THE EFFECT OF THREE TYPES OF STRAPPING ON CHRONIC ANKLE INSTABILITY SYNDROME

By

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I, Harsha Moti, do hereby 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 dissertation to:

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ABSTRACT

BACKGROUND:

Acute ankle sprains and chronic ankle instability syndrome (CAIS) may be managed effectively through conservative management approaches such as strapping. There are two main types of strapping viz. rigid tape which is used to stabilise the joint and limit joint motion and elastic tape which permits joint motion but provides dynamic support. Kinesio™ tape is becoming increasingly popular in the management of various conditions. It is reportedly beneficial in reducing pain, improving circulation, increasing proprioception and correcting muscle function. Due to claimed benefits of Kinesio™ tape, it should, in theory, be beneficial in the management of individuals with CAIS particularly in terms of reducing pain and improving proprioception.

AIM:

To investigate the effect of three types of strapping applied in the method described for the application of Kinesio™ tape in the management of CAIS.

METHODS:

This study consisted of three groups of 15 participants (recruited through convenience sampling) with each group receiving a different tape (i.e. rigid, elastic or Kinesio™ tape), all three groups, however, received the same taping method which was the Kinesio™ tape functional correction application. After obtaining informed consent each participant underwent a case history, physical examination and a foot an ankle orthopaedic examination. Thereafter, baseline measurements of subjective pain rating (NRS-101), pain threshold (analogue algometer), ankle dorsiflexion, plantarflexion and inversion (analogue goniometer) and proprioception (Biodex Biosway portable balance system) were documented. Depending on the group, the particular tape was then applied and a follow up consultation was made for two to three days later where the tape was removed, measurements were reassessed and the tape was reapplied. At the final consultation three to four days later, the tape was removed and final measurements were assessed and documented. Statistical intra- (using Wilcoxon Signed Ranks Test) and inter-group (using the Mann-Whitney U-test) analyses of the data were performed due to a skewed distribution of the variables. Data was analysed using SPSS version 21.0 with the level of significance set at 0.05.

RESULTS:

The mean (± SD) age of the participants was 24.8 (4.7) and there were 23 male participants in total. Intra-group analyses of subjective outcome measurements showed significant increases ($p < 0.05$) in subjective pain rating in all three groups across all consultations. Similarly, intra-group analyses of objective outcome measurements found significant increases ($p < 0.05$) in pain threshold and dorsiflexion range of motion in all three groups across all consultations. Plantarflexion and inversion range of motion also showed significant increases ($p < 0.05$) but these were not consistent across all consultations. Intra-group analyses of the sway index showed no significant improvements ($p > 0.05$) in Groups Two and Three across the three consultations. Only Group One showed significant increases during the eyes open foam surface (EOFoS) ($p = 0.013$) and eyes closed foam surface (ECFoS) ($p = 0.047$) test conditions between Consultations One and Two.

Inter-group analyses of subjective outcome measurements showed no significant increases ($p > 0.05$) in subjective pain rating across each of the three consults in all three groups. Inter-group analyses of objective outcome measurements revealed a significant increase in pain threshold ($p = 0.040$) between Groups Two and Three at Consultation One. There was a significant increase in plantarflexion between Groups One and Three at Consultation Two ($p = 0.021$) and Consultation Three ($p = 0.030$). There were no other significant results amongst the three groups.

CONCLUSION:

The results suggest that pain rating, pain threshold and ankle dorsiflexion would improve if taping is applied in the manner described for Kinesio™ tape irrespective of the type of taping used in the management of CAIS. The taping method did not result in a significant difference in proprioception. Further studies, with larger sample sizes are required to confirm the findings of this study and to determine the role of taping in the management of CAIS.

LIST OF DEFINITIONS

Apprehension: Predicting fear or suspicion (Oxford Concise Medical Dictionary, 2010).

Axis: A line through the midline of the body or through one of the parts of the body or a line along which a body part rotates (Oxford Concise Medical Dictionary, 2010).

Contractile: Having or concerned with the power or property of contracting (Oxford Concise Medical Dictionary, 2010).

Dorsiflexion: Backward flexion of the foot or hand or their digits i.e. bending towards the upper surface (Oxford Concise Medical Dictionary, 2010).

Enthesis: The insertion site where ligaments and tendons attach to bone (Oxford Concise Medical Dictionary, 2010).

Genu varum: Pathological outward curving of the legs at the knee joint (Oxford Concise Medical Dictionary, 2010).

Giving way: Unconstrained occurrence of unwarranted inversion of the foot (Gribble et al., 2013).

Hinge joint: A form of diarthrosis (freely movable joint) that allows angular movement in one plane only, increasing or decreasing the angle between the bones. Examples are the knee joint and the elbow joint (Oxford Concise Medical Dictionary, 2010).

Joint instability: The sensation of the ankle joint feeling unstable during activities of daily living (Gribble et al., 2013).

Laxity: The quality or state of being loose (Oxford Concise Medical Dictionary, 2010).

Non-contractile: Body tissue that does not contract actively (Oxford Concise Medical Dictionary, 2010).

Pes planus: The absence of the medial longitudinal arch of the foot so that the sole of the foot on the medial aspect of the foot is in contact with the ground (Oxford Concise Medical Dictionary, 2010).

Plantarflexion: Movement of the foot in which the foot or toes flex downward toward the sole (Oxford Concise Medical Dictionary, 2010).

Transverse: Perpendicular to the long axis of the body (Oxford Concise Medical Dictionary, 2010).

LIST OF SYMBOLS AND ABBREVIATIONS

°: Degree

™: Trademark

±: Approximately

>: Greater than

<: Less than

≤: Less than or equal to

=: Equal to

%: Percentage

m: Meters

mm: Millimeters

kg: Kilograms

$kg.m^{-2}$: Kilograms per meter squared

n: Sample size

vs.: Versus

Yrs: Years

AAOS: American Association of Orthopedic Surgeons

AMA: American Medical Association

ATFL: Anterior talofibular ligament

BBPBS: Biodex Biosway portable balance system

BESS: Balance Error Scoring System

BMI: Body mass index

CAIS: Chronic ankle instability syndrome

CDC: Chiropractic Day Clinic

CFL: Calcaneofibular ligament

CMAS: Combined mechanism ankle support

COG: Centre of gravity

CTSIB: Clinical test for sensory integration and balance

Dev: Deviation

DUT: Durban University of Technology

ECFiS: Eyes closed firm surface

ECFoS: Eyes closed foam surface

EMG: Electromyography

EOFiS: Eyes open firm surface

EOFoS: Eyes open foam surface

FAAM: Foot and Ankle Ability Measure

FADI: Foot and Ankle Disability Index

FAOS: Foot and Ankle Outcome Score

IREC: Institutional Research Ethics Committee

JPS: Joint position sense

KT: Kinesio™ tape

MCT: Motor control test

m-CTSIB: Modified clinical test for sensory integration and balance

MRI: Magnetic Resonance Imaging

NRS-101: Numerical pain rating scale

NSAIDS: Non-steroidal anti inflammatory drugs

PTFL: Posterior talofibular ligament

RICE: Rest, ice, compression and elevation

ROM: Range of motion

SEBT: Star excursion balance test

SLE: Systemic lupus erythematosus

SPSS: Statistical package for the social sciences

SOT: Sensory organisation test

Std: Standard

VAS: Visual analogue scale

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CHAPTER ONE

INTRODUCTION

1.1. INTRODUCTION TO THE STUDY

Chronic ankle instability syndrome (CAIS) refers to local ankle pain and swelling, instability and an occasional sensation of "giving way" at the affected ankle following an acute lateral ankle sprain (Hiller et al., 2011; Gribble et al., 2013). It has been reported that 20-30% of acute ankle sprains may progress to CAIS (Lee and Lin, 2008; van Rijn et al., 2008). CAIS may occur as a result of a misdiagnosis, mechanical or functional instability arising from acute lateral ankle ligament injuries or inadequate treatment (Hertel, 2002; de Vries et al., 2011). The condition often affects an individual's ability to perform daily activities such as walking, running and prolonged standing (Lee and Lin, 2008; van Rijn et al., 2008).

The severities of ankle sprains are graded according to the integrity of the ligaments. Injuries where the ligaments are mildly stretched or partially torn may be classified as a Grade One or Grade Two ankle sprains while those in which the ligaments are completely disrupted or torn are classified as Grade Three ankle sprains. The evaluation, grading and diagnosis of ankle sprains are usually established with the help of a case history and physical examination along with an orthopaedic examination of the foot and ankle (namely the anterior drawer test). Occasionally, the use of diagnostic imaging such ultrasound and magnetic resonance imaging (MRI) may also be required to make a diagnosis (Kerkhoffs et al., 2012).

The management of ankle sprains and CAIS includes conservative and non-conservative care with Grade One and Grade Two responding to conservative care, while Grade Three may show little to no improvement to the conservative approach and may require non-conservative management such as surgical interventions (Wolfe et al., 2001; Carnes and Vizniak, 2010). Appropriate conservative management of acute ankle sprains may prevent its progression to CAIS (Ajis and Maffulli, 2006); however, this does not apply to all sprains as certain injuries may still require surgical intervention. Conservative management of CAIS includes various treatment modalities e.g. cryotherapy, support or compression modalities (e.g. strapping or bracing) (Carnes and Vizniak, 2010), joint manipulation of the talocrural and subtalar joints and electromodalities (e.g. therapeutic ultrasound) (Pellow and Brantingham, 2001; Zammit and Herrington, 2005). The conservative management of CAIS falls within the chiropractic scope of practice of primary care which may explain why patients may consult a chiropractor for the treatment of CAIS (Pellow and Brantingham, 2001).

Strapping is one of the most commonly used modalities as it stabilises the ankle joint and is helpful in the prevention of further ankle sprains (Wolfe et al., 2001). There are various types of strapping; the most commonly used tapes are rigid and elastic with each having their own unique function. Rigid tape limits movement and provides stability, while elastic tape is more flexible and allows greater freedom of movement of the joint as well as providing necessary support to the involved area (Perrin, 2012).

Kinesio™ tape is a relatively new tape on the market which is thin and pliable and is compared to the first layer of the skin. It is different to rigid and elastic strapping in terms of its function as it reportedly aids lymphatic drainage which reduces oedema and also improves proprioception (Kinesiotaping® Association International, 2011). The manufacturers' of Kinesio™ tape claim that it stimulates mechanoreceptors within the skin, modulates pain with its effects on the skin and superficial fascia, as well as decreases inflammation by reducing the restrictive load placed on the affected area. They have proposed that this is achieved by the use of their own exclusive taping technique, making it a popular new intervention in the treatment of ankle sprains (Kinesiotaping® Association International, 2011; KT Tape, 2011; Hettle et al., 2013). Kinesio™ tape is composed of 100% cotton and elastic fibres and is reportedly safe to use in any phase of treatment and in conjunction with a wide range of modalities (Kinesiotaping® Association International, 2011).

1.2. PROBLEM STATEMENT AND RATIONALE

Research has shown that Kinesio™ tape is effective in the treatment of ligamentous injury by improving balance which is important as impaired proprioception has been shown to be a cause of recurring injury (Fong et al., 2009; Jackson et al., 2016). Currently, there is little evidence to confirm if it is the method of application of the tape or the physical properties of the tape itself which contributes to its effectiveness. This is one of the first studies to independently assess the manufacturers' claim of the efficacy of Kinesio™ tape in the treatment of various soft tissue conditions. Given the growing popularity of Kinesio™ tape and its proposed benefits (Kinesiotaping® Association International, 2011), it would be interesting to determine its relative effectiveness compared to rigid and elastic tape applied in the same manner as Kinesio™ tape to pain, balance deficits and restricted range of motion. Further research into the use of

Kinesio™ tape for CAIS will provide useful information with regards to its role in rehabilitation, thereby permitting affected individuals to return quicker to normal activities (Halseth et al., 2004).

1.3. AIMS AND OBJECTIVES

The aim of this study was:

To investigate the effect of three types of strapping applied in the method described for the application of Kinesio™ tape in the treatment of CAIS.

The objectives of this study were:

Objective One:

To determine the effects of three types of strapping on CAIS in terms of pain threshold, foot range of motion and sway index (i.e. objective findings).

Objective Two:

To determine the effects of three types of strapping on CAIS in terms of pain reduction (i.e. subjective findings).

Objective Three:

To compare the objective and subjective findings in each of the three groups in order to determine the most effective tape for the treatment of CAIS.

1.4. THE HYPOTHESIS

An alternate hypothesis (H_a) was set which stated that:

Kinesio™ tape will be more effective than rigid and elastic tape in terms of subjective and objective outcomes in the treatment of CAIS.

1.5. SCOPE OF THE STUDY

The results of 45 participants with CAIS who met the criteria for inclusion into this study are reported and discussed in this partial dissertation. Following inclusion into the study, participants were randomly allocated into one of the three groups: rigid tape group, elastic tape group and Kinesio™ tape group. Subjective and objective measurements were taken pre- and post-strapping and the results compared. At the first consultation, after obtaining informed consent from the participant, a case history, physical and a foot and ankle orthopaedic examination were conducted. Baseline measurements were assessed and the tape was applied. At the second consultation two to three days later, the tape was removed, measurements were reassessed and the tape was reapplied. At the final consultation three to four days later, the tape was removed and the measurements were taken. Each participant was seen over a period of seven days. Data was statistically analysed using version 21.0 of Statistical Package for the Social Sciences (SPSS) and the level of significance was set at 0.05.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

Chronic ankle instability syndrome results in an individual being unable to perform certain actions with ease such as walking on an uneven surface or participating in high impact sports due to ligamentous damage. This would have occurred during previous episodes of ankle sprains resulting in pain, decreased range of motion and instability of the ankle joint (Doherty et al., 2013; Hung, 2015).

This chapter will briefly describe the relevant osseous anatomy of the ankle joint as well as the muscles and ligaments associated with ankle sprains. It then describes ankle sprains and their progression to CAIS looking at the clinical presentation and pathophysiology of both these conditions. Lastly, the conservative and non-conservative management of ankle sprains and CAIS with emphasis on strapping due to its relevance to the study will be described.

2.2. A SUMMARY OF THE RELEVANT ANATOMY OF THE ANKLE JOINT

2.2.1. OSSEOUS ANATOMY

The ankle joint is a synovial hinge joint made up of three bony structures viz. the tibia, fibula and talus. The tibia is found on the antero-medial surface and the fibula on the postero-lateral surface of the leg. The extension of the tibia and fibula inferiorly form the medial and lateral malleoli found on the medial and lateral surfaces of the ankle. Both the distal ends of the tibia and fibula make up the ankle joint by articulating with the medial and lateral superior surface of the talus, respectively (Moore et al., 2013).

2.2.2. THE JOINT CAPSULE

The key support structures of the ankle joint capsule are the collateral ligaments; these are found on either side of the capsule and provide it with most of its support as a result of the capsule being thin anteriorly and posteriorly. The capsule is covered by a loose synovial membrane under which lies a fibrous layer which extends from the articular surfaces of the tibia and malleoli to the talus. The synovial cavity within the joint capsule may be found to extend as far as the interosseous ligament between the tibia and fibula (Moore et al., 2013).

2.2.3. LIGAMENTS

Ligaments are densely-packed connective tissue bands that attach one bone to another (Hauser and Dolan, 2011). They have three main functions which include dissipating compressive loads placed on a joint allowing it to move through its normal range of motion with ease; viscoelasticity which allows the joint to maintain equilibrium at all times and, lastly, it has a sensory component allowing proprioceptive data to be monitored during joint activity (Rein et al., 2015).

2.2.3.1. Macroscopic features of ligaments

The ligaments of the ankle joint (**Table 2.1**) are found on both the lateral and medial aspects of the ankle which provide it with considerable support. The lateral ligament complex of the ankle is made up of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL) and the posterior talofibular ligaments (PTFL).

The functions of these ligaments are to prevent inversion or excessive internal rotation stress to the ankle joints. The medial ligament complex is made up of the strong deltoid ligament which fans out from the medial malleolus into four adjoining segments, the tibiocalcaneal ligament which is the most weak and superficial division followed by the deeper and stronger tibionavicular ligament, anterior tibiotalar ligament and posterior tibiotalar ligament. The deltoid ligament prevents eversion or excessive external rotation stress to the ankle joint. The deltoid ligament is stronger than those of the lateral ligament complex due to its strong attachments to the medial malleolus, talus, calcaneus and navicular (Moore et al., 2013; Rein et al., 2015).

2.2.3.2. Microscopic features of ligaments

The primary component of ligaments is water which makes up two thirds of its composition while other components such as collagen, proteoglycans, elastin, proteins and glycoproteins contribute the remaining one third. Collagen makes up most of the dry weight of the ligament and its unique cross-linked arrangements of fibres are the reason for its considerable strength. Fibroblasts may be found between the bundles of collagen and are responsible for production and homeostasis of the extracellular matrix which contains proteoglycans. These proteoglycans are responsible for binding water and provides the ligaments with its viscoelasticity, allowing it to expand lengthwise when under stress and return to its normal length when the stress has been dissipated (Hauser and Dolan, 2011).

The epiligament is a cellular layer that overlies the actual ligament which is rich in sensory and proprioceptive nerves which are found abundantly near the enthesis of the ligaments. Their main role is to engage muscle activity to stabilise the affected area when there has been damage to a ligament through a neurological feedback system (Hauser and Dolan, 2011). The primary proprioceptors found in the ligaments are the same proprioceptors found within a joint capsule, with the difference being that they are fewer in number compared to the joint capsule. These proprioceptors include Ruffini corpuscles and Pacinian corpuscles which respond to tension and compression forces, respectively (Watkins, 2009).

Rein et al. (2015) observed no significant differences in the histology of the ATFL, CFL and PTFL; therefore, it remains unclear why the ATFL is injured more frequently in comparison to the CFL and PTFL.

Table 2.1 Structure, location and function of the ligaments of the ankle

Ligament	Structure and Morphology	Location	Function
Anterior talofibular ligament	Flat, weak band Length ± 15-20mm Width ± 6-8mm Thickness ± 2mm	Extends from the lateral malleolus running anteriorly and inferiorly to attach to the neck of the talus.	Acts primarily when the ankle is in the plantar flexed position to resist inversion.
Calcaneo-fibular ligament	Round cord Length ± 20-30mm Width ± 4-8mm Thickness ± 3-5mm	Extends from the tip of the lateral malleolus running posteriorly and inferiorly to attach to the lateral surface of the calcaneus.	Acts to resist inversion of the ankle joint during ankle range of motion.
Deltoid ligament	Large, strong, fan-like ligament Length ± 10-	Extends from the medial malleolus to the navicular, calcaneus and talus.	Acts primarily to stabilise the joint during eversion and external rotation.

	45mm Width ± 5-16mm Thickness ± 2-10mm		
Posterior talofibular ligament	Thick, strong band Length ± 30mm Width ± 5mm Thickness ± 5-8mm	Extends from the malleolar fossa running horizontally, medially and posteriorly to attach to the lateral tubercle of the talus.	Acts primarily to prevent rotatory instability within the transverse plane of the ankle.

Data summarised from Nyska and Mann (2002); van den Bekerom et al. (2008); Moore et al. (2013)
± = approximately

2.2.4. MUSCLES OF THE LEG AND FOOT

Muscles are contractile tissues found within the body which produce force and initiate motion (Vizniak, 2012). The contractile portion of the muscle is the belly, which is attached to bone via tendons which are non-contractile.

The numerous muscles of the foot and ankle are more simply understood when divided into compartments as each compartment plays a different role in movement of the ankle joint. The anterior compartment of the leg contains the dorsiflexors of the foot and ankle and includes the tibialis anterior, extensor digitorum longus, extensor hallucis longus and fibularis tertius. The lateral compartment of the leg contains the evertors of the foot and ankle and consists of the fibularis longus and brevis muscles. The posterior compartment of the leg contains the plantarflexors and invertors of the foot and ankle and includes the gastrocnemius, soleus, plantaris, popliteus, flexor hallucis longus, flexor digitorum longus and tibialis posterior muscles (Moore et al., 2013).

The muscles that are most commonly involved in movement of the foot and ankle are shown in **Table 2.2**.

Table 2.2 The origin, insertion, innervation, action and compartment of the muscles most commonly involved in the movement of the foot and ankle

Muscle	Origin	Insertion	Innervation	Action	Compartment
Extensor digitorum longus	Proximal two thirds of fibula, interosseous membrane and lateral condyle of tibia (anterior surface)	Dorsal surface of digits two-five (via dorsal expansion to middle and distal phalanges)	Deep fibular (peroneal) nerve (L4, L5, S1)	Extension of digits two-five (at metatarsophalangeal and interphalangeal joints), dorsiflexion and eversion	Anterior compartment
Extensor hallucis longus	Anterior middle third of fibula and interosseous membrane	Base of distal phalanx of big toe (dorsal surface)	Deep fibular (peroneal) nerve (L4, L5, S1)	Extension of the big toe (at metatarsophalangeal and interphalangeal joints), dorsiflexion and inversion	Anterior compartment
Fibularis (peroneus) tertius	Distal third of anterior fibula (distal and lateral aspect of extensor digitorum longus)	Base of fifth metatarsal (dorsal surface)	Deep fibular (peroneal) nerve (L5, S1)	Eversion and dorsiflexion	Anterior compartment
Tibialis anterior	Anterior proximal tibia (lateral tibial condyle, proximal two thirds of the antero-lateral surface of the tibia and interosseous membrane)	Medial cuneiform and base of first metatarsal (medial plantar surfaces)	Deep fibular (peroneal) nerve (L4, L5, S1)	Dorsiflexion and inversion	Anterior compartment
Fibularis (peroneus) brevis	Distal lateral half of fibula	Base of fifth metatarsal (lateral aspect)	Superficial fibular (peroneal) nerve (L5, S1)	Eversion and plantarflexion	Lateral compartment
Fibularis (peroneus) longus	Head and proximal lateral shaft	Medial cuneiform and base of first metatarsal	Superficial fibular (peroneal) nerve (L5,	Eversion and plantarflexion	Lateral compartment

	of tibia	(plantar surface)	S1)		
Flexor digitorum longus	Posterior middle third of tibia	Base of distal phalanges two-five (plantar surface)	Tibial nerve (L5, S1, S2)	Flexion of toes two-five (at metatarsophalangeal and interphalangeal joints), plantarflexion and inversion	Posterior compartment (deep muscle)
Flexor hallucis longus	Posterior inferior two thirds of fibula and interosseous membrane	Distal phalanx of big toe (plantar surface)	Tibial nerve (L5, S1, S2)	Flexion of big toe (at metatarsophalangeal and interphalangeal joints), plantarflexion and inversion of foot	Posterior compartment (deep muscle)
Gastrocnemius	Medial head: above medial condyle of femur (posterior surface) Lateral head: above lateral condyle of femur (posterior surface)	Calcaneus (via Achilles tendon)	Tibial nerve (S1, S2)	Plantarflexion of foot	Posterior compartment (superficial muscle)
Plantaris	Distal Posterolateral femur	Calcaneus (via Achilles tendon)	Tibial nerve (S1, S2)	Plantarflexion of foot	Posterior compartment (superficial muscle)
Popliteus	Lateral femoral condyle	Proximal posterior tibia	Tibial nerve (L4, L5, S1)	Unlocks knee from extended position	Posterior compartment (deep muscle)
Soleus	Soleal line of tibia and upper fibula	Calcaneus (via Achilles tendon)	Tibial nerve (S1, S2)	Plantarflexion and inversion	Posterior compartment (superficial muscle)
Tibialis posterior	Posterior proximal two thirds of tibia, fibula and interosseous membrane	Fans out over plantar surface of foot (navicular, medial, intermediate and lateral cuneiforms, second, third and fourth	Tibial nerve (L4, L5, S1)	Plantarflexion and inversion	Posterior compartment (deep muscle)

	metatarsals, cuboid and calcaneus.	

Data summarised from Vizniak (2012); Moore et al. (2013)

2.2.5. THE ROLE OF MUSCLES AND LIGAMENTS DURING THE GAIT CYCLE

The gait cycle of walking is made up of a series of movements that include stages of single and double support (Baharuddin et al., 2009). There are two main phases of the gait cycle of walking i.e. the swing phase and stance phase. Most of the movement that occurs within these phases happens in the sagittal plane, with the main movements being dorsiflexion and plantarflexion. The main plantarflexors used during the gait cycle are the gastrocnemius and soleus muscles, while the primary dorsiflexor is the tibialis anterior (Krishnaswamy, 2010). A summary of the activity of the leg muscles during the normal gait cycle is presented in **Table 2.3**.

Table 2.3 Activity of the leg muscles during the walking gait cycle

Gait cycle phase	**Muscle activity**
Heel strike	Eccentric contraction of ankle dorsiflexors.
Loading response	Eccentric contraction of ankle dorsiflexors.
Mid stance	Eccentric contraction of ankle plantarflexors.
Terminal stance	Concentric contraction of ankle plantarflexors.
Pre-swing	Concentric contraction of ankle plantarflexors.
Initial swing	Ankle dorsiflexors remain concentrically contracted throughout swing phase.
Mid swing	Ankle dorsiflexors remain concentrically contracted throughout swing phase.
Terminal swing	Concentric contraction of ankle dorsiflexors changes to isometric or eccentric contraction.

Data summarised from Árnadóttir et al. (2011); Moore et al. (2013)

The gait cycle of running is made up of a series of movements including a support phase in which only one foot makes contact with the ground, and a non-support phase in which there is no contact between the feet and ground (Baharuddin et al., 2009). The phases of the gait cycle during running are also categorised into the swing phase and stance phase with the addition of two float phases during which both feet do not make contact with the ground. The stance phase of the running gait cycle is broken down into three movements: right heel strike (assuming initial contact is being made with the right foot), mid-stance and toe-off. The stance phase is followed by the first double limb unsupported phase, also known as the float phase. The swing phase is broken down into two movements, left heel strike and mid stance; this is followed by the second double limb unsupported phase and ultimately returning to the initial movement of right heel strike (Magee, 2014).

During the walking gait cycle, the dorsiflexors are activated just before lift-off and remain so throughout the swing phase. At this point, the plantarflexors remain relaxed and only become activated once the dorsiflexors relax. The muscle activity during the running gate cycle is the reverse of the walking gait cycle. The plantarflexors are active during the time when the foot is in contact with the ground while the dorsiflexors are active around mid-cycle. The plantarflexors concentrically contract at toe-off and eccentrically contract on landing on the forefoot or mid-foot, while the dorsiflexors of the ankle eccentrically contract during heel strike and concentrically contract during swing (Novacheck, 1998; Cappellini et al., 2006).

Due to the varied directions in which the fibres of the lateral ligaments of the ankle lie, they are stressed during different motions of the ankle. The ATFL has two bands i.e. the inferior and superior bands. During plantarflexion, the inferior band relaxes and the superior band becomes stressed (at the same time limiting inversion) and during dorsiflexion, the inferior band becomes stressed while the superior band relaxes. The superior band of the ATFL is mostly affected during an inversion ankle sprain due to the fact that it restricts inversion. The CFL remains stressed during its range of motion, lying vertically during flexion and horizontally during extension. It is stressed in the varus position and relaxes in the valgus position. The PTFL is the strongest of the three ligaments and is not frequently injured during an ankle sprain. It is relaxed during plantarflexion and stressed during dorsiflexion (Golanó et al. 2010).

2.3. RANGE OF MOTION OF THE ANKLE

The primary movements of the ankle are dorsiflexion and plantarflexion which occur around the transverse axis. Inversion, eversion, abduction and adduction also occur; mostly when the ankle joint is in the plantar flexed or open packed position. Dorsiflexion usually occurs as a result of contraction of the anterior muscles of the leg namely tibialis anterior, extensor digitorum longus, extensor hallucis longus and fibularis tertius. The triceps surae (consisting of the gastrocnemius and soleus muscles) passively restrict dorsiflexion along with tension in the medial and lateral ligaments of the ankle. Plantarflexion occurs as a result of contraction of the posterior muscles of the leg namely; gastrocnemius, soleus, plantaris, popliteus, flexor hallucis longus, flexor digitorum longus and tibialis posterior (Moore et al., 2013). The use of specific instrumentation determines the values of range of motion, there are various methods of assessing range of motion including the inclinometer, goniometer or a tape measure. Variations in values may be accounted for by the use of different measurement tools (Konnor et al., 2012).The normal range of motion values established by the goniometer vary in the literature (**Table 2.4**).

Table 2.4 Reported mean normal ankle range of motion values

Reference	Dorsiflexion	Plantarflexion	Inversion	Eversion
Roaas and Andersson (1982)	15.3°	39.6°	27.7°	27.7°
Norkin and White (2009) (AAOS, 1965)	20°	50°	35°	15°
Norkin and White (2009) (AMA, 1988)	20°	40°	30°	20°
Michmizos and Krebs (2014) (Boone and Azen, 1979)	12.6°	56.2°	36.8°	20.7°

AAOS = American Association of Orthopaedic Surgeons; AMA = American Medical Association.

A wide range of factors may account for the differences in range of motion values observed in **Table 2.4** such as participant position, measurement tools used as well as whether the range of motion was assessed during active or passive movement. The standard analogue goniometer was used to determine the values established by AAOS (1965), Boone and Azen (1979) and Roaas and Andersson (1982). The landmarks used for placement of the goniometer were not clearly defined in these studies. For this study, however, the landmarks according to Norkin and White (2009) were the reference points used in this study. Goniometer placement for dorsiflexion and plantarflexion was as follows: the goniometer fulcrum was centered over the lateral malleolus (lateral surface), the proximal arm was aligned with the midline of the fibula, while the distal arm was aligned parallel to the fifth metatarsal (lateral aspect). Goniometer placement for inversion was as follows: the goniometer fulcrum was centered over the anterior ankle, midway between the medial and lateral malleoli, the proximal arm was aligned with the anterior midline of the leg (using the tibial tuberosity as reference to the midline), while the distal arm was aligned with the midline of the second metatarsal (dorsal surface).

The range of motion measurements taken by AAOS (1965) as cited by Norkin and White (2009) and Roaas and Andersson (1982) were done with the participants in the supine position with the knee in about 45° of flexion. On the other hand, Boone and Azen (1979) as cited by Michmizos and Krebs (2014) measured the range of motion of the foot and ankle while the participants were seated (i.e. hip in the flexed position). Moreover, the measurements established by Boone and Azen (1979) were assessed during active range of motion and those by Roaas and Andersson (1982) assessed during passive range of motion. All of these factors may have contributed to a variation in results when assessing range of motion of the foot and ankle; the exact landmarks and placement of the goniometer were also not clearly stated. The factors contributing to the final range of motion values established by the AMA (1988) have not been clearly defined in the literature.

2.4. ANKLE SPRAINS

2.4.1. DESCRIPTION AND EPIDEMIOLOGY

Inversion ankle sprains occur as a result of combined excessive plantar flexion and inversion of the talocrural joint (Moore et al., 2013). The aetiology of ankle sprains is multifactorial and ranges from improper balance of body weight, genu varum, improper footwear and muscle imbalances to proprioceptive deficits following a pre-existing ankle injury (Carnes and Vizniak, 2010). Although the most common symptoms associated with ankle sprains include local pain, swelling and bruising, the severity is primarily determined by the extent of ligamentous damage which may be classified as Grade One, Two or Three. A description of the three grades is provided in **Table 2.5**.

Table 2.5 Classification, pathology, clinical features and description of ankle sprains

Grade	Pathology	Signs and symptoms	Description
Grade One Mild	Single ligament involved Usually ATFL Mild stretch of ligament No instability	Little or no bruising Localised oedema Localised tenderness (usually antero-lateral) Pain at extremes of movement	None or mild limp (lasting ± 2 days). Can slowly rise up on toes. Painful hop. No joint laxity.
Grade Two Moderate	Large scale of injury Complete tear of ATFL or partial tear of ATFL as well as CFL Mild to moderate instability	Bruising on one side of foot More extensive oedema More generalised area of tenderness Pain on most movement	Prominent limp (lasting ± 2-14days). Unable to rise up on toes. Unable to hop or run. Slight laxity when

			stretched.
Grade Three Severe	Significant injury Complete tear of anterior capsule and talo fibular ligament and associated tear of ATFL and CFL	Diffuse bruising Extensive oedema (on both sides of foot) Generalised tenderness (on both sides of foot)	Unable to bear weight. Almost complete loss of movement. Positive laxity and instability tests.

Data summarised from Carnes and Vizniak (2010). ATFL = anterior talo fibular ligament; CFL = calcaneo-fibular ligament; ± = approximately

Ankle sprains are frequent injuries with a prevalence ranging from 6-25%, of which 20-25% occur as a result of high contact sports (Jerosch and Bischof, 1996). Inversion ankle sprains involving the lateral ligaments of the ankle are the most common type of ankle sprain, accounting for 85% of all ankle sprains (Ferran and Maffulli, 2006). Incidence rates of residual symptoms following ankle sprains have been reported at 40-50% of individuals with approximately 20-30% of acute ankle sprains progressing to CAIS (Jerosch and Bischof, 1996; van Rijn et al., 2008).

In their systematic review, Fong et al. (2007) established that the ankle was the second most commonly injured joint followed by the knee. They also reported that ankle sprains were most frequently observed in sports which were played on courts and in team sports, such as basketball, handball, volleyball, rugby and soccer. A systematic review by Doherty et al. (2013) reported a higher incidence of ankle sprains in females than males with the ratio being 13.6 vs. 6.94 per 1000 exposures, respectively; the exact cause of these results were not clearly defined. The same article also stated the difference in incidence of ankle sprains between adolescents and adults was 1.94 vs. 0.72 per 1000 exposures, respectively.

2.4.2. PATHOPHYSIOLOGY OF ANKLE SPRAINS

To prevent injury to the ankle, it is important to understand its pathomechanics (Bahr and Krosshaug, 2005). Previous literature on ankle sprains describes the mechanism of injury purely as excessive plantar flexion and inversion, but more recent studies have provided evidence that there is also some degree of internal rotation of the talus involved in an ankle sprain, along with inversion and plantar flexion (Fong et al., 2012).

2.4.2.1. Macroscopic features of ankle sprains

Wright et al. (2000) reported that strain to the lateral ligaments of the ankle occur as a result of exaggerated rear foot internal rotation and inversion, along with occasional external rotation of the leg. During an ankle sprain, there are excessive forces placed on the ankle joint compromising the tensile strength of the ligaments. Of the three lateral ligaments involved in ankle sprains, the ATFL is most vulnerable to injury and is most frequently injured, followed by the CFL which is not injured as readily as the ATFL in a mild ankle sprain, but is found to be involved more often in those sprains which are graded as two or three. The PTFL is the strongest of these three ligaments and is rarely injured (Moore et al. 2013).

2.4.2.2. Microscopic features of ankle sprains

On a microscopic level, the inversion injury involves damage to the connective tissue and musculature on the lateral aspect of the leg and foot. Along with soft tissue damage, there is additional insult to the joint capsule and ligamentous proprioceptors within the ankle resulting in proprioceptive deficits affecting the musculature of the lower leg which in turn lead to impairment in its function and continued instability (Herb and Hertel, 2014).

2.5. CHRONIC ANKLE INSTABILITY SYNDROME

Chronic ankle instability syndrome occurs as a result of a significant previous inversion ankle sprain. Symptoms need to persist for more than 12 months following the initial injury to make a diagnosis of CAIS (Gribble et al., 2013). The consequences of the injury involve an inability to perform some actions with ease such as walking on an uneven surface or participating in high impact sports due to ligamentous damage. This would have occurred during previous episodes of ankle sprains resulting in pain, decreased range of motion, loss of muscle strength and instability of the ankle joint (Hockenbury and Sammarco, 2001; Hiller et al., 2011). The main causes for the development of CAIS from acute ankle sprains can be attributed to misdiagnosis, functional instability as a result of ligamentous damage, reduced fibular and subtalar motion, scar formation, inadequate treatment and inadequate rehabilitation (Hertel, 2002).

2.5.1. PATHOPHYSIOLOGY OF CHRONIC ANKLE INSTABILITY SYNDROME

Chronic ankle instability syndrome follows the similar pathomechanics as an acute ankle sprain, with the only difference being that individuals seem to have a predisposition to developing recurring sprains as a result of mechanical and functional changes that occur within the ankle following the initial injury. These changes are described in **Tables 2.6** and **2.7**, respectively. It is important to understand that mechanical and functional instability are not the sole causes of CAIS, but they do explain how various factors contribute to the diagnosis of CAIS (Hertel, 2002; Herb and Hertel, 2014).

Mechanical instability plays a crucial role in the development of CAIS as it is associated with excessive joint range of motion and pathological laxity as a result of injury to the ankle ligaments following an ankle sprain (Herb and Hertel, 2014; Wilson and Bialocerkowski, 2015).

Table 2.6 Mechanical instability in the development of CAIS

Mechanical instability	Description
Pathological laxity	Pathological laxity may be defined as a complete loss of control of a joint during its range of motion. Non-pathological laxity may be defined as an extreme physiological range of motion within a joint resulting in apprehension at its end range (Magee, 2014). Injury to the ankle ligaments often results in laxity within the joint, thereby, resulting in instability. The degree of laxity is directly proportional to the severity of ligamentous damage. Instability is most common within the talocrural joint and occurs primarily as a result of injury to the ATFL and CFL (Hertel, 2002; Hiller et al., 2011).
Arthrokinematic impairments	Arthrokinematics may be defined as the movement between the two articular surfaces of a joint. Impairments in arthrokinematics may occur as a result of incongruent joint surfaces within the ankle and is a contributing factor towards mechanical instability (Hertel, 2002). One theory on the cause of joint incongruence was proposed by Mulligan (1995) who suggested that antero-inferior displacement of the lateral malleolus which occurs during an ankle sprain has a direct effect on the laxity of the ATFL due to its attachment to the fibular. This causes the ankle to supinate beyond its normal range of motion before the ATFL becomes engaged. This creates weakness and the possibility for recurring sprains. Another theory by Tabrizi et al. (2000) proposed that hypomobility or restrictions in normal ankle range of motion, particularly dorsiflexion, has been shown to be a risk factor for recurring ankle sprains due to the resultant altered biomechanics of the sprained ankle. As a result, inversion and internal rotation occurs with greater ease due to the joint being unable to reach its closed pack position.
Synovial and degenerative changes	Synovial hypertrophy and impingement or degenerative changes within the joint space has also been postulated as causes of mechanical instability. The presence of synovial inflammation resulting in pain and recurring injury may have occurred as a result of hypertrophied synovial tissue impingement between the osseous structures of the ankle (Hertel, 2002). DiGiovanni et al. (2000) identified a

	prevalence of anterolateral impingement syndrome in 67% and talocrural synovitis prevalent in 49% of individuals who required surgery as a result of ankle instability. The results of the study by DiGiovanni et al. (2000) indicate the presence of synovial impingement and inflammation suggesting that one may be associated with the other. Gross and Marti (1999) reported a link between recurring ankle sprains and degenerative changes such as loose bodies, osteophytes and sclerosis found within the ankle joint.

Functional instability may be defined as the failure to voluntarily or involuntarily control dynamic movement during range of motion of a particular joint (Magee, 2014). The initial notion of functional instability was described by Freeman (1965) as inadequate proprioceptive function due to damaged mechanoreceptors within the ankle ligaments. Although this is an important contribution towards understanding functional instability, it does not explain why injury to the ankle ligaments inclines individuals towards the development of functional ankle instability (Hertel, 2002; Herb and Hertel, 2014).

Table 2.7 Functional instability in the development of CAIS

Functional instability	Description
Impaired proprioception	Individuals who suffer from recurring ankle sprains are more than likely to have deficits in proprioceptive function (Hertel, 2002). Proprioception may be described as the sensation of movement that is obtained through receptors in the body; these receptors receive information from peripheral afferents which is critical for the maintenance of balance (Kim and Choi, 2015). Proprioception plays a pivotal role in activities of daily living with its most important task being postural stability, as impairment in function may predispose individuals to recurring injury (Docherty et al., 2006; Lee and Lin, 2008). The literature provides us with considerable details regarding the role of proprioception and its impairment following injury, but it does not clearly explain how the aberration in proprioception leads to instability. Studies dating back to Freeman (1965), suggest that damage to the articular mechanoreceptors that occur as a result of an ankle sprain leads to the inability to detect proprioceptive sensations (Raymond et al., 2012).
Impaired neuromuscular control	Individuals who suffer from recurring ankle sprains were found to have impaired neuromuscular firing patterns. This was established by determining the peroneal muscle reflexive response times to inversion or supination stresses. It was found that the impaired reflexive response times of the peroneal muscles in individuals with CAIS could have been a result of the following: impaired proprioception, slow nerve conduction velocity or inadequate functioning of neuromuscular recruitment strategies (Hertel, 2002).
Impaired postural control	Postural stability may be defined as the natural capacity of the body to preserve an erect position while maintaining the centre of gravity (COG) within normal range (Lee and Linn, 2008). Impairments in postural control are supposedly due to alterations in proprioception and neuromuscular control. The ankle strategy of postural control aims to maintain the bodies COG within the normal range during single leg stance by pronating and supinating the foot. In CAIS, individuals have to rely more on the hip

	strategy (a balance strategy where the hips and the head move in opposite directions in order for the body to try to maintain its balance) which is not as effective as the ankle strategy to sustain a single leg stance. In the presence of ankle joint dysfunction, the change in postural control strategy occurs as a result of alterations in central neural control (Hertel, 2002).The concept of postural control and sway index will be discussed further in this chapter.
Muscular strength deficits	Adequate joint range of motion relies greatly on an optimally functioning muscular system as co-contraction of the muscles surrounding the joint aids in dynamic stabilisation. Eccentric co-contraction is particularly important during activities such as running and jumping as it decreases the forces between the ground and foot. In individuals with muscle strength deficits, there is insufficient muscle co-contraction to disperse this large force resulting in increased strain to the tissues around the ankle joint, thereby making it more inclined to injury (Perron et al., 2014). Recently, it was shown that muscular strength was diminished in the evertor and plantarflexor muscles of the affected ankle after eight weeks following an initial inversion ankle sprain; muscle strength was assessed using the Biodex System 3 dynamometer (Perron et al., 2014).

2.5.2. CLINICAL PRESENTATION OF CHRONIC ANKLE INSTABILITY SYNDROME

Individuals with CAIS often have difficulty performing activities of daily living with ease such as walking on an uneven surface or participating in high impact sports (Hockenbury and Sammarco, 2001). This could be as a result of ligamentous damage or disrupted arthrokinematics of the ankle joint which would limit movement (Tabrizi et al., 2000).

The frequently described clinical features of CAIS include acute pain, swelling along the talocrural and subtalar joint lines, the sensation of apprehension when walking on an unstable surface, functional and mechanical instability as well as a decline in ankle strength (Chan, et al., 2011; Hiller et al., 2011). It is important to understand that although these are the most commonly reported clinical features of CAIS, there is a vast array of clinical features described in the literature that may be quite confounding. Many authors have their own theories on the clinical presentation according to their findings which is why the use of diagnostic criteria and a thorough physical assessment are important to confirm the diagnosis of CAIS (Courtney et al., 2011; Hiller et al., 2011).

2.5.3. DIAGNOSTIC CRITERIA OF CHRONIC ANKLE INSTABILITY SYNDROME

The diagnostic criteria for CAIS were initially proposed by Kessler and Hertling (1983) and were described as follows:

An individual should present with at least four of the six clinical features mentioned below to be diagnosed with CAIS:

- Ankle pain
- Ankle instability
- Oedema of the ankle
- Weakness of the ankle
- Stiffness of the ankle joint
- Crepitus within the ankle joint

Although pain does not often accompany instability, it could indicate soft tissue tears (particularly those of the peroneal muscles) or deficits within the osteochondral complex (Botha, 2013). Instability (both mechanical and functional) may be assessed objectively and subjectively, respectively. Mechanical instability may be assessed by the use of manual stress tests, stress radiographs as well as ultrasound and MRI. Functional instability may be assessed by the sensation of giving way or the feeling of apprehension during movement, the use of the Foot and Ankle Disability Index (FADI) and the Foot and Ankle Ability Measure (FAAM) may also be helpful (Mansour et al., 2011; Seah and Mani-Babu, 2011; Botha, 2013). The concept of stiffness may occur as a result of adhesions that form during the process of ligament healing. Crepitus is most easily assessed through palpation; the different sensations felt during palpation provide an indication of the damage that may be occurring within the affected joint. Abrasions of the articular cartilage may present as soft, fine crepitus, whereas more substantial damage to the articular cartilage or bone may present as a creaking crepitus (Magee, 2014).

Since the initial diagnostic criteria were proposed, there is paucity in the literature with regards to the inconsistency of diagnostic criteria for CAIS. Zhang (2012) suggested that mechanical and functional instability should be included as inclusion criteria in the diagnosis of CAIS but the International Ankle Consortium as cited in Gribble et al. (2013) recommend a set of inclusion and exclusion criteria for the diagnosis of CAIS to be used in controlled research (**Table 2.8**).

Table 2.8 Standard inclusion criteria for CAIS as proposed by the International Ankle Consortium

Inclusion criteria	Description
1. History of at least one severe ankle sprain	The sprain should have occurred more than 12 months prior to participation in the study. The initial sprain should be associated with inflammatory symptoms. The initial sprain should have left the individual with a minimum of one interrupted day of desired physical activity.
2. The sensation of the injured ankle giving way and/or recurrent sprains and/or feelings of instability	The individual should have reported at least two or more sensations of giving way of the affected ankle. The individual should have reported at least two sprains involving the affected ankle. The individual should have reported feelings of instability during activities of daily living.
3. The general self-reported foot and ankle functional questionnaire is recommended only if self-reported function is pertinent to the research	Foot and Ankle Ability Measure (FAAM) and Foot and Ankle Outcome Score (FAOS) are questionnaires that are currently endorsed.

Data summarised from Gribble et al. (2013)

The standard exclusion criteria for CAIS proposed by the International Ankle Consortium (Gribble et al., 2013) are as follows:

- History of surgery to musculoskeletal system of lower limb.
- History of fracture in lower limb requiring realignment.
- Acute injury to other musculoskeletal structures of the affected limb three months prior to participation in study.

2.6. MANAGEMENT OF ANKLE SPRAINS AND CHRONIC ANKLE INSTABILITY SYNDROME

The primary goals of managing ankle sprains are to keep swelling to a minimum, preserve range of motion, restore proprioception as well as prevent further injury (Wolfe et al., 2001). Inadequate management of acute ankle sprains and poor or early functional rehabilitation may be a cause of ankle sprains progressing to CAIS (Hertel, 2002; Petersen et al., 2013).

The management of ankle sprains may be divided into two categories viz. conservative and non-conservative approaches. Conservative approaches include the use of the rest, ice, compression, elevation (RICE) protocol as well as early joint mobilisation, anti-inflammatory drugs, rehabilitation, strapping and bracing. Non-conservative approaches include surgical and other invasive procedures (Seah and Mani-Babu, 2011; Acar et al., 2015).

2.6.1. CONSERVATIVE MANAGEMENT

Most individuals with a Grade One, Grade Two and certain Grade Three ankle sprains are effectively managed using the conservative management approach (Petersen et al., 2013). The initial management of ankle sprains usually comprises of the RICE protocol within the first 72 hours following the injury (van den Bekerom et al., 2012).

Rest may be defined as selective, general activity, excluding stress or strain that may impair the process of healing (van den Bekerom et al., 2012). Rest is advocated to reduce stress to the area as continuous activity will delay healing and repair of the affected area. The delay in healing may disrupt the delicate fibrin bond formed during the initial healing process (van den Bekerom et al., 2012). Research has shown that early functional mobilisation increases the rate of healing more effectively than prolonged rest, concluding that non-strenuous activity may prove to be more beneficial than prolonged rest during injury (Tiemstra, 2012).

Cryotherapy has a multitude of benefits in the management of ankle injuries ranging from analgesia to vasoconstriction. Ice acts as an anti-inflammatory agent by reducing the inflammation that occurs as a result of the increased metabolic demand following injury, as well as inhibiting bleeding by promoting vasoconstriction. The most effective method of ice application is ten minutes on, ten minutes off, ten minutes on again, every two hours for a period of three days. This method has shown to be more beneficial in terms of pain relief compared to the application of ice for 20 minutes every two hours (Carnes and Vizniak, 2010; Tiemstra, 2012; van den Bekerom et al., 2012).

The role of compression in acute ankle injuries is to reduce swelling and bruising caused by exudation and bleeding from damaged capillaries. Compression is usually achieved by the use of strapping applied with firm pressure. Care needs to be taken in terms of the amount of pressure applied as tight strapping will stop circulation. Strapping and bracing may be used in both acute and chronic ankle sprains to reduce swelling and provide support, respectively (Carnes and Vizniak, 2010; van den Bekerom et al., 2012). The role of strapping will be discussed in further detail later in this chapter.

Elevation of the affected limb above the level of the heart is recommended in acute ankle injuries to reduce the strain placed on the affected vessels. Elevation also helps to promote lymphatic drainage thus limiting oedema which may delay healing (van den Bekerom et al., 2012).

Along with the RICE protocol, the literature describes various conservative treatment regimens and modalities used in the management of ankle sprains and CAIS. The technique of manipulation and mobilisation of the ankle has been shown to be more effective in comparison to immobilisation (Tiemstra, 2012; Carnes and Vizniak, 2010). Non-steroidal anti inflammatory drugs (NSAIDs) have also been shown to provide significant relief of pain and return to activity. NSAIDs are beneficial in reducing inflammation; however, abuse of these drugs also carry the risk of impaired healing of bones and tendons as well as gastro-intestinal upset (Tiemstra, 2012; Nalamachu et al., 2013).

An ankle brace is a support mechanism that fits the ankle joint providing it with stability during activity in individuals with ankle instability. There are various types of ankle braces available which can be differentiated into two categories i.e. non-rigid and semi-rigid. Non-rigid ankle braces are usually composed of a canvas or similar material with tie-up laces whereas the semi-rigid brace is composed of a thermoplastic material and consists of a supportive band that extends over both malleoli; this band is usually reinforced with the presence of Velcro straps (Callaghan, 1997; Kemler et al., 2011). Ankle braces have been shown to be of greater benefit to athletes in terms of cost, efficacy and convenience of application when compared to taping and other functional treatment methods (Callaghan, 1997; Kemler et al., 2011).

2.6.2. STRAPPING

Strapping is a popular method for the treatment of ankle sprains (Trégouët et al., 2013; Acar et al., 2015) and will be discussed in detail due to its relevance to this study. The proposed benefit of strapping is to limit excessive or abnormal movement at the ankle joint by providing stability as well as aiding functional rehabilitation (Bandyopadhyay and Mahapatra, 2012; Forbes et al., 2013). The physical demands of different sports, varying degrees of injury as well as variations in anthropometry that vary from one individual to the next are some of the main reasons that strapping is so popular and is relatively versatile allowing it adapt to the environment in which it is required (Trégouët et al., 2013). Comfort, flexibility and perceived stability are just a few of the benefits strapping provides when compared to bracing, accounting for its growing popularity.

2.6.2.1. Rigid and elastic strapping

There are two main types of tapes viz. rigid strapping and elastic strapping. These tapes have been used in the sporting fraternity as well as emergency departments for the purpose of prophylaxis, assisting rehabilitation to prevent re-injury as well as to treat acute injuries. Rigid tape has only 30% stretch to it and as a result, is commonly used to support structures. This type of tape is strong and porous with zinc-oxide adhesive which ensures its strength; it is commonly used in conditions where stabilisation of the joint is necessary. Some disadvantages of using rigid tape include difficulty in ensuring the tape does not wrinkle during application. If the tape is incorrectly applied, this may predispose the individual to further injury. Prophylactic taping can result in psychological dependence on the tape providing a false sense of stability to the area in which it is applied (Perrin, 2012; Acar et al., 2015).

Elastic tape permits more joint movement by allowing a greater range of motion of the joint. Its composition of 100% cotton smooth backing material allows for its flexibility and enhances proprioceptive feedback by subconsciously allowing muscle contraction to occur, thereby controlling involuntary movement. The main role of elastic tape is to provide support; the flexible property of this tape allows it to provide support without restricting circulation. Some disadvantages of this tape is its short-term effectiveness (approximately 20 minutes) as its adhesive capacity is lost during activity, thus making it expensive to use on a daily basis (Wilkerson, 2002; Bandyopadhyay and Mahapatra, 2012; Perrin, 2012; Acar et al., 2015).

Before applying any form of tape, there are certain precautions that need to be assessed. It is vital to enquire about any allergies that an individual may have. Most rigid and elastic tapes contain latex and strong adhesives that may irritate sensitive skin; therefore, it is important to enquire about any skin allergies prior to application. Another factor that needs to be taken into account is the application of tape and the development of friction rubs and blisters. If the tape is applied incorrectly, it may pull on the skin in the region of the anchors where the tension is greatest during activity, forming blisters or even tearing of the skin. Joint range of motion that may be required during activity needs to be assessed prior to tape application. Joint mobility should not be completely restricted and the movement required for each individual needs to be taken into consideration during their particular activity whether it is sporting activity or activities of daily living. Precaution also needs to be taken when considering the use of rigid tape for support as circulation may be compromised if it is applied too tightly (Perrin, 2012).

Different taping methods have been described in the literature with various reasons as to why they are applied and are considered to be effective (Perrin, 2012). The methods and the reasons for application are summarised in **Table 2.9**.

Table 2.9 Popular taping methods for ankle sprains

Method of taping	Purpose of taping
Figure of 8	This type of taping is used to give support to a joint by limiting excessive movement.
Stirrup	This type of taping is used to give support to a joint by limiting excessive movement and restricting joint movement.
Open Gibney	This type of taping is used for both inversion and eversion ankle sprains but permits more plantar flexion than a closed basket weave.
Closed basket weave	This type of taping method is used for both inversion and eversion ankle sprains; however, range of motion particularly plantarflexion is more restricted than with the open Gibney method.
Open basket weave	This taping method is used to provide joint support and control oedema.
Subtalar sling	This taping method is used to resist excessive subtalar motion particularly inversion.

Data summarised from Wilkerson (2002); Carnes and Vizniak (2010)

2.6.2.2. Kinesio™ tape

Kinesio™ tape was created by a chiropractor, Dr Kenzo Kase in 1979, and was introduced to the international market approximately ten years ago. The tape was designed to improve the function of various tissues and physiological systems in the body by the use of its own unique taping method (Kinesiotaping® Association International, 2011). The manufacturers of Kinesio™ tape claim that it has an effect on five major physiological systems namely the skin, fascia, lymphatic, muscular and joints (Kinesiotaping® Association International, 2011). Due to the fact that the skin is the largest sensory organ and is rich in sensory receptors, pain is modulated by the effects of Kinesio™ tape on the skin and superficial fascia. This occurs through stimulating or unloading mechanoreceptors in the skin through compressive and decompressive forces, respectively. Both these forces are responsible for alleviating pain (Kinesiotaping® Association International, 2011).

The effect of Kinesio™ tape on deep fascia includes breaking surface adhesions caused by immobility. The application of Kinesio™ tape to facilitate mobility of the tissue is what contributes to breaking these surface adhesions allowing increased movement to the area. It is hypothesised that Kinesio™ tape is also responsible for proprioception when applied to the skin. The tape's stimulating effects on the mechanoreceptors in the skin relays information on joint position sense, kinaesthesia and force sense which may be responsible for assisting or enhancing proprioception (Kinesiotaping® Association International, 2011; Jackson et al., 2016). Kinesio™ tape also promotes superficial lymphatic drainage by increasing the flow of interstitial fluid through lifting of the skin which promotes infiltration of the fluid through the tissues via a pressure gradient; this occurs with the application of specific taping patterns created for Kinesio™ tape and ultimately reduces swelling and decreases pain. The effects of Kinesio™ tape on muscle activity include maintaining the balance between length tension ratios through reciprocal inhibition so as to reduce muscle fatigue and increase range of motion. Joint biomechanics are also preserved by the application of Kinesio™ tape through maintenance of the agonist/antagonist muscle balance ratio, thereby reducing muscle strain and assisting the function of tendons and ligaments. The exact mechanism of action on the joint and lymphatic systems are not clearly explained in the literature (Kinesiotaping® Association International, 2011).

Kinesio™ tape is reportedly safe to use in any phase of treatment be it acute, chronic or rehabilitative and can be used in conjunction with a variety of modalities. It is different to other tapes due to the fact that it is latex free and is composed of 100% cotton and elastic fibres. It is also water resistant and may be worn for up to three to five days (Halseth et al., 2004; Kinesiotaping® Association International, 2011).

2.6.2.3. Techniques of Kinesio™ tape

The description of the techniques presented is adapted from Kinesiotaping® Association International (2011). There are six kinesiotaping corrective techniques which are used to treat a range of conditions, these include: mechanical correction, fascia correction, space correction, ligament or tendon correction, functional correction and circulatory or lymphatic correction. The mechanical correction is responsible for inhibiting abnormal movement patterns; the tape does this by creating a stimulus of a perceived resting position which then allows for functional range of motion. The fascia correction is aimed at movement of fascia, it can create movement, unload movement or direct movement of fascia depending on the tension applied in the tape. The superficial fascia is targeted with mild (approximately 10-25%) tension in the tape while the deep fascia is targeted through greater (25-50%) tension in the tape. The space correction is effective in reducing tissue tension in areas of increased load through lifting. The tape is applied by creating a change in direction of the tape over the target tissues with minimal tension in the tape. The ligament or tendon correction is responsible for reducing the stress on the affected areas. The proposed mechanism of action is targeting the mechanoreceptors in the skin which relays information to the brain of perceived normal tension within the tendons and ligaments. Ligament applications require almost maximum (75-100%) tension in the tape creating the perception of maximum support while tendons require an intermediate (50-75%) tension in the tape so as to engage the Golgi tendon organ and elongate the affected soft tissue.

The functional correction technique is the one used in this study and is responsible for facilitating or inhibiting movement. It is effective in managing hyper-mobile joints, tissues that have been overstretched and tissues that have been reinjured. It acts on pre-loaded motion by creating tension (50-75%) in the tape which stimulates the mechanoreceptors in the affected area. The circulatory or lymphatic correction is responsible for channelling swelling in the direction of lymph nodes. A fan cut is usually used during this application where the anchor is applied in the region of the lymph nodes while the tails are applied with minimal tension (0-20%) over the affected area. The little tension in the tape guides excess fluid through the superficial lymphatic channels towards the lymph nodes where it is then dispersed.

2.6.2.4. Recent studies (2011-2015) on strapping

Research has shown that strapping is relatively effective in the treatment of ankle ligamentous injury (Fong et al., 2009). Recent studies (2011-2015) that report on the effect of bracing and taping on ankle injuries as well as the comparison between bracing and taping are tabulated in **Table 2.10**.

Table 2.10 A summary of randomised clinical trials on conservative treatment of ankle injuries with taping, bracing and splinting between 2011 and 2015

Modality	Reference	Sample	Intervention	Outcome	Summary of results
Lace up ankle brace	McGuine et al. (2011)	2081 participants	Brace group: Don-Joy ankle stabilising brace Control group: No ankle brace provided	Brace compliance Athlete exposure to a competition, practice or conditioning session Injuries occurring during a football match that resulted in termination of play	Lower incidence of acute ankle injuries reported in individuals who used the lace up brace (0.48 per 1000 exposures) as compared to the control group (1.12 per 1000 exposures), confidence interval 0.24-0.65 and $p < 0.001$. However, the brace did not play a role in reducing the severity of existing injuries in the lower limb.
Kinesio™ tape (KT) vs. non-elastic sports tape (rigid tape)	Briem et al. (2011)	30 male participants	KT group: KT of peroneus longus Rigid tape group: application for inversion ankle sprain Placebo group: no tape	Muscle activity through EMG Perceived stability	There was a significant increase in mean muscle activity in the rigid tape group compared to the placebo group. the KT group showed no significant differences in mean or maximum muscle activity when compared to the placebo group
Athletic tape vs. KT	Bicici et al. (2012)	15 male participants	No tape Placebo group: 'I' shaped tape cut and applied with no tension Athletic tape group: used anchors, stirrups, heel locks and closure straps KT group:	Agility Endurance Balance Co-ordination These were assessed using the following tests: Hopping test, Single Limb Hurdle Test, Standing Heel Rise Test, Vertical Jump Test, The SEBT and	There was no significant difference in performance between KT and athletic tape during the Hopping Test, Single Limb Hurdle Test, dynamic balance and SEBT. However, there was a significant decrease with the athletic tape group during the Vertical Jump Test (placebo tape group $p = 0.002$; athletic tape group $p = 0.002$; KT tape group $p < 0.001$) and the Standing Heel Rise Test (placebo tape group $p = 0.035$; athletic tape group $p = 0.043$; KT

			application for tibio fibular ligament and peroneal muscle support	Kinesthetic Ability Trainer Test (assessing dynamic balance)	tape group $p < 0.001$). Functional performance was not limited in the KT group.
Taping vs. Semi-rigid bracing	Lardenoye et al. (2012)	100 participants Taping: 50 Bracing: 50	Taping method and Brace used were not defined	Patient satisfaction questionnaire Skin complication questionnaire Numeric pain rating scale Karlsson scoring scale Range of motion	The bracing group was found to be far superior to the taping group in terms of patient comfort and satisfaction, as well as rate of skin irritation ($p < 0.0001$). Pain and functional outcomes were found to be similar between both groups.
KT	Nambi and Shah (2012)	30 participants KT group: 15 (10 male, 5 female) Mulligan's mobilisation group: 15 (12 male, 3 female)	KT group: First session: KT application for lymphatic correction to lateral ankle and tendon correction for Achilles tendon Second and third session: KT application for tibialis anterior and application for fibularis longus and brevis muscles Mulligan group: Mulligan's mobilisation with movement	Subjective pain rating measured with NPRS Dorsiflexion range of motion measured by knee-to-wall principle	The outcome of this study revealed that both KT and Mulligan's mobilisation with movement technique are effective in the management sub-acute lateral ankle sprains in terms of decreasing pain and increasing range of motion. The KT group showed significant improvements in both pain reduction ($p = 0.01$) (55.7%) and ankle dorsiflexion ($p = 0.000$) (27.6%); however, the Mulligan group showed greater effects on pain reduction ($p = 0.01$) (74.9%) and significantly higher increases in ankle dorsiflexion ($p = 0.000$) (71.07%) when compared to the KT group.
Taping vs. Bracing	Forbes et al. (2013)	8 male participants	Tape group: open basket weave Brace group: Air cast	Range of motion: Specifically plantarflexion and inversion	The aim was to limit ankle range of motion and increase proprioception under simulated soccer activity with the use of prophylactic taping and bracing.

			air support brace Placebo group: No support	Proprioception through JPS	Application of prophylactic taping reduced active plantarflexion and inversion ($p < 0.05$). Tape and control groups lost restrictive ability at 15 minutes ($p < 0 .001$) while brace group maintained effectiveness up to 45 minutes. Non weight bearing JPS was increased following application of the prophylactic support at 0 minutes ($p < 0.01$) however; proprioceptive ability of tape was lost at 15 minutes ($p < 0.01$) as compared to the brace group.
KT	Shields et al. (2013)	60 participants Healthy: 20 (7 males, 13 females) Copers: 20 (9 males, 11 females) Unstable: 20 (9 males, 11 females)	KT group: application for lateral ankle sprain	Centre of pressure and time-to-boundary evaluated by an in-ground force plate	There were no significant changes found in the three groups following application of tape, which suggests that KT is not effective in the management of proprioceptive deficits. However, in a summary of centre of pressure variables, proprioceptive deficits in the sagittal plane were found in the unstable ankle group. The implications of this finding suggest that different trial lengths should be conducted for the different variables to confirm postural control differences between the three different groups.
Comparison of ankle taping styles	Trégouët et al. (2013)	12 participants	Control group: no tape Elastic adhesive bandage wrap group Non elastic bandage group: basket weave	Muscle activation through EMG Range of motion through an electrogoniometer	The outcome of this revealed a significant decrease in rate of inversion between the three groups in terms of tape conditions as well as before and after exercise ($p < 0.01$). Significant results were noted in muscle latency measured by EMG after exercise ($p < 0.01$). However, results were insignificant when compared amongst the three groups.

KT	Simon et al. (2014)	28 participants 14 healthy (2 male, 12 female) 14 with unstable ankles (8 male, 6 female)	KT group: KT for inversion ankle sprain Control group: no tape	Proprioception evaluated by eversion force sense at baseline, immediately after application of tape and 72 hours after application of tape.	At baseline and immediately after tape application the KT group showed significant increase in force sense errors when compared to the control group. However, after 72 hours, no differences were noted in force sense errors between the two groups.
Elastic tape vs. KT	Acar et al. (2015)	73 participants Elastic group: 35 KT group: 38	KT group: lymphatic correction Elastic group: application for acute ankle sprains	Karlsson score Numerical pain rating scale Ankle girth Active ROM	The results of this study showed that KT and elastic tape were equally effective in the treatment of acute ankle sprains.
Strapping vs. splinting	Bilgic et al. (2015)	51 participants Elastic group: 25 (14 male, 11 female) Splint group: 26 (15 male, 11 female)	Elastic bandage and splint used were not specified	Oedema measured by graduated container filled with warm water Pain measured by VAS	This study showed that elastic bandage was far superior to the splint in terms of reducing oedema in acute ankle sprains ($p = 0.025$)
KT vs. placebo tape	de-la-Torre-Domingo et al. (2015)	30 participants KT:15 (5 male, 10 female) Placebo: 15 (10 male, 5 female)	KT group: KT for lateral ankle sprain Placebo: Pre tape Cramer®	Composite SOT score Composite SOT strategy	Results showed an immediate improvement in SOT scores following tape application in both KT and placebo groups. Composite SOT score: $p \leq 0.01$; SOT condition 2: $p = 0.014$; SOT strategy 2: $p = 0.413$; composite SOT strategy: $p \leq 0.01$. No significant differences were established in the majority of the balance measurements during the follow-ups between the groups.

CMAS	Hadadi et al. (2015)	40 participants 20 healthy (10 male,10 female) 20 with CAIS (10 male,10 female)	CMAS orthotic	Single limb stance balance test	The outcome of this study showed a decrease in postural sway in the CAIS group but not in the healthy group. Significant differences were noted between the groups for the Cumberland Ankle Instability Tool, Foot and Ankle Ability Measure, activities of daily living and the Foot and Ankle Ability Measure sports score ($p < 0.001$).
KT	Nunes et al. (2015)	36 participants Intervention group: 18 (15 male, 3 female) Control group: 18 (13 male, 5 female)	Intervention group: KT fan cut Control group: KT inert application	Swelling via volumetry, perimetry, and relative volumetry at three days and 15 days following application of tape	No significant differences were noted in volumetry, perimetry and relative volumetry between the two groups at three days and 15 days following an acute ankle sprain.

vs. = versus; < = less than; > = greater than; ≤ = less than or equal to; = equal to; KT = Kinesio™tape; CAIS = chronic ankle instability syndrome CMAS = Combined mechanism ankle support; EMG = electromyography; MCT = motor control test; JPS= joint position sense; ROM = range of motion; SEBT = Star Excursion Balance Test; SOT = Sensory Organisation Test; VAS = visual analogue scale.

Of the three conservative approaches described in **Table 2.10**, ankle braces seems to be a more effective support mechanism as compared to ankle taping and splinting in the management of ankle injuries. Lardenoye et al. (2012), Forbes et al. (2013) and Hadadi et al. (2015) observed that an ankle brace was superior to ankle tape in terms of patient comfort, patient satisfaction, proprioceptive capacity and improvement of static balance. However, an earlier study by McGuine et al. (2011) reported that although an ankle brace is effective in prophylactic management, it does not reduce the severity of existing injuries in the lower limb. Bicici et al. (2012), Acar et al. (2015) and de-la-Torre-Domingo et al. (2015) compared the results of Kinesio™ tape to athletic tape, elastic tape and placebo tape, respectively in the management of ankle injuries. All three studies revealed no significant differences between the Kinesio™ tape group and other respective taping groups indicating that the type of tapes used were insignificant. There was no consistent taping method applied in these studies. It would be interesting to determine the outcomes of these studies if a consistent taping method was applied.

Nambi and Shah (2012) compared the effects of Kinesiotaping to Mulligan's mobilisation with movement technique and reported that although both groups were effective in the reduction of pain and increase in dorsiflexion range of motion, the Mulligan's mobilisation group showed significantly better results in terms of pain reduction and increased dorsiflexion range of motion than the Kinesio™ tape group.

Shields et al. (2013), Simon et al. (2014) and de-la-Torre-Domingo et al (2015) assessed the effect of Kinesio™ tape on proprioception and reported conflicting results. Shields et al. (2013) assessed the effect of Kinesio™ tape on proprioception in healthy, 'copers' and unstable ankles and reported no significant improvements in proprioceptive deficits between the three groups. Simon et al. (2014) assessed the effect of force sense errors in eversion between a Kinesio™ tape group and a control group (healthy ankles with no tape applied). They evaluated the force sense errors at baseline, immediately after application of tape and 72 hours following application of tape. They reported a significant increase in force sense errors in the Kinesio™ tape group at baseline and immediately following application of tape; however, these force sense errors decreased when evaluated at 72 hours and no differences were noted between the two groups at the 72 hour assessment. The authors explained that their findings indicate that Kinesio™ tape has an effect on proprioceptive deficits when worn for extended periods.

De-la-Torre-Domingo et al. (2015) assessed Sensory organisation test (SOT) scores between a Kinesio™ tape group and a control group. They reported an improvement in SOT scores in both groups, but no significant differences were noted between the two groups indicating that the improvements in SOT scores may have been as a result of increased confidence in performing the tests.

Briem at al. (2011) and Trégouët et al. (2013) reported conflicting results in the assessment of muscle activation through EMG. Briem et al. (2011) assessed muscle activity in three group's viz. Kinesio™ tape group, rigid tape group and placebo groups; they reported an increase in mean muscle activity in the rigid tape group when compared to the placebo group. The Kinesio™ tape group however, did not show any increases in muscle activity when compared to the placebo group. Trégouët et al. (2013) assessed muscle activation and range of motion between three group's viz. control group, elastic tape group and rigid tape group. They reported insignificant results on improvements in muscle activity; they did however, find a significant decrease in inversion range of motion between all three groups. Nunes et al. (2015) evaluated the effect of Kinesio™ tape on ankle swelling in acute lateral ankle sprains and found no reduction in volumetry, perimetry and relative volumetry between the Kinesio™ tape and placebo groups at the three assessments immediately post-, three days post-and 15 days post-application of the tape.

Bilgic et al. (2015) compared elastic bandage taping to ankle splinting, in terms of reducing ankle oedema and pain. They concluded that elastic taping was superior to ankle splinting in reducing ankle oedema in the management of acute ankle sprain. The authors did not provide any physiological reasons for why the action for elastic taping was considered superior to splinting.

There are a number of factors that need to be considered when drawing a comparison to the clinical trials discussed; these include different taping techniques, sample sizes in each of the studies, ratio of males to females as well as number of groups and control groups in the study.

2.6.2.5. Studies on Kinesio™ tape

Studies on Kinesio™ tape have reported mixed results when assessing the proposed benefits of the tape. Hendrick (2010) assessed the role of Kinesio™ tape compared to an ASO™ ankle brace in the recovery of a Grade One lateral ankle sprain. She found that there was no significant difference between the two groups in terms of pain and most physical activity, apart from the single leg squat test in which the brace group was able to do more single leg squats when assessed at different time intervals. Bicici et al. (2012) investigated the effect of different tapes on functional performance in basketball players with CAIS and found no significant changes in results between the Kinesio™ tape group and athletic tape group when measuring dynamic balance, although improvements were observed in the Kinesio™ tape group when measuring static balance but the reasons for these were not explained.

Acar et al. (2015) found no differences in the Karlsson scores, pain, swelling and the need for additional analgesics between the elastic bandage and Kinesio™ tape groups in the management of acute ankle sprains in an emergency department setting. Jackson et al. (2016), however, reported positive results in terms of balance using Kinesio™ tape in individuals with CAIS. The Balance Error Scoring System (BESS) was used to assess balance at 48 and 72 hours following tape application. The results of the Kinesio™ tape group and a placebo group (which received no tape) were compared; improved balance in the Kinesio™ tape group was observed at 48 hours which was sustained at 72 hours even though the tape had been removed. This indicates that the application of Kinesio™ tape was effective in the management of balance in individuals with CAIS. The authors utilised the "closed loop" theory proposed by Adams (1971) to explain the results. This states that a particular stimulus (in this case the tape) applied to an area on the body initiates an immediate afferent feedback from the affected area. Jackson et al. (2016) further reported that the longer the tape is left on the skin, the greater its effect on proprioception and that the tape needs to be on for a period of at least 72 hours for it to show significant improvements in balance. Earlier, Simon et al. (2014) reported significant improvements in proprioception in individuals with CAIS when the tape was applied for a period of 72 hours. They hypothesised that this occurs through the mechanism of 'perceptual trace' in which the central nervous system creates a new perceptual trace in response to the stimulus it receives; in this case the tape increased afferent stimulation creating a new 'perceptual trace'. It was proposed that Kinesio™ tape stimulated the appropriate proprioceptors in the skin, ligaments, tendons and joint capsule in the ankle region and this increased afferent input into the central nervous system allowed individuals to precisely reproduce force sense. Simon et al. (2014) suggested the clinical implications of their study were to improve proprioceptive awareness where it is reduced as a result of injury by the stimulation of the proprioceptors; it is this improvement in proprioceptive awareness that may possibly reduce the risk of recurring injury.

Although the studies mentioned demonstrate varied results when assessing the proposed benefits of Kinesio™ tape, to date, there is paucity in the literature to determine if the method of application of the Kinesio™ tape or the physical properties of the tape itself is responsible for its reported effectiveness. This study will independently test the efficacy of Kinesio™ tape in terms of reducing pain, increasing movement and improving proprioception with CAIS as the primary injury.

2.6.3. NON-CONSERVATIVE MANAGEMENT

Periarticular hyaluronic acid injections have been of benefit to individuals with acute ankle sprains compared to placebo injections. The benefits include a quicker return to sporting activity and a reduced risk of systemic adverse effects as a result of it being injected locally. One disadvantage of this treatment is the considerable cost which makes it an unfavourable option in the management of ankle sprains and CAIS (Seah and Mani-Babu, 2010).

The decision for performing surgery in individuals with severe ankle sprains should be considered very carefully as the majority of ankle sprains are adequately managed through a conservative approach (Petersen et al., 2013). It has been recommended that surgery only be advised in individuals with CAIS when persistent symptomatic mechanical instability is present or they have failed to respond to adequate functional rehabilitation (Tiemstra, 2012; Petersen et al., 2013). Research has shown that there are certain trends that follow those individuals who underwent surgery compared to those who received conservative care for their ankle injury such as an increase in stiffness of the ankle, prolonged recovery time as well as impairment in mobility, making non-conservative management the treatment of choice. Therefore, it is proposed that surgery only be considered in those individuals who have failed to respond to conservative care so as to preserve long-term optimal function of the ankle (Chan et al., 2011; Tiemstra, 2012). It was found that early functional rehabilitation following surgery showed a faster return to work and sporting activity compared to immobility following surgery (Seah and Mani-Babu, 2010).

2.7. ASSESSING PROPRIOCEPTION WITH THE BIODEX BIOSWAY PORTABLE BALANCE SYSTEM

Activities of daily living such as walking, running and even just standing rely strongly on the need for an optimally functioning proprioceptive system (Lee and Lin, 2008). Proprioception can be evaluated by assessing the ability of the joint to replicate a particular angle (joint position sense), detect movement (kinesthesia) and precisely generate a particular force (force sense) (Riemann and Lephart, 2002; Kim and Choi, 2015).

There are various methods of assessing proprioception ranging from questionnaires to electronic devices such as an electrogoniometer and force platforms (Kim and Choi, 2015). The Biodex Biosway portable balance system (BBPBS) is a versatile device, providing consistent objective measurements of an individual’s neuromuscular control and their ability to maintain their centre of gravity (COG) on both stable (static) and unstable (dynamic) surfaces. This is important as a deficit in neuromuscular control may alter the ability of the body to maintain its COG which may eventually lead to recurring injury or falls (Biodex Medical Systems, 2008). The standard assessment for differentiating proprioceptive problems due to visual, vestibular or somatosensory disturbances is the Clinical Test for Sensory Integration and Balance (CTSIB). The literature states that the CTSIB test is most effective in identifying individuals with balance deficits and their resultant compensation patterns by assessing the sway index and stability index (Biodex Medical Systems, 2008). Validity and reliability tests of the CTSIB were conducted by Cohen et al. (1993) who investigated balance in neurologically asymptomatic adults and in those with diagnosed vestibular disorders. They reported a significant impairment in performance in individuals with vestibular disorders. Older adults and individuals with vestibular disorders also showed a wider variation in results compared to younger and middle aged adults.

The CTSIB consists of six test conditions:

- Condition One: Eyes open firm surface
- Condition Two: Eyes closed firm surface
- Condition Three: Visual conflict on firm surface
- Condition Four: Eyes open on a dynamic surface
- Condition Five: Eyes closed on a dynamic surface
- Condition Six: Visual conflict on a dynamic surface

The modified CTSIB (m-CTSIB) was pertinent to this study; this eliminates two of the six conditions mentioned above. The two eliminated test conditions are associated with visual conflict on a static and dynamic surface. These test conditions are usually omitted from the m-CTSIB as they require specialised glasses which provide a transparent warped image. The (m-CTSIB) uses four test settings to determine the contribution of visual, vestibular and somatosensory inputs. These include eyes opened on a firm surface (EOFiS), eyes closed on a firm surface (ECFiS), eyes open on a foam surface (EOFoS) and eyes closed on a foam surface (ECFoS) (**Table 2.11**) (Biodex Medical Systems, 2008).

Table 2.11 Integration of different senses during the m-CTSIB using the BBPBS

Condition	Integration of senses
1- Eyes open on a firm surface	Incorporates visual, vestibular and somatosensory inputs.
2- Eyes closed on a firm surface	Eliminates visual input to evaluate vestibular and somatosensory inputs.
3- Eyes open on a foam surface	Evaluates somatosensory interaction with visual input.
4- Eyes closed on foam surface	Evaluate somatosensory interaction with vestibular input.

Data summarised from Biodex Medical Systems (2008)

The m-CTSIB measures stability index and sway index. The stability index may be defined as the participants sway angle and direction from the centre. The standard deviation of the stability index records how much the participant has swayed; this is known as the sway index. The m-CTSIB normal sway index range is evaluated on the BBPBS and is listed in **Table 2.12**.

Table 2.12 BBPBS normal sway index ranges for m-CTSIB

Condition	Sway index
Condition 1: Eyes Open firm surface	0.21-0.48
Condition 2: Eyes closed firm surface	0.48-0.99
Condition 3: Eyes Open foam surface	0.38-0.71
Condition 4: Eyes Closed foam surface	1.07-2.22
If the participant is unable to complete a test	“Fell”

Data summarised from Biodex Medical Systems (2008)

2.8. THE EFFECT OF BODY MASS INDEX ON BALANCE

Body mass index (BMI) may be calculated by taking an individual’s weight and dividing it by their height squared (Flegal et al., 2014). The different BMI categories include underweight (individuals with a BMI under 18.5 $kg.m^{-2}$), normal weight (those with a BMI of between 18.5 and 24.9 $kg.m^{-2}$), overweight (individuals with a BMI between 25.0 and 29.9 $kg.m^{-2}$) and obese (those who have a BMI which exceeds 30 $kg.m^{-2}$).

Balance plays an integral part in performing activities of daily living and is maintained through the coordination of muscular kinetic chains. The coordination of these muscular kinetic chains ensure dynamic balance and muscular control are maintained during activity (Greve et al., 2007). Greve et al. (2007) reported that an increased BMI with concomitant low muscle mass are high risk factors for reduced balance which may result in falls. They explain that these falls occur through impaired muscular control and dynamic balance deficits found in obese individuals which result in biomechanical failure. Gribble et al. (2016) investigated the effects of certain clinical tests on balance and the effects of BMI on the prevalence of lateral ankle sprains in football players. They reported poor balance and a significantly higher BMI in the athletes who had suffered previous ankle sprains compared to those who were injury free.

2.9. CONCLUSION

Inversion ankle sprains are the most common type of ankle injuries (Ferran and Maffulli, 2006). Inversion ankle sprains involve excessive plantarflexion and inversion of the foot with some degree of internal rotation of the talus (Fong et al., 2012).Approximately 20-30% of all acute ankle sprains will progress to CAIS (Jerosch and Bischof, 1996; van Rijn et al., 2008). Individuals who suffer from CAIS often complain of pain, swelling along the ankle joint line and a sense of apprehension when walking on an uneven surface (Chan et al., 2011; Hiller et al., 2011). The management of ankle sprains and CAIS involve both conservative and non-conservative approaches (Acar et al., 2015). Most cases of ankle sprains and CAIS are managed effectively with conservative management, with strapping being one of the most popular treatment methods (van den Bekerom et al., 2012; Acar et al., 2015). The proposed benefit of strapping is to reduce excessive motion of the affected joint, as well as provide stability to the affected area (Bandyopadhyay and Mahapatra, 2012). Due to the various types of tapes available and the wide variety of taping methods, it is unclear as to which tape and which method are most effective in the management of ankle injuries.

Kinesio™ tape made its international debut approximately ten years ago, and is gaining popularity in the treatment of various conditions (Kinesiotaping® Association International, 2011). The results of several studies (**Table 2.10**) provide some evidence on the effectiveness of Kinesio™ tape in the management of CAIS. This study will assess the efficacy of Kinesio™ tape in terms of reducing pain, increasing movement as well as improving proprioception, using CAIS as the test condition. The outcomes of this study aim to contribute to the treatment protocol involved in CAIS by highlighting the advantages and disadvantages of the different types of tapes used and evaluating the properties of the actual tape versus the method of application itself (Halseth et al., 2004).

CHAPTER THREE

MATERIALS AND METHODS

3.1. STUDY DESIGN

This study paradigm was quantitative with an investigative design into the effects of three types of strapping on chronic ankle instability syndrome.

3.2. STUDY LOCATION

This study was conducted at the Durban University of Technology's (DUT) Chiropractic Day Clinic (CDC).

3.3. APPROVAL TO CONDUCT THE STUDY AND PARTICIPANT CONFIDENTIALITY

Permission to conduct this clinical trial was obtained from DUT's Institutional Research Ethics Committee (IREC) to ensure the study followed the ethical guidelines set out for research on humans (IREC number: 086/14) (**Appendix A**).

Participant confidentiality was maintained at all times over the study period and all participants were required to sign an informed consent form at the initial visit. Data collection sheets (**Appendix B**) were used to document all the relevant details and these were strictly controlled by the use of codes which ensured that no personal information such as names were disclosed in this study. It was also made clear to each participant prior to commencement of the study that they would be free to leave the study at any point should they wish to do so without prejudice.

3.4. PARTICIPANT POPULATION AND RECRUITMENT OF PARTICIPANTS

The population of this study included individuals with CAIS who resided in the eThekwini Municipality and surrounding areas. It was, however, not possible to ascertain the size of this population.

Participants were recruited via advertisements in the form of flyers (**Appendix C**), which were placed on the notice boards at DUT, local clinics and shopping malls as well as in local newspapers. Participants were also recruited via word of mouth at sporting events (e.g. athletic events). Permission was sought from the relevant authorities before any advertisements were used. All prospective participants who were interested in participating in the study were required to contact the researcher telephonically to determine if they were eligible to participate in the study. A series of screening questions were asked during the telephonic interview (**Table 3.1**).

Table 3.1 Questions asked during telephonic screening to determine participant eligibility for the study

Screening questions		Expected response
1.	Are you between the ages of 18 and 45 years of age?	Yes
2.	Have you had a history of at least one or more acute ankle sprains previously which has left you with pain, swelling and a feeling of weakness in the ankle?	Yes
3.	Do you have any history of arthritis such as rheumatoid arthritis or SLE?	No
4.	Have you ever suffered an ankle sprain which required you to be in a cast for a period of time or have undergone surgery?	No
5.	Do you have any foot abnormalities i.e. a flat foot or a high arch?	No
6.	Do you have any broken skin in the ankle region?	No
7.	Do you have any circulatory problems i.e. do you suffer from feet that are always swollen or cold?	No
8.	Do you have any skin allergies (e.g. eczema or psoriasis)?	No
9.	If you have been strapped or taped before for any condition, did you have any skin reaction to the tape?	No

SLE = Systemic lupus erythematosus

3.5. SAMPLING METHOD AND SAMPLE SIZE

The sampling method that was utilised in this study was convenience sampling (Johnson and Christensen, 2012). The sample size was 45 individuals divided into three groups of 15 participants each. This sample size was based on the study by Pellow and Brantingham (2001) who used a sample size of 30 with 15 participants in each group. Financial, time and human resources constraints also contributed to the final sample size selected.

3.6. INCLUSION AND EXCLUSION CRITERIA

3.6.1. INCLUSION CRITERIA

1. Participants had to have been between the ages of 18 and 45 years (Pellow and Brantingham, 2001).This age group was selected so as to exclude younger individuals in which growth plates of the tibia and fibula have not completely fused (Crowder and Austin, 2005). This age group also excluded older individuals with degenerative changes in the ankle, changes in ligamentous composition as well as a loss of proprioception predisposing them to falls (Loeser, 2010).
2. Participants with no history of inflammatory joint disease such as rheumatoid arthritis or SLE.
3. Participants may not have been on any pain medication, anti-inflammatory medication or any medication for the past month prior to participating in the study.
4. Participants had to have met the diagnostic criteria for CAIS which included a history of at least one severe ankle sprain which has resulted in the sensation of the ankle giving way, recurring sprains and/or the feeling of instability (Gribble et al., 2013).

3.6.2. EXCLUSION CRITERIA

1. Participants with hypermobility of the mortice joint. This was determined by an orthopaedic examination of the foot and ankle (**Appendix D**).
2. A Grade Three pes planus which was determined using the Feiss line (Nilsson et al., 2012).
3. Skin ulcers located in the region of the involved foot and ankle.
4. Participants who reported a history of allergic reactions to tape or strapping.
5. A participant with a BMI exceeding 25.0 $kg.m^{-2}$, as a higher BMI has been reported to have a negative effect on dynamic balance (Greve et al., 2007).

3.7. OUTCOME MEASURES

The subjective assessment of pain rating was determined using the Numerical Pain Rating Scale (NRS-101).Jensen et al. (1986) found the NRS-101 to be the most reliable test when compared to five other tests in the evaluation of subjective pain rating. These five tests included the visual analogue scale, an eleven-point box scale, a six-point behavioural rating scale, a four-point verbal rating scale and a five-point verbal rating scale.

The objective assessments of pain threshold, range of motion and proprioception were obtained using the analogue algometer, goniometer and Biodex Biosway portable balance system (BBPBS) respectively.The validity and reliability of the analogue algometer was tested by Fischer (1987), who reported that the algometer is useful in quantifying pain intensity in soft tissues. Gajdosik and Bohannon (1987) reported that the validity and reliability of measuring the range of motion by a goniometer may be a challenge due to variance in study designs. However, they explained that the full circle goniometer is the most reliable measurement tool when assessing extremity range of motion due to its accuracy in measuring a circle through its degree intervals or its comparison to geometric angles. The full circle goniometer was used in this study. The validity and reliability of the BBPBS system was determined by Sherafat et al. (2013) who observed that postural control is accurately measured through the sway indices on both static and dynamic surfaces. All measurements were assessed and recorded on a data collection sheet (**Appendix B**).

3.8. PROCEDURE

The study took place in four stages:

3.8.1. STAGE ONE

All prospective participants were pre-screened telephonically (**Table 3.1**). If the prospective participant was eligible, he/she was invited for a consultation at the DUT CDC.

3.8.2. STAGE TWO

On arriving at the DUT CDC, the prospective participant was given a verbal explanation of the research procedure and a letter of information (**Appendix E)** and informed consent (**Appendix F**) to read. He/she was then given an opportunity to ask any questions regarding the research prior to giving his/her consent in writing. Once informed consent was obtained, each participant was then asked to remove their shoes and henna stain markers were applied on the affected foot to ensure goniometer measurements were taken at the exact same point at each visit. Four henna markers were applied to the foot viz. one on the lateral malleolus of the affected foot, one in the midline between the fibula head and lateral malleolus, one between the medial and lateral malleolus and the last one in the midline between the tibial tuberosity and the midline between the medial and lateral malleolus; these markers were applied according to the landmarks described by Norkin and White (2009). A case history (**Appendix G**), physical examination (**Appendix H**) as well as a foot and ankle orthopaedic examination (**Appendix D**) was then completed.

Participants were then randomly allocated into one of three groups using simple random sampling (by randomly drawing a piece of paper out of a hat) (Rossi et al., 2013).

- Group 1 received strapping with rigid tape applied using the Kinesio™ tape functional correction application
- Group 2 received strapping with elastic tape applied using the Kinesio™ tape functional correction application
- Group 3 received strapping with Kinesio™ tape applied using the Kinesio™ tape functional correction application

Baseline assessments of pain rating, pain threshold, foot and ankle range of motion and proprioception were then documented in the data sheet (**Appendix B**). The hair in the relevant area of the ankle was then shaved.

The tape was then applied using the Kinesio™ tape functional correction application. This method is described as the application of a single strip of Kinesio™ tape, referred to as an "I-strip" anchored on the plantar surface of the medial aspect of the affected foot and brought up proximally towards the middle of the fibula where it created the second anchor, the rigid and elastic tape were applied using the same method as described for Kinesio™ tape. At this point, if any participant complained of any irritation to the skin, the tape was removed immediately and they were excluded from the study and were advised to promptly seek medical care. If the participant did not suffer any immediate adverse reactions to the tape a follow-up appointment was scheduled for two to three days later.

3.8.3. STAGE THREE

At the first follow-up visit, the tape was removed by the researcher and the participant was reassessed and another set of subjective pain rating and objective (pain threshold, foot and ankle range of motion and proprioception) data were recorded on data sheet (**Appendix B**). Following this, new tape was applied using the method described above. The final follow-up consultation was scheduled for three to four days later.

3.8.4. STAGE FOUR

At the final consultation, the tape was removed, the procedure was repeated as described for Stage Three with the exception that no tape was applied.

The reason for the time interval of two to three days following the first consultation and three to four days following the second consultation is that Kinesio™ tape is reportedly most effective within the first three to five days following application; this is the approximate time period for new skin cells to generate, thereby affecting the tape's adhesive ability (KT Tape, 2011).

3.8.5. SUMMARY OF RESEARCH PROCEDURE

Participants were recruited via advertisements and word of mouth.

↓

Prospective participants were telephonically screened (**Table 3.1**).

↓

Eligible participants were invited for a consultation at the DUT CDC.

↓

Participants were given a verbal explanation of the research procedure before being handed a letter of information and informed consent to read and sign.

↓

Once informed consent was obtained, henna dots were applied on the affected ankle and participants then underwent a case history, physical examination as well as a foot and ankle orthopaedic examination.

↓

Participants were then randomly allocated into one of three groups (i.e. rigid, elastic and Kinesio groups). Baseline measurements of subjective pain rating, pain threshold, range of motion and proprioception were assessed and documented in the data sheet and the skin in the region of the involved ankle was prepared prior to application of the tape.

↓

The relevant tape was applied using the Kinesio™ tape functional correction application and if the participant did not suffer any immediate adverse reactions to the tape, a follow-up consultation was made for two to three days later.

↓

At the first follow-up consultation, the tape was removed and the participant was reassessed and another set of data was recorded. Following this, the tape was reapplied as described above and the final follow-up consultation was scheduled for three to four days later.

↓

At the final follow-up consultation, the tape was removed, the procedure was repeated as described above with the exception that the tape was not reapplied.

3.9. ETHICAL CONSIDERATIONS

The medical ethics principals of beneficence, non-maleficence and justice were accounted for in this clinical trial. Beneficence is defined as the responsibility of the researcher to act in the best interest of the patient at all times, non-maleficence is the responsibility of the researcher to ensure there is no harm done to the patient. Justice is defined as ensuring that medical resources are fairly distributed between all patients (Oxford Concise Medical Dictionary, 2010).

3.9.1. ADVERSE REACTION TO TAPING

Strapping techniques are non-invasive and were applied within the safety procedure parameters, ensuring that no discomfort or restricted circulation to the affected area occurred. If a participant suffered any adverse reaction to the tape, they were requested to seek medical advice and were compensated with an amount of R250 towards their initial medical consultation.

3.9.2. PARTICIPANT CONFIDENTIALITY

To maintain participant confidentiality, names were not used on the data sheets; each participant was allocated a file number to identify them. The research data is kept in the patient's file at the DUT CDC and will remain in the file for a period of 15 years, after which it will be shredded.

3.9.3. INFORMED CONSENT

Informed consent (**Appendix F**) was obtained from each participant prior to commencement of the research study. Participants were not coerced into participating in the study and it was explained to them that they were free to leave the study at any point if they wished to do so without prejudice.

3.10. STATISTICAL ANALYSES

The statistical aspect of the research study focused mostly on descriptive statistics using cross-tabulation tables and bar graphs.The Kolmogorov test for normality indicated that most of the variables did not have a normal distribution pattern. Hence, non-parametric testing such as the Wilcoxon Signed Ranks Test and the Mann-Whitney tests were used for intra-group and inter-group analyses, respectively. The data was reduced and analysed using statistical software SPSS version 21.0 and the level of significance was set at 0.05 (Singh, 2016).

CHAPTER FOUR

RESULTS

4.1. SELECTED DEMOGRAPHICS OF THE PARTICIPANTS

A total of 45 individuals participated in this study. Participants were randomly allocated into one of three groups with 15 participants in each group. The number and percentage of males and females in each group and in total is shown in **Table 4.1**. The mean, median, standard deviation and range of the age and selected physical characteristics of the participants is tabulated in **Table 4.2**. The age range of the participants was 19 to 42 years. The BMI of all participants were within the normal limits not exceeding 25 $kg.m^{-2}$ (World Health Organization Global Data Base on Body Mass Index, 2016).

Table 4.1 The number (n) and percentage of males vs. females within each group and in total

Group	Values	Males	Females	Total
1	*n*	6	9	15
	Percentage	40.0%	60.0%	100.0%
2	*n*	8	7	15
	Percentage	53.3%	46.7%	100.0%
3	*n*	9	6	15
	Percentage	60.0%	40.0%	100.0%
Total	*n*	23	22	45
	Percentage	51.1%	48.9%	100.0%

Table 4.2 The mean, median, standard deviation and range of the age and selected physical characteristics of the participants

Group	Values	Age (yrs)	Height (m)	Weight (kg)	BMI ($kg.m^{-2}$)
1	*n*	15.0	15.0	15.0	15.0
	Mean	24.3	1.7	64.0	22.7
	Median	24.0	1.7	59.0	23.7
	Std dev	3.9	0.1	11.2	2.2
	Range	14.0	0.4	42.0	6.1
2	*n*	15.0	15.0	15.0	15.0
	Mean	23.6	1.6	60.5	22.8
	Median	22.0	1.7	58.0	23.9
	Std dev	4.1	0.1	9.0	2.4
	Range	15.0	0.3	28.0	6.3
3	*n*	15.0	15.0	15.0	15.0
	Mean	26.6	1.7	68.6	23.3
	Median	25.0	1.7	70.0	23.9

	Std dev	5.8	0.1	10.8	2.0
	Range	22.0	0.3	35.0	6.3
Total	*n*	45.0	45.0	45.0	45.0
	Mean	24.8	1.7	64.4	22.9
	Median	24.0	1.7	65.0	23.9
	Std dev	4.7	0.1	10.7	2.2
	Range	23.0	0.5	45.0	6.4

Yrs = years; m = meters; kg = kilograms; $kg.m^{-2}$ = kilogram per meter square; BMI = body mass index; std dev = standard deviation

4.2. SUBJECTIVE OUTCOME MEASURES

4.2.1. NUMERICAL PAIN RATING SCALE (NRS-101)

The subjective outcome measure was the Numerical Pain Rating Scale (NRS-101). The mean NRS-101 values for each group at each consultation are depicted graphically in **Figure 4.1**. The mean NRS-101 values were similar for each group at the respective consultations. An overall decrease in the mean NRS-101 values was observed in each of the three groups as the consultations increased.

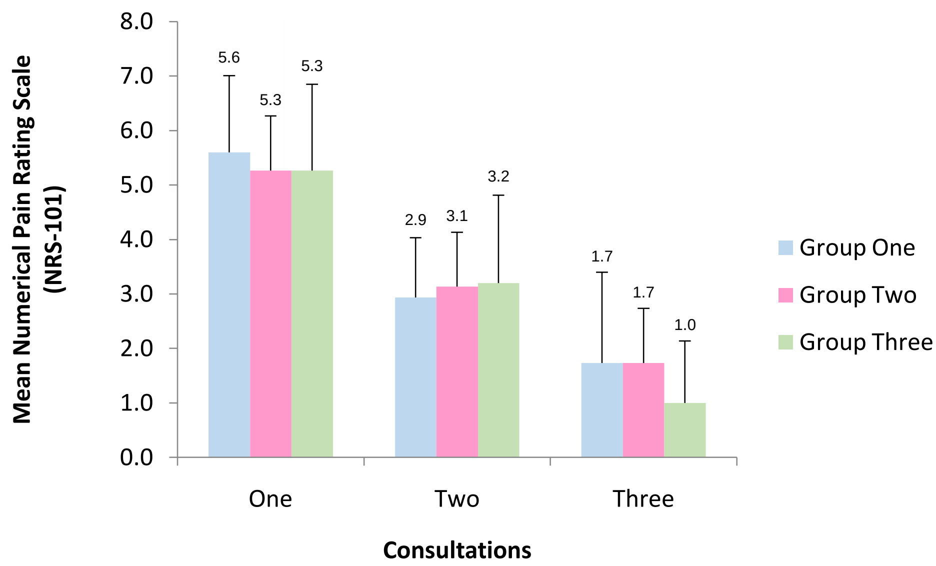


Figure 4.1 The mean (± SD) NRS-101 values for each group at each consultation

*The numbers above the standard deviation bars are the actual mean values

4.3. OBJECTIVE OUTCOME MEASURES

4.3.1. PAIN THRESHOLD

Pain threshold was assessed using an analogue algometer. The mean pain threshold in each group at each consult is shown in **Figure 4.2**. There was an increase in the pain threshold in all three groups as the consultations increased.

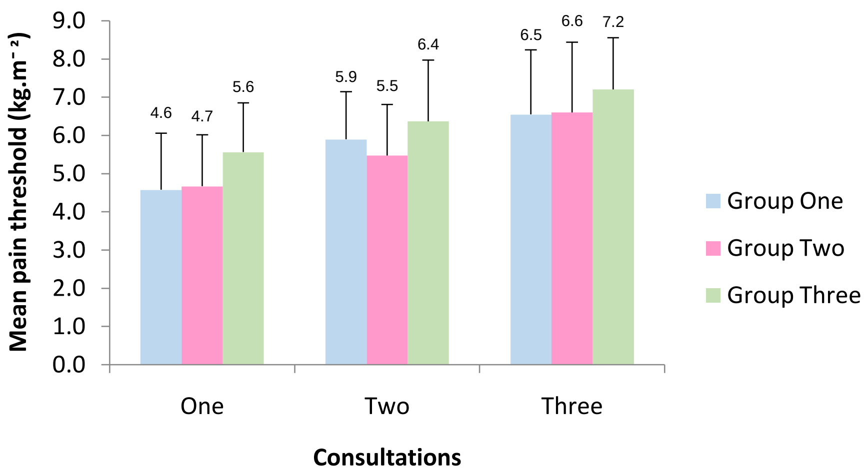


Figure 4.2 The mean (± SD) pain threshold values (kg.m^{-2}) for each group at each consultation

* The numbers above the standard deviation bars are the actual mean values

4.3.2. RANGE OF MOTION

Dorsiflexion, plantarflexion and inversion were the ranges of motion of the ankle that were evaluated in this study. The mean values of ankle dorsiflexion, plantarflexion and inversion are depicted graphically in **Figures 4.3**, **4.4** and **4.5**, respectively. An increase in ankle dorsiflexion, plantarflexion and inversion was seen in all three groups as the consultations increased.

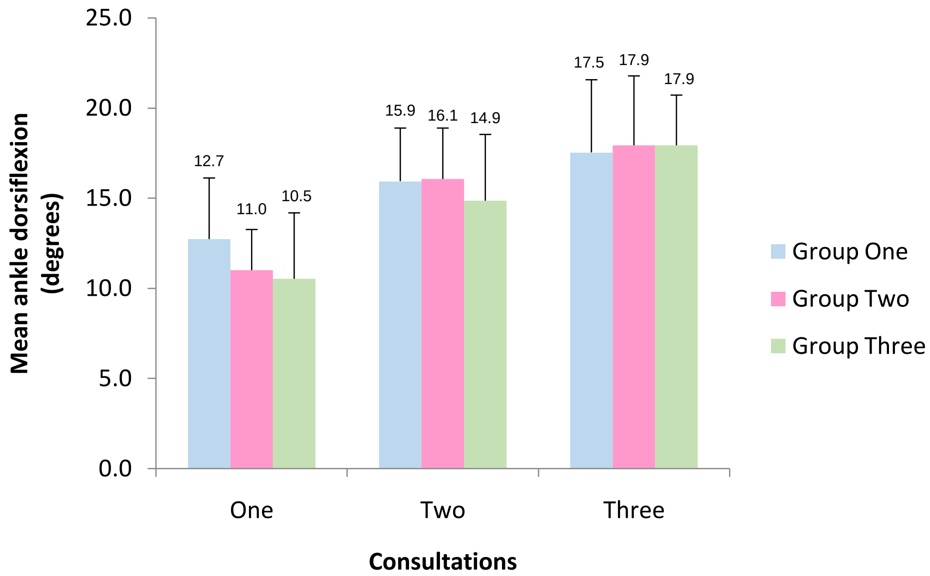


Figure 4.3 The mean (± SD) dorsiflexion values for each group at each consultation

* The numbers above the standard deviation bars are the actual mean values

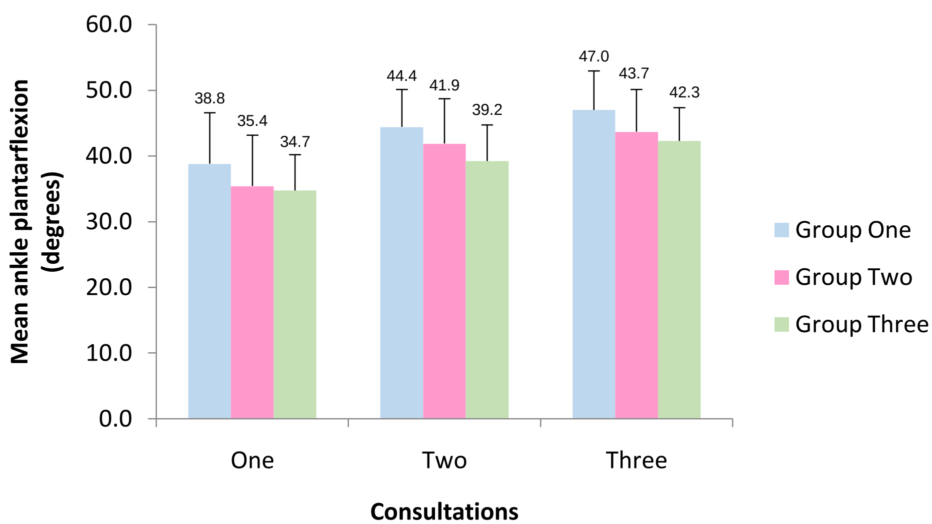


Figure 4.4 The mean (± SD) plantarflexion values for each group at each consultation

* The numbers above the standard deviation bars are the actual mean values

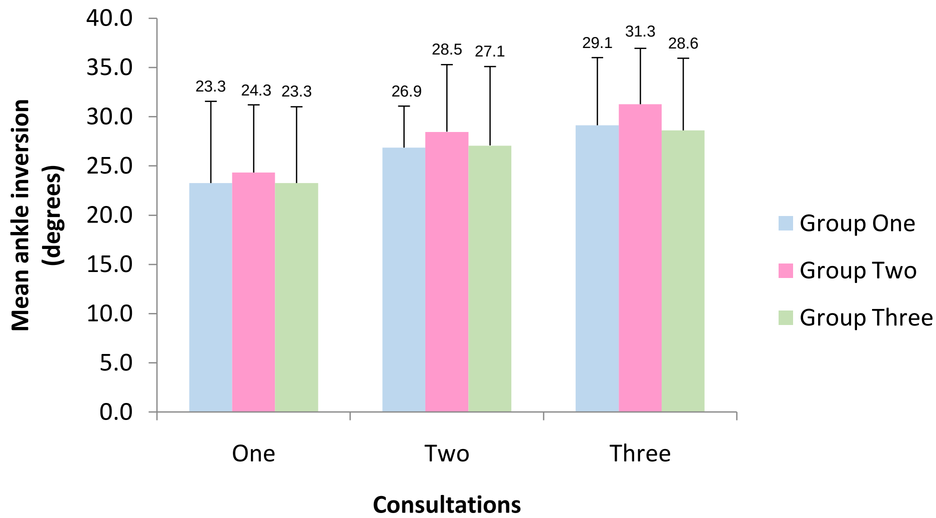
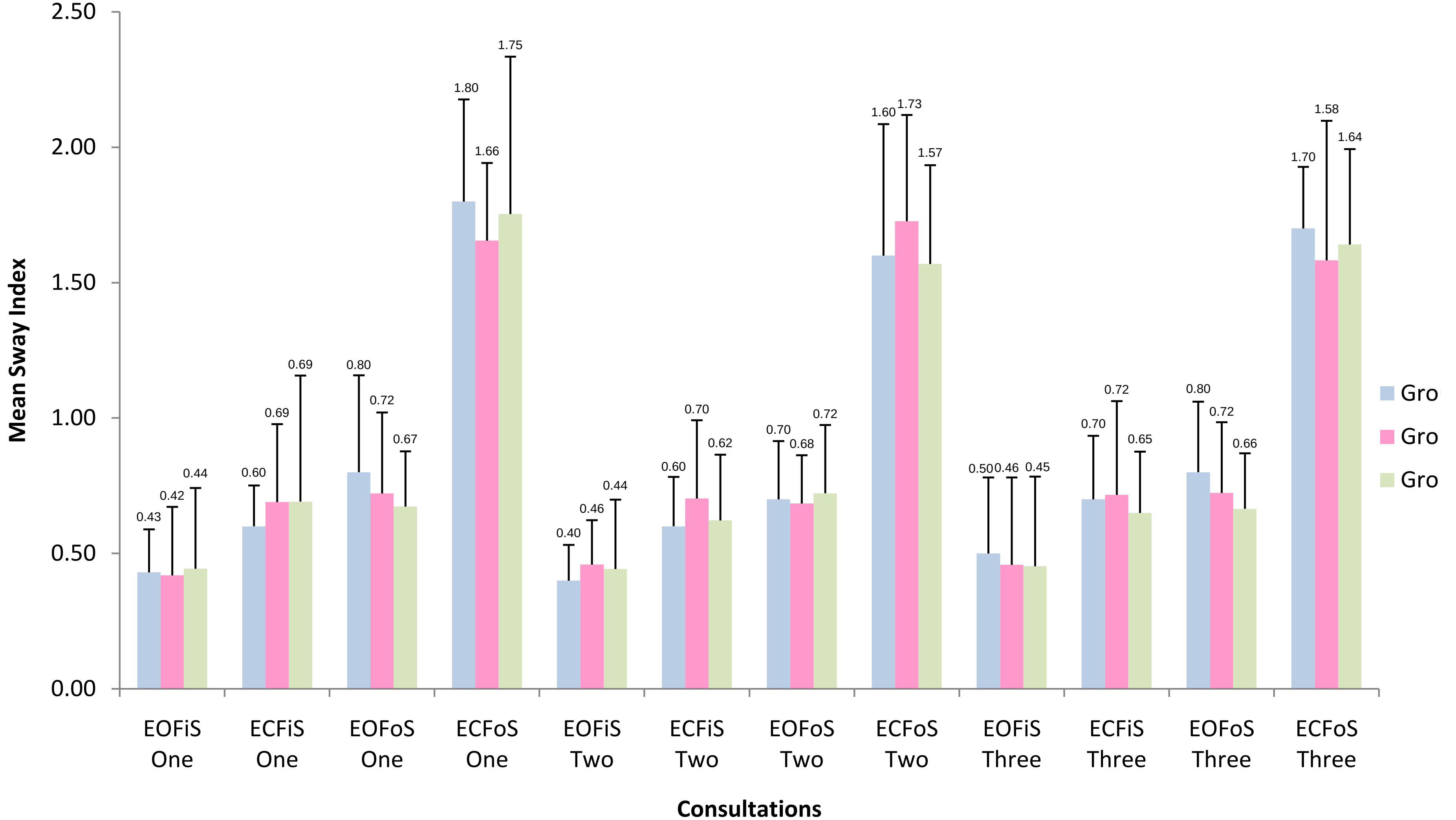


Figure 4.5 The mean (± SD) ankle inversion values for each group at each consultation

* The numbers above the standard deviation bars are the actual mean values

4.3.3. SWAY INDEX

The sway index was evaluated using the BBPBS and the test used to specifically measure the sway index was the m-CTSIB. The m-CTSIB is made up of four tests, with each test being performed for a maximum of 30 seconds; Test One is eyes open on a firm surface (EOFiS); Test Two is eyes closed on a firm surface (ECFiS); Test Three is eyes open on a foam surface (EOFoS) and Test Four is eyes closed foam surface (ECFoS). The mean sway index for all four tests at each consultation is shown in **Figure 4.6**. There was a slight increase in the mean EOFiS from Consultation One to Three in all three groups. There were slight increases in the mean ECFiS values between Consultation One and Three in Group One and all three consultations in Group Two. A decrease in the mean ECFiS value was observed in Group Three between Consultation One and Consultation Two followed by an increase between Consultation Two and Consultation Three. No change in the mean EOFoS value was observed from Consultation One to Three in Group Two and Group Three, however, Group One showed a slight decrease in ECFoS value between Consultation One and Two followed by a slight increase between Consultation Two and Three. There was a slight decrease in ECFoS in Groups One and Three at the second consultation. A slight increase in the ECFoS was observed in Group One, decrease in Group Two and no change in Group Three from Consultations Two to Three.



EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

Figure 4.6 The mean (± SD) sway index for each test in each group at each consultation

* The numbers above the standard deviation bars are the actual mean values

4.4. INTRA-GROUP ANALYSES

4.4.1. GROUP ONE OBJECTIVE MEASUREMENTS

Intra-group analyses of the objective outcome measures were conducted using the Wilcoxon Signed Ranks Test as shown in **Table 4.3**. For Group One, there was a significant difference ($p < 0.05$) in the mean pain threshold and ankle dorsiflexion values between each consultation and between the baseline and final assessment. For plantarflexion, there was a significant increase from Consultation One to Two and between Consultation One and Three. For inversion, there was a significant difference only between Consultation One and Three (the increase was significant) ($p < 0.05$). For the sway index, the only significant findings were for EOFoS and ECFoS between Consultation One and Two (the decreases were significant) ($p < 0.05$).

Table 4.3 The Wilcoxon Signed Ranks Test for pain threshold, ankle dorsiflexion, plantarflexion, inversion and sway index for Group One

Outcome measure	Z, mean and *p*-values	Consult One vs. Consult Two	Consult Two vs. Consult Three	Consult One vs. Consult Three
Pain threshold	Z score	-2.897	-2.107	-3.011
	Mean	5.3	6.2	5.6
	p value	0.004	0.035	0.003
Dorsiflexion	Z score	-3.310	-1.976	-3.143
	Mean	14.3	16.4	15.1
	p value	0.001	0.048	0.002
Plantarflexion	Z score	-3.331	-1.887	-3.425
	Mean	41.6	45.7	42.9
	p value	0.001	0.059	0.001
Inversion	Z score	-1.949	-1.446	-2.474
	Mean	25.1	28.0	26.2
	p value	0.051	0.148	0.013
BBPBS (EOFiS)	Z score	-0.171	-1.162	-0.710
	Mean	0.4	0.5	0.5
	p value	0.865	0.245	0.477
BBPBS (ECFiS)	Z score	-0.126	-.086	-0.796
	Mean	0.6	0.7	0.7
	p value	0.900	0.932	0.426
BBPBS (EOFoS)	Z score	-2.480	-1.068	-1.222
	Mean	0.8	0.8	0.8
	p value	0.013	0.286	0.222
BBPBS (ECFoS)	Z score	-1.988	-0.171	-1.363
	Mean	1.7	1.7	1.8
	p value	0.047	0.865	0.173

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.4.2. GROUP TWO OBJECTIVE MEASUREMENTS

The intra-group analyses for the objective outcome measures for Group Two are tabulated in **Table 4.4**. There was a significant increase ($p < 0.05$) in the mean pain threshold and ankle dorsiflexion values between each consultation and between the baseline and final assessment. For plantarflexion and inversion, a significant difference was observed only between Consultation One and Two and Consultation One and Three (the increase was significant) ($p < 0.05$). There were no significant differences in the sway index during all four tests ($p > 0.05$).

Table 4.4 The Wilcoxon Signed Ranks Test for pain threshold, ankle dorsiflexion, plantarflexion, inversion and sway index for Group Two

Outcome measure	Z, mean and *p*-values	Consult One vs. Consult Two	Consult Two vs. Consult Three	Consult One vs. Consult Three
Pain threshold	Z score	-2.502	-2.784	-3.124
	Mean	5.1	6.1	5.7
	p value	0.012	0.005	0.002
Dorsiflexion	Z score	-3.378	-2.335	-3.337
	Mean	13.6	17.0	14.5
	p value	0.001	0.020	0.001
Plantarflexion	Z score	-3.183	-0.114	-3.303
	Mean	38.7	42.8	39.6
	p value	0.001	0.909	0.001
Inversion	Z score	-2.799	-1.870	-2.958
	Mean	26.4	29.9	27.8
	p value	0.005	0.061	0.003
BBPBS (EOFiS)	Z score	-1.382	-0.824	-1.005
	Mean	0.5	0.5	0.5
	p value	0.167	0.410	0.315
BBPBS (ECFiS)	Z score	-0.345	-0.597	-0.199
	Mean	0.7	0.7	0.7
	p value	0.730	0.551	0.842
BBPBS (EOFoS)	Z score	-0.199	-0.256	0.000
	Mean	0.7	0.7	0.7
	p value	0.842	0.798	1.000
BBPBS (ECFoS)	Z score	-0.408	-1.819	-0.909
	Mean	1.7	1.7	1.7
	p value	0.683	0.069	0.363

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.4.3. GROUP THREE OBJECTIVE MEASUREMENTS

The intra-group analyses of Group Three objective outcome measures are shown in **Table 4.5**. There was a significant difference in the mean pain threshold and ankle dorsiflexion values between each consultation and between the baseline and final assessment; the increase in the pain threshold at each consultation was significant ($p < 0.05$). There were significant increases in plantarflexion and inversion ($p < 0.05$) between Consultation One and Two and between

Consultation One and Three. There were no significant improvements in the sway index during all four tests ($p > 0.05$).

Table 4.5 The Wilcoxon Signed Ranks Test for pain threshold, ankle dorsiflexion, plantarflexion, inversion and sway index for Group Three

Outcome measure	Z, mean and *p*-values	Consult One vs. Consult Two	Consult Two vs. Consult Three	Consult One vs. Consult Three
Pain threshold	Z score	-2.330	-2.422	-3.068
	Mean	6.0	6.8	6.4
	p value	0.020	0.015	0.002
Dorsiflexion	Z score	-3.430	-3.191	-3.423
	Mean	12.7	16.4	14.2
	p value	0.001	0.001	0.001
Plantarflexion	Z score	-3.168	-1.788	-2.868
	Mean	37.0	40.8	38.5
	p value	0.002	0.074	0.004
Inversion	Z score	-2.308	-0.562	-2.358
	Mean	25.2	27.9	26.0
	p value	0.021	0.574	0.018
BBPBS (EOFiS)	Z score	-0.028	-0.057	-0.171
	Mean	0.4	0.5	0.5
	p value	0.977	0.955	0.865
BBPBS (ECFiS)	Z score	-0.188	-0.569	-0.682
	Mean	0.7	0.7	0.7
	p value	0.851	0.570	0.495
BBPBS (EOFoS)	Z score	-0.142	-1.138	-0.738
	Mean	0.7	0.7	0.7
	p value	0.887	0.255	0.460
BBPBS (ECFoS)	Z score	-0.909	-0.682	-0.454
	Mean	1.7	1.6	1.7
	p value	0.363	0.495	0.650

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.4.4. GROUPS ONE, TWO AND THREE SUBJECTIVE MEASUREMENTS

The intra-group analyses of the subjective outcome measures for Groups One, Two and Three were conducted using the Wilcoxon Signed Ranks Test (**Table 4.6**). All three groups demonstrated a significant difference in pain rating across each consult and between the baseline and final assessments (the decrease was significant) ($p < 0.05$).

Table 4.6 The Wilcoxon Signed Ranks Test for pain rating for Groups One, Two and Three between each consultation

Outcome measure	**Z, mean and *p*-values**	**Consult One vs. Consult Two**	**Consult Two vs. Consult Three**	**Consult One vs. Consult Three**
Group One	Z score	-3.450	-2.005	-3.311
NRS-101	Mean	4.3	2.3	3.7
	p value	0.001	0.045	0.001
Group Two	Z score	-3.446	-2.710	-3.438
NRS-101	Mean	4.2	2.4	3.5
	p value	0.001	0.007	0.001
Group Three	Z score	-3.336	-3.346	-3.431
NRS-101	Mean	4.3	2.1	3.2
	p value	0.001	0.001	0.001

NRS-101 = Numerical pain rating scale

4.5. INTER-GROUP ANALYSES

4.5.1. OBJECTIVE OUTCOMES MEASURED AT CONSULTATION ONE

The inter-group analyses of objective outcome measures conducted using the Mann-Whitney test for Consultation One is shown in **Table 4.7**. There was a significant difference ($p < 0.05$) in pain threshold between Groups Two and Three only. There were no statistically significant differences in the range of motion and sway index between Groups One and Two, Two and Three and One and Three ($p > 0.05$).

Table 4.7 The objective outcome measurements of Consultation One between each group

Outcome measure	Mann-Whitney, Z, mean and *p*-values	Group One vs. Group Two	Group Two vs. Group Three	Group One vs. Group Three
Pain threshold	Mann-Whitney	108.000	63.000	76.000
	Z score	-0.187	-2.055	-1.515
	Mean	4.7	5.2	5.1
	p value	0.852	0.040	0.130
Dorsiflexion	Mann-Whitney	77.000	111.000	75.000
	Z score	-1.487	-0.063	-1.568
	Mean	11.9	10.8	11.6
	p value	0.137	0.950	0.117
Plantarflexion	Mann-Whitney	85.500	105.500	69.000
	Z score	-1.122	-0.292	-1.813
	Mean	37.1	35.1	36.8
	p value	0.262	0.770	0.070
Inversion	Mann-Whitney	99.000	95.000	112.000
	Z score	-0.563	-0.730	-0.021
	Mean	23.8	23.8	23.3
	p value	0.573	0.466	0.983
BBPBS (EOFiS)	Mann-Whitney	92.500	109.500	95.000
	Z score	-0.830	-0.124	-0.726
	Mean	0.4	0.4	0.4
	p value	0.406	0.901	0.468
BBPBS (ECFiS)	Mann-Whitney	109.000	98.000	92.000
	Z score	-0.145	-0.602	-0.851
	Mean	0.7	0.7	0.7
	p value	0.884	0.547	0.395
BBPBS (EOFoS)	Mann-Whitney	77.000	106.500	66.500
	Z score	-1.474	-0.249	-1.910
	Mean	0.8	0.7	0.8
	p value	0.141	0.803	0.056
BBPBS (ECFoS)	Mann-Whitney	88.000	103.000	103.000
	Z score	-1.017	-0.394	-0.394
	Mean	1.8	1.8	1.8
	p value	0.309	0.694	0.693

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.5.2. OBJECTIVE OUTCOMES MEASURED AT CONSULTATION TWO

The inter-group analyses of the objective outcome measures for Consultation Two are shown in **Table 4.8**. There was a significant difference ($p < 0.05$) in ankle plantarflexion between Groups One and Three only. There were no statistically significant differences in the pain threshold, ankle dorsiflexion, ankle inversion or sway index between Groups One and Two, Two and Three and One and Three ($p > 0.05$).

Table 4.8 The objective outcome measurements of Consultation Two between each group

Outcome measure	Mann-Whitney, Z, mean and *p*-values	Group One vs. Group Two	Group Two vs. Group Three	Group One vs. Group Three
Pain threshold	Mann-Whitney	97.000	74.000	91.000
	Z score	-0.644	-1.598	-0.894
	Mean	5.7	6.0	6.2
	p value	0.520	0.110	0.371
Dorsiflexion	Mann-Whitney	110.500	93.000	95.500
	Z score	-0.085	-0.824	-0.716
	Mean	16.0	15.5	15.4
	p value	0.933	0.410	0.474
Plantarflexion	Mann-Whitney	86.500	88.000	57.500
	Z score	-1.086	-1.020	-2.300
	Mean	43.2	40.1	41.8
	p value	0.278	0.308	0.021
Inversion	Mann-Whitney	99.000	103.500	108.000
	Z score	-0.563	-0.376	-0.188
	Mean	27.7	27.8	27.0
	p value	0.573	0.707	0.851
BBPBS (EOFiS)	Mann-Whitney	88.000	95.000	110.500
	Z score	-1.017	-0.726	-0.083
	Mean	0.5	0.5	0.4
	p value	0.309	0.468	0.934
BBPBS (ECFiS)	Mann-Whitney	97.000	95.000	103.000
	Z score	-0.643	-0.726	-0.394
	Mean	0.7	0.7	0.6
	p value	0.520	0.468	0.693
BBPBS (EOFoS)	Mann-Whitney	105.000	109.500	105.000
	Z score	-0.311	-0.125	-0.311
	Mean	0.7	0.7	0.7
	p value	0.756	0.901	0.756
BBPBS (ECFoS)	Mann-Whitney	94.000	93.000	103.500
	Z score	-0.767	-0.809	-0.373
	Mean	1.7	1.7	1.6
	p value	0.443	0.418	0.709

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.5.3. OBJECTIVE OUTCOMES MEASURED AT CONSULTATION THREE

The inter-group analyses of the objective outcome measures at Consultation Three are shown in **Table 4.9**. There was a significant difference ($p < 0.05$) in ankle plantarflexion between Group One and Three only. There were no statistically significant differences in the pain threshold, ankle dorsiflexion, ankle inversion or sway index between Groups One and Two, Two and Three or One and Three ($p > 0.05$).

Table 4.9 The objective outcome measurements of Consultation Three between each group

Outcome measure	Mann-Whitney, Z, mean and *p*-values	Group One vs. Group Two	Group Two vs. Group Three	Group One vs. Group Three
Pain threshold	Mann-Whitney	111.500	86.500	80.500
	Z score	-0.042	-1.079	-1.328
	Mean	6.6	6.9	6.9
	p value	0.967	0.281	0.184
Dorsiflexion	Mann-Whitney	108.000	104.500	104.500
	Z score	-0.189	-0.343	-0.341
	Mean	17.7	17.9	17.7
	p value	0.850	0.732	0.733
Plantarflexion	Mann-Whitney	81.500	97.500	61.000
	Z score	-1.296	-0.632	-2.166
	Mean	45.5	43.0	44.7
	p value	0.195	0.528	0.030
Inversion	Mann-Whitney	95.500	92.500	109.500
	Z score	-0.709	-0.834	-0.125
	Mean	30.2	30.0	28.9
	p value	0.478	0.404	0.900
BBPBS (EOFiS)	Mann-Whitney	101.000	108.500	95.000
	Z score	-0.478	-0.166	-0.726
	Mean	0.5	0.5	0.5
	p value	0.633	0.868	0.468
BBPBS (ECFiS)	Mann-Whitney	110.000	106.000	110.000
	Z score	-0.104	-0.270	-0.104
	Mean	0.7	0.7	0.7
	p value	0.917	0.787	0.917
BBPBS (EOFoS)	Mann-Whitney	98.000	98.500	92.500
	Z score	-0.602	-0.581	-0.830
	Mean	0.8	0.7	0.8
	p value	0.547	0.561	0.407
BBPBS (ECFoS)	Mann-Whitney	93.000	95.000	104.500
	Z score	-0.809	-0.726	-0.332
	Mean	1.7	1.6	1.7
	p value	0.419	0.468	0.740

EOFiS = eyes open firm surface; ECFiS = eyes closed firm surface; EOFoS = eyes open foam surface; ECFoS = eyes closed foam surface

4.5.4. SUBJECTIVE OUTCOMES MEASURED AT CONSULTATIONS ONE, TWO AND THREE

The inter-group analyses of subjective outcome measures at Consultations One, Two and Three are tabulated in **Table 4.10**. There were no significant changes in pain rating in all three groups' at all three consultations ($p > 0.05$).

Table 4.10 The subjective outcome measurements of Consultations One, Two and Three between each group

Outcome measure	Mann-Whitney, Z, mean and *p*-values	Group One vs. Group Two	Group Two vs. Group Three	Group One vs. Group Three
Consultation One	Mann-Whitney	90.000	111.000	93.000
NRS-101	Z score	-0.966	-0.064	-0.830
	Mean	5.5	5.3	5.5
	p value	0.334	0.949	0.406
Consultation Two	Mann-Whitney	103.000	110.000	102.000
NRS-101	Z score	-0.407	-0.106	-0.445
	Mean	3.0	3.2	3.1
	p value	0.684	0.915	0.656
Consultation Three	Mann-Whitney	108.500	77.000	84.000
NRS-101	Z score	-0.171	-1.522	-1.227
	Mean	1.7	1.4	1.4
	p value	0.864	0.128	0.220

NRS-101 = Numerical pain rating scale

CHAPTER FIVE

DISCUSSION

5.1. SELECTED DEMOGRAPHIC AND ANTHROPOMETRIC DATA

All 45 participants of this study were healthy individuals with the exception of CAIS. The mean (± SD) age (**Table 4.2**) of the participants was influenced by the inclusion criteria of 18 to 45 years. This age range was selected to exclude the possibility of growth plate injuries in individuals younger than 18 years as complete fusion of the epiphyses of the distal tibia and fibula occurs at about18 years of age (Crowder and Austin, 2005). Changes in ligamentous composition with increasing age, impairments in proprioception predisposing individuals to falls (Loeser, 2010) and ankle degeneration were the reasons that the maximum age limit in this study was set at 45 years (Chan et al., 2011). It was also in keeping with the study of Pellow and Brantingham (2001).

There was a relatively similar distribution of males and females in this study (**Table 4.1**). This was similar to the observations of Hadadi et al. (2015), De-la-Tore-Domingo et al. (2015) and Bilgic et al. (2015) (**Table 2.10**) who had a similar number of males and females in their study with the latter having a minor preponderance of males compared to females. Bicici et al. (2012) and Forbes et al. (2013) only included males in their study; Acar et al. had a greater number of females and males in their studies, respectively. The reasons for the variability in the number of male and female participants in the various studies have not been explained in the literature, but could be based on participant accessibility and availability.

The BMI of the participants did not exceed the normal limit of 25 $kg.m^{-2}$ (World Health Organization Global Data Base on Body Mass Index, 2016) (**Table 4.2**). An increased BMI has been shown to have a negative effect on balance as it requires greater effort to maintain postural stability (Greve et al., 2007). Gribble et al. (2016) reported poor balance in football players who had suffered previous lateral ankle sprains. These individuals had a significantly higher BMI compared to the group who had not suffered ankle sprains in the previous sporting season.

5.2. THE EFFECTS OF TAPING ON SUBJECTIVE OUTCOME MEASURES

The outcome measure used to assess the subjective pain rating of participants was the NRS-101. Intra-group analyses of NRS-101 showed a significant decrease in pain rating between each consultation (**Table 4.6**). Inter-group analyses revealed no significant differences in the mean NRS-101 scores between each group (**Table 4.10**). The intra-group result of this study was similar to Nambi and Shah (2012), who reported significant differences in numerical pain rating scale pre- and post-assessment. The inter-group result of this study was similar to that of Hendrick (2010) who evaluated the use of Kinesio™ tape compared to an ankle brace in the treatment of a Grade One lateral ankle sprain and found no significant difference between the two groups in terms of pain level. Acar et al. (2015) tested pain rating, ankle girth, active range of motion as well as Karlsson scores between elastic tape and Kinesio™ tape groups; they reported no significant differences in these parameters between the two groups. In terms of pain reduction at subsequent consultations, the results of this study were similar to that of Acar et al. (2015) across all groups. The reduction in pain rating (mean) values between the initial and final consultations were 3.7, 3.5 and 3.2 in Groups One, Two and Three, respectively (**Table 4.6**), indicating that the tapes provided a significant reduction in subjective pain rating over a period of seven days. These tapes and taping methods are, therefore, beneficial to the patient with regards to short-term pain reduction.

The manufacturers of Kinesio™ tape claim that it reduces pain through its effects on the skin and superficial fascia. They propose that this occurs by stimulating or unloading mechanoreceptors in the skin through compressive and decompressive forces, respectively (Kinesiotaping® Association International, 2011). Shakeri at al. (2013) postulated that Kinesio™ tape reduces pain through neuromuscular pathways. They proposed larger diameter nerve fibres receive a greater afferent stimulus thereby controlling the input received from smaller nerve fibres conducting the nociceptive stimulus, thus reducing pain. The exact cause for the reduction of pain with the use of Kinesio™ tape is still not clearly understood and further research is required to elucidate this phenomenon (Slocum, 2014).

The proposed mechanism of action for the reduction of pain with the use of regular strapping is also by afferent stimulation into the central nervous system. Another postulated mechanism for the reduction of pain with strapping is by reducing the swelling in the area which may be applying pressure on nociceptors causing pain. However, the exact reason for the reduction in pain rating is still unknown (Briem et al., 2011; Perrin, 2012). The outcome of these findings may suggest that the reason for the changes in the intra-group analyses only and not the inter-group analyses as well may be due to the mechanism of action of the tape and not the properties of the tape itself.

5.3. THE EFFECTS OF TAPING ON OBJECTIVE OUTCOME MEASURES

The objective outcome measures assessed in this study were pain threshold, range of motion and sway index.

5.3.1. PAIN THRESHOLD

Intra-group analyses of pain threshold showed a significant increasing trend in results as consultations increased (**Figure 4.2**, **Tables 4.3, 4.4** and **4.5**). Inter-group analysis showed no other significant changes between all three groups except at Consultation One between Groups Two and Three (**Tables 4.7**). The increase in pain threshold may be as a result of maintenance of the muscle balance ratio responsible for preserving joint biomechanics. Inflammation and oedema which occurs within the ligaments and tendons as a result of sprain or strain may be reduced by correcting and maintaining the balance between agonist and antagonist muscles in the area (Kinesiotaping® Association International, 2011). Another possible explanation for increased pain threshold could be the effect of the tape on afferent stimulation into central nervous system similar to the mechanism described for subjective pain rating (**Section 5.2**) (Briem et al., 2011; Perrin, 2012).

5.3.2. RANGE OF MOTION

Intra-group analyses of range of motion revealed a statistically significant increase in dorsiflexion range of motion as consultations increased (**Tables 4.3**, **4.4** and **4.5**). There were also significant increases in plantarflexion and inversion, but these were not consistent between the different consultations (**Tables 4.3**, **4.4** and **4.5**). Range of motion examination at the initial consultation revealed a limited dorsiflexion range of motion value (**Figure 4.3**) in most individuals when compared to the normal range of motion values described in **Table 2.4**. Plantarflexion improvements were inconsistent across the three visits (i.e. significant increases were noted between Consultations One and Two and Consultations One and Three in all three groups) in comparison to dorsiflexion which showed improvements across all three consultations

(**Tables 4.3**, **4.4** and **4.5**). Improvements in ankle inversion were the most inconsistent of the three ranges of motion evaluated in this study. Significant increases were noted between Consultation One and Consultation Three in Group One, between Consultations One and Two and Consultations One and Three in Group Two and between Consultations One and Two and Consultations One and Three in Group Three (**Tables 4.3**, **4.4** and **4.5**). The mechanism of injury of an ankle sprain involves excessive plantarflexion and inversion. As a result of this change in ankle biomechanics, dorsiflexion is often found to be restricted following an ankle sprain and may have occurred due to stiffness in the triceps surae muscle, restricted glide of the talus posteriorly, or restricted range of motion within the tibio-fibular, subtalar and mid-tarsal joints (Denegar et al., 2002). The functional correction technique of Kinesio™ tape is targeted at managing hypermobility by facilitating and inhibiting certain movements (Kinesiotaping® Association International, 2011). By using this application, unwarranted inversion range of motion was controlled which may have improved dorsiflexion and plantarflexion, thereby restoring arthrokinematic motion.

The initial and final range of motion values taken at Consultations One and Three are tabulated in **Table 5.1**.

Table 5.1 The initial and final (mean) ankle range of motion values documented at Consultations One and Three

Consultation	Group	Dorsiflexion	Plantarflexion	Inversion
One	Group One	12.7°	44.4°	23.3°
	Group Two	11.0°	41.9°	34.3°
	Group Three	10.5°	39.2°	23.3°
Three	Group One	17.5°	47.0°	29.1°
	Group Two	17.9°	43.7°	31.3°
	Group Three	17.9°	42.3°	28.6°

The final range of motion values obtained in this study are in the range of those described in the literature (**Table 2.4**). However, it must be noted that measurements described in **Table 2.4** were those of individuals with no ankle injury. The dorsiflexion range of motion values observed at Consultation One were similar to those reported by Boone and Azen (1979) as cited by Michmizos and Krebs (2014) (**Table 2.4**). The plantarflexion range of motion values documented at Consultation One was similar to those reported by AMA (1988) as cited by Norkin and White

(2009) (**Table 2.4**). The inversion range of motion values documented at Consultation One was similar to those reported by Roaas and Anderson (1982) (**Table 2.4**).

The final dorsiflexion range of motion values documented at Consultation Three were closer to those values reported by AAOS (1965) and AMA (1988) (**Table 2.4**). The final plantarflexion range of motion values documented at Consultation Three were within the range of the values reported by AAOS (1965) and AMA (1988) (**Table 2.4**). The final inversion range of motion values documented at Consultation Three were within the range of values reported by Roaas and Anderson (1982) and AMA (1988) (**Table 2.4**).

When comparing the range of motion values of this study to those described in the literature, it is also important to consider patient position. The values reported in **Table 5.1** were assessed with the patient in the seated position (hip flexed) similar to Boone and Azen (1979), whereas the values reported by AAOS (1965) and Roaas and Andersson (1982) (**Table 2.4**) were assessed with the individual in the supine position with the knee flexed to 45°.

The initial ranges of motion values documented at Consultation One were not within the normal range as described in **Table 2.4**. However, following application of the tape the range of motion values increased and was found to be closer to those values described in **Table 2.4** at Consultation Three. Since most of the values in **Table 5.1** showed an increase in range of motion (with the exception of Group Two inversion), it is possible that the taping method is the reason for this increase in range of motion.

Inter-group analyses of range of motion showed no significant results in dorsiflexion and inversion at all three consultations. However, at Consultations Two and Three a significant increase was observed between Group One and Group Three in plantarflexion. As mentioned previously, the mechanism of injury of an ankle sprain involves excessive plantarflexion and inversion which may result in restricted dorsiflexion due to stiffness in the triceps sure muscle (Denegar et al., 2002). It is possible that the tape application may have had an effect on the stiffness in the triceps surae muscle thereby increasing plantarflexion range of motion. The results of the present study can be compared to the study by Nambi and Shah (2012) which also showed significant improvements in ankle dorsiflexion in the Kinesio™ tape group (**Table 2.10**). Conversely, the study by Trégouët et al. (2013) reported conflicting results when compared to the present study. They reported a significant decrease in inversion range of motion whereas intra-group analyses found variably significant increases in inversion range of motion in all three groups in the present study.

5.3.3. PROPRIOCEPTION

Inter-group analyses of sway index (BBPBS) showed insignificant results under the four test conditions measured between each group at each consultation. However, intra-group analyses demonstrated significant changes in Group One between Consultations One and Two for the EOFoS and ECFoS test conditions. A possible reason for the inconsistent results could be that the tape was not applied long enough to provide a significant change in results. Simon et al. (2014) reported that proprioceptive improvements were not observed within the first 72 hours following application of tape; however, after 72 hours, proprioceptive improvements became more apparent.

Bicici et al. (2012), Acar et al. (2015) and De-la-Tore-Domingo et al. (2015) compared Kinesio™ tape to athletic tape (amongst others), elastic tape and placebo tape, respectively, in the management of ankle injuries (**Table 2.10**). Bicici et al. (2012) tested agility, endurance, balance and co-ordination amongst placebo tape, no tape, athletic tape and Kinesio™ tape groups. In these studies, no significant differences were found between the groups for any of the outcome measures as is similar in the present study. De-la-Tore-Domingo et al. (2015) tested composite SOT scores and strategies and reported no significant differences between most of the balance measurements between the Kinesio™ tape and placebo groups. These results are comparable to those of the present study in terms of insignificant changes in balance measurements. Shields et al. (2013) evaluated the effects of proprioception on healthy, 'copers' and unstable ankles and reported no significant improvements in the three groups (**Table 2.10**). This is comparable to the results of the present study in terms of no consistent, significant improvements in the sway index which is an indicator of proprioception.

Mechanoreceptors found within joint capsules, ligaments, muscles and skin are responsible for maintaining proprioception via their input into the central nervous system (Holmes and Delahunt, 2009). During an initial ankle sprain there is damage to the ankle ligaments and joint capsule depending on the extent of the injury. This may result in the disruption of mechanoreceptor function within these structures which may impact proprioception (Denegar and Miller III, 2002; Holmes and Delahunt, 2009). Holmes and Delahunt (2009) also reported that proprioceptive imbalances found in individuals with CAIS should be managed by focusing on the deficits in the feed-forward neuromuscular control pattern instead of the reflexive feed-back neuromuscular control patterns. By adequately addressing and managing the preparatory feed-forward mechanism, there is more likely to be an improvement in the sway index. Therefore, replicating this study with the addition of an adequate rehabilitation program may lead to an increase in the sway index.

Simon et al. (2014) reported proprioceptive improvement in individuals with CAIS following application of Kinesio™ tape for 72 hours. They explained that an improvement in proprioception was directly proportional to the length of time the tape was on the affected area and that proprioceptive awareness in individuals with CAIS increased and found to be similar to that of uninjured individuals. Jackson et al. (2016) also reported that Kinesio™ tape was effective in the management of proprioceptive deficits found in individuals with CAIS. They explained that improvement in proprioception occurred as a result of the "closed loop" theory which is associated with the tape constantly stimulating afferent feedback from the affected area. The effect of the stimulation was long-lasting especially when the stimulus was present for 72 hours or more and the effect was present even after the stimulus (tape) was removed. Jackson et al. (2016) also found significant improvement in balance scores using the Balance Error Scoring System in individuals with CAIS.

The results of the current study conflict with those of Simon et al. (2014) and Jackson et al. (2016) as there was no consistent significant improvement in the sway index even though the tape was applied for more than 72 hours. The minimum amount of time that the tape was applied for during the first and second consultation was 72 hours and during the second and third consultation 48 hours, which makes a total of 120 hours (minimum) that the tape was on each participant (a brief interval of not more than 30 minutes was allowed for the removal of tape and reapplication at Consultation Two). The BBPBS (an objective measurement tool) was used in this study to evaluate sway index compared to the subjective Balance Error Scoring System used by Jackson et al. (2016) to assess balance. The possible reasons for the conflicting results could be either the BBPBS was not sensitive enough to detect the changes noted in the sway index or, the "closed loop" theory of afferent stimulation needs to be revisited to evaluate its reliability. Another important point is that the Balance Error Scoring System is subjective and that results from this method may differ from one clinician to the next. It would be interesting to observe the outcome of the current study if the Balance Error Scoring System was used to evaluate proprioception. Further research into this area is recommended and future studies should look at comparing the results of the BBPBS to the Balance Error Scoring System to establish which test is more reliable.

5.4. LIMITATIONS OF THE STUDY

- Due to budget constraints, the lack of objective diagnostic imaging such as ultrasound meant that the study relied solely on clinical presentation and examination findings; the extent of ligament integrity could not be objectively evaluated.
- Analogue instrumentation, such as the algometer and goniometer, was utilised in this study instead of digital instrumentation. An error of parallax may have occurred during goniometric assessments despite all efforts to try to minimise errors.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

The aim of this study was to investigate the effect of three types of strapping, applied using the method described for Kinesio™ tape, in the treatment of CAIS. The results of the study revealed that regardless of the tape used, all three groups showed significant pain reduction, and increases in pain threshold and ankle dorsiflexion. These findings suggest that the method of taping (as described for Kinesio™ tape) is beneficial for these clinical parameters rather than the type of tape used. Despite some explanations provided in the literature (mentioned in Chapters Two and Five), the exact mechanism of action of this particular taping method is poorly understood and needs further investigation.

With respect to the Alternate Hypothesis (H_a) set at commencement of the study that Kinesio™ tape will be more effective than rigid and elastic tapes in terms of subjective and objective outcomes in the treatment of CAIS, we are unable to accept this hypothesis based on the results of this study.

The results of this study can be summarised as follows (irrespective of the tape used):

- An improvement of subjective pain rating across all three consultations
- An improvement of pain threshold across all three consultations
- Consistent increases in dorsiflexion across all three consultations
- Inconsistent increases in plantarflexion and inversion across the three consultations
- Inconsistent changes in sway index across all three consultations

In conclusion, there were no significant subjective and objective differences observed amongst the three different types of tapes used. There are, however, certain advantages of Kinesio™ tape that would suggest it being used as the tape of choice in comparison to rigid or elastic tape in the treatment of CAIS. Kinesio™ tape has been described as resembling the first layer of skin; it is composed of 100% cotton and elastic fibres and is latex free. It is also resistant to water and may be worn for up three to five days (Halseth et al., 2004; Kinesiotaping® Association

International, 2011). The composition and feel of Kinesio™ tape makes it less bulky and does not restrict range of motion and the fact that it is latex free means that it is less likely to cause skin irritation compared to other tapes. No participant in this study reported any adverse skin reactions to Kinesio™ tape or any of the other two tapes. Its water resistant properties contribute to the comfort of the tape as it does not stay wet as the other tapes do. The tape can stay on comfortably for up to three to five days which make it more convenient for the patient as elastic tape is most effective only for short periods and rigid tape restricts movement and is not comfortable to wear for prolonged periods. As a result, the benefits of the physical characteristics of Kinesio™ tape may suggest why it would be a tape of choice compared to rigid or elastic tape. For a clinician, the taping method described for Kinesio™ tape can be utilised for pain reduction, increasing pain threshold and improving ankle dorsiflexion in individuals with CAIS. In the absence of objective findings e.g. ultrasound or MRI, it is difficult to speculate the exact mechanism of action of the taping technique. The results of this study do not support this taping technique for improving balance in these individuals. Further studies with larger sample sizes, however, are required to confirm the findings of this study.

6.2. RECOMMENDATIONS

It is recommended that future studies should:

- Compare different taping methods using different tapes in order to provide better understanding on whether in fact it is the tape or the method in which it is applied or a combination of the two that account for its effectiveness.
- Compare the efficacy of Kinesio™ tape and other tapes for improving proprioception using BBPBS and the Balance Error Scoring System with larger sample sizes.

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APPENDIX A

ETHICS CLEARANCE CERTIFICATE:

Institutional Research Ethics Committee
Faculty of Health Sciences
Room MS 49, Mansfield School Site
Gate 8, Ritson Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900
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http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

28 November 2014

IREC Reference Number: **REC 85/14**

Ms H Moti
P O Box 438
Umbogintwini
4120

Dear Ms Moti

The effects of 3 types of strapping on chronic ankle instability syndrome

I am pleased to inform you that Full Approval has been granted to your proposal REC 85/14.

The Proposal has been allocated the following Ethical Clearance number **IREC 086/14**. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY

APPENDIX B

DATA COLLECTION SHEET:

File no: __________

Date: ____________

Group: ___

1) **NUMERICAL PAIN RATING SCALE:** With 0 being no pain and 10 being worst pain ever experienced

BASELINE MEASUREMENT: Date	**FOLLOW UP:** Date	**FINAL MEASUREMENT:** Date

2) **ALGOMETER READINGS:**

	BASELINE MEASUREMENT:	**FOLLOW UP:**	**FINAL MEASUREMENT:**
AFFECTED ANKLE			
UNAFFECTED ANKLE			

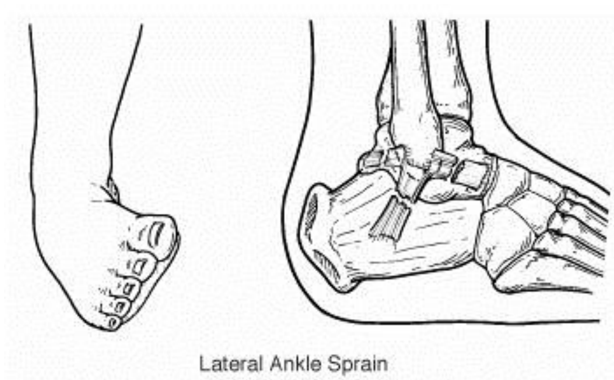
3) **INCLINOMETER READINGS:**

	BASELINE MEASUREMENT:	**FOLLOW UP:**	**FINAL MEASUREMENT:**
PLANTARFLEXION			
DORSIFLEXION			
INVERSION			

APPENDIX C

Are you between the ages of **18** and **45** and suffer from

RECURRENT ANKLE SPRAINS



Research is currently being carried out at the Durban University of Technology Chiropractic Day Clinic

FREE TREATMENT

Is available to those who qualify to participate in this study

For more information contact Harsha Moti on 031 373 2205

APPENDIX D

DUT DURBAN UNIVERSITY OF TECHNOLOGY | FACULTY OF HEALTH SCIENCES | CHIROPRACTIC DEPARTMENT

FOOT AND ANLKE REGIONAL EXAMINATION

Patient:_______________________________________File no:________Date:___________

Intern / Resident___________________________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

Anteriorly

	R	L
Medial maleoli		
Med tarsal bones, tibial (post) artery		
Lat.malleolous, 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		

DURBAN UNIVERSITY OF TECHNOLOGY

APPENDIX E

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF INFORMATION

Dear participant, welcome to my research project.

Title of research study:
The effects of three types of strapping on chronic ankle instability syndrome.

Principal investigator: Harsha Moti (B.Tech: Chiropractic)

Co-Investigators: Dr. J. Shaik (M.Tech: Chiropractic; M. Med. Sci. (SM))
Dr. V. Varatharajullu (M.Tech: Chiropractic)

Introduction and Purpose of the study:
You have been selected to participate in a study that investigates the effect of different forms of strapping in the treatment of chronic ankle instability syndrome (CAIS).Strapping is an effective method used for the treatment of CAIS as it stabilizes the ankle joint and is helpful in the prevention of further ankle sprains (Wolfe et al, 2001). There are two main types of strapping i.e. rigid and elastic, each having their own unique method of application. Rigid strapping has limited stretch to it, thereby, preventing excessive movement of the area. Elastic strapping is more flexible and allows more motion in the joint when compared to rigid tape (Mattacola and Dwyer, 2002). Kinesio™ tape is a new tape on the market which has its own exclusive method of application which permits full range of motion by decreasing the load to the area in which it is applied. . Manufacturer's claim that it prevents injury and reduces pain, and is becoming more popular in the treatment of ankle sprains (kttape.com). Given the popularity of Kinesio™ tape and its proposed benefits, it would be interesting to determine its relative effectiveness compared to rigid and elastic tape applied in the same manner as Kinesio™ tape.

Outline of the procedures:
You will be required to attend three consultations.

a) **First consultation**:
The first consultation at the Chiropractic Day Clinic (CDC) will be done to establish if you are eligible for the research according to inclusion and exclusion criteria. The researcher will do a case history, physical examination and an orthopedic examination of the foot and ankle which will take a maximum of 2 hours. Kinesio™ tape or rigid tape or elastic tape will be applied depending on which group you are allocated into.

b) **Second consultation**:
The tape will be removed by the researcher, you will be reassessed and another set of measurements will be documented. Following this, you will receive another application of tape.

c) **Third consultation**:
The tape will be removed, you will be reassessed and final measurements will be documented.

Inclusion Criteria: To be part of this study you must...

- Be between 18 and 45 years of age
- Not have any history of inflammatory joint disease
- Must have had a history of at least one or more acute ankle sprains in your lifetime which has left you with pain, swelling and a feeling of weakness in the ankle

Exclusion criteria: You will not be eligible to take part in this study if you...

- Have a history of grade 2 and 3 ankle sprains
- Have foot abnormalities such as Grade 3 pes planus
- Have broken skin around the ankle area
- Have a Body Mass Index (BMI) exceeding 25.0 kg/m^2

Risks/discomforts and Benefits

The treatment is safe and non-invasive and is unlikely to cause any adverse effects. However, should you have sensitive skin and suffer an allergic reaction to the tape or any irritation to the skin, the tape will be removed immediately and you will be excluded from the study and be advised to seek medical care promptly. R250 towards the initial consult to the medical professional will be covered by the study on condition that a valid medical certificate is produced.

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

In the event that you do not meet the inclusion criteria or infringe on the exclusion criteria of the study, you will be withdrawn from the study. Your participation 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, however, should you require 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 will be kept at the CDC for 15 years, after which it will be shredded. All the results of this study will be made available at the Durban University of Technology library in the form of a dissertation. No personal information will be disclosed.

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:

Researcher:	Miss. H. Moti	Tel: 031 373 2205
Supervisor:	Dr. J. Shaik (M.Tech: Chiropractic; M. Med. Sci. (SM))	Tel: 031 373 2611
Co-supervisor:	Dr. V. Varatharajullu (M.Tech: Chiropractic)	Tel: 031 373 2611
IREC Research	Administrator (IREC)	Tel: 031 373 2900

APPENDIX F

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ____________ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: IREC 086/14
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the 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 the 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.

____________________	__________	______	_________________________
Full Name of Participant	**Date**	**Time**	**Signature/ Right Thumb print**

I, ______________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

_________________	__________	___________________
Full Name of Researcher	**Date**	**Signature**
_________________	__________	___________________
Full Name of Witness (If applicable)	**Date**	**Signature**
_________________	__________	___________________
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

APPENDIX G

CHIROPRACTIC PROGRAMME

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 I (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

DUT DURBAN UNIVERSITY OF TECHNOLOGY

APPENDIX H

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

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:**