

F. PASSIVE MOVEMENTS

Tissue approx_____
Bone-bone_____
Tissue stretch_____
Tissue stretch_____
Patellar movement_____

RESISTED ISOMETRIC MOVEMENTS

Knee: Flexion:_____
Extension:_____
Internal rotation:_____
External rotation:_____

Ankle: Plantarflexion_____
Dorsiflexion_____

LIGAMENTOUS ASSESSMENT

One-Plane Medial Instability

Valgus stress (abduction)
Extended_____
Resting Position_____

One-Plane Lateral Instability

Varus stress (adduction)
Extended_____
Resting Position_____

One-Plane Anterior Instability

Lachman Test (0-30º)_____
Anterior Drawer Sign _____

One-Plane Posterior Instability

Posterior "sag" Sign_____
Posterior Drawer Test_____

Anterolateral Rotatory Instability

Slocum Test_____
Macintosh Test_____

Anteromedial Rotatory Instability

Slocum Test_____

Posterolateral Rotatory Instability

Jacob _____
Hughston's Drawer Sign_____
Reverse pivot shift test _____

Posteromedial Rotatory Instability

Hughston's Drawer Sign_____

TESTS FOR MENISCUS INJURY

McMurray_____ Anderson med-lat grind_____ "Bounc

PLICA TESTS

Mediopatellar Plica _____ Hughston's Plica_____ Plica "S

TESTS FOR SWELLING

Brush/Stroke Test _____ Patellar Tap Test_____

TESTS FOR PATELLA FEMORAL PAIN SYNDROME

Clarke's Sign _____ Passive patella tilt test_____ Waldr

OTHER TESTS

Wilson's_____ Quadriceps Contusion Test_____ Fairbar

JOINT PLAY

Movement of the tibia on the femur P to A:_____ A to P:_____
Translation of the tibia on the femur M to L:_____ L to M:_____
Long axis distraction of the tibiofemoral joint _____
Inf, sup, lat, + med glide of the patella _____
Movement of the inf. tibiofibular joint A to P:_____P to A:_____ Mo

PALPATN

Tenderness_____ Swelling_____ Joint li
Leg:_____ Poplite

REFLEXES AND CUTANEOUS DISTRIBUTION

	R	L
Patellar Reflex (L3,L4)		
Medial Hamstring Reflex (L5,S1)		

DERMATOMES

	R	L		R	L
L2			S1		
L3			S2		
L4			S3		
L5					

Appendix I DURBAN UNIVERSITY OF TECHNOLOGY

Patient Name: ***File #:*** ***Page:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: *Numerical Pain Rating Scale (Patient)* *Intern Rating* ***A:***
Least ***0 1 2 3 4 5 6 7 8 9 10*** *Worst*

0: ***P:***

E:

Special attention to: ***Next appointment:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: *Numerical Pain Rating Scale (Patient)* *Intern Rating* ***A:***
Least ***0 1 2 3 4 5 6 7 8 9 10*** *Worst*

O: ***P:***

E:

Special attention to: ***Next appointment:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature***

S: *Numerical Pain Rating Scale (Patient)* *Intern Rating* ***A:***
Least ***0 1 2 3 4 5 6 7 8 9 10*** *Worst*

O: ***P:***

E:

Special attention to: ***Next appointment:***

Appendix J

Participant Name				
Gender	Male		Female	
Height (m)				
Weight (kg)				

PRE-INTERVENTION				
Navicular Position	**L**		**R**	
Passive non weight bearing	**L**		**R**	
Active non weight bearing	**L**		**R**	
Partial weight bearing	**L**		**R**	
Weight bearing at step length	**L**		**R**	

POST-INTERVENTION				
Navicular Position	**L**		**R**	
Passive non weight bearing	**L**		**R**	
Active non weight bearing	**L**		**R**	
Partial weight bearing	**L**		**R**	
Weight bearing at step length	**L**		**R**	

Assistant examiner: _____

Signature:_____ Date:_____

AppendixK

ASSISTANT EXAMINER TRAINING AND AGREEMENT

It is noted that the markings will be made by the principle researcher during the physical examination in order to remove variability between the assistant examiners. Also all tests will be performed bilaterally, before and after the myofascial interventions.

Navicular Position Test

Participant positioning: The participant is required to stand heel to toe, with each foot on a level raised platform and feet placed comfortably apart.

Measurement: The navicular position is measured by placing the central point of the goniometer onto the mark made at the navicular tuberosity. One arm is placed over the mark made on the first metatarsal head and the second arm is placed over the mark made on the achillies tendon. The goniometer is then taken off and the findings are recorded into the data sheet (Appendix J) by the assistant examiner. A positive degree is indicative of supination as the navicular moves above an imaginary line made between the first metatarsal head and the point on the achillies tendon. Pronation is where the navicular moves below this point and indicated by a negative degree.

Great Toe Range of Motion

All goniometric measurements of first metatarsal extension are relative to the first metatarsal and the hallux. The one arm of the goniometer will be placed on a line drawn on the mid point of the firtst metatarsal and head. The second arm will be taken to the most medial pont on the distal interphalangeal joint of the great toe The assistant examiner will record the measures onto the data sheet provided (Appendix J).

Passive Non Weight Bearing: requires the participant to sit lengthwise on an examination table with the relevant foot over the edge of the table. The participant's foot is then placed into sublatar neutral by the principal researcher (Achieved through dorsiflexion of the fourth and fifth metatarsals). The researcher then dorsiflexes the hallux maximally while the assistant examiner records the great toe range of motion.

Measurement: is done by placing the one arm of the goniometer along the line made on the first metatarsal, with the midpoint of the goniometer on the mark made on the first metatarsal joint. The assistant examiner will then move the second arm to the mark made on the distal interphalangeal joint and record the data.

Active Non Weight Bearing: The participant will be placed in the same position as above. This measurement requires the participant to hold his foot in subtalar neutral after it

has been established by the researcher. The researcher then extends the hallux until the first metatarsal head in believed to move into a plantar direction.

Measurement: The assistant examiner will then place the axis of the goniometer along the dorsum of the foot, at the midpoint of the first metatarsal joint. The arms of the goniometer then measure extension relative to the dorsum of the first metatarsal and hallux.

Partial Weight Bearing: the participant sits at the edge of the examination table with their knees at 90 degrees. The foot examined is then positioned so that the great toe is perpendicular to the heel of the contralateral foot (heel to toe). The participant is then asked to maximally raise the heel to a point where the entire hallux is still in contact with the floor.

Measurement: The assistant examiner will then record great toe extension using the same markings as for the passive non weight bearing test.

Weight Bearing at Step Length: The participant is asked to stand on two level platforms at step length, with the relevant foot posterior. As for partial weight bearing the participant is asked to raise the heel maximally to a point where the entire hallux remains in contact with the floor. The participant is allowed to stabilise themselves using a crutch.

Measurement: Great toe extension is then recorded by the assistant examiner on the same points as for passive non weight bearing

I, _____, am in agreement with the set procedure outlined in the clinic protocol, with regards to the examination and recording of the above mentioned tests. I will be blinded as to which intervention each participant receives and will carry out the examinations to the best of my abilities.

As per our verbal discussion, I hereby agree in writing that I am competent in measuring the mentioned tests and am willing to participate as an assistant examiner in your research project.

Assistant examiner signature**:* _____ ***Date: _____

Jeff Puttergill: _____ ***Date:*** _____

(Principal researcher)

Dr. HM Kretzmann: _____ ***Date:*** _____

(supervisor)

Appendix L

PERMISSION TO UNDERTAKE RESEARCH AT THE DUT CHIROPRACTIC DAY CLINIC

Dear Dr C Korporaal

With the commencement of this study, it is required that permission be gained for use of the facilities of the DUT Chiropractic Day Clinic for research purposes.

A clinic room is required for 60 participants for which case history, physical and regionals will be completed. Participants will be included into the study after meeting inclusion criteria after which goniometric measures and force plate measures will be taken. These measures will be taken before and after the clinical intervention.

I hereby ask permission to undertake research and make use of facilities at the DUT Chiropractic Day Clinic.

Yours thankfully

Jeff Puttergill (Researcher)

Permission Granted: YES NO (Please circle)

Sign: _____ Date: _____

Dr C Korporaal

Sign: _____ Date: _____

Dr HM Kretzmann (Supervisor)

Appendix M

PERMISSION TO MAKE USE OF THE BIOSWAY PORTABLE BALANCE SYSTEM

Dear Prof. L Puckree

With the commencement of my study, it is required that permission be gained for the use or the Biosway Portable Balance System. Measures of postural stability and limits of stability will be measured according to the Biosway Portable Balance System Operation Manual (Biosway Operation Manual, N.D.) I hereby ask permission to make use of this measurement tool inside the DUT Chiropractic Day Clinic.

Yours thankfully

Jeff Puttergill (Researcher)

Permission Granted: **YES NO (Please Circle)**

Sign: _____ Date: _____

Prof. L Puckree (Head of Faculty)

Sign: _____ Date: _____

Dr HM Ktretzmann (Supervisor)

Appendix N

SAMPLE ALLOCATOR AGREEMENT AT THE DUT CHIROPRACTIC DAY CLINIC:

As per our verbal discussion, I hereby agree in writing that I will willingly participate as a sample allocator in your research project. I am in agreement to the set procedure proposed in the PG4a document. I am also aware of what is required of me as a sample allocator.

I trust you find the above in order.

Regards

Linda Twiggs

Sign: _____ Date: _____

Jeff Puttergill (Principle researcher): _____ Date: _____

Dr HM Kretzmann (Supervisor): _____ Date: _____

Random Allocation Sheet - Appendix O

Group 1 - Placebo Ultrasound		Group 2 - Ischaemic Compression		Group 3 - Myofascial Release	
Name/File Number		Name/File Number		Name/File Number	
	1		16		31
	2		17		32
	3		18		33
	4		19		34
	5		20		35
	6		21		36
	7		22		37
	8		23		38
	9		24		39
	10		25		40
	11		26		41
	12		27		42
	13		28		43
	14		29		44
	15		30		45

Allocator (Mrs. L Twiggs) _____

Appendix P – Raw datasheet

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Placebo Ultrasound Weight (59.7kg)	69	68	67	54	45	50	42	88	68	44	71	54	53	78	44
Placebo Ultrasound Height (1.64m)	1.72	1.63	1.75	1.57	1.59	1.56	1.62	1.78	1.51	1.56	1.71	1.61	1.59	1.88	1.58
Average Body Mass Index (21.9)	23.3	25.6	21.9	21.9	17.8	20.5	16.0	27.8	29.8	18.1	24.3	20.8	21.0	22.1	17.6
Ischaemic Compression Weight (64kg)	47	82	73	70	63	44	57	82	75	68	46	69	60	60	64
Ischaemic Compression Height (1.67m)	1.47	1.72	1.86	1.70	1.86	1.56	1.72	1.65	1.50	1.80	1.52	1.72	1.67	1.60	1.62
Average Body Mass Index (23.2)	21.8	27.7	21.1	24.2	18.2	18.1	19.3	30.1	33.3	21.0	19.9	23.3	21.5	23.4	24.4
Myofascial Release Weight (72kg)	55	71	90	76	61	65	61	62	83	102	91	82	59	72	54
Myofascial Release Height (1.64m)	1.49	1.80	1.73	1.64	1.64	1.65	1.70	1.52	1.76	1.64	1.61	1.65	1.58	1.59	1.61
Average Body Mass Index (26.8)	24.8	21.9	30.1	28.3	22.7	23.9	21.1	26.8	26.8	37.9	34.9	30.1	23.6	28.5	20.8

Placebo Ultrasound: Subject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Left															
Navicular Position (pre)	-20	-10	-15	-2	-9	-8	-11	-10	-13	-11	-14	-19	-12	-3	-9
(post)	-20	-10	-11	-2	-10	-1	-22	-12	-14	-13	-12	-22	-10	-1	-6
Passive NWB GTE (pre)	49	33	36	49	45	50	34	40	28	60	36	29	29	26	40
(post)	45	30	30	40	43	45	31	38	23	47	40	32	25	31	45
Active NWB GTE (pre)	18	31	35	34	45	28	23	32	30	26	27	31	35	16	35
(post)	30	30	29	23	34	20	22	28	26	32	24	37	20	21	38
Partial WB GTE (pre)	70	37	45	64	66	50	42	50	42	72	38	60	63	51	46
(post)	73	45	37	55	64	60	37	52	35	66	35	58	44	46	51
WB GTE at Step Length (pre)	82	60	50	70	67	55	46	56	44	81	27	59	50	67	68
(post)	79	46	26	75	70	49	39	60	44	76	56	42	26	47	60
Right															
Navicular Position (pre)	-13	-12	-19	-12	-5	-3	-25	-10	-20	-7	-16	-13	-9	-8	-8
(post)	-15	-10	-15	-10	-4	-9	-22	-10	-20	0	-8	-18	-8	-8	-7
Passive NWB GTE (pre)	40	39	25	37	63	47	39	37	22	46	48	40	36	36	56
(post)	36	39	27	35	62	38	33	47	30	48	46	35	42	24	53
Active NWB GTE (pre)	22	29	30	22	50	28	27	31	13	25	25	37	34	20	51
(post)	18	33	29	40	52	17	27	48	21	36	32	35	40	21	56
Partial WB GTE (pre)	58	35	45	55	76	60	35	59	42	69	35	64	66	56	62
(post)	63	46	30	50	78	55	36	58	41	71	33	56	58	55	62
WB GTE at Step Length (pre)	53	52	36	68	77	59	38	59	19	78	47	67	53	61	39
(post)	45	44	29	72	57	55	38	63	45	73	52	60	70	61	70
Combined Navicular	-2	2	8	2	0	1	-8	-2	-1	5	10	-8	3	2	4
Combined Passive NWB GTE	-8	-3	-4	-11	-3	-14	-9	8	3	-11	2	-2	2	-7	2
Combined Active NWB GTE	8	3	-7	7	-9	-19	-1	13	4	17	4	4	-9	6	8
Combined Partial WB GTE	8	19	-23	-14	0	5	-4	1	-8	-4	-5	-10	-27	-6	5
Combined WB GTE at Step	-11	-22	-31	9	-17	-10	-7	8	26	-10	34	-24	-7	-20	23
PSO Overall Stability (pre)	0.2	0.4	0.5	0.4	0.3	0.1	0.2	0.4	0.1	0.2	0.3	0.2	0.1	0.2	0.1
(post)	0.3	0.6	0.5	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.1
PSO AP Stability (pre)	0.2	0.4	0.4	0.3	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1
(post)	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
PSO ML Stability (pre)	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0	0.1	0.1	0	0.1	0.1	0
(post)	0.1	0.3	0.2	0	0	0.1	0	0	0.1	0.1	0.1	0	0	0.1	0

PSO Overall Sway (pre)	0.24	0.36	0.43	0.64	0.26	0.13	0.26	0.24	0.12	0.38	0.26	0.17	0.14	0.21	0.19
(post)	0.21	0.45	0.3	0.23	0.21	0.17	0.22	0.14	0.15	0.18	0.21	0.14	0.19	0.22	0.14
PSO AP Sway (pre)	0.23	0.38	0.44	0.65	0.27	0.13	0.25	0.24	0.11	0.37	0.26	0.18	0.14	0.2	0.18
(post)	0.21	0.45	0.31	0.22	0.22	0.17	0.21	0.14	0.13	0.18	0.17	0.14	0.18	0.21	0.14
PSO ML Sway (pre)	0.12	0.16	0.18	0.13	0.08	0.09	0.1	0.16	0.06	0.11	0.15	0.08	0.08	0.12	0.05
(post)	0.11	0.27	0.18	0.1	0.06	0.09	0.9	0.06	0.1	0.08	0.17	0.05	0.09	0.1	0.05
PSC Overall Stability (pre)	5.3	5.7	1.3	6.3	7.4	2.3	1.9	5.8	2.6	7.9	5.6	5.8	4.7	3.9	3.4
(post)	6.4	6.9	3	6.4	6.7	7.3	2.9	6.8	5.6	7.5	7.8	6.9	3.7	2.8	3.5
PSC AP Stability (pre)	5.2	5.4	1.1	6.1	7.4	2.3	1.6	5.7	2.5	7.8	5.6	5.7	4.5	3.8	3.3
(post)	6.4	6.5	2.9	6.3	6.6	7.3	2.5	6.8	5.5	7.5	7.8	6.9	3.1	2.5	3.4
PSC ML Stability (pre)	0.3	1.6	0.4	1.4	0.3	0.1	0.9	1	0.7	0.5	0.3	1	1.2	0.7	0.3
(post)	0.2	2	0.7	0.8	0.6	0.1	1.5	0.2	1	0.5	0.7	0.3	1.7	1.2	0.7
PSC Overall Sway (pre)	1.13	1.27	0.72	0.68	0.58	0.35	0.46	0.5	0.77	0.45	1.47	1.13	0.66	0.71	0.39
(post)	0.61	1.4	1.64	1.7	0.94	0.85	0.59	0.48	0.5	0.48	1.07	0.91	1.59	0.5	0.4
PSC AP Sway (pre)	1.13	1.26	0.78	0.76	0.58	0.35	0.62	0.49	0.75	0.45	1.48	1.18	0.63	0.71	0.39
(post)	0.61	1.53	1.69	1.68	0.95	0.85	0.63	0.48	0.47	0.48	1.08	0.9	2.04	0.57	0.41
PSC ML Sway (pre)	0.24	1.08	0.3	0.66	0.25	0.11	0.24	0.32	0.27	0.25	0.28	0.17	0.31	0.23	0.17
(post)	0.18	0.86	0.5	0.72	0.2	0.1	0.2	0.13	0.34	0.22	0.44	0.34	0.15	0.27	0.26
Limits of Stability Overall (pre)	63	71	55	48	44	70	56	64	74	39	67	74	56	59	66
(post)	85	72	62	59	49	80	72	86	73	50	80	72	65	65	72
LS Front (pre)	68	80	87	38	72	71	62	69	88	30	85	64	69	67	88
(post)	85	67	80	51	40	87	92	87	86	46	88	72	75	68	98
LS Back (pre)	80	76	50	34	55	52	54	97	78	46	85	76	84	71	100
(post)	98	83	76	98	81	96	79	91	93	67	74	52	100	40	71
LS Right (pre)	72	84	57	70	39	87	75	74	88	46	89	84	75	91	63
(post)	89	89	78	81	68	81	65	96	81	80	88	82	81	86	74
LS Left (pre)	76	78	50	65	43	80	65	98	85	74	79	91	81	54	62
(post)	90	85	64	81	68	95	81	99	69	36	85	85	76	89	73
LS Front Right (pre)	60	74	63	45	38	67	40	62	79	55	65	79	54	73	70
(post)	82	84	59	54	39	75	61	82	88	48	69	71	78	63	83
LS Front Left (pre)	68	76	63	47	48	89	65	56	59	47	50	97	42	61	64
(post)	87	78	79	72	65	76	75	79	85	43	91	72	67	72	71
LS Back Right (pre)	63	64	53	68	65	87	67	50	84	66	74	88	51	52	70
(post)	80	64	64	54	65	80	69	81	82	68	76	74	61	48	81
LS Back Left (pre)	74	81	56	78	64	88	57	85	82	60	63	74	61	55	58
(post)	84	76	50	69	60	85	79	98	64	77	86	83	87	78	65

Ischaemic Compression	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Left															
Navicular Position (pre)	-20	-20	-3	-5	-10	-17	-4	-14	-10	-15	-8	-15	-8	-20	-4
(post)	-19	-22	-8	-9	-6	-21	-3	-15	-30	-10	-7	-16	-8	-9	-6
Passive NWB GTE (pre)	14	31	43	60	58	62	57	33	25	51	33	35	37	36	49
(post)	5	33	40	65	60	70	62	29	52	61	43	34	31	44	50
Active NWB GTE (pre)	12	24	43	55	48	61	45	18	13	35	35	31	30	28	45
(post)	6	20	40	64	46	61	48	19	33	41	34	27	32	22	45
Partial WB GTE (pre)	38	40	60	68	62	64	73	28	40	50	68	59	62	42	58

(post)	39	33	60	60	77	65	77	44	54	39	68	53	49	53	57
WB GTE at Step Length (pre)	55	39	59	68	84	40	86	49	58	47	77	46	68	41	61
(post)	54	42	63	71	75	58	71	53	55	47	78	38	62	58	61
Right															
Navicular Position (pre)	-16	-15	-9	-6	-4	-7	-12	-20	-16	-10	-9	-11	-10	-7	-14
(post)	-13	-17	-11	-8	-9	-19	-15	-19	-14	-6	-7	-15	-13	-5	-16
Passive NWB GTE (pre)	19	20	46	60	65	22	56	51	50	62	46	35	32	30	27
(post)	12	22	43	63	65	20	47	45	56	69	37	28	33	40	23
Active NWB GTE (pre)	12	10	39	32	51	28	48	30	19	44	24	15	26	43	16
(post)	12	13	43	32	50	45	43	39	25	48	25	20	32	38	21
Partial WB GTE (pre)	42	31	32	50	68	50	71	47	60	42	61	41	49	46	38
(post)	57	35	60	58	82	44	69	59	55	38	65	40	62	46	38
WB GTE at Step Length (pre)	54	30	57	67	90	30	78	55	65	36	73	42	35	57	30
(post)	45	38	68	71	88	32	76	57	55	35	81	57	49	56	66
Combined Navicular	4	-4	-7	-6	-1	-16	-2	0	-18	9	3	-5	-3	13	-4
Combined Passive NWB GTE	-16	4	-6	8	2	6	-4	-10	33	17	1	-8	-5	18	-3
Combined Active NWB GTE	-6	-1	1	9	-3	17	-2	10	26	10	0	1	8	-11	5
Combined Partial WB GTE	16	-3	28	0	29	-5	2	28	9	-15	4	-7	0	11	-1
Combined WB GTE at Step	-10	11	15	7	-11	20	-17	6	-13	-1	9	7	8	16	36
PSO Overall Stability (pre)	0.2	0.4	0.3	0.2	0.4	0.5	0.4	0.2	0.2	0.3	0.2	2	0.3	0.2	0.2
(post)	0.1	0.2	0.2	0	0.4	0.4	0.5	0.2	0.3	0.3	0.2	0.2	0.4	0.2	0.2
PSO AP Stability (pre)	0.2	0.3	0.3	0.1	0.3	0.3	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.1
(post)	0.1	0.2	0.1	0	0.2	0.3	0.5	0.2	0.2	0.2	0.1	0.1	0.3	0.2	0.2
PSO ML Stability (pre)	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0	0.1	0.2	0	0.1
(post)	0	0	0.2	0	0.2	0.1	0.2	0	0.1	0.2	0.1	0.1	0.2	0.1	0
PSO Overall Sway (pre)	0.22	0.31	0.3	0.15	0.3	0.39	0.4	0.26	0.25	0.25	0.19	0.18	0.21	0.24	0.18
(post)	0.18	0.21	0.21	0.09	0.32	0.28	0.43	0.23	0.27	0.4	0.2	0.23	0.25	0.27	0.24
PSO AP Sway (pre)	0.2	0.3	0.31	0.14	0.29	0.43	0.4	0.24	0.18	0.23	0.19	0.17	0.19	0.23	0.16
(post)	0.17	0.18	0.13	0.09	0.26	0.27	0.43	0.23	0.26	0.39	0.18	0.2	0.26	0.24	0.23
PSO ML Sway (pre)	0.13	0.16	0.1	0.13	0.2	0.14	0.15	0.14	0.22	0.15	0.07	0.1	0.17	0.07	0.14
(post)	0.05	0.13	0.19	0.03	0.27	0.18	0.19	0.07	0.14	0.18	0.12	0.14	0.15	0.17	0.08
PSC Overall Stability (pre)	7.6	2.9	8	0.5	6.6	2.7	5.1	6.3	3	6.1	4.4	2.7	5.9	3.6	2.1
(post)	2.9	1.2	5.4	0.6	3.6	1.9	6.1	6.3	3.5	2.5	4.6	3.6	5	2.8	0.7
PSC AP Stability (pre)	7.5	2.3	8	0.3	6.5	2.2	5	6.3	2.5	6	4.4	2.5	5.9	3.6	1.8
(post)	2.9	1.1	5.3	0.6	2.6	1.7	6	6.3	2.9	2.4	4.6	3.5	5	2.7	0.6
PSC ML Stability (pre)	1	1.8	0.3	0.3	0.6	1.1	1	0.3	1	0.3	0.6	0.8	0.2	0.4	0.9
(post)	0.5	0.3	0.5	0.2	2	0.5	0.8	0.3	1.4	0.4	0.2	0.8	0.4	0.6	0.3
PSC Overall Sway (pre)	0.7	0.64	0.63	0.4	0.5	1.77	1.62	0.72	2.12	0.99	0.45	1.03	1.5	0.76	0.75
(post)	0.55	0.67	0.38	0.28	0.87	1.26	0.81	0.66	1.65	1.26	0.49	1.52	0.91	0.91	0.36
PSC AP Sway (pre)	0.72	0.74	0.63	0.29	0.51	2.03	1.59	0.72	2.39	0.98	0.46	0.98	1.5	0.79	0.84
(post)	0.55	0.71	0.38	0.32	1.66	1.36	0.8	0.66	1.82	1.3	0.49	1.51	0.91	0.95	0.4
PSC ML Sway (pre)	0.31	0.4	0.21	0.37	0.29	0.48	0.44	0.18	0.76	0.3	0.33	0.46	0.23	0.32	0.31
(post)	0.18	0.21	0.29	0.11	0.48	0.47	0.24	0.24	1.07	0.32	0.21	0.49	0.28	0.48	0.12
Limits of Stability Overall (pre)	51	58	70	60	63	30	55	59	66	48	73	67	66	61	71
(post)	73	82	73	51	45	44	59	66	63	70	70	73	76	68	72
LS Front (pre)	66	63	50	49	41	18	62	62	78	44	76	91	79	54	87
(post)	96	89	71	29	34	17	76	66	63	76	65	71	77	54	74

LS Back (pre)	84	84	100	71	85	63	61	57	53	41	79	77	83	90	68
(post)	72	81	72	64	60	88	56	71	56	86	68	61	99	85	73
LS Right (pre)	45	58	76	83	83	62	72	56	76	92	70	71	68	66	76
(post)	78	89	89	46	54	84	66	67	62	90	84	77	93	61	92
LS Left (pre)	45	74	95	54	78	52	58	55	79	72	79	63	76	73	79
(post)	85	80	94	50	91	66	79	67	64	66	66	84	82	77	66
LS Front Right (pre)	55	65	77	66	58	26	85	75	81	73	77	70	87	67	72
(post)	76	92	84	76	50	44	64	64	65	78	79	85	83	78	69
LS Front Left (pre)	45	53	72	60	79	46	49	69	49	40	81	69	73	50	61
(post)	90	73	80	70	76	85	58	74	79	72	68	76	75	81	64
LS Back Right (pre)	51	74	71	81	64	61	50	60	69	33	75	60	37	65	83
(post)	82	84	61	66	63	63	58	78	58	69	85	75	78	77	85
LS Back Left (pre)	77	45	85	61	79	59	53	72	64	65	61	75	88	56	89
(post)	61	89	88	78	73	83	62	76	84	71	76	74	83	87	94

Myofascial Release	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Left															
Navicular Position (pre)	-8	-7	-14	-12	-2	-10	-8	-22	-8	-11	-8	-7	-5	-19	-21
(post)	-4	-7	-11	-9	-8	-16	-10	-22	-8	-3	-8	-4	-6	-18	-15
Passive NWB GTE (pre)	52	46	22	31	55	37	56	28	45	33	25	42	55	24	39
(post)	43	40	18	52	50	33	48	32	40	30	30	35	52	23	39
Active NWB GTE (pre)	35	33	12	52	45	30	50	25	27	20	15	24	45	15	37
(post)	32	37	9	44	45	35	47	24	27	26	25	35	47	16	22
Partial WB GTE (pre)	30	34	0	16	55	40	30	45	47	58	39	40	51	25	56
(post)	36	45	8	44	60	34	62	46	48	56	50	35	51	7	70
WB GTE at Step Length (pre)	73	29	5	50	63	10	40	54	55	65	48	33	33	18	67
(post)	63	37	11	47	45	9	34	62	60	66	51	35	33	46	65
Right															
Navicular Position (pre)	-11	-13	-15	-18	-10	-8	-5	-21	-4	-11	-10	-14	-11	-17	-15
(post)	-7	-15	-9	-20	0	-10	-3	-22	-2	-10	-10	-6	-10	-16	-13
Passive NWB GTE (pre)	30	27	40	48	40	44	54	26	44	33	30	30	52	40	42
(post)	36	27	37	50	43	41	55	21	44	34	20	27	43	48	32
Active NWB GTE (pre)	30	25	24	28	30	26	45	15	26	26	30	18	47	36	35
(post)	27	30	24	25	35	30	44	13	33	26	23	21	45	43	27
Partial WB GTE (pre)	20	20	17	20	51	31	40	33	57	38	56	28	55	27	59
(post)	38	17	25	28	47	36	53	23	52	58	55	26	52	26	76
WB GTE at Step Length (pre)	25	30	21	35	57	10	40	52	58	68	50	14	50	33	62
(post)	65	27	34	27	48	12	42	45	56	65	38	14	37	24	55
Combined Navicular	8	-2	9	1	4	-8	0	-1	2	9	0	11	0	2	8
Combined Passive NWB GTE	-3	-6	-7	23	-2	-7	-7	-1	-5	-2	-5	-10	-12	7	-10
Combined Active NWB GTE	-6	9	-3	-11	5	9	-4	-3	7	6	3	14	0	8	-23
Combined Partial WB GTE	24	8	16	36	1	-1	45	-9	-4	18	10	-7	-3	-19	31
Combined WB GTE at Step	30	5	19	-11	-27	1	-4	1	3	-2	-9	2	-13	19	-9
PSO Overall Stability (pre)	0.2	0.5	0.3	0.3	0.1	0.3	0.2	1.7	0.4	0.2	0.4	0.2	0.5	0.3	0.2
(post)	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.5	0.2	0.2
PSO AP Stability (pre)	0.1	0.3	0.2	0.2	0.1	0.2	0.1	1.4	0.3	0.1	0.3	0.1	0.5	0.2	0.1

(post)	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.5	0.2	0.1
PSO ML Stability (pre)	0.1	0.2	0.1	0.1	0	0.2	0.1	0.8	0.2	0.2	0.2	0	0.1	0.1	0.1
(post)	0.1	0.1	0.1	0	0.1	0.2	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1
PSO Overall Sway (pre)	0.28	0.48	0.24	0.25	0.1	0.22	0.18	0.43	0.53	0.22	0.25	0.2	0.47	0.3	0.2
(post)	0.3	0.17	0.19	0.21	0.2	0.18	0.2	0.16	0.24	0.2	0.23	0.22	0.41	0.22	0.23
PSO AP Sway (pre)	0.17	0.45	0.24	0.24	0.1	0.2	0.18	0.47	0.5	0.1	0.27	0.2	0.47	0.29	0.19
(post)	0.31	0.16	0.18	0.21	0.2	0.19	0.22	0.14	0.24	0.19	0.23	0.22	0.41	0.23	0.23
PSO ML Sway (pre)	0.07	0.28	0.1	0.14	0.02	0.16	0.08	0.48	0.27	0.22	0.17	0.9	0.17	0.12	0.11
(post)	0.09	0.14	0.12	0.07	0.09	0.13	0.1	0.12	0.09	0.12	0.13	0.08	0.15	0.09	0.12
PSC Overall Stability (pre)	3.4	2.5	0.8	5.4	2.7	6.1	7.6	1.7	3.4	7.2	4	5.7	2.1	4	3.1
(post)	3.7	1.4	1.6	6.4	0.3	6.1	7	1.3	1.5	7	6.1	1.4	0.7	3.9	1.6
PSC AP Stability (pre)	3.1	1.6	0.8	5.4	2.7	6	7.5	1.4	3.4	6.9	3.7	5.7	2.1	3.4	2.9
(post)	3.6	1	1.2	6.3	0.3	6.1	6.9	0.8	1.5	6.6	6	0.9	0.7	3.9	1.6
PSC ML Stability (pre)	1	1.7	0	0.4	0.5	1	0.8	0.8	0.2	2.1	1	0.1	0.2	2	1.2
(post)	0.3	0.7	0.9	0.4	0.1	0.4	0.6	0.9	0.1	2.2	0.8	0.9	0.3	0.4	0.2
PSC Overall Sway (pre)	1.41	0.97	0.52	1.37	0.58	0.68	1.43	0.43	0.94	0.51	1.68	0.62	0.8	0.55	0.51
(post)	0.97	0.44	0.29	1.27	0.29	0.92	1.22	0.41	0.98	0.98	2.22	0.72	0.79	0.7	1.01
PSC AP Sway (pre)	1.74	0.98	0.53	1.4	0.58	0.67	0.8	0.47	0.94	0.56	2.05	0.62	0.85	0.63	0.56
(post)	0.97	0.68	0.36	1.27	0.31	0.91	0.9	0.6	0.98	0.9	2.28	0.85	0.78	0.72	1.01
PSC ML Sway (pre)	0.28	0.8	0.07	0.27	0.08	0.21	0.27	0.48	0.14	0.47	0.48	0.14	0.22	0.48	0.15
(post)	0.18	0.42	0.15	0.17	0.1	0.31	0.34	0.32	0.08	0.63	0.24	0.29	0.29	0.26	0.2
Limits of Stability Overall (pre)	45	65	60	67	57	67	51	79	42	72	54	61	44	48	48
(post)	52	66	60	75	64	78	55	82	62	63	52	77	45	55	74
LS Front (pre)	45	69	45	56	81	58	51	82	74	73	53	50	22	39	93
(post)	30	75	75	75	75	91	65	78	68	60	56	83	36	60	94
LS Back (pre)	51	56	77	89	96	95	70	98	64	94	46	99	92	79	61
(post)	78	69	94	86	81	69	85	99	87	43	33	98	91	93	83
LS Right (pre)	52	74	65	72	75	80	64	96	29	97	68	75	75	76	60
(post)	76	86	70	91	82	96	77	98	97	69	67	78	49	76	89
LS Left (pre)	63	59	71	79	58	70	53	63	63	87	59	79	83	69	65
(post)	76	75	69	75	56	75	64	96	68	71	35	90	80	81	81
LS Front Right (pre)	47	71	67	69	59	65	51	89	56	61	64	70	55	54	52
(post)	72	65	58	63	48	77	67	81	62	63	55	79	39	60	63
LS Front Left (pre)	41	71	66	73	41	65	54	76	46	72	69	65	51	53	54
(post)	57	54	58	76	62	68	65	73	58	52	75	75	35	50	72
LS Back Right (pre)	61	60	80	63	62	75	46	89	39	78	56	63	55	51	40
(post)	57	69	69	75	76	84	66	86	71	82	63	81	71	51	62
LS Back Left (pre)	48	66	66	81	85	76	72	82	36	58	63	53	65	39	39
(post)	57	57	76	79	74	86	70	92	71	88	68	72	71	57	82