THE RELATIVE EFFECTIVENESS AND CORRECT SEQUENCING OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION TECHNIQUES (PNFT) AND ACTIVE ROCKER-BOARD EXERCISES IN THE REHABILITATION OF CHRONIC ANKLE SPRAINS.

By

Dominique Gaines

Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic at the Durban Institute of Technology.

I, Dominique Gaines, do declare that this dissertation is representative of my own work in both conception and execution.

Dominique Gaines Date:

APPROVED FOR FINAL EXAMINATION BY:

Supervisor Date

Dr. A. Jones

M. Dip: Chiro (TN), CCSP (USA), CCFC (SA).

DEDICATION:

This is dedicated to my parents who have given me all the support and encouragement necessary to complete not only this dissertation, but my formal training as well. I have a great deal of respect and love for you both and I hope to have the opportunity to demonstrate this to you over the coming years, I am truly grateful for all the two of you have sacrificed and done for me.

ACKNOWLEDGEMENTS:

My thanks goes to the following:

Dr Andrew Jones, my supervisor and mentor. Without your support, encouragement and input, none of this would have been possible. Thank you for giving up so much of your time and yourself for me, words cannot explain my gratitude.

Dr Charmaine Korporaal, for your unfailing friendship, help and support, you are an inspiration.

Pat and Linda, in reception, thank you both for your support and understanding throughout this long process. Thanks too for all the laughs we shared over my equipment and mishaps, and for putting up with me in your space all the time. Mrs. Ireland, for your efficiency and dedication to my research.

To the Clinicians at DIT, for your enquiries as to how things were going, your offers for help and support, and ability to make long, tiring days go a little smoother and keep me smiling. Your encouragement will not be forgotten.

All the patients who participated in my study. Without you, none of this would have been possible. You were reliable, enthusiastic and made my study a pleasure. This means more than you will ever know, thanks.

TABLE OF CONTENTS

CHAPTER FIVE

LIST OF TABLES:

LIST OF BAR CHARTS

ABSTRACT:

OBJECTIVES:

The objectives of this study were: to determine the relative effectiveness of Proprioceptive Neuromuscular Facilitation as compared to the Active Rocker-Board Exercises in the rehabilitation of chronic ankle sprains; as well as to determine the best sequence of applying these techniques to chronic ankle sprains in terms of objective clinical findings.

SUMMARY OF THE BACKGROUND DATA:

Previously the focus has been on the improvement of strength prior to proprioception (Calliet, 1997; Flemister et al. 1998 and Buhler et al. 2002). However according to Oloff (1994); Vegso (1995); Calliet (1997); Kawaguchi (1999); Buhler et al. (2002) and McGrew et al. (2003), focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalization of the relationship of the anatomical structures. All research in this regard has never assessed the

assumption that the strength of the relevant musculature would return (Blokker et al.1992 and Klaue et al.1998).

STUDY DESIGN:

This is a prospective unblinded, randomised, controlled two way swop-over clinical trial with all participants having an equal opportunity of being in either of the possible two groups.

METHODS:

Thirty patients with chronic ankle sprains were screened for limitations at the ankle joint including reduced range of motion or muscle strength and/or pain at the ankle.

These participants were randomly divided into two groups (each having an even number i.e.: 15 per group). The patients were all within the age range of 18 to 65 years old. The first group of participants was initially treated with PNFT's for a period of four weeks and five follow-up visits and then began a four week and five follow-up Active Rocker-Board Rehabilitation Program. The second group was initially started on the Active Rocker-Board Program and then was treated with PNFT's for the ankle region. The time spent by both groups in the different rehabilitation programs was equal. Participants therefore had a total of ten treatments over a period of eight weeks.

There were no subjective readings taken in this study, all the readings were objective and were carried out by the examiner with confirmation from the clinician present at The Chiropractic Day Clinic, when necessary.

There were seven means of collecting the data in this study namely: Goniometer and Algometer readings, Romberg's test, Maximum Weight-Bearing Dorsiflexion values, Time and Activities (Patients attempted to complete as many of the specified Rockerboard exercises as possible, these included: Dorsiflexion, Plantarflexion, Lateral tilting of the ankle, Rotation and Lateral Flexion of the trunk all of which were done first with their eyes open and then closed; the next set involved standing on one leg then the other for as long as possible also with the eyes open and then closed; the patients also tried to stand on the Board and catch Medicine Balls, of varying weights and from different directions; the last set involved squatting on the Board with the eyes open then closed) successfully completed by the patient on the Rocker-board, Strength of the Ankle Musculature and A General Foot and Ankle Assessment for restrictions at the ankle joint.
Objective readings were recorded at the beginning of week's one, five and eight forming three sets of data.

The sample size of each group in this study was small, consisting of only fifteen participants; therefore non-parametric tests were used in the analysis of the data.

The data was recorded by the researcher and assessed using the specific testing principles.

For every variable assessed in this study, wherever possible : tests were conducted that compared the results recorded on each side at periods one and two in terms of equal treatment effects as well as the carry-over effect of treatment one into period two and the overall period effects of both treatments together, where the effect of treatment two subsequent to treatment one was assessed.

The statistical package SPSS (as supplied by SPSS Incorporated, Marketing Department – 1999, Chicago, USA) was used in the collection and analysis of the data in this study and the calculations, shown in the sections that follow, were done by using Excel and SAS as well as the SPSS software.

The level of significance was set at α0.05 and p values were used in assessment i.e.: there was a 95% confidence level to the statistical analysis of the data.

RESULTS AND CONCLUSIONS:

The overall conclusion that can be drawn, from the results obtained in this study is: that although both treatments are shown to be equally effective and result in significant improvements in certain readings, treatment B (Proprioception Training - Active Rocker Board exercises) is shown to be more effective than treatment A (Proprioceptive Neuromuscular Feedback Techniques – hold-relax stretching Technique) in four out of the eight objective readings. The sequencing however, of the two treatments in the rehabilitation programme is proven to be irrelevant as long as both components are included in the rehabilitation of chronic ankle sprains.

The purpose of this study was to highlight an area in the management and rehabilitation of chronic ankle sprains, which was unclear, and to provide some clarity via research results as to which sequencing procedure is the most effective in reaching the set goals. The results of this study contribute to more effective patient management, by Chiropractors and other health care providers in the future, and hence improve overall patient relationships and management.

CHAPTER ONE – INTRODUCTION

1.1. BACKGROUND TO THE PROBLEM

The ankle sprain is probably the single most common injury in sport (Garrick and Requa, 1988; Kawaguchi, 1999; McGrew et al. 2003) with eighty-five percent of ankle injuries being ankle sprains (Garrick, 1977), approximately 27,000 ankle sprains daily in the United States (McGrew et al. 2003).

An ankle sprain is defined as a joint injury in which some of the fibres of a supporting ligament are ruptured, but the continuity of the ligament remains intact. (Gatterman, 1990:415). Chronic ankle sprains are common in athletes (especially in runners and joggers) whether recreational or competitive due to repetitive use of extremities (Oloff, 1994; Calliet, 1997; Cooper et al. 1998; Kawaguchi, 1999; Austin, 2002; Hammer, 2002; Smith, 2002; McGrew et al. 2003).

The surrounding musculature and associated neural structures may be affected and if left unresolved, these deficits will lead to chronic instability, which may affect future athletic performance and put the athlete at greater risk for re-injury (Kesson and Atkins, 1998; Kawaguchi, 1999 and McGrew et al. 2003). The instability associated with chronic ankle sprains is characterised by either a relatively frequent (every 2-3 months) severe sprain, or minor episodes caused by minimal mis-steps occurring daily or more often (Coker, 1991:2433).

Previous history of an ankle injury distinguishes chronic functional instability from an acute injury (Tropp et al.1985: 261; Reid, 1992; Coker, 1991).

According to Mack (1982), ankle injuries account for twenty to twenty-five percent of time lost due to injury in running and jumping sports.

1.2. STATEMENT OF THE PROBLEM

The purpose of this prospective unblinded, randomised, cross-over study was to determine the relative effectiveness of two rehabilitation techniques Proprioceptive neuromuscular facilitation techniques (PNFT) and Active Rocker-Board exercises as well as to ascertain the best sequence of applying these techniques in the management of chronic ankle sprains. With the focus being on improvements in the reduced range of motion (flexibility), reduced muscle strength and possible pain at the ankle joint in terms of objective clinical findings.

These objective findings were used to determine which sequence of rehabilitation was the most effective in the rehabilitation of chronic ankle sprains i.e. whether flexibility or strength at the ankle joint should be the initial focus of rehabilitation, specifically in chronic ankle sprains. Objective measurements used in this study included the use of the extremity range of motion goniometer where the patient was placed in a prone position with their knee extended. The patient was then asked to actively dorsiflex the foot while the examiner moved the foot passively into dorsiflexion. One arm of the Goniometer was aligned with the fifth metatarsal and the other arm aligned with the fibular head (Jonson and Gross, 1997:255). Zero degrees was taken when the foot was in the neutral position and these measurements were taken at the first, fifth and tenth consultations, <u>maximum weight-bearing dorsiflexion</u> during which the patient's stood on the involved leg and dorsiflexed the ankle while flexing the knee, until no further dorsiflexion could take place without lifting the heel off the ground. A large set square was used to measure the vertical distance (x) from the front of the knee to the ground, and the horizontal distance (y) from this point to the back of the heel was similarly measured. The degree of dorsiflexion was calculated using simple trigonometry, an <u>algometer</u> before taking a reading the algometer was set to zero and the patient was placed in the prone position with the ankle and foot being in the neutral position. The end of the algometer was placed perpendicular to the tendon and the pressure applied, the patient's expressed to the examiner when the sensation of pressure became one of pain (this is known as the pressure threshold as noted by Travell, Simons and Simons, 1992:138).The higher the pressure reading on the algometer, the less tender the area under investigation therefore a lower reading indicated a greater tenderness at the area being examined Fischer(1986:836), the <u>Romberg Test</u> which was conducted with the patient standing on both legs with their eyes open while resisting a downward pressure on their out-stretched forearms, while the researcher assessed their ability to hold this position (a positive test being if the patient fell to one side)

(Reid, 1992:862). This was repeated with the patient's eyes closed to determine whether the source of the possible instability was due to a disturbance of the leg and ankle proprioceptors, as a result of damage resulting from chronic ankle sprains, or due to a cerebellar lesion or other non organic cause, The amount of time spent on the rocker-board at each consultation as well as the activities which the patient was capable of completing were noted as a means of 1) monitoring the patient's functional ability: in terms of strength, range of motion and proprioception and 2) recording any improvements in this regard as a result of the treatment which the patient had received, muscle strength of the triceps surae muscle group was measured with a digital scale that was mounted on the wall at the foot of the bed the patient, whilst lying supine, then applied a force to the scale as they plantar flexed the foot at the ankle. A reading was frozen and recorded and this reading was compared between the two ankles and between treatments (i.e.: This reading was taken at the beginning of the first, fifth and eighth week). A shoulder support was supplied to prevent pressure being transmitted into the bed instead of onto the scale, the foot was also assessed for any fixations (before and after treatment) as part of the specific foot and ankle regional examination, in which the integrity and amount of joint play available at the ankle were assessed.

The measurements in each individual category were recorded and compared, using very specific tests to determine (wherever possible) equal carry-over effects, equal treatment effects, equal treatment effects for period one and equal period effects, as well as overall effectiveness of treatments where these tests could not be performed. Intra- and inter-group comparisons were made, and the efficacy of both rehabilitation sequences was compared.

1.3. NEED FOR RESEARCH INTO REHABILITATION SEQUENCING

If ankle rehabilitation is not optimal, injuries may result in long-term residual symptoms and disability (McGrew et al. 2003), this is re-enforced by the statement that incomplete or absent rehabilitation may be a cause for continuing symptoms such as a feeling of instability, crepitus, weakness and stiffness at the ankle (Reid, 1992:250).

Proprioceptive neuromuscular facilitation techniques (PNFT) have been recommended for increasing strength, flexibility and range of motion (Prentice, 1994: 164).

In contrast to this, proprioception training (PT) has proven to be equally effective and important in ankle rehabilitation (Thomson et al.1991: 41). PT treats existing proprioceptive deficits and restores ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al.1999) allowing for increased strengthening of the triceps surae as indicated by Reid (1992:240) and supported by Calliet (1997), Kawaguchi (1999) and McGrew et al. (2003). PT can also be used for restoration of balance (Cooper et al.1998, Kuligowski et al. 1999), range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al. 2003).

Previously the focus has been on the improvement of strength prior to the establishment of full range of motion and proprioception at the ankle (Calliet, 1997; Flemister et al. 1998 and Buhler et al. 2002). However according to Oloff (1994), Vegso (1995), Calliet (1997), Kawaguchi (1999), Buhler et al. (2002) and McGrew et al. (2003), the initial focus should lie in obtaining a functional range of motion (increased flexibility), and proprioceptive ability and strength will follow with normalization of the relationship of the anatomical structures.

All research in this regard has never assessed the assumption that the strength of the relevant musculature would return (Blokker et al.1992 and Klaue et al.1998).

This study involved comparing the two chosen rehabilitative techniques, these being: 1) PNFT of the Achilles tendon and the Peroneal muscle group, Triceps Surae and Anterior and Posterior Tibialis muscles and 2) Proprioceptive Training for the ankle (in the form of Active Rocker-Board exercises).
The main objective was to determine which rehabilitation sequence was the most effective in the management chronic ankle sprains, with regards to the restoration of full functional range of motion and strength as well as the reduction of pain and discomfort at the ankle joint, and consequently where the focus should lie in chronic ankle sprain rehabilitation.

CHAPTER TWO – LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews all the related available literature and includes a description of the ankle joint anatomy and biomechanics as well as the incidence and prevalence of ankle sprains. The diagnosis and grading of ankle sprains will be briefly discussed, as will the differential diagnoses, mechanism of injury involved in a chronic ankle sprain and the natural history of ankle sprains. Past treatment options for chronic ankle sprains will also be discussed and the particular techniques chosen for this study will be explained in terms of their history, expected outcomes and application to the chronic ankle sprain.

An ankle sprain is defined as a joint injury in which some of the fibres of a supporting ligament are ruptured, but the continuity of the ligament remains intact (Gatterman, 1990:415). The type of instability associated with chronic ankle sprains is characterized by either, a relatively frequent (every 2-3 months) severe sprain, or minor episodes caused by minimal mis-steps occurring daily or more often (Coker, 1991:2433). Previous history of an ankle injury distinguishes chronic functional instability from an acute injury (Tropp et al.1985: 261; Coker, 1991 and Reid, 1992).

2.2 ANATOMY AND BIOMECHANICS OF THE ANKLE

2.2.1 ANATOMY

2.2.1.1 THE ANKLE JOINT

The ankle, mortise or talocrural joint is a hinge type of synovial joint (Moore, 1992:487).

It is located between the inferior ends of the tibia and fibula, which form a deep socket or boxlike (three-sided) mortise, into which the pulley shaped trochlea (superior articular aspect) of the talus fits. The fibula has an articular facet on its lateral malleolus, which faces medially and articulates with the facet on the lateral surface of the talus. The tibia articulates with the talus in two places: (1) the lateral surface of it's medial malleolus; and (2) it's inferior surface forms the roof of the mortise, which is wider anteriorly than posteriorly and slightly concave from anterior to posterior. The talus has three articular facets, which articulate with the inferior surface of the tibia and malleoli. The trochlea of the talus is wider anteriorly than posteriorly, convex from anterior to posterior, and slightly concave from side to side (Moore, 1992:488).

The fibrous capsule is thin anteriorly and posteriorly, but it is strengthened and supported medially and laterally by strong collateral ligaments (the deltoid and lateral ligaments respectively). It is attached superiorly to the borders of the articular surfaces of the tibia and malleoli. It is attached inferiorly to the talus close to the superior articular surface, except anteroinferiorly, where it is attached to the dorsum of the neck of the talus (Moore, 1992:488).

The strong medial (deltoid) ligament is attaches the medial malleolus to the tarsus (tarsal bones). The apex of the ligament is attached to the margins and tip of the medial malleolus. It's broad base fans out and attaches to three tarsal bones (talus, navicular and calcaneus). The deltoid ligament consists of four parts, which are named according to their bony attachments: (1) tibionavicular, (2) and (3) anterior and posterior tibiotalar and (4) tibiocalcaneal ligaments. They strengthen the joint and hold the calcaneus and navicular bones against the talus. They also help to maintain the medial side of the foot and the medial longitudinal arch (Moore, 1992:488).

The "lateral ligament" consisting of three parts (anterior and posterior talofibular ligaments and the calcaneofibular ligaments) attaches the lateral malleolus to the talus and the calcaneus and is not as strong as the deltoid ligament (Moore, 1992:488). Despite this, the ankle joint depends on these structures as well as the interosseous membrane, which maintain the integrity of the mortise, for it's stability (Reid, 1992:215).

The anterior talofibular ligament passes anteromedially from the lateral malleolus, as a flat band 2 to 5 mm thick and 10 to 12 mm long, to the neck of the talus. It is almost horizontal and relaxed in the neutral position, resisting anterior shear (Reid, 1992:218), this ligament is not very strong (Moore, 1992:488, 489).

The posterior talofibular ligament is thick and fairly strong. It attaches anteriorly to the digital fossa of the fibula and runs horizontally medially and slightly posteriorly to the tubercle of the posterior process of the talus (Reid, 1992:218; Moore, 1992:488, 489).

The calcaneofibular ligament is a large; strong, round cord about 6mm wide that passes posteroinferiorly from the tip of the lateral malleolus to the lateral surface of the calcaneus. It is extracapsular and is crossed superficially by the tendons of the fibularis (peroneus) longus and brevis muscles (Reid, 1992:218; Moore, 1992:488, 489).

The synovial capsule of the ankle joint lines the fibrous capsule and occasionally projects superiorly for a short distance into the inferior tibiofibular ligament. The synovial cavity of the ankle joint is somewhat superficial on each side of the tendocalcaneus. Therefore when the ankle joint is inflamed the synovial fluid may increase causing swelling in this region (Moore, 1992:489).

2.2.1.2 SUBTALAR JOINT

The functional unit of the ankle must include the subtalar joint, at which the key motions of inversion and eversion take place (Reid, 1992:215).

The subtalar (talocalcanean) joint is a synovial joint distal to the ankle joint, where the inferior surface of the talus rests on and articulates with the superior surface of the calcaneus. It is surrounded by a fibrous articular capsule, which is lined with a synovial membrane, and is attached near the margins of the articular facets. The fibrous capsule is weak but it is supported by medial, lateral and posterior talocalcaneal ligaments. In addition it is supported anteriorly by the interosseous talocalcaneal ligament (Moore, 1992:490, 491).

2.2.1.3 DISTAL TIBIOFIBULAR JOINT

This is a fibrous joint of the syndesmosis type where the rough, convex, triangular articular area on the medial surface of the inferior end of the fibula articulates with a facet on the inferior end of the tibia. A small superior projection of the synovial capsule of the ankle joint extends into the inferior part of the distal tibiofibular joint.

A strong interosseous ligament, continuous superiorly with the interosseous membrane, forms the principal connection between the tibia and fibula at this joint. It consists of strong bands that extend from the fibular notch of the tibia to the medial surface of the distal end of the fibula. The distal tibiofibular joint is also strengthened anteriorly and posteriorly by the strong anterior and posterior tibiofibular ligaments. They extend from the borders of the fibular notch of the tibia to the anterior and posterior surfaces of the lateral malleolus respectively. The inferior, deep part of the posterior tibiofibular ligament is called the transverse tibiofibular ligament. This strong band closes the posterior angle between the tibia and fibula.

This articulation forms a strong union, between the distal ends of the tibia and fibula, upon which much of the strength of the ankle joint is dependent.
Slight movement of the distal tibiofibular joint occurs, to accommodate the talus, during dorsiflexion of the foot at the ankle joint (Moore, 1992:487).

2.2.1.4 NERVE SUPPLY OF THE ANKLE

The articular nerves of the distal tibiofibular joint are derived from the deep fibular (peroneal), tibial and saphenous nerves (Moore, 1992:487). The talocrural joint receives additional nerve supply from a division of the common fibular (peroneal) nerve (Moore, 1992:490).

The nerves giving motor supply to the ankle musculature are also of importance in this study. The Anterior Tibialis and Peroneus Tertius are supplied by the deep peroneal nerve (a branch of the Sciatic nerve L4, L5, S1) and the common peroneal nerve (Moore, 1992:445; Reider, 1999:290). The Peroneus Longus and

Brevis muscles are supplied by the superficial peroneal nerve as well as the common peroneal nerve (Moore, 1992:447; Reider, 1999:292). The gastrocnemius and soleus muscles are supplied by the branches of the tibial nerve, which is the largest branch of the Sciatic nerve (Reider, 1999:291). The posterior tibialis is supplied by the deep peroneal nerve and the tibial nerve (Reider, 1999:291).

The nerves associated with proprioception are sensory in nature, sending information from these mechanoreceptors to the brain allowing us to know the location of one body part in relation to another, the degree of joint flexibility, the degree of muscle contraction and tendon stress, and the head and body position in movement, providing us with a conscious awareness of body position and movement known as the kinaesthetic sense (predictive nature with regards to the maintenance of balance) (Adragna et al. 1990:553).

2.2.1.5 MUSCLES RELATED TO THE ANKLE JOINT

The **Tibialis Anterior** muscle is a component of the anterior, extensor compartment of the lower leg, along with the extensor digitorum longus, extensor hallucis longus and the peroneus (fibularis) tertius muscles.

This long, thick muscle (tibialis anterior) lies against the lateral surface of the tibia, where it is easy to palpate. Its proximal attachments are the lateral condyle and superior half of the lateral surface of the tibia. The distal attachments are the medial and inferior surfaces of the medial cuneiform bone and the base of the first metatarsal bone. The main actions of this muscle are dorsiflexion and inversion of the foot. The Anterior Tibialis is innervated by the deep fibular (peroneal) nerve (L4 and L5) (Moore, 1992:444-445; Travell, Simons and Simons, 1992: 356-359).

As the **Extensor Digitorum Longus** and **Extensor Hallucis Longus** have no effect on the movement at the ankle joint these have not been explained in this study.

The **Fibularis (Peroneus) Tertius** muscle is small and variable and is also a component of the extensor compartment of the lower leg. It consists of a partially separated part of the extensor digitorum longus muscle. The two muscles are fused at their proximal attachments, but distally the tendon of the fibularis tertius does not attach to a digit. The proximal attachments of this small muscle are the inferior third of the anterior surface of the fibula and the interosseous membrane. The distal attachments are to the dorsum of the base of the fifth metatarsal bone. The main actions of the Fibularis Tertius muscle are dorsiflexion and eversion of the foot. This muscle is innervated by the deep fibular (peroneal) nerve (L4, L5 and S1) (Moore, 1992:445-446; Travell, Simons and Simons, 1992:373-375).

The **Fibularis (peroneus) Longus** muscle together with the Fibularis (peroneus) Brevis muscle make up the lateral compartment of the leg. The Fibularis Longus is the longer more superficial of the two fibularis (peroneal) muscles and it arises much more superiorly on the body of the fibula.

The Fibularis Longus muscle is a narrow muscle that extends from the head of the fibula to the sole of the foot. Its tendon can be palpated and be observed proximal and posterior to the lateral malleolus. The proximal attachments are the head and two thirds of the lateral surface of the fibula. The distal attachments are to the base of the first metatarsal bone and medial cuneiform bone.

The main action of the Fibularis (Peroneus) Longus muscle is eversion of the foot; this muscle also assists in weak plantarflexion of the foot. When one stands on one foot the Fibularis Longus muscle also helps to steady the leg on the foot. The Fibularis Longus is enclosed in a common synovial sheath with the Fibularis (Peroneus) Brevis muscle. It passes inferior to the fibular (peroneal) trochlea on the calcaneus to enter a groove on the anteroinferior aspect of the cuboid bone. It then crosses the sole of the foot, running obliquely and distally to reach its distal attachment. This muscle is innervated by the superficial fibular (peroneal) nerve (L5, S1 and S2) (Moore, 1992:448; Travell, Simons and Simons, 1992:371-372, 375).

The **Fibularis (Peroneus) Brevis** muscle is a fusiform muscle and it lies deep to the Fibularis (Peroneus) Longus muscle, as its name indicates it is shorter than the Fibularis Longus. The proximal attachments of this muscle are to the inferior two thirds of the lateral surface of the fibula. The distal attachments are to the dorsal surface of the tuberosity on the lateral side of the base of the fifth metatarsal bone. The main action of this muscle is eversion of the foot and with the Fibularis (Peroneus) Longus muscle also assists weak plantarflexion of the foot. Its tendon grooves the posterior aspect of the lateral malleolus and can be felt inferior to the lateral malleolus, where it lies in a common tendon sheath with the Fibularis (Peroneus) Longus muscle. The tendon of the Fibularis Brevis can easily be traced to its distal attachment. This muscle is also innervated by the superficial fibular (peroneal) nerve (L5, S1 and S2) (Moore, 1992:448; Travell, Simons and Simons, 1992:372-373, 375).

The **Extensor Digitorum Longus** and **Extensor Hallucis Longus** muscles are not directly involved in the movements at the ankle joint and are therefore not relevant to this study and have not been included in this chapter.

In the posterior compartment of the lower leg there are three superficial muscles and four deep muscles.

The three superficial muscles are the Gastrocnemius, Soleus and Plantaris muscles (Moore, 1992: 449). The Gastrocnemius and Soleus form a tripartite muscle that is referred to as the triceps surae.

The deep group of muscles in the posterior lower leg consists of the Popliteus, Flexor Digitorum Longus, Flexor Hallucis Longus and Posterior Tibialis muscles (Moore, 1992:452).

The **Gastrocnemius** muscle is the most superficial of the muscles in the posterior compartment; it forms most of the prominence of the calf. The Gastrocnemius is a fusiform, two-headed, two joint muscle. Its medial head is slightly larger and extends a little more distally than does the lateral head. The heads come together at the inferior margin of the popliteal fossa where they form the inferolateral and inferomedial boundaries of this fossa. The proximal attachment of the lateral head is to the lateral aspect of the lateral condyle of the femur. The proximal attachment of the medial head is to the popliteal surface of the femur, superior to the medial condyle. The distal attachment of the lateral and medial heads is to the posterior surface of the calcaneus via tendocalcaneus (this attachment is shared with the soleus muscle).

The actions of the Gastrocnemius muscle are plantarflexion of the foot, raising of the heel during walking and flexion of the knee joint. As its fibres are mainly vertical, contraction of this muscle produces rapid movement during running and jumping. These muscles help to steady the legs; consequently they are active when standing. When standing on the toes or when high heels are worn, these muscles are especially active. The Gastrocnemius is innervated by the tibial nerve (S1 and S2) (Moore, 1992:449, 451; Travell, Simons and Simons, 1992:398-401).

The **Soleus** muscle is a broad, flat, fleshy, multipennate muscle. It lies deep to the Gastrocnemius and can be palpated on either side of it, inferior to the midcalf. The proximal attachments of the Soleus are in a horseshoe shape and are to the posterior aspect of the head of the fibula, superior fourth of posterior surface of the fibula, soleal line and the medial border of the tibia. The distal attachment of this muscle is to the posterior surface of the calcaneus via the tendocalcaneus. The main action of this muscle is plantarflexion of the foot along with the Gastrocnemius muscle however it does not act on the knee joint; it also steadies the leg on the foot. Due to its broad, multipennate structure the contractions of this muscle are strong although slower than those of the Gastrocnemius muscle. The Soleus is innervated by the tibial nerve (S1 and S2) (Moore, 1992:450-451; Travell, Simons and Simons, 1992:430-431, 435,436).

The **Plantaris** muscle is variable in size and extent and is not always present. It has a small, fusiform belly and a long slender tendon, which runs obliquely between the gastrocnemius and soleus muscles. It attaches to the inferior end of the lateral supracondylar line of the femur and the oblique popliteal ligament. It weakly assists the Gastrocnemius in plantarflexing the foot and flexing the knee joint. It is innervated by the tibial nerve (S1 and S2) (Moore, 1992: 450-451; Travell, Simons and Simons, 1992:434, 435, 439).

The **Popliteus** muscle acts on the knee joint not the foot and ankle and therefore is not relevant in this study. **The Flexor Digitorum Longus** and **Flexor Hallicus Longus** are also not involved with movement at the ankle joint and therefore have not been included in this particular study.

The **Tibialis Posterior** muscle is a large fusiform muscle and is the deepest one in the posterior crural compartment. It lies between the Flexor Digitorum Longus and the Flexor Hallicus Longus in the same plane as the tibia and fibula. Its tendon can be seen and palpated posterior to the medial malleolus, especially when the foot is inverted against resistance. The proximal attachments of the Tibialis Posterior muscle are to the interosseous membrane, posterior surface of the tibia, inferior to the soleal line and to the posterior surface of the fibula. The distal attachments are to the tuberosity of the navicular, cuneiform, and cuboid bones as well as to the bases of the second, third and fourth metatarsal bones. The main actions of this muscle are plantarflexion and inversion of the foot (Moore, 1992:455, 457; Travell, Simons and Simons, 1992:461, 462).

2.2.2 BIOMECHANICS OF THE ANKLE

2.2.2.1 THE ANKLE

The ankle joint is uniaxial; its main movements are dorsiflexion and plantarflexion with the range of plantarflexion being greater than that of dorsiflexion, there is however considerable variation in these movements (Moore, 1992: 488). When the foot is plantarflexed, some rotation, abduction and adduction are possible at the ankle joint (Moore, 1992:488). The physiological loading of the mortise, formed by the articular surfaces of the ankle joint, accounts for 30 percent of the stability during rotation and 100 percent of the stability during inversion and eversion (Reid, 1992:219).

The ankle joint is very strong during dorsiflexion because (1) it is supported by powerful ligaments and (2) it is crossed by several tendons that are tightly bound down by thickenings of the deep fascia called retinacula.

Its stability is greatest in dorsiflexion because in this position the trochlea of the talus fills the mortise formed by the malleoli. During this action, the grip of the malleoli on the trochlea is strongest because this movement forces the wider anterior part, of the superior articular surface, of the trochlea posteriorly, spreading the tibia and fibula malleoli slightly apart. This spreading is limited by the strong interosseous ligament and by the anterior and posterior tibiofibular ligaments that unite the bones (Moore, 1992:489, 490), and requires some movement of the proximal tibiofibular joint (Moore, 1992:488).

The normal value for dorsiflexion of the foot is noted as 15º to 20º past neutral Baker and Todd (1965:61). According to Magee (1992:471), for minimal normal locomotion to occur, the ankle should be able to dorsiflex ten degrees and plantarflex between twenty and twenty five degrees.

The ankle joint is relatively unstable during plantarflexion. During this movement the trochlea of the talus moves anteriorly in the mortise, causing the malleoli to come together. The grip of the malleoli on the trochlea is not as strong in this position as in dorsiflexion and some side movement of the foot can be demonstrated when the foot is in full plantarflexion. The wedge-shaped form of the trochlea assists the ankle ligaments in preventing posterior displacement of the foot during sudden jumps and stops (Moore, 1992:489, 490).

During plantarflexion, the Anterior Talofibular ligament provides protection against pathological inversion movements at the ankle joint (Reid, 1992:218, 219).

Although the ankle is unstable in plantarflexion, appropriate training and conditioning strengthens the joint in this position (Moore, 1992:487-490).

External rotation of the foot at the ankle is primarily restrained by the Calcaneofibular ligament (Reid, 1992:219). This ligament is slightly tensed with the foot in the neutral position and moderately resists pathological inversion of the foot (Reid, 1992:218).

2.2.2.2 THE SUBTALAR JOINT

The subtalar joint works with the ankle joint to translate rotations occurring in the tibia about its vertical axis into rotations in the foot about a sagittal axis. These coupled actions are necessary to allow the rapid rotations that occur in the leg to be absorbed by a relatively fixed foot (Reid, 1992:215).

Inversion and eversion of the foot are the main movements that occur at this joint. The joint permits slight gliding and rotation that assist with inversion and eversion of the posterior part of the foot. Movements of the subtalar joint are closely associated with those at the talocalcaneonavicular and calcaneocuboid joints (Moore, 1992:490-491). During plantarflexion, the Calcaneofibular ligament is oriented almost completely horizontally stabilising only the subtalar joints (Reid, 1992:218).

2.3 INCIDENCE AND PREVALENCE OF ANKLE SPRAINS

The majority (85%) of injuries to the ankle are ankle sprains (Garrick, 1977:241). The ankle sprain is probably the single most common injury in sport (Oloff, 1994:243; Garrick and Requa, 1988; Kawaguchi, 1999). As approximately 27,000 ankle sprains occur each day in the United States and they account for more than 25%of injuries and associated time loss in some sports (Mack, 1982:71; McGrew et al. 2003:34). At least 95% of isolated ankle sprains are of the lateral ligaments (Reid, 1992:217). Recurrent ankle sprains are equally common in both the weekend warrior and the high level athlete (Greenman, 1996:552).

An ankle sprain is defined as a joint injury in which some of the fibres of a supporting ligament are ruptured, but the continuity of the ligament remains intact (Gatterman, 1990:415). The type of instability associated with chronic ankle sprains is characterized by either a relatively frequent (every 2-3 months) severe sprain, or minor episodes caused by minimal mis-steps occurring daily or more often (Coker, 1991:2433). Previous history of an ankle injury distinguishes chronic functional instability from an acute injury (Tropp et al.1985: 261; Coker, 1991 and Reid, 1992).

Most ankle injuries or sprains occur during participation in sports activities; with athletes (recreational or competitive) especially runners and joggers being more prone to injury due to repetitive use of the extremities and alterations in training schedules and shoe wear (Calliet, 1997; Cooper et al. 1998; Austin, 2002; Hammer, 2002; Smith et al.2002 and McGrew et al. 2003). Chronic ankle sprains are sports related when there are constant stresses and forces around the ankle, which lead to chronic bone and joint changes (Reid, 1992:222). It was shown that players who had a history of previous ankle problems suffered more ankle sprains than those with no history (Tropp, 1985:261).

Injuries to the ankle may also be due to either underlying structural deficits/ malalignment of the lower extremity (Cooper et al.1998; Austin, 2002), other underlying factors which would predispose a person to these injuries are: age, overuse, male sex, vascular compromise and excessive hindfoot varus and valgus (Cooper et al.1998). Rupture of the Achilles tendon and ankle sprains are also commonly encountered as a result of traumatic sports injuries (Oloff, 1994; Kawaguchi, 1999).

The classic presentation of chronic ankle sprains is in an 18-65 year old male recreational or competitive athlete involved in ballistic sports activities as well as running and jogging and sports where changes in direction and speed are made quickly (Reid, 1992; Oloff, 1994).

With chronic ankle sprains patients usually present with a history of trauma aggravated by activity and relieved by rest (Reid, 1992:215). Giving way is the most common symptom of chronic lateral ankle ligament tear (Coker, 1991:2433). Many patients remain symptomatic in terms of, or a combination of, pain, swelling, crepitus, decreased range of motion or functional instability. It can be concluded that complications such as chronic functional instability, synovitis, tendinitis, weakness and stiffness of the involved joint may arise (Baker and Todd, 1995; Kawaguchi, 1999).

Achilles contracture / tightness and insidiously increasing pain and stiffness in the region of the Achilles tendon can also be a long term complication of chronic ankle sprains and can predispose patients to further sprain if not rehabilitated correctly and returned to its normal length and functioning (Baker and Todd, 1995; Reid, 1992). This is more common post traumatically (repetitive or single insult), but may also be congenital in origin (Baker and Todd, 1995:61), which is a direct contributing factor in the development of functional instability (Calliet, 1997: 211). Failure of the tendon to hypertrophy appropriately along with the muscle in compensation for this instability may also predispose it (the Achilles tendon) to microtrauma and subsequent, recurrent or chronic tendonitis (Reid, 1992: 202 203) leading to contracture (Baker and Todd, 1995:61). The result of the tightness from the Achilles tendon contracture has been directly linked to the limitation of dorsiflexion at the mortise and subtalar joints of the ankle, normal being noted as 15º to 20º past neutral Baker and Todd (1995:61). This decrease in flexibility[1] at the ankle can also be as a result of Achilles tendon dysfunction (Oloff, 1994).

Therefore the eventual instability and compensating hypomobility in related joints leads to the pain becoming persistent culminating in:

- ❖ permanent tenderness and discomfort with walking and with daily activities (Reid, 1992: 201 and Kaikkonen et al.1994: 469) and
- ❖ decreased range of motion (Baker and Todd, 1995:61; Kerr et al.1998: 51) and
- ❖ decreased strength (Travell, Simons and Simons, 1992:15; Oloff, 1994)

2.4 THE MECHANICAL HYPOTHESES

2.4.1 HISTORICAL BACKGROUND

The sequence of rehabilitation of any contracture, decreased range of motion (flexibility) of a joint, and muscle strength and function has been focused on the improvement of strength prior to proprioception (Calliet, 1997; Flemister et al.

[1] Flexibility: The ability of the muscles to elongate as a joint or bony segment moves through a range of motion (Vegso.1995: 476-477)

1998; Buhler et al. 2002). However according to McGrew et al. (2003) and supported by Oloff (1994); Vegso (1995); Calliet (1997); Kawaguchi (1999) and Buhler et al. (2002), this is a common mistake in rehabilitation and focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalisation of the relationship of the anatomical structures.

All research in this regard has never assessed the assumption that the strength of the relevant musculature would return (Blokker et al.1992 and Klaue et al.1998).

A successful rehabilitation program following an ankle sprain should take into account these factors: 1) An understanding of the structure and function of this physiological unit, it's associated receptors and their involvement with the locomotor system; 2) Restoration and improvement of the athlete's functional ability without re-injury; 3) specific exercise training to meet demands placed on the body as a whole and to allow return of full participation in the chosen endeavour (Kawaguchi, 1999).

2.5 MECHANISM OF INJURY

In athletes the most frequently injured structure in the body is the lateral ligament complex of the ankle (Garrick, 1977:241). At least 95% of isolated ankle sprains are of the lateral ligaments, which are damaged by excessive inversion accompanied by either plantarflexion or rotation (Reid, 1992:217, 220). As inversion of the foot tends to occur with active plantarflexion, inversion injuries of the ankle tend to occur more often than eversion injuries when the foot is in plantarflexion (Moore, 1992:490).

In severe ankle sprains many fibres of the lateral ligaments are torn, either partially or completely, resulting in instability of the ankle joint (Moore, 1992:490).

A sprained ankle results from twisting of the weight-bearing foot and is nearly always an inversion injury i.e.: the foot is forcefully inverted (Moore, 1992:490). A major mechanism of injury is landing from a jump. Landing on another player's foot in a crowded area or changing direction, particularly if associated with deceleration, are vulnerable situations for ankle sprains. This tendency is exaggerated when there is an uneven surface. In contact sports, a direct blow or an opponent grabbing the foot may also precipitate a sprain.

Other contributing factors to injury include a significant varus heel, weak musculature (especially peronei), tight heel cords, tarsal coalition, generalised ligamentous laxity, low profile boots, narrow, long cleats (on soccer, football and field hockey boots) and previous ankle injury (Reid, 1992:220, 221).

Chronic ankle sprain may occur during such activities as ballet, where poor postural habits and insufficient strength of the muscles controlling the subtalar joint can lead to gradual stretching of the ligaments (Reid, 1992:222).

2.6 PATHOMECHANICS OF ANKLE SPRAINS

When the foot is in the neutral position, the anterior talofibular ligament is oriented horizontally and is relaxed, resisting anterior shear; the calcaneofibular ligament is slightly tensed and only moderately resists a pathologic inversion of the ankle; the posterior talofibular ligament is also relaxed being stressed with the foot in plantar or dorsiflexion (Reid, 1992:218).

During plantarflexion, the Anterior Talofibular ligament, which works with the deltoid ligament in limiting internal rotation, is tightened and is oriented almost vertically, thus being parallel to the long axis of the tibia and providing protection against pathological inversion movements at the ankle joint (Reid, 1992:218, 219). Due to the fact that at least 95% of isolated ankle sprains are of the lateral ligaments, which are damaged by excessive inversion accompanied by either plantarflexion or rotation (Reid, 1992:217, 220), the Anterior Talofibular Ligament is the most commonly damaged ligament in ankle sprains.

Rupture of this ligament results in various manifestations of chronic rotational instability, of which talar tilt and anterior subluxation (anterior drawer) are well known (Reid, 1992:219, 220). As the anterior talofibular ligament is fused with the fibrous capsule of the ankle joint, this part of the capsule may also be torn in injuries of the anterior talofibular ligament (Moore, 1992:490).

It can be concluded from the biomechanical and anatomical factors at the ankle that the Anterior Talofibular ligament is probably the most important stabilising component of the lateral ligamentous apparatus (Reid, 1992:220).

External rotation of the foot at the ankle is primarily restrained by the Calcaneofibular ligament (Reid, 1992:219). This ligament is slightly tensed with the foot in the neutral position and moderately resists pathological inversion of the foot (Reid, 1992:218). Partial or complete tearing of this ligament usually occurs as the result of an avulsion type fracture-dislocation of the ankle joint, with the tip of the lateral malleolus (of the fibula) being pulled away by violent inversion of the fixed foot (Moore, 1992:490).

During dorsiflexion the Posterior Talofibular ligament (the main factor in this position as this ligament is the main restrictor of plantarflexion) is stressed, particularly in trauma, however this ligament is rarely injured (Reid, 1992:218). When injury to this ligament does take place it is usually during parachute jumping, in ice-hockey where the player slides into the board at high speed, and on awkward landing during certain jumping activities (Reid, 1992:218).

2.7 PROPRIOCEPTION

Proprioceptors are receptors, which inform the central nervous system about the state of our joints and muscles. They respond to muscle length and tension during static and moving conditions and give the brain feedback on mechanical stresses and body function (Kerr et al. 1998:125; Buhler et al. 2002:8-15). They enable one to know the position of their body and all of its components in space, but not necessarily at a conscious level, this is proprioception (Kerr et al. 1998:125). With proprioceptive exercises the patient retrains the ankle and decreases the chances of re-spraining this joint (Cooper and Sammarco, 1998:367).

Rehabilitation programs often neglect the proprioceptive training, which can make a difference in the patient's outcome after treatment (Oloff, 1994:247).

According to McGrew et al. (2003) and supported by Oloff (1994); Vegso (1995); Calliet (1997); Kawaguchi (1999) and Buhler et al. (2002), this is a common mistake in rehabilitation and focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalisation of the relationship of the anatomical structures. Proprioception is also acknowledged as an important component in the rehabilitation process by Thompson (1991); Reid (1992) and Cooper and Sammarco (1998).

2.8 CHRONIC ANKLE INSTABILITY

Inadequate protection and rehabilitation of the ankle joints allow re-injury and eventually produce chronic instability (Reid, 1992:228).

The bony configuration of the ankle joint, the movement of the fibular and the dynamic stabilising role of the peroneal muscles play an important role with the ligaments in terms of ankle stability (Reid, 1992:217, 218).

Giving way is the most common symptom of chronic lateral ankle ligament tear (Coker, 1991:2433), and after what is considered appropriate ligament healing, a degree of instability may remain in approximately 20% to 40% of patients (Calliet, 1997:211).

Continuing symptoms following a sprained ankle such as pain, swelling, a feeling of instability, crepitus, weakness and decreased range of motion or functional instability and stiffness can be as a result of incomplete or absent rehabilitation. It can be concluded that unless properly rehabilitated these complications such as chronic functional instability, synovitis, tendinitis, weakness and stiffness of the involved joint may arise (Baker and Todd, 1995).

The main causes of these symptoms are instability, joint stiffness due to a loss of fibular and subtalar joint motion, tight sensitive scar tissue and incomplete rehabilitation (Reid, 1992:250). This inadequate rehabilitation is represented by some of the following factors: muscle weakness, poor proprioceptive control, and pain inhibition secondary to impingement or peroneal subluxation (Reid, 1992:251).

Bassewitz and Shapiro (1997) suggest that causes, other than inadequate rehabilitation, for persistent pain at the ankle may be a result of posttraumatic impingement syndrome, occult osteochondral injury, peroneal tendon damage, syndesmosis injury or chronic instability.

Instability undoubtedly occurs because of loss of proprioception at the ankle following an ankle sprain (Calliet, 1997:211).

Injuries to the tibial and peroneal nerves as the result of ankle sprains contribute to early re-injury, peroneal muscle weakness, incomplete rehabilitation, and eventually significant long-term damage to other structures so that by the time neural recovery is complete, chronic instability has been established (Reid, 1992:253).

One of the primary goals of treatment is the prevention of long-term functional instability. The most obvious cause is post-traumatic ligamentous laxity, seen in patients with a talar tilt of more than ten degrees difference between sides. Lesser laxity however, does not always seem to correlate with less instability and therefore other factors must also be considered.

Subtalar stiffness and loss of motion easily ensues from post-traumatic oedema, particularly when cast immobilisation has been the treatment of choice. Failure to restore this subtalar motion throws increasing stress on the talocrural joint during all cutting and turning movements, gradually contributing to further stretching of already lengthened ligaments.

Although tests of lateral talar tilt may be normal (a talar tilt of more than five degrees in comparison with the other side is considered significant), mechanical instability cannot be ruled out until the absence of an anterior drawer sign is demonstrated. An Anterior Drawer test of four millimetres or more is considered significant (Coker, 1991:2433; Reid, 1992:251-252).

Unfortunately, despite excellent treatment (see 2.15), some individuals develop severe, recurrent instability of the ankle that does not respond to exercise techniques and is too severe to treat without ankle orthosis. These people require reconstructive surgery of their ankle ligaments (Reid, 1992:251, 252).

2.9 NATURAL HISTORY OF ANKLE SPRAINS

According to Reid (1992:226), grade one ankle sprains usually recover over a period of eight days (range of two to ten days) and grade two ankle sprains usually recover over a period of twenty days (range of ten to thirty days). Grade three ankle sprains recover over a period of forty days (range of thirty to ninety days).

Healing of the ligaments is as follows: Macrophages occur at the edge of the tear, followed by newborn fibroblasts. These fibroblasts replicate around capillary buds and gradually mature. Microfibroblasts appear 24 to 48 hours after leukocytes appear. By 72 hours, collagen fibres appear. The clot that appears in the space created by the tear is the site of cellular infiltration. Then collagen synthesis occurs; the collagen gradually re-organises into parallel bands, which are thickened by the formation of fibrous scar tissue. Tension applied during these stages of organisation aligns the strands into parallel bands; hence the value of elongation exercises during healing (Calliet, 1997:211).

A more detailed description of connective tissue healing is given by Reid (1992:74, 75).

Phase One: Reaction Phase:

The initial inflammatory response to trauma occurs in this phase. Included in this response are vasodilation, exudation of fluids, haemorrhage, oedema, stimulation of pain fibres, phagocytosis of debris, an immune response, and the initiation of cell division and other elements required for healing. This response is manifested as swelling, pain, and loss of function (Reid, 1992:74, 75).

Phase Two: Regeneration Phase:

The main activities occurring in this phase include elimination of debris, revascularization and fibroblastic proliferation. Phagocytosis eliminates debris so as to protect the devitalised tissue from infection. Capillary buds form as an indirect stimulation from oxygen deprivation in damaged tissues; fibroblasts are attracted to the area and produce collagen (Reid, 1992:74, 75).

Phase Three: Remodelling Phase:

This phase usually lasts about six months and is characterised by contraction of the scar tissue and subsequently by maturation of collagen (Reid, 1992:74, 75).

Contraction of the scar is an asset in that it decreases the size of the defect in the torn tissue; however it may limit motion and cause pain, so gentle stretching is necessary throughout the healing process. There is substantial evidence to suggest that ligaments serve important roles as signal sources for the locomotor system. If the evidence of their mechanoreceptor importance is valid, more effort should be made to substitute for their function once this function is disrupted by trauma. The introduction of significant amounts of proprioceptive training in rehabilitation programs following ligament injury or surgery is essential (Reid, 1992:77).

2.10 DIAGNOSIS AND GRADING OF ANKLE SPRAINS

<u>EXAMINATION PROCEDURE:</u>

In order to evaluate and correctly diagnose ankle sprains, and in particular chronic ankle sprains, there is a protocol, which needs to be followed.

At the patient's initial consultation a full patient history is taken, this includes asking questions which give the examiner specific information regarding the following: Whether the patient has a previous history of ankle sprain as well as previous treatment thereof, whether the patient could bear weight on the injured ankle after the injury and which activities were possible or impossible.

The examiner determines whether the patient has any systemic diseases and whether there is any relevant family history, which may influence the ankle instability and recovery. The answers to these questions and many others help the examiner reach a tentative diagnosis and guide further examination and treatment (Reid, 1992:222).

The next step in this process, after a thorough physical examination is carried out to determine the severity of any related symptoms and to give a clearer indication of the patient’s general state of health, is inspection and palpation of the normal and then the abnormal (injured) ankles (Reid, 1992:222, 223). [The examiner examines the uninjured ankle first to put the patient at ease and to establish a baseline for comparison (McGrew et al. 2003:35-36).]

This examination includes the observation of gait and inspection at rest (including registering the condition of the skin), thorough palpation for specific areas of tenderness, range of motion testing, muscle strength evaluation, a neurological examination (especially of the motor and sensory branches of the peroneal and sural nerves), a vascular examination (establishing the presence of the posterior tibial and dorsalis pedis pulses) and specific ligamentous examinations (Reid, 1992:224; McGrew et al. 2003:35).

Pain is not always proportional to injury and therefore careful assessment of the areas of swelling and tenderness help determine which bands of the ligaments are affected. Viewing the ankle from behind also gives an idea of the definition of the Achilles tendon. Excessive deformity arouses suspicion of an ankle fracture, diastasis, or talar or subtalar dislocation (Reid, 1992:222, 223).

After the general assessment of the ankle is complete the examiner performs four specific stress tests to test for any instability at the ankle joint. These are: The Anterior Drawer Test, the Lateral Tilt Test (Inversion and Eversion Test), the Thompson Test and the Tests for Syndesmosis Sprains.

An examination of the knee for proximal tibiofibular joint problems or a proximal fibular fracture is important. The knee should furthermore be assessed for ligamentous laxity, which could be a contributing, or even primary causative factor in the functional instability found at the ankle joint (Reid, 1992:224).

2.10.1 ORTHOPAEDIC TESTS FOR ANKLE STABILITY

The following tests were performed and compared between the normal and pathological ankles in order to assess the ankle for any gross instability:

2.10.1.1 ANTERIOR DRAWER TEST

This is the primary test for ankle instability and tests the anterior talofibular ligament, anterior capsule and calcaneofibular band (Reid, 1992:223).

The Anterior Drawer is performed by having the patient sit up with the knee bent to 90 degrees and the leg hanging freely over the edge of the table. This allows the calf musculature to be relaxed and the ankle to fall into the natural amount of plantarflexion for that patient. The examiner stabilises the distal tibia/fibula with one hand and uses the other hand to cradle the heel and pull anteriorly, while applying a posterior force to the leg, looking for a dimple over the Anterior Talofibular ligament and estimating the translation of the talus in relation to the mortise (Reider, 1999:294; McGrew et al. 2003:36, 38).

The key to diagnosing pathological laxity of the anterior talofibular ligament is finding a difference of at least 3mm to 5mm laxity between the two ankles (Reider, 1999:294-295). The positive test is often accompanied by a “clunking sensation” (Reid, 1992:223).

2.10.1.2 TALAR TILT TEST

Also known as the Inversion Stress Test or Varus Stress Test. The integrity of the Calcaneofibular Ligament is evaluated with this test, when performed during plantarflexion it involves the anterior talofibular ligament more.

The patient is seated in the same position as used for the anterior drawer test (with the knee at 90 degrees). This time, the examiner grasps the patient’s forefoot with one hand and maximally dorsiflexes the ankle to place the calcaneofibular ligament under tension and to lock the subtalar joint. While maintaining this position, the examiner grasps the patient's calcaneus with the opposite hand and attempts to invert the heel. In the normal patient, very little movement is felt in response to this stress, and the resistance is firm. When the calcaneal ligament is compromised, the examiner feels the talus rock into inversion. Injury is diagnosed if an asymmetric increase in varus laxity is noted.

This test is difficult to evaluate as the motion of the talus is hard to visualise and can only be sensed by feel. If the examiner does not maximally dorsiflex the ankle when performing this exam, substantial inversion movement occurs at the subtalar joint, therefore making it difficult to detect whether abnormal inversion is taking place at the ankle joint (Reider, 1999:295).

2.10.1.3 TESTS FOR SYNDESMOSIS SPRAINS

The squeeze test is performed by the examiner compressing the fibula to the tibia above the level of the injury. A positive test is indicated by pain, which occurs distally over the area of the interosseous ligament, or it's supporting structures i.e.: in the anterolateral ankle (Bassewitz and Shapiro, 1997:10).

The external rotation test is performed holding the talus in the neutral position and applying a passive external rotation stress to the involved foot and ankle with the knee held at 90 degrees. This test is positive if pain is produced over the area of the syndesmotic ligaments (Bassewitz and Shapiro, 1997:10).

2.10.1.4 THOMPSONS TEST FOR ACHILLES TENDON RUPTURE

The Thompson Test is a manipulative test for confirming the diagnosis of Achilles tendon rupture. This being commonly overlooked as the patient is still able to plantarflex the ankle with intact toe flexors. To perform the Thompson test, the patient is placed prone on the examination table with both feet dangling from the end. In this position, the examiner can see the swelling and ecchymosis in the case of Achilles tendon rupture. Normally resting tension in the gastrocnemius muscle complex holds the foot in slight plantarflexion when the patient is lying prone. The Thompson test itself is performed by grasping the patient’s calf with one or both hands and gently squeezing the muscle. When the Achilles tendon is intact, the foot passively plantarflexes when the calf is squeezed. In the presence of a partial tear of the Achilles or injuries to the gastrocnemius aponeurosis the normal plantarflexion response occurs (Reider, 1999:296, 297).

2.11 GRADING OF ANKLE SPRAINS

Grade One Sprains

Grade one sprains are mild injuries, characterised by stretching of the anterior talofibular ligament without any instability, that produce pain lasting a few minutes to a few days. The signs and symptoms of grade one ankle sprains include no evidence of haemorrhage, minimal swelling, point tenderness, no varus laxity and a negative anterior drawer sign.

Frequently they do not require specific therapy and, in their mildest form, allow rapid resumption of activity with little or no detectable swelling (Reid, 1992:239).

A Grade One ligamentous sprain (Anterior Talofibular Ligament) is a partial tear showing only evidence of microscopic disruption (McGrew et al. 2003:39). According to the Jackson Protocol, which evaluates the functional status of the extremity, a grade one sprain has minimal swelling and the patient is able to bear weight on the extremity (McGrew et al. 2003:39).

Grade Two Sprains

Although a moderate degree of anterior draw may be present with severe grade two injuries, these sprains may essentially be considered stable (Reid, 1992:239-242). These sprains are characterised by a wide spectrum of injury, displaying mild to moderate instability, and may involve either a complete tear of the anterior talofibular ligament or a partial tear of both the anterior talofibular and the calcaneofibular ligaments. The signs and symptoms of grade two ankle sprains include some haemorrhage, localised swelling, decreased definition of the Achilles tendon margin, a possible positive anterior drawer sign, and no varus laxity (Reid, 1992:226).

A Grade Two tear is partial and is one that can be seen grossly but has remaining ligamentous integrity (McGrew et al. 2003:39). According to the Jackson Protocol, a grade two sprain has moderate swelling and causes moderate pain on weight bearing (McGrew et al. 2003:39).

Grade Three Sprains

A grade three sprain is by definition an unstable one with the involvement of two ligaments (Reid, 1992:242). A grade three sprain is a severe injury in which there is significant instability and complete tearing of the anterior capsule and the talofibular ligament with an associated tear of the anterior talofibular and calcaneofibular ligaments. These injuries are characterised by diffuse swelling on both sides of the Achilles tendon, early haemorrhage, lateral and medial tenderness, a positive anterior drawer test and positive findings of laxity at the ankle joint (Reid, 1992:226).

A Grade Three tear involves complete disruption of the ligament (McGrew et al. 2003:39). According to the Jackson Protocol, a grade three sprain has global swelling and is associated with an inability to bear weight (McGrew et al. 2003:39).

2.12 DIFFERENTIAL DIAGNOSES

When assessing the ankle sprain, it is important to bear in mind and rule out fracture, dislocation, tendon injuries, and other ligamentous disruptions. The location of tenderness and swelling, obvious deformity, excessive oedema, or increasing pain and swelling with weight bearing should raise suspicions of a more complex diagnosis. The most common of these problems are the fifth metatarsal fractures, cracks or avulsions of the fibular malleolus, and osteochondral lesions of the talar dome (Reid, 1992:224).

2.12.1 EVERSION/DELTOID LIGAMENT SPRAINS

A sprain is an injury to a ligament, implying a partial or full tear (McGrew et al. 2003:34). When the foot is forcibly everted this causes a pull on the strong medial (deltoid) ligament and often tears off the medial malleolus (Moore, 1992:490). Tenderness, swelling and ecchymosis over the deltoid ligament suggest a sprain involving this structure (Reider, 1999:286).

2.12.2 SYNOVITIS

Synovitis presents most commonly with pain at either the anterolateral or anteromedial tibiotalar joint line or both. The alternating motion of the tibia and talar neck during extreme motion of the ankle joint may contribute to chronic irritation at these areas. Pain at the joint line usually increases over a period of weeks or months. This is diagnosed by palpating between the medial malleolus and the anterior tibial tendon or between the lateral malleolus and the extensor digitorum longus tendon. Ankle effusion is usually not present in synovitis. The origin of anterolateral ankle pain may be confused with anterior tibiofibular ligament sprains, as these injuries also cause lateral ankle tenderness. By injecting 3 ml of 1 % lidocaine into the ankle joint the pain of synovitis should disappear, but pain from a chronic ligament sprain will remain. This differentiates these two conditions (Cooper and Sammarco, 1998:2501).

2.12.3 SYNOVIAL IMPINGEMENT

Patients with this condition complain of chronic pain and swelling over the anterior and anterolateral ankle with activity. These symptoms are often accompanied by a subjective feeling of instability and occasionally true giving way. There is always a history of a moderately severe ankle injury. There are two possible etiological explanations for this condition and the associated symptoms: first: The lesion may be secondary to traumatic synovial thickening, with incomplete resorption of the associated exudate. A small portion of the inflammatory infiltrate still exists between the talus and the fibula; it eventually becomes hyalinized secondary to pressure and gives rise to symptoms. Second: It has been suggested that meniscoid lesions, which are tears of the anterior tibiofibular ligament, become interposed between the talus and the lateral malleolus. Any redundant synovium is removed after an arthroscopy is performed; this excision should reduce the symptoms and prevent further joint irritation (Reid, 1992:258, 259).

2.12.4 BONY IMPINGEMENT SYNDROME

The talar anterior impingement syndrome is related to osteophytes on the neck of the talus or, more frequently on the anterior tibia. Dorsiflexion causes impingement of the bony spurs, along with the trapping and pinching of the hypertrophied and chronically swollen synovium. These lesions are seen occasionally after repeated ankle inversion injuries.

Alternatively the osteophytes may correlate with the tibial and talar attachments of the anterior capsule and may relate to chronic traction stresses seen in runners. The athlete may simply complain of ankle pain and swelling proportional to activities. In mild cases it can occur only with activities requiring sudden starts and stops or changes in direction, but in severe cases the symptoms occur with simple running or jogging. The feeling of pinching can be reproduced by forced dorsiflexion, and pain is experienced with palpation along the anterior talocrural joint line. Dorsiflexion is eventually limited by bony impingement and pain (Reid, 1992:258).

2.12.5 ANKLE FRACTURES AND DISLOCATIONS OFTEN ASSOCIATED WITH ANKLE SPRAINS

2.12.5.1 AVULSION OF THE TIP OF THE FIBULA

Avulsion fractures of the fibula commonly occur 2 to 6 cm proximal to the distal end of the lateral malleolus and are often associated with fracture-dislocations of the ankle joint (which occur in severe ankle injuries) e.g. : Pott's Fracture. This injury often occurs when the foot is fixed against some object and is then thrown into an excessively inverted position (e.g.: when a person slips). The body weight is then violently transferred to the lateral ligaments of the ankle (Moore, 1992:490), which tear resulting in the talus being forcibly tilted against the lateral malleolus, and shearing it off (Moore, 1992:437).

The distal portion of the body of the fibula is subcutaneous. Hence the fibula just proximal to the lateral malleolus is the part that is commonly fractured. The tip of the lateral malleolus extends more distally (1 to 2 cm) and posteriorly than the medial malleolus. This is important when diagnosing and treating injuries in the ankle region (Moore, 1992:437).

2.12.5.2 FRACTURES OF THE TALUS

Fractures of the neck of the talus occur during severe dorsiflexion of the ankle (e.g.: when a person is pushing extremely hard on the brake pedal of a car during a head-on collision. In some injuries, the body of the talus is dislocated posteriorly (Moore, 1992:440).

2.12.5.2.1 OSTEOCHONDRAL FRACTURES OF THE TALAR DOME

Talar dome lesions are classically caused by inversion mechanisms and are inherent sequelae of "simple" ankle sprains. They are most commonly found on the anterolateral and posteromedial quadrants of the dome, depending on the sagittal plane attitude of the foot during injury. Staging of these injuries is based on the morphology of the fracture: Stage one is a compression of cartilage and subchondral bone, Stage two is a partial fracture, Stage three is a complete fracture through subchondral bone, and Stage four is a displaced fragment. Diagnosis is made from plain radiographs, bone scans and CT (Oloff, 1994:246).

Osteochondral lesions of the talar dome are uncommon, accounting for only 4 percent of all osteochondritis lesions and 0.9 percent of all fractures. Trauma has been suggested as the only cause for these lesions and lateral lesions have been reproduced in cadaver studies in the directions of inversion with dorsiflexion, medial lesions have been reproduced in the same manner in the movements of inversion, plantarflexion and lateral rotation of the tibia on the talus (Reid, 1992:256).

The undoubted association with trauma, in many cases, means that a high index of suspicion is important in the differential diagnosis of chronic ankle pain after injury. The major symptoms include a deep aching or pain aggravated by exercise, ankle swelling, occasional crepitus, clicking, true locking, or catching sensation. The clinical signs include synovial thickening, effusion, and occasional joint line tenderness and stiffness manifested as a loss of range of motion in one direction or both directions. In all cases symptoms seem to be magnified with activity (Reid, 1992:256).

There is, with most people, a definite past history of an inversion sprain of the ankle or an ankle fracture, occasionally this lesion is associated with true or functional instability (Reid, 1992:256).

2.12.5.2.2 FRACTURES OF THE LATERAL PROCESS OF THE TALUS AND SMALL TARSAL BONES

Another syndrome that may be included in the spectrum of lesions of the ankle is post-traumatic chondromalacia of the lateral wall of the talus, with associated synovial reaction. The athlete complains of pain located over the anteroinferior aspect of the fibula, the associated anterolateral talus and the joint line. There is usually a history of single or repeated inversion injuries. It is suggested that pain and compression at foot strike makes the athlete, usually a runner, tighten the tibialis posterior and anterior tendons and inhibits the peroneal tendons. This makes the runner susceptible to multiple inversion strains (Reid, 1992:259).

Fractures of the metatarsals usually occur when a heavy object falls on the foot or the foot is run over by a heavy metal wheel (Moore, 1992:441).
Stress fractures may occur in the weight-bearing metatarsal bones and are called either “march fractures” or “fatigue fractures” (Moore, 1992:493).

2.12.5.3 FRACTURES OF THE BASE OF THE FIFTH METATARSAL

In the evaluation of a suspected ankle sprain, palpation of the base of the fifth metatarsal should be performed. Fractures of the base of the fifth metatarsal are not routinely picked up on ankle radiographs, and clinical examination can save time and any delays in diagnosis (McGrew et al. 2003:40). The spiral fracture of the base and diaphysis of the fifth metatarsal is the least common fracture type in an athlete, and is due to a fall from a height or a severe inversion sprain with superimposed loading (Reid, 1992:159).

The second most common fracture of the fifth metatarsal is the avulsion fracture of the base caused by the peroneus brevis muscle. This injury associated with an inversion sprain, is frequently seen in jumping sports.

The third pattern is a transverse fracture line of the proximal diaphysis. These fractures are seen in running and jumping athletes and usually represent stress reactions, although acute fractures do occur with inversion sprains (Reid, 1992:159-160).

When the foot is violently inverted, the tuberosity of the fifth metatarsal may be avulsed (pulled off) by the tendon of the Fibularis (Peroneus) Brevis muscle (Moore, 1992:441). This kind of fracture is associated with a severely sprained ankle (Moore, 1992:448). Injury to the associated superficial fibular (peroneal) nerve results in an inverted foot owing to paralysis of the fibular (peroneal) muscles, which evert the foot (Moore, 1992:448).

2.12.6 DISTAL TIBIOFIBULAR DISORDERS

2.12.6.1 OCCULT TIBIOFIBULAR DIASTASIS AND SYNDESMOSIS SPRAINS

Complete tearing of the anterior and posterior tibiofibular ligaments and the interosseous membrane (which maintains the integrity of the tibiofibular mortise) results in diastasis of this joint, which is a serious injury (Reid, 1992:215).

Diastasis of the tibiofibular joint and widening of the mortise with a displaced fibular fracture, at or above the level of the joint, is unacceptable. Widening of 1 to 2 mm may lead to an increase in joint forces of 30 to 40 percent, and in a young active individual, cause rapid, degenerative changes (Reid, 1992:265).

Tenderness over the anterior-inferior tibiofibular ligament may be associated with syndesmosis sprain. In more severe injuries, the tenderness continues up the leg owing to injury of the interosseous membrane (Reider, 1999:281).

2.12.6.2 TIBIOFIBULAR SYNOSTOSIS

Fibular motion during activity may be restricted by post-traumatic distal tibiofibular synostosis secondary to interosseous membrane damage and distal tibiofibular ligament injury. Although usually secondary to an ankle fracture, it may occur with an ankle sprain, particularly if there is an element of diastasis. The most frequent presenting complaints are chronic pain and swelling after activity. The discomfort is most severe during push-off. Dorsiflexion may be limited to the neutral position (Reid, 1992:254, 255).

2.12.7 TARSAL COALITION

Tarsal coalition is a fibrous, cartilaginous, or osseous union of two or more tarsal bones that is of congenital origin. There is evidence of a hereditary component. Embryologically, if there is failure of segmentation (into the various tarsal components), congenital defects with tarsal coalitions of the hindfoot and midtarsal areas may result. Many of these disorders are asymptomatic but when symptoms are present they may simply be local pain or diffuse aching in the arch, sometimes in association with intermittent peroneal muscle spasm (Reid, 1992:187). The onset of symptoms usually occurs after some unusual activity or trauma, frequently an ankle sprain (Reid, 1992:187).

2.12.8 ACHILLES TENDINITIS

This is a condition that affects the Achilles tendon however there is a debate as to whether tendonitis is the correct terminology. The word “itis” means inflammation and in conducted studies where tissues were biopsied, no inflammatory cells were found (Buhler et al. 2002:9). Therefore a true case of tendonitis would be as the result of a direct trauma to the area, as there would be swelling and probable inflammation (Buhler et al. 2002:9).

The word “osis” means condition of and therefore this is believed to be the more correct terminology (Buhler et al. 2002:10).

Tendinosis is a chronic degenerative process that occurs when overuse continues without intervention. It is the inflammation of the fibrous tissue that connects muscle to bone, leading to pain and movement restriction (Buhler et al. 2002:8, 10). There is often swelling and crepitus along the entire course of the Achilles tendon; this is best demonstrated with the patient standing. Tendinosis often presents with a painless mass in the affected heel cord proximal to the insertion (Smith, 2002:197).

2.12.9 PERONEAL TENDON PATHOLOGY

Peroneus Brevis splits are usually chronic injuries and result from mechanical irritation and propagation of the split from the sharp border of the fibula; the peroneus longus also acts as a wedge and assists the splitting of the brevis component of the peroneus muscle. Contributing factors for this condition include: injury to the superior retinaculum, a shallow fibular groove and hindfoot valgus. There is pain and tenderness in the posterolateral ankle and on resisted foot eversion a subluxation or dislocation can be palpated (Smith, 2002:200).

Peroneus Longus rupture occurs either as an acute tear or as a chronic longitudinal tear and are rare. There is associated prolonged pain in the lateral foot and ankle in the middle-aged athlete (Smith, 2002:200).

2.12.9.1 SUBLUXING PERONEAL TENDON

Peroneal tendon subluxation or dislocation can be acute or chronic and is often missed when acute. The anatomy associated with this condition includes: a shallow retromalleolar groove, pes planus, hindfoot valgus, and lax superior peroneal retinaculum. The mechanism in acute injuries is a forced dorsiflexion with the peroneals actively contracted as occurs in athletic cutting manoeuvres. Calcaneal fractures can also be associated with peroneal tendon dislocations (Smith, 2002:200).

The condition occasionally occurs spontaneously owing to anatomic variations of the bony groove and surrounding collagen, but invariably the precipitating cause is an ankle sprain. The athlete may present with pain, swelling, or the sensation of “popping” or “snapping” around the lateral malleolus. The latter is often associated with functional instability. Examination reveals tenderness along the peroneal sheath posterior to the fibular malleolus, with prominence of the sheath demonstrated by resisted dorsiflexion with eversion. There are great variations in laxity present (Reid, 1992:254).

2.12.9.2 PERONEAL TENDONITIS

Tendinitis of the peroneus longus and brevis usually occurs in patients who attempt to return to vigorous activity after a period of inactivity. However, tendinitis can be directly related to ankle and calcaneal fractures. Symptoms include pain in the posterolateral ankle area, especially during running or other activities that place an eversion force on the ankle (Smith, 2002:199).

2.12.9.3 STENOSING PERONEAL TENOSYNOVITIS

Stenosing tenosynovitis of the Flexor hallucis Longus (FHL) or “dancer’s tendinitis” is seen most often in professional dancers. The position of *en pointe,* which requires the ability to go from, a neutral foot to maximum plantarflexion, places tremendous strain on the FHL. The repetitive motion of the tendon through the entirety of the fibro-osseous canal in the ankle and foot can lead to chronic inflammation of the FHL. Patients who have FHL stenosing tenosynovitis present with posteromedial ankle pain and report a history of forceful plantar-flexing activities. There are often palpable nodules and pain and crepitus along the course of the tendon (Smith, 2002:201).

The patient complains of pain on the outer side of the ankle that is aggravated with exercises and relieved with rest. The tenderness is along the peroneal sheath and is made worse with active and passive motion. No mechanical instability is present and occasionally crepitus is felt. This injury has been associated with inversion injuries, fractures of the os calcis or ankle, or simply overuse. Patients with diffuse chronic complaints related to the lateral malleolar area, sometimes associated with functional instability, should be suspected of having this syndrome (Reid, 1992:254).

2.12.10 EXTENSOR DIGITORUM BREVIS STRAIN

A strain is an injury to a musculotendinous unit, implying a partial or full tear (McGrew et al. 2003:34). Extensor digitorum brevis is one of the short extensors of the toes and lies on the dorsal aspect of the foot deep to the tendons of the extensor digitorum longus. It attaches proximally to the superior surface of the calcaneus, distal to the groove for the peroneus brevis tendon, it also attaches to the adjacent ligamentous structures. It attaches distally to the dorsal surface of the proximal phalanx of the great toe and often unites with the tendon of the extensor hallucis longus (Travell, Simons and Simons, 1992:503-504). This muscle extends all three phalanges of the second, third and fourth toes (Travell, Simons and Simons, 1992:507).

Contusion and tearing of the muscle fibres of the Extensor Digitorum Brevis muscle results in a haematoma, which produces a swelling anteromedial to the lateral malleolus. Patients with this condition often tend to think they have a badly sprained ankle but state that the ankle is not painful (Moore, 1992:464).

Avulsion fracture of the dorsolateral aspect of the calcaneus secondary to a pull-off mechanism by the Extensor Digitorum Brevis is not rare. A 10% incidence was found in a one year review of all emergency room cases of ankle trauma. Such fracture is likely to result from an inversion injury of the foot (Travell, Simons and Simons, 1992:510).

2.12.11 CUBOID SYNDROME

Occasionally the uncommon peroneal cuboid syndrome (locked cuboid, calcaneal cuboid fault syndrome, subluxed cuboid) is diagnosed. Following an inversion sprain, sudden forced dorsiflexion, or excessive training on uneven terrain, there may be a minimal subluxation or malposition of the cuboid in a lateral and dorsal direction. Frequently, a flexible pronated foot alignment is already present, allowing the peroneus longus to exert its greatest mechanical advantage. Because the cuboid is the fulcrum for the tendon, there is a dorsal thrust on its lateral aspect tending to rock the medial cuboid down, producing the so-called locked cuboid. Pain, which may be present even during walking, is located along the course of the peroneus longus. There may be associated peroneal tendinitis. Maximum discomfort is elicited by pressure over the peroneal groove on the plantar surface of the calcaneus (Reid, 1992:174, 175).

2.12.12 NERVE INJURIES ASSOCIATED WITH ANKLE SPRAINS

Neuropraxia of the superficial peroneal nerve (SPN) is an uncommon cause of leg and foot pain in the athlete. Injury can occur anywhere along the nerve, however it is more common for the distal sensory nerve to be involved. Stretch injuries of the SPN have been reported as sequelae of ankle sprains, and compression injuries are seen at the deep fascial exit and on the dorsum of the foot. The superficial peroneal nerve descends within the lateral compartment in contact with the proximal fibula, piercing the origin of the peroneus longus muscle to lie superficial to the peroneus brevis muscle in relation to the middle portion of the fibula. The superficial peroneal nerve is subject to several types of trauma resulting in pathological changes and symptoms. Ankle sprains involving plantarflexion and inversion may cause a stretch injury to the nerve (Oloff, 1994:247-248).

Occasionally an ankle sprain is associated with a permanent footdrop (i.e.: the foot falls into plantarflexion when it is raised from the ground (Moore, 1992:444) secondary to traction or a haematoma in the epineural sheath (Reid, 1992:253).

The peroneal nerve moves 5 to 8 mm during full inversion, and during forced inversion this traction is associated with a compression effect of the peroneus longus muscle closing over the nerve, pushing it against the bone. This effect is magnified by the associated plantarflexion (Reid, 1992:253). It is important to be aware of the potential for these injuries with ankle sprain, if there is detectable footdrop or weakness, protection with a cast, splint, or orthosis may be necessary until recovery is apparent (Reid, 1992:253).

2.12.13 SINUS TARSI SYNDROME

This is a subtle syndrome associated with persistent ankle pain. The sinus tarsi, also known as the talocalcaneal sulcus, is an anatomic space between the inferior neck of the talus and the superior aspect of the distal calcaneus. This area includes subtalar ligaments and careful palpation is needed to differentiate it from the more typically injured lateral ligaments (McGrew et al. 2003:40). Within the sinus tarsi reside the muscle belly of the extensor digitorum brevis and an associated fat pad. The sinus tarsi may be palpated as a depression immediately beneath the anterior talofibular ligament. Slight inversion of the heel accentuates this space, allowing deeper palpation of the lateral talar neck. Tenderness in the sinus tarsi often indicates injury or arthritis involving the posterior facet of the subtalar joint (Reider, 1999:284).

2.13 PAST TREATMENT PROTOCOLS FOR CHRONIC ANKLE SPRAINS

“Possible treatment options, which have been successfully implemented in this condition i.e.: ankle sprains (in the acute phase) include non-steroidal antiinflammatory drugs, cryotherapy, modification of activities, ultrasound, and laser. In the resolving condition (i.e.: in the more chronic and rehabilitation phases) the use of heat prior to stretching regimes followed by ice massage and the progression to pain free isometric and eccentric loading programs has also been utilized" (Reid, 1992: 205, 206; McGrew et al. 2003:39). McGrew et al. (2003), also stated that functional stirrup bracing for ankle sprains, to promote weight bearing and normalize gait, was very effective in the treatment of ankle sprains and that in 95% of ankle sprains this functional bracing was the treatment of choice when compared to surgical intervention.

McGrew et al. (2003) did recognize the need for post - ankle sprain rehabilitation and that this should be progressive and functional.

The following is a more specific protocol for the treatment of ankle sprains as according to Reid (1992).

GRADE ONE SPRAINS:

As they approach the severity of a second-degree injury, early application of ice and pressure, protected weight bearing, and a follow up strengthening program assume more importance. Occasionally NSAID's speed recovery when rapid return to sport is required. It is wise to protect the ankle with taping or a brace for pivoting sports such as basketball, football, squash or soccer, for about six weeks to prevent re-injury (Reid, 1992:239).

GRADE TWO SPRAINS:

A program is outlined below for a sprain on the more severe end of the spectrum of injury. It may be modified according to the patient's pathology, age, occupation and recreational needs (Reid, 1992:239).

Stage One: Immediately after injury

Immediate application of ice and compression with the ankle elevated at every opportunity ensures minimum recovery time by minimising oedema and haemorrhage. Within the first few hours, minimal weight bearing is encouraged, as is the attempt to gain dorsiflexion or at least maintain the neutral position of the ankle. This treatment may be supplemented by NSAID's (Reid, 1992:239).

Stage Two: Acute Phase

The acute phase of inflammation lasts several days, and continuation of the ice, compression and active range of motion exercises in dorsi and plantarflexion directions as well as into eversion, avoiding inversion movements is still important at this stage. Resisted work is not started until at least 50 % of the weight can be taken comfortably using crutches (Reid, 1992:239).

Stage Three: Subacute Phase

The subacute stage begins at 48 hours to 5 days after injury. Ultrasound, hot and cold contrast baths, and interferential current therapy can be used as well as short wave diathermy. The duration and speed of progress is often related to the degree of intra-articular contusion, haemorrhage or effusion. The main aim during this period is to progress the weight bearing and resisted exercises while minimising and dispersing oedema. This stage may last 5 to 14 days and terminates when the patient is able to gently hop (Reid, 1992:239). Range of motion is emphasised using a wedge board and the calf stretch position should be used frequently (Reid, 1992:240; Prentice, 1994:443). The gastrocnemius should be stretched in two distinct ways, with the leg straight and then bent at approximately 45 degrees. The bent-knee method is used to isolate the soleus muscle and allow it to be stretched to a greater degree by putting the gastrocnemius in a relaxed position. This should be done for 30 to 45 seconds and repeated several times, three times a day (Prentice, 1994:431). Strengthening progresses from isometric to isotonic as pain permits (Reid, 1992:240). Isometric exercise is useful when an injury is immobilised for a long time and isotonic exercises can be divided into two types: concentric and eccentric muscular contractions. Concentric contractions cause a shortening of the muscle, where eccentric contractions are a lengthening of the muscle used for anti-gravity and deceleration actions (Prentice, 1994:424). During maximal effort, twice as much force is generated eccentrically than concentrically therefore concentric exercises can begin before eccentric exercises (Andrews and Harrelson, 1991:237). At no time during this period should inversion be encouraged. At this stage some form of ankle brace should be used to prevent re-injury and to provide support and protection while the strengthening program is completed (Reid, 1992:240). Ligamentous healing as early as three weeks after a lateral ligament sprain allows the initiation of strengthening of the invertors and evertors of the ankle. The tensile strength of the ligaments at this point could be assumed to be sufficient to withstand the stress of eversion and inversion exercise, the active portion of treatment involving a ten minute tilt-board (rocker-board) workout (Donatelli, 1990:223, 224). The specific exercises commonly used in this phase of ankle rehabilitation are further discussed later in this chapter under the heading of: The indications for proprioceptive training.

Stage Four: Rapid Progression

The ability to hop indicates that the athlete is capable of sustaining forces of several times body weight and is ready to progress to strengthening and activities. Resisted isotonic invertor exercises can be done now without the concern of stretching the healing ligament. The emphasis on proprioceptive work using balance boards, simultaneously with skipping is an excellent method of strengthening (Reid, 1992:240).

Proprioceptive exercises, using a tilt-board, are initiated to rehabilitate and retrain the damaged mechanoreceptors in the joint capsule and accompanying ligaments thereby improving proprioception at these joints (Donatelli, 1990:222, 223). Early weight-bearing is an effective means of reducing proprioceptive loss, and patient's progress through a series of specific exercises which strengthen the ankle and retrain the sense of balance and proprioception at the ankle joint (Prentice, 1994:444).

Unconscious proprioception modulates muscle function and initiates reflex stabilisation (Prentice, 1994:119). Therefore the objectives of proprioceptive training are to refine joint sense awareness in order to initiate this muscle reflex stabilisation to prevent re-injury (Prentice, 1994:128). Articular structures also have a significant sensory function that plays a role in dynamic joint stability, chronic injury and rehabilitation training (Prentice, 1994:119). Simply restoring mechanical restraints or strengthening the associated muscles neglects the co-ordinated neuromuscular controlling mechanism required for joint stability during the sudden changes in joint position common to sports and daily activities (Prentice, 1994:118).

Ultrasound and laser are important modalities in reducing chronic thickening. By the end of this stage the normal “spring” should have been restored to walking, any limp eliminated and at least 80 % strength returned (Reid, 1992:240). These values are assessed by means of isokinetic testing (Donatelli, 1990:224).

Stage Five: Final Rehabilitation

Stage Five may be reached as early as 2 to 3 weeks, but it usually takes longer this period is used to return the athlete to full activity. Running is progressed and subtalar and talocrural joints as well as the fibula are assessed for full range of movement. The evertor /invertor ratio should be balanced at 80 % (Reid, 1992:241, 242). This is shown in Reid (1992) to be measured and recorded via isokinetic testing of the invertor and evertor muscle strength at 30, 60 and 120 degrees (Reid, 1992:249). This ratio has previously also been assessed by means of isokinetic testing by Donatelli (1990:223, 224).

GRADE THREE SPRAINS:

The most conservative method of treatment includes 3 to 6 weeks of immobilisation, progressing weight bearing as tolerated. This step is followed by an elastic support and gradual rehabilitation of movement and strength (Reid, 1992:242). Generally these injuries are surgically treated however this is debated amongst many who are moving towards a more conservative approach (Reid, 1992:242-250).

2.14 INDICATIONS AND CONTRAINDICATIONS FOR SPECIFIC TREATMENTS CHOSEN FOR THIS STUDY

2.14.1 INDICATIONS FOR PNFT"S

Subject's abilities to perform tasks, in daily activities and sports, are disturbed by limited range of motion at the ankle joint. It has also been suggested that occasionally some subjects with shortened calf muscles may have movement limitation in dorsiflexion before the extreme of the articular range of motion has been reached (Kaikkonen et al. 1994:469).

Full range of motion and flexibility are essential and consequently loss of flexibility and range of motion in the lower extremities can have a significant effect on normal gait and running patterns, followed by a decrease in performance and conditioning (Vegso, 1995).

Full range of motion at a joint may be prevented because of a fixed contracture (shortening) of the muscle, ligaments and/or joint capsule on one aspect of the joint. We can utilize the viscoelastic properties of these tissues, and by applying a sustained stretch to these shortened structures for some minutes can encourage lengthening or "creep" of the tissues. Provided this is done on a regular basis and the increase in length is maintained, then it is possible to regain full range of movement (Kerr et al. 1998:51). This is reinforced by Vegso (1995: 476, 477) and Juehring and Weinert (2000: 200) who state that stretching exercises done on a regular basis may help improve the tensile strength and elasticity of ligaments and fascia. Heel cord stretching is suggested as an important part of both rehabilitation and prevention of ankle sprains (Coker, 1991:2418). This is reiterated by Baker and Todd (1995:67) who claim that Achilles tendon stretching should be one of the components included in a rehabilitation program.

The amount of stretching achieved by tensile forces is proportional to the amount of applied force. It is also a true that a low force stretching technique requires more time to produce an equal amount of stretching. However, the proportion of tissue lengthening that remains after tensile stress is removed is greater for the low force, long duration method. High force, short duration stretching favours the recoverable, elastic-type deformation. This principle does not necessarily prohibit the use of high force, prolonged duration stretching, but obviously high force application may generate pain, trigger spasm, and produce tissue rupture.

Furthermore, elongation of connective tissue is accompanied by some structural weakening, and high force stretching appears to produce more structural weakening for a given amount of stretch. Hence low force; prolonged duration stretching is usually a more comfortable, safer, and effective method (Reid, 1992:81,82).

It has been noted by Buhler et al. (2002) that once you relax a muscle it functions normally (Buhler et al. 2002). Stretching exercise is useful in facilitating the relaxation of the muscles, thereby reducing unnecessary muscle tone, increasing joint mobility, and restoring optimal neurological patterning (Haldeman, 1992: 453, 529, 537). PNF stretching has been found to help strengthen the muscles that are contracted, and therefore is a good therapeutic tool for increasing active and passive flexibility (Appleton, 2003). It has also been documented to be a valuable tool for restoring normal movement patterns, strength, endurance and ultimately full function (McAtee, 1993).

Proprioceptive Neuromuscular Facilitation Techniques (PNFT's) have been recommended for increasing strength; flexibility and range of motion as PNFT have been shown to be "one of the fastest and most effective ways known to increase static and passive flexibility" (Prentice, 1994:164; Appleton, 2003). In this respect there have been various studies (Blanke et al.1982; Abraham et al. 1986 and Akdogan et al.2002) in which PNFT was compared to weight shifting, stool stepping and gait exercises, static stretching, ballistic stretching and placebo. In these studies it was found that PNFT was more effective in improving weight bearing gait only and not functional activity and / or strength.

It was found by McAtee (1993) in a review of 14 studies done on PNF that in 8 of them PNF was significantly more effective than static, ballistic or passive stretching for increasing range of motion and flexibility. This point is reinforced by Wilkinson et al. (1992) who state that the majority of studies show PNF techniques to result in greater gains than static stretching or ballistic stretching.

The deformity of connective tissue varies widely depending on the amount, duration and speed of application of stress, as well as the tissue temperature. Attempts at gaining a permanent increase in range of motion should make use of conditions that are conducive to plastic deformation: 1) Tissue temperature, 2) Slow, prolonged stretching and 3) Long duration (Reid, 1992:81).

2.14.2 CONTRA-INDICATIONS FOR PNFT'S

Patients with high blood pressure, heart disease and those who are unaware of the valsalva manoeuvre occurring during PNF should exercise caution when doing PNF (Anderson and Burke, 1991:63-85).

PNF stretching is also not recommended for children and adolescents whose bones are still growing as these people are usually already flexible enough that the strong stretches produced by the PNF contraction have a much higher risk of damaging tendons and connective tissue (Appleton, 2003).

Whether excessive lengthening can ever take place in normal skeletal muscles is doubtful, for the permissible ranges of joint movement are possibly too small (Comas, 1977:45). However, overly aggressive stretching can result in undesired adverse effects such as microtrauma of muscle fibres. Ballistic stretching is not a favourable method as the muscles stretch rapidly and the intrafusal muscle spindles are activated causing a reflex protective muscle contraction, which is a contradictory aim of increased muscle flexibility (Andrews and Harrelson, 1991:142). A quick stretch may be contra-indicated in many orthopaedic conditions because the extensibility limits of a damaged musculotendinous unit or joint structure may be exceeded, thus exacerbating the injury (Prentice, 1994:168). The impulses from the golgi tendon organs can override the impulses coming from the muscle spindles, allowing the muscle to reflexively relax after the initial reflex resistance to the change in length. Thus lengthening the muscle and allowing it to remain in a stretched position for an extended period of time is unlikely to produce any injury to the muscle (Prentice, 1994:43).
The aetiology of injuries to the tendons and muscles of the lower leg is often a repeated eccentric muscle contraction (Prentice, 1994:424).

So many times when we do therapies that increase flexibility and mobility, we set the person up for further injury because we haven’t really looked at whether or not we improve stability for that increased mobility. In most cases the ankle does not have the stability to stabilise the increase in mobility and therefore one needs to re-establish proprioceptive integrity to the ankle musculature (Buhler et al. 2002:8-15).

2.14.3 INDICATIONS FOR PROPRIOCEPTIVE TRAINING

In contrast to this, proprioception training (PT), which is used to re-educate the proprioceptors and golgi tendon organs in musculature, via weight bearing activities, co-ordination exercises and balance (wobble boards) (Thomson et al.1991: 41), allows the patient to improve their sense of where his or her body part is in space and to help with balance (Cooper et al.1998). These active exercises should be considered early and performed with or without resistance (Calliet, 1997:152).

Proprioceptors are receptors that inform the central nervous system about the state of our joints and muscles. They respond to muscle length and tension during static and moving conditions and give the brain feedback on mechanical stresses and body function (Kerr et al. 1998:125; Buhler et al. 2002:8-15). They enable one to know the position of their body and all of its components in space, but not necessarily at a conscious level. This is proprioception (Kerr et al. 1998:125).

Golgi tendon organs are sensory organs in series with the contractile elements and provide information regarding the force being generated by the contractile extrafusal units (Kerr et al. 1998:128-129). Their continual reports to the central nervous system are responsible for maintaining muscle tone and for ensuring that movements will be smooth and co-ordinated (Adragna et al. 1990:415).

They consist of a small bundle of tendon fibres (intrafusal fasciculi) wrapped in a capsule. The golgi tendon organs are very sensitive and highly active when the tendon is stretched, whether that stretch is active or passive. Golgi tendon organs give information about the specific musculotendinous unit in which they reside and not an average for the whole muscle. In this way accurate information is received. Active contraction of the muscle fibres will cause a greater firing rate than a passive stretch because active contraction is more effective in elongating the tendon and deforming the golgi tendon organs (Kerr et al. 1998: 128, 129). Their role extends to that of proprioception and unlike muscle spindles the golgi tendon organs respond to tension, as the stimulation of these sensors rises, the golgi tendon organs inhibit the contraction of the muscle fibres supplied, and thus the level of muscle contraction is reduced (Kerr et al. 1998:131).
The re-education programme must include both open and closed kinetic chain activities. These should progressively stress and strengthen the appropriate structures (Kerr et al. 1998:87). As the person is able to bear more weight on their ankle, there should be a corresponding increase in the use of closed chain activities, which more closely simulate functional activities for all the joints of the

lower extremity (Kawaguchi, 1999). The physical therapy should consist of passive progressing to isokinetic and proprioceptive training (i.e.: the focus is on strength before proprioception) (Oloff, 1994:247).

The patient’s range of motion at the ankle should be progressed, within a protected stress level, by making use of the stabilisation device, the wobble/balance board (Kawaguchi, 1999; McGrew et al. 2003).

The wobble board is a more advanced version of the rocker-board (a wooden platform that can only tilt on one axis). It is recommended that one master the rocker-board first (Kibler, 2001) as in the case of inversion sprains, an unrestricted lateral motion might increase the patient’s complaints and be detrimental to their progress, therefore a towel is often placed under one side of the wobble board to increase it’s stability alternatively the more stable rocker-board can be used (Kawaguchi, 1999). This technique of stabilising the wobble board could have been used in this study, however it was possible and more viable to make use of the more stable rocker board for a number of reasons, firstly access to the more stable device was easy, secondly new equipment was being ordered for the study and the rocker board was best suited to this study. The patients involved all had a history of chronic ankle sprains (the majority of them inversion sprains) and the use of the wobble board in these patients is contraindicated as re-injury of the ankle could occur, therefore to avoid these further sprains, which would disturb the treatments and the patients progress, the more stable rocker board device was chosen.

This balance training is aimed at treating existing proprioceptive deficits and restoring ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al.1999). It has been recommended by Eils et al. (2001) based on their placebo-controlled evaluation of PT, that multi station proprioceptive exercise programs could be utilised for rehabilitation. PT also allows for the increased strengthening of the triceps surae as indicated by Reid (1992:240) and supported by Calliet (1997), Kawaguchi (1999) and McGrew (2003); and can be used for restoration of balance (i.e.: needing to improve proprioception) (Kuligowski et al. 1999), multi-axial range of motion and flexibility at the ankle joint (Calliet,1997; Kawaguchi,1999; McGrew et al. 2003). These strength gains are an important component of enhancing proprioception (Kawaguchi, 1999). The emphasis on proprioceptive work using balance boards is an excellent method of strengthening (Reid, 1992:243). As the patient's complete their exercises on the rocker-board, these exercises are classified as closed kinetic chain exercises in which the distal segment of the lower extremity is stabilised or fixed on the rocker-board at all times. There are advantages to using closed chain exercises as opposed to open chain exercises and these are mainly: from a biomechanical perspective, they are safer and produce stresses and forces that are potentially less of a threat to healing structures. They are also more functional since they involve weight-bearing activities, which are important, as the majority of daily activities involve a closed kinetic chain system (Prentice, 1994:98, 100).

The patient begins with repetitions of dorsiflexion, plantarflexion, inversion and eversion and finally circumduction. The emphasis should be on endurance as strength gains are also an important component of enhancing proprioception (Kawaguchi, 1999).

The basic exercises are the two-footed side to side and the two-footed forward to back balance. The more advanced versions are: where the patient performs these exercises on one foot at a time (Kibler, 2001).

The patient is progressed with double support to single leg exercises. They also stand at different angles to the axis of motion to influence different muscles. Exercises include various positions as well as bouncing, throwing and catching a ball, the intensity of which can be altered by varying the weights and sizes of the medicine balls, the clinician can also throw the balls to a variety of locations, requiring a shift in the centre of gravity and instantaneous adjustment of balance. Positions may also be maintained with eyes open and closed which further influence proprioception (Prentice, 1994:128, 429, 443, 444; Kawaguchi, 1999; Calliet, 1997: 212; Reid, 1992:243).

Circulation to the foot and lower leg is also enhanced by an active exercise program (Calliet, 1997:152).

2.14.4 CONTRA-INDICATIONS FOR PROPRIOCEPTIVE TRAINING

In the case of inversion sprains, an unrestricted lateral motion might increase the patient's complaints and be detrimental to their progress (Kawaguchi, 1999).

2.15 COMPLICATIONS

Continuing symptoms following a sprained ankle such as pain, swelling, a feeling of instability, crepitus, weakness and decreased range of motion or functional instability and stiffness can be as a result of incomplete or absent rehabilitation. It can be concluded that unless properly rehabilitated these complications such as chronic functional instability, synovitis, tendinitis, weakness and stiffness of the involved joint may arise (Baker and Todd, 1995).

Symptoms of residual functional instability are: frequent giving way and sprains, difficulty running on uneven surfaces, difficulty jumping and cutting and chronic swelling (Reid, 1992:252).

According to Reid (1992:252), besides being a painful, inconvenient symptom, functional instability increases the possibility of degenerative changes in the ankle, particularly if associated with demonstrable mechanical instability.

If the mortise is widened due to disruption of the interosseous membrane and tibiofibular ligaments, degenerative changes quickly ensue (Reid, 1992:216, 217). Degenerative changes have been demonstrated on roentgenograms of at least 75 percent of individuals with significant functional instability and were confirmed at arthroscopic surgery in many (Reid, 1992:252).

Bosien et al. (1955) in Reid (1992:252), was the first to deal with long-term problems, stating that 43 percent of patients with residual detectable instability had ankle symptoms and 66 percent had peroneal weakness. It was also shown that players who had a history of previous ankle problems suffered more ankle sprains than those with no history (Tropp, 1985:261).

Instability undoubtedly occurs because of loss of proprioception at the ankle following an ankle sprain (Calliet, 1997:211).

In 1965 Freeman et al. (in Reid, 1992:252), used a modified Rhomberg test to define the possible association of a proprioceptive deficit in patients with functional instability. They postulated that significant ligament damage would damage sensory nerve endings and produce a situation where there was inadequate biofeedback from the joint. Of those individuals with functional instability, 34 percent had a positive test that was dramatically reduced to 7 percent with therapy.

There is also a learning curve that demonstrates some improvement with training and a tendency to delayed peroneal motor response and exaggerated angular displacement on sudden inversion stress with a modified force platform during the first few months after injury. The inability to maintain postural equilibrium correlated with functional instability but not with mechanical instability (Nawoczenski et al. 1985 in Reid, 1992:252).

These studies lend some support to Freeman's postulate on altered neural responses. However the results could also be interpreted to indicate peroneal muscle weakness instead of inadequate feedback. Indeed, improvement in all these parameters after therapy correlate well with improved strength (Reid, 1992:252).

2.16 CONCLUSIONS

There is a great deal of controversy as to the most effective treatment protocol for chronic ankle sprains, and in terms of rehabilitation, which technique is more effective in the 1) restoration of maximum function and movement at the ankle joint and 2) the reduction or elimination of pain and discomfort often experienced with chronic ankle sprains.

This has been researched and debated by many, and there appears to be a lack of available literature where the two specific techniques used in this study are compared. Thus there is little or no supporting information in the literature, which reaches any conclusive results in this regard.

The sequence of rehabilitation of any contracture, decreased range of motion (flexibility) of a joint, and muscle strength and function has been focused on the improvement of strength prior to proprioception and flexibility (Calliet, 1997; Flemister et al. 1998 and Buhler et al. 2002).

However according to McGrew et al. (2003) and supported by Oloff (1994); Vegso (1995) Calliet (1997); Kawaguchi (1999) and Buhler et al. (2002), this is a common mistake in rehabilitation and focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalisation of the relationship of the anatomical structures.
All research in this regard has never assessed the assumption that the strength of the relevant musculature would return (Blokker et al.1992 and Klaue et al.1998).

The main aim of this research study was to compare the sequencing of Proprioceptive Neuromuscular Facilitation Techniques followed by Active Proprioceptive Training Exercises (in the form of Active Rocker-Board Exercises), to initial Active Proprioceptive Training followed by Proprioceptive Neuromuscular Facilitation Techniques. In order to reach some definitive results about each technique's effectiveness, and the importance of the order of application of these techniques, in the rehabilitation and management of chronic ankle sprains. As well as to determine whether, in fact, the strength of the ankle musculature returns with normalisation of the anatomical relationships at the ankle joint, or whether to regain strength at the ankle joint, the initial focus should be on muscle training before flexibility and proprioception, which can be subsequently improved.

The purpose of this study was to highlight an area in the management and rehabilitation of chronic ankle sprains, which was unclear, and to provide some clarity via research results as to which sequencing procedure is the most effective in reaching the set goals. The results of this study will contribute to more effective patient management, by Chiropractors and other health care providers, in the future and hence improve overall patient relationships and management.

CHAPTER THREE – MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter will include a detailed description of the study design, patients selected to participate in this study and the interventions used. The measurements obtained and the statistical procedures used in the analysis of the data are also discussed.

3.2 THE STUDY DESIGN

This study was designed as a prospective unblinded, randomised controlled two way cross-over clinical trial in which two rehabilitation techniques Proprioceptive neuromuscular facilitation techniques (PNFT) and Active Rocker-Board exercises were compared in the treatment of chronic ankle sprains. Participants had a total of ten treatments over a period of eight weeks (four weeks of each rehabilitation technique) consisting of either 1) PNFT of the Peroneal, Triceps surae, and Anterior and Posterior Tibialis muscles as well as the Achilles tendon first and then Active Rocker-Board exercises. Or 2) Rocker-Board rehabilitation exercises first and then PNFT of the Peroneal, Triceps Surae, and Anterior and Posterior Tibialis muscles as well as the Achilles Tendon.

Data collected as the result of intra-group and inter-group tests was statistically analysed to determine which rehabilitation sequence was the most effective in the management of chronic ankle sprains, in terms of the objectives outlined for this study, and to identify and assess differences within each group.

3.3 STUDY DESIGN PROTOCOL

3.3.1 OBJECTIVES

The aim of this study was to determine the relative effectiveness of proprioceptive neuromuscular facilitation as compared to the active rocker-board exercises in the rehabilitation of chronic ankle sprains as well as to determine the best sequence of applying these techniques to chronic ankle sprain in terms of objective clinical findings.

The first objective was to determine which of the two rehabilitation techniques being studied (PNFT's and Active Rocker-Board Exercises) was more efficient in restoring strength, flexibility and range of motion at the ankle joint as well as reducing any residual pain or discomfort at the ankle joint (as the result of a chronic ankle sprain.)

The second objective was to determine the best possible sequence of applying these two rehabilitation techniques to chronic ankle sprains in order for optimal rehabilitation results to be achieved.

3.3.2 THE SUBJECTS

3.3.2.1 PARTICIPANT SELECTION

Participants were selected by means of convenience sampling. Advertisements informing the public about the study were placed in newspapers, at the Durban Institute of Technology campus and at running, hiking, gymnastics and cycling clubs. Only patients presenting to the Chiropractic Day Clinic at the Durban Institute of Technology with chronic ankle sprains (i.e.: complaining of a history of ankle sprains and resulting residual ankle symptoms) were considered as potential participants for the study. The participant evaluation and selection process began with all possible patients undergoing a cursory telephonic discussion with the examiner to exclude subjects that did not fit the criteria for the study. Participants successfully complying with this interview (appendix one)were evaluated at an initial consultation, during which each of them received a letter of information (appendix ten) and signed an informed consent form (appendices 9a and 9b) explaining the study and allowing them to withdraw at any time from the study with no repercussions. To determine whether the patient could participate in the study: on the initial visit a brief medical history (appendix two), specific ankle history and physical examination (appendix three) were performed as well as a foot and ankle regional examination (appendix four). These were briefly conducted and on establishing that the patient was a suitable candidate were thoroughly executed.

The required number of participants for this study was thirty and in order to compensate for the possibility that some of these participants may withdraw or be non-compliant with the study in some way thirty three were initially included in this study.

As was expected there were three participant withdrawals from the study due to 1) non-compliance in terms of follow – up treatments, 2) one of the student participants sought treatment for another region (Lower Back) during the research process and 3) one participant suffered an acute ankle sprain during the course of the research. After a discussion with the statistician, involved in this study, it was decided to disregard their results as none of these participants completed the research process.

3.3.3 INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria

1) Patient were between the ages of 18 and 65 (Oloff, 1994 and Appleton, 2003)
2) Patients included suffered from nocturnal heel pain (Travell, Simons and Simons, 1992 and Chaitow and Delany, 2002).

3) Patients had reduced range of motion of the ankle especially in dorsiflexion i.e.: could not fully extend knee or squat when standing if the heel was kept flat on the floor or could do so only on their toes (Kawaguchi, 1999; Buhler et al. 2002 and McGrew et al. 2003).

4) Patients had pain in the calf, especially when climbing up steep slopes or when walking on a slanted surface (Travell, Simons and Simons, 1992:406, 412, 439-446).

5) Patients with Chronic ankle sprains(i.e. at least twenty days after the initial injury) (Chazan, 1998; Reid, 1992:241). These patients are effectively at stage four of the Rehabilitation Program and can perform resisted invertor exercises (Reid, 1992:240).

Exclusion Criteria

1) Patients undergoing therapy for tight Achilles or gastrocnemius MFTP'S

2) Recent history of foot or ankle fracture, dislocation, surgery, (i.e.: in the last 6 weeks).

3) Peripheral neuropathy, nerve root entrapment or any condition other than those as a result of chronic ankle sprain causing pain are excluded (Grand and Ordet, 1992).

4) Participants with systemic disease or metabolic arthritides causing pain or symptoms are excluded e.g.: neurofibroma, hyperuricemia, gout, pseudogout, rheumatoid arthritis, ankylosing spondylitis, generalized or localized osteoporosis, ossific or calcific infiltration, Diabetes Mellitus, blood dyscrasias or liver dysfunction (Reid, 1992 and Grand and Ordet, 1992).

5) Patients with contusion of the heel pad and stress fracture of calcaneus or tibialis posterior and peroneal tendinitis (Reid, 1992:201-202).

6) Hypermobility and inflammatory reactions as well as patients with irreversible contractures (Grand and Ordet, 1992:110-112).

7) Those patients who have an acute or sub-acute ankle sprain i.e. in the last twenty days (Reid, 1992:239; Chazan, 1998).

8) Those patients whose foot cannot be placed in subtalar neutral position, which is a biophysical criterion for normalcy (Clinical Biomechanics v DIT).

9) Patients with a detectable footdrop / weakness (Reid, 1992:253).

Those participants that were accepted into the study were asked not to change their lifestyle, daily activities and regular medication or exercise programs in any way therefore preventing exclusion from the study.

Those who were rejected i.e. : those who did not meet the inclusion criteria were referred to other interns in the chiropractic day clinic for treatment of their condition.

3.3.4 PARTICIPANT EXAMINATION

At the initial consultation, once the patients were randomly assigned to their groups, each patient underwent a complete case history (appendix 1) including particular information about their “ankle history”(Whether they had suffered from recurrent ankle sprains and the types of treatment, if any, that they had received etc was noted), physical examination (appendix 3) and foot and ankle regional examination (appendix 4). The diagnosis of chronic ankle sprain was reached by the researcher, and this was confirmed by the clinician present based on the findings of these examinations.

Participants accepted into the study were informed of the intended treatment procedure (appendix 10), including the importance of attending all their follow-up treatments, and were given the opportunity to ask any questions. They then signed an informed consent form (appendix 9a and 9b) allowing the researcher to begin treatment with the patients understanding that they were able to withdraw from the study at any stage with no repercussions.

3.3.5 PARTICIPANT SAMPLING - ALLOCATION TO GROUPS

Once accepted into the study (via inclusion and exclusion criteria) the participants were allocated to one of two groups in the following manner. There was an envelope containing thirty four folded pieces of paper, fifteen allocated to each group (i.e.: 15 with group 1written on them, and 15 with group 2 written on them (plus four : two for each group to compensate for any drop out patients). The participants withdrew a piece of paper from the envelope and thus were randomly assigned to one of the two groups according to which number they drew from the envelope. Group One was treated with PNFT of the Achilles tendon and ankle musculature first and then with Active Rocker-Board exercises. The Second Group were treated with Active Rocker-Board rehabilitation exercises first and then with PNFT of the relevant structures at the ankle joint (i.e.: the Achilles tendon and associated musculature).

3.3.6 TREATMENT

All of the thirty participants accepted into the study were given ten treatments (The best attempt was made to ensure that participants had two visits in the first week and one in each of the following three weeks of a particular rehabilitation technique, they were then swapped to the other group and had two treatments in the fifth week and one in each of the following three weeks of the other rehabilitation technique, unfortunately due to uncontrollable circumstances such as work commitments, illness etc the follow – ups were sometimes as far apart as 12 days or more, this was avoided as far as possible) the participants were evenly distributed (i.e.: 15 per group) into two groups.

3.3.6.1 GROUP ONE

The first group of participants was initially treated with PNFT; of the Peroneal muscle group, Triceps surae and the Anterior and Posterior Tibialis muscles as well as the Achilles tendon, they were then placed on a course of Active Rocker-Board exercises for the ankle.

Proprioceptive neuromuscular facilitation techniques (PNFT's) are a combination of passive and isometric stretching in order to achieve maximum static flexibility. PNF refers to any of several post-isometric relaxation stretching techniques in which a muscle group is passively stretched, then contracts isometrically against resistance while in the stretched position, and then is passively stretched again through the resulting increased range of motion (Appleton, 2003). This particular technique is also often referred to as the Lewit Technique of Stretching (Travell, Simons and Simons, 1992:12).

The physiological basis of PNF is based on the stretch reflex, which results in the stimulation of golgi tendon and muscle spindles. The resulting impulses to the brain lead to contraction and relaxation of the muscle. Injury leads to a delay in muscle spindle and golgi tendon stimulation with resulting muscle weakness. PNF is responsible for re-educating the motor units, which are lost due to injury (www.angelfire.com. Proprioceptive neuromuscular facilitation).

During an isometric stretch when the muscle performing the isometric contraction is relaxed, it retains its ability to stretch beyond its initial maximum length. PNF takes immediate advantage of this increased range of motion by immediately subjecting the contracted muscle to a passive stretch.

The isometric contraction of the muscle accomplishes the following:

1) It helps to train the stretch receptors of the muscle spindle to immediately accommodate a greater muscle length.

2) The intense muscle contraction, and the fact that it is maintained for a period of time, serves to fatigue many of the fast twitch fibres of the contracting muscle. This makes it harder for the fatigued muscle fibres to contract in resistance to a subsequent stretch.

3) The tension generated by the contraction activates the golgi tendon organ, which inhibits contraction of the muscle via the lengthening reaction. Voluntary contraction during a stretch increases the tension on the muscle, activating the golgi tendon organs more than stretch alone. When voluntary contraction is stopped, the muscle is even more inhibited from contracting against a subsequent stretch.

PNF uses this period of time to train the stretch receptors to get used to the new, increased, muscle length (Appleton, 2003).

In this study the hold-relax technique was applied: After an initial passive stretch for 10-15 seconds the muscle being stretched is isometrically contracted for 7-15 seconds after which the muscle is briefly relaxed for 2-3 seconds and then immediately subjected to a passive stretch which stretches the muscle even further than the initial passive stretch. This final stretch is held for 10-15 seconds. The muscle is then relaxed for 20 seconds before performing another sequence of PNFT (Appleton, 2003).

The initial recommended procedure is to perform the PNF technique 3-5 times for a given muscle group (Appleton, 2003). In this study the PNFT sequence(i.e. two passive stretches with an active resisted period and very short rest period between them) was repeated three times per muscle group.

The specific patient positioning and order in which the involved muscles were stretched were as follows:

Peroneal Muscle Group:

To stretch the Peroneus Longus and Brevis muscles the patient was placed in the supine position with the foot extending off the end of the table. After fully inverting and adducting the foot, the clinician then dorsiflexes the foot , the hold-relax technique is then applied to the muscles and the clinician takes up the available slack that develops, moving the foot gently into dorsiflexion and inversion.

To stretch the Peroneus Tertius muscle the patient remains in the supine position with the foot extending off the table and the foot is then moved from dorsiflexion to plantarflexion while maintaining inversion. The clinician then applies the hold-relax technique to the muscle and takes up the slack that develops by maintaining a slow steady pull towards inversion and plantarflexion (Travell, Simons and Simons, 1992:387).

To prevent a reactive cramp in the **Anterior Tibialis** muscle the clinician then proceeds to stretch this muscle in the following manner:

The patient remains in the same position as for the previous stretches(which have already been explained) with the inclusion of a supportive pillow under the slightly flexed knee (Travell, Simons and Simons, 1992:365).

The stretching of the Anterior Tibialis begins with placing the foot in the position of maximum available plantarflexion, passive pronation of the foot is then added by the clinician to further enhance the elongation of the muscle. The clinician then follows the procedure of the hold-relax technique and takes up any slack, which develops in the muscle, in the direction of plantarflexion and pronation of the foot (Travell, Simons and Simons, 1992:365).

The Gastrocnemius Muscle:

The patient lies prone for this stretch with the legs extending off the end of the bed so that the knee remains straight as the clinician applies a firm pressure to the ball of the foot to maximally dorsiflex the foot at the ankle. The same hold-relax technique which is previously explained is used, with the clinician taking up the developing slack in the gastrocnemius muscle in the direction of dorsiflexion while carefully maintaining the straight positioning of the patient’s knee (Travell, Simons and Simons, 1992:415).

The Soleus and Plantaris Muscles:

The stretching procedure of these muscles is most effective with the patient lying prone. The clinician then applies a gentle pressure with the goal of fully dorsiflexing the foot. This stretch is always administered with the patient's knee flexed to release any tightness in the gastrocnemius muscle that would block ankle dorsiflexion and prevent full stretch of the Soleus muscle (Travell, Simons and Simons, 1992:449). The hold-relax technique is utilized in order to maximise the stretch attained at the ankle joint and particularly in the Soleus muscle.

The Plantaris Muscle is stretched simultaneously with the gastrocnemius muscle due to their nearly identical attachments (Travell, Simons and Simons, 1992:450) and therefore the same Proprioceptive Neuromuscular Facilitation occurs in the Plantaris muscle as in the Gastrocnemius muscle as a result of the specific hold-relax technique.

The Tibialis Posterior Muscle:

For this stretch the patient lies prone and relaxed on the bed with the legs extending off the end. The clinician grasps the ball of the foot and gently but firmly everts and dorsiflexes the foot. Following the hold-relax method of Proprioceptive Neuromuscular Facilitation Techniques the clinician continues to take up the resultant slack which develops in the Tibialis Posterior muscle in the direction of eversion and dorsiflexion of the foot (Travell, Simons and Simons, 1992:468).

These stretches were preceded by the application of a heat pack to the involved muscle groups for approximately fifteen seconds to warm the muscle and thereby enhance the stretch of the muscles (Reid, 1992:98, 559). The most important post-stretch procedure is to have the patient actively perform three FULL cycles of the range of motion that fully lengthens and fully shortens every muscle that was treated. This encourages the patient to use those muscles throughout the full normal range in ordinary daily activities (Travell, Simons and Simons, 1992:137). This procedure was included in this study.

This group had five treatments of PNFT over a period of four weeks and then was changed to Active Rocker-Board exercises with which group two were initially treated.

3.3.6.2 GROUP TWO

The second group was treated initially with a specific type of PT (Proprioceptive Training) namely Active Rocker-Board rehabilitation exercises. These have proven to be equally effective and important in ankle rehabilitation as the PNFT's (Thomson et al.1991: 41). PT treats existing proprioceptive deficits and restores ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al.1999), allowing for increased strengthening of the triceps surae as indicated by Reid (1992:240) and supported by Calliet (1997); Kawaguchi (1999) and McGrew et al. (2003) and can be used for restoration of balance, (Cooper et al.1998, Kuligowski et al. 1999) range of motion and flexibility, at the ankle joint (Calliet,1997; Kawaguchi,1999; McGrew et al. 2003).

The participants were then treated with PNFT of the Peroneal muscle group, Triceps surae and the Anterior and Posterior Tibialis muscles as well as the Achilles Tendon.

The patient must obtain proper strength and balance through proprioceptive training with a stabilization device, such as a balance board (McGrew et al. 2003). In this study the patients began (with a two foot stance) with two sets of ten repetitions each of dorsiflexion, plantarflexion, inversion and eversion as well as two sets of ten repetitions of lateral bending and rotation of the body to either side. As the patients progressed there was a necessary increase in closed kinetic chain activities, which closely simulate functional activities for the ankle joints. Therefore the difficulty of the exercises was increased with the patients eventually being able to repeat the aforementioned exercises with the eyes closed and with a one leg stance. The last progression of the active exercises involved the patients being able to balance on the rocker-board and throw and catch medicine balls (of varying sizes) from different angles (Calliet, 1997; Kawaguchi, 1999; Kibler, 2001).

This group had five treatments of PT (Active Rocker-Board Exercises) over a period of four weeks and was then treated with an equal amount of follow-ups over the same length of time of the PNFT technique of ankle sprain rehabilitation.

3.4 MEASUREMENTS AND OBSERVATIONS

There were no subjective means of gathering data in this study, all the measurements taken were objective and were recorded by the examiner and when necessary were confirmed by the clinician on duty in the Chiropractic Day Clinic.

3.4.1 OBJECTIVE MEASUREMENTS

3.4.1.1 GONIOMETER:

The Goniometer was used to measure simultaneously the range of motion at the ankle (especially into dorsiflexion), and the flexibility of the Achilles tendon and related musculature. Reliability has been tested by various people and the following concluded:" Joint motion measured by Goniometry should differ by at least 5 Degrees before a real increase or decrease in joint motion has occurred (Boone et al. in Kerr et al. 1998).Validity has also been tested (Gogia et al. in Kerr et al. 1998)and the following was noted when comparing the Universal Goniometer measurements to X-ray that there was a good agreement between the two. In this study, the degree of ankle dorsiflexion available was measured according to the procedure described by Jonson and Gross (1997:255) who concluded that this means of measuring ankle dorsiflexion showed high intra-examiner reliability. The patient was placed in a prone position with their knee extended. The patient was then asked to actively dorsiflex the foot while the examiner moved the foot passively into dorsiflexion. One arm of the Goniometer was aligned with the fifth metatarsal and the other arm aligned with the fibular head (Jonson and Gross, 1997:255). Zero degrees was taken when the foot was in the neutral position and these measurements were taken at the first, fifth and tenth consultations. The Goniometer used in this study was hand-held and was used in each instance by the researcher using the same procedure for all participants and at all visits where measurements were taken (described above).

3.4.1.2 MAXIMUM WEIGHT BEARING DORSIFLEXION:

Maximum weight bearing ankle dorsiflexion is another objective means of assessing the amount of flexibility at the ankle joint. The patient's stood on the involved leg and dorsiflexed the ankle while flexing the knee, until no further dorsiflexion could take place without lifting the heel off the ground. A large set square was used to measure the vertical distance (x) from the front of the knee to the ground, and the horizontal distance (y) from this point to the back of the heel was similarly measured. The degree of dorsiflexion was calculated using simple trigonometry. (Appendix 8 and 8a)

3.4.1.3 TIME AND ACTIVITIES ON ROCKER BOARD:

The amount of time spent on the rocker-board at each consultation as well as the activities which the patient was capable of completing were noted as a means of monitoring the patient's functional ability: in terms of strength, range of motion and proprioception. Any improvements, in this regard, as a result of the treatment which the patient had received were also recorded for analysis. There were five sets of exercises (tasks one to five, all of which had subdivisions of specific exercises to be completed) which the patients were asked to complete at each of the relevant follow-ups (dependant on which group the patients were in). For each of these tasks/activities there was a maximum score which the patients worked towards. The objective was for the patients to obtain a higher score on every occasion for each of the exercises, or to maintain the maximum score in subsequent visits, if already achieved. Tasks one and two were each marked out of a possible score of 100 points, depending on however many exercises the patients successfully completed. Task three was allocated a highest possible score of 200 points, the scores attained by the patients were therefore given as a value out of 200. Task four was marked out of a total score of 90 points and Task five was evaluated as a total out of a possible score of 40 points. These scores, for each individual at visits one, six and ten, were added together, to give three total scores out of a maximum value of 730 per participant. These totals were utilised in the assessment of the sequencing and effectiveness of the two rehabilitation programs, the results and discussion of which are seen in chapters four and five.

3.4.1.4 GENERAL FOOT ASSESSMENT:

The foot was assessed (as a part of the specific foot and ankle regional) for any fixations present and any reduction of these as an indirect result of the treatments was noted at the first, fifth and tenth visits.

3.4.1.5 ALGOMETER:

An algometer reading was taken in a Posterior to Anterior direction at the insertion of the Achilles tendon (the point was marked with a henna pencil for specificity) to determine the degree of tenderness/pain at this region and to note any improvements in this regard with the treatments being utilized. This reading was taken with the foot in the neutral position before the start of the treatment for that particular visit. Pressure algometry is used to determine general and local pain sensitivity as it involves the induction of a specific pain level in response to a measured force applied perpendicularly to the skin (Travell, Simons and Simons, 1992:27).The Algometer used in this study was a force Gauge fitted with a rubber disc having a surface of $1cm^2$. Pressure was applied to a defined surface on the body (namely the Achilles tendon insertion) through the rubber disc. The Gauge was calibrated in kg/cm^2. Before taking a reading the algometer was set to zero and the patient was placed in the prone position with the ankle and foot being in the neutral position. The end of the algometer was placed perpendicular to the tendon and the pressure applied, the patient's expressed to the examiner when the sensation of pressure became one of pain (this is known as the pressure threshold as noted by Travell, Simons and Simons, 1992:138).The higher the pressure reading on the algometer, the less tender the area under investigation therefore a lower reading indicated a greater tenderness at the area being examined Fischer(1986:836). The difficulties encountered when using this apparatus for pain pressure threshold readings can be partly ameliorated by averaging the lowest two of three readings if they are in reasonable agreement (Travell, Simons and Simons, 1992:28).

3.4.1.6 ROMBERG TEST:

Another objective means of testing the patient's balance and proprioception status is via the Romberg Test. This test was conducted with the patient standing on both legs with their eyes open while resisting a downward pressure on their out-stretched forearms, while the researcher assessed their ability to hold this position (a positive test being if the patient fell to one side) (Reid, 1992:862). This was repeated with the patient's eyes closed to determine whether the source of the possible instability was due to a disturbance of the leg and ankle proprioceptors, as a result of damage resulting from chronic ankle sprains, or due to a cerebellar lesion or other non organic cause. This was investigated in a study in 1965 by Freeman et al. who found that 34 percent of individuals with functional instability had a positive test that was dramatically reduced to 7 percent after therapy (Reid, 1992:252).

3.4.1.7 MUSCLE STRENGTH MEASUREMENT WITH DIGITAL SCALE:

In order to measure the strength of the Triceps Surae muscle group, initially and at follow-up consultations, a digital scale mounted on the wall at the foot of the bed was used. The patient, whilst lying supine, then applied a force to the scale as they plantar flexed the foot at the ankle. A reading was frozen and recorded and this reading was compared between the two ankles and between treatments (i.e.: This reading was taken at the beginning of the first, fifth and eighth week). A shoulder support was supplied to prevent pressure being transmitted into the bed instead of onto the scale. Although a thorough literature review was conducted, evidence supporting this method of muscle strength measurement was not found, therefore the reliability and validity of these readings is questionable. The reviewed literature stated manual muscle testing (in the form of resisted isometric testing) as the accepted method for testing muscle strength and function, or when necessary and practical the use of isokinetic machines such as the CYBEX are used (Donatelli, 1990:217; Andrews and Harrelson, 1991:47, 48; Prentice, 1994:263; O'Sullivan and Schmitz, 1994:118, 120).

3.5 THE LOCATION OF THE DATA

The data in this study included primary and secondary data.

3.5.1 THE PRIMARY DATA:

The primary data consisted of the following:

- The Case History (appendix two)
- The Relevant Physical Examination (appendix three)
- The Foot and Ankle Regional Examination (appendix four)
- General Assessment of The Foot and Ankle for any Fixations etc. (appendix four)
- Goniometer Readings at The Ankle (appendix six)
- Algometer Readings at The Achilles Tendon Insertion (appendix five)
- Maximum Weight Bearing Dorsiflexion Values (appendix eight and eight a)

- Time and Successful Activities Completed on The Rocker Board (appendix seven)

- Romberg's test (recorded on soape note)

- Assessment of the Strength of the Ankle Musculature using a Digital Scale (recorded on soape note)

3.5.2 THE SECONDARY DATA:

The secondary data was collected from a variety of different sources as all the available literature was screened and the relevant data selected for this particular study. These sources included journal articles, textbooks and the Internet.

3.6 SOLVING THE SUBPROBLEMS AND HYPOTHESES

3.6.1 STATEMENT OF THE PROBLEM:

In the review of the available literature with regards to the management of chronic ankle sprains the following was found:

Previously the focus has been on the improvement of strength prior to proprioception and flexibility (Calliet, 1997; Flemister et al. 1998 and Buhler et al.

2002). However according to Oloff (1994); Vegso (1995); Calliet (1997); Kawaguchi (1999); Buhler et al. (2002) and McGrew et al. (2003), focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalization of the relationship of the anatomical structures. All research in this regard has never assessed the assumption that the strength of the relevant musculature would return (Blokker et al.1992 and Klaue et al.1998).

The purpose of this study was to compare these two rehabilitative techniques, PNFT (of the Achilles tendon and peroneal, triceps surae and anterior and posterior tibialis muscle groups) and Proprioceptive training (in the form of Active Rocker-Board exercises) for the ankle in terms of objective findings to determine their relative effectiveness and the best sequence in which these techniques should be applied to chronic ankle sprains.

The first subproblem of this study was to determine which of the two rehabilitation techniques being studied (PNFT's and Active Rocker-Board Exercises) were more efficient in restoring strength, flexibility and range of motion at the ankle joint as well as reducing any residual pain or discomfort at the ankle joint (as the result of a chronic ankle sprain) in terms of objective clinical findings.

The second subproblem of this study was to determine the best possible sequence of applying these two rehabilitation techniques to chronic ankle sprains in terms of objective clinical findings in order for optimal rehabilitation results to be achieved at the ankle joint following a chronic ankle sprain.

3.6.2 HYPOTHESES:

It was hypothesised that if the focus of management and rehabilitation of chronic ankle sprains was in obtaining a functional range of motion (increased flexibility) and restoring proprioceptive ability at the ankle joint, that strength of the involved musculature would follow with normalization of the relationship of the anatomical structures.

3.7 STATISTICAL ANALYSIS

The statistical package SPSS (as supplied by SPSS Incorporated, Marketing Department – 1999, Chicago, USA) was used in the collection and analysis of the data in this study.

3.7.1 METHODS OF DATA ANALYSIS:

The sample size of each group in this study was small, consisting of only fifteen participants; therefore non-parametric tests were used in the analysis of the data.

The data was recorded by the researcher and assessed using the specific testing principles.

For every variable assessed in this study, wherever possible : tests were conducted that compared the results recorded on each side at periods one and two in terms of equal treatment effects as well as the carry-over effect of treatment one into period two and the overall period effects of both treatments together, where the effect of treatment two subsequent to treatment one was assessed.

The calculations, shown in the sections that follow, were done by using Excel, SAS and SPSS software.

CHAPTER FOUR - RESULTS

Statistical analysis of crossover design for an ankle rehabilitation study.

4.1) Introduction:

This chapter shows the results obtained from the statistical analysis of the primary data collected during the research program. The measurement criteria included:

1) Algometer Readings
2) Goniometer Readings
3) Maximum Dorsiflexion Readings
4) Plantarflexion Readings (Strength assessment)
5) Total Scores for Active Rocker Board Exercises
6) Romberg'sTest for Balance
7) Assessment of the Feet for any Fixations

These will be explained further in Chapter Five.

4.2) Criteria regarding the Admissibility of the data:

Data was collected from patients who met research criteria and who participated in the research program. There were no subjective readings taken and all the above mentioned objective readings were taken and recorded by the researcher.

As stated at the end of Chapter three: The data analysis will be based on

1) A multivariate crossover design for variables 1 to 4.

2) A univariate crossover design for variable 5.

3) Appropriate one and two sample tests for variables 6 and 7.

<u>For each of the variables 1 to 5 the data that will be analyzed will be values of the variables obtained from taking:</u>

1) the difference between the period 1 value and the corresponding baseline value (hereafter referred to as the **period 1 observation**).

2) the difference between the period 2 value and the corresponding baseline value (hereafter referred to as the **period 2 observation**).

Since the values of variables 6 and 7 are non-numerical (describing some condition), use will made of tables of counts and follow up tests to show the nature of differences between values for different periods.

The following specific calculations, referenced at the end of this thesis, were made using Excel, SAS and SPSS software.

1) **ALGOMETER OBSERVATIONS:**

Pressure algometry is used to determine general and local pain sensitivity as it involves the induction of a specific pain level in response to a measured force applied perpendicularly to the skin (Travell, Simons and Simons, 1992:27). Patients expressed to the examiner when the sensation of pressure became one of pain (this is known as the pressure threshold as noted by Travell, Simons and Simons, 1992:138).

The values of the means of the algometer observations are shown in the table below.

Table 1 – Means of algometer observations for both sides for different periods and groups

Group	Sequence	Means			
		L1	R1	L2	R2
1	A then B	3.7107	2.2180	5.2347	6.0467
2	B then A	3.5753	3.4293	5.0427	6.0827

L1 is left hand side, period 1, R2 is right hand side period 2 etc.

1.1 **Test for equal carry-over effects:**

The hypothesis to be tested is that the carry-over effects (difference between the sums of group 1 and group 2 means) are simultaneously equal to zero for the ankles on both sides (left and right). For group1 the carry-over effect of treatment A is of interest (since A is administered before B) and for group 2 the carry-over effect of treatment B is of interest. The estimates of these effects can be obtained from table 1 and are shown in the table below.

Table 2 – Estimates of carry-over effects (algometer observations)

Side

Left[1)]	Right[2)]
0.3274	-1.2473

1) Estimate of carry-over effect (left) = (3.7107 + 5.2347) – (3.5753 + 5.0427) = 0.3274

2) Estimate of carry-over effect (right) = (2.218 + 6.0467) – (3.4293 + 6.0827) = -1.2473

The test statistic F = 0.15 with a p-value of 0.8591 is not significant. This means that the carry-over effects are simultaneously equal to zero for the two sides (left and right).

1.2 <u>Test for equal treatment effects given equal carry-over effects</u>

The hypothesis to be tested is that the treatment effects (difference between the sums of treatment A and treatment B means) are simultaneously equal to zero for the ankles on both sides (left and right). The estimates of these effects can be obtained from table 1.

Table 3 – Estimates of treatment effects (algometer observations)

Side

Left[1)]	Right[2)]
-0.0566	-1.1713

1) Estimate of treatment effect (left) = (3.7107 + 5.0427) – (3.5753 + 5.2347) = -0.0566

2) Estimate of treatment effect (right) = (2.218 + 6.0827) – (6.0427 + 3.4293) = -1.1713

The test statistic F = 0.74 with a p-value of 0.4867 is not significant. This means that the treatment effects were simultaneously equal to zero for the two sides (left and right). This meaning that the two treatments both showed an improvement in the patient's pain threshold values at the insertion of the Achilles tendon but that they were, in this regard, equally effective.

1.3 <u>**Test for equal treatment effects for period 1**</u>

When testing the hypothesis that the mean improvements of the two sides (left and right) are the same for both treatments at the end of period 1, F = 0.516 with a p-value of 0.603. This means that the treatments were equally effective, on both ankles, at the end of period 1.

1.4 <u>**Test for equal period effects**</u>

This test is only performed when carry-over effects are equal, which is the case for this data. The hypothesis to be tested is that the period effects (difference between the period 1 and period 2 means) are simultaneously equal to zero for the ankles on both sides (left and right). The estimates of these effects can be obtained from table 1 and are shown in table 4.

Table 4– Estimates of period effects (algometer observations)

Side	
Left[1)]	Right[2)]
-2.9914	-6.4821

1) Estimate of period effect (left) = (3.7107 + 3.5753) – (5.2347 + 5.0427) = -2.9914

2) Estimate of period effect (right) = (2.2180 + 3.4293) – (6.0467 + 6.0827) = -6.4821

The test statistic F = 20.57 with a p-value < 0.0001 is highly significant. This means that there is a significant improvement in pain tolerance (it is higher) on at least one of the sides by performing the second treatment after the first one.

When testing for a period effect for the two sides separately, F = 5.35 with a p-value of 0.0283 (left hand side) and F = 42.63 with a p-value < 0.0001 (right hand side). This means that there is a significant improvement in pain tolerance on both sides by performing the second treatment after the first one. There seems to be a greater improvement in pain tolerance on the right hand side (when compared to the left hand side) by performing the second treatment after the first one (t = -2.603 with a p-value of 0.014). This is not the case after the first treatment (t = 1.094 with a p-value of 0.283).

2 **DORSIFLEXION OBSERVATIONS:**

Maximum weight bearing ankle dorsiflexion is an objective means of assessing the amount of flexibility at the ankle joint. The patient's stood on the involved leg and dorsiflexed the ankle while flexing the knee, until no further dorsiflexion could take place without lifting the heel off the ground.

The values of the means of the dorsiflexion observations are shown in the table below.

Table 5 – Means of dorsiflexion observations for both sides for different periods and groups

Group	Sequence	Means			
		L1	R1	L2	R2
1	A then B	-0.2607	-0.9673	-1.5380	-1.3700
2	B then A	-6.0540	-3.0773	-7.9880	-4.2507

2.1 Test for equal carry-over effects

The estimates of these effects can be obtained from table 5 and are shown in the table below.

Table 6 – Estimates of carry-over effects (dorsiflexion observations)

Side	
Left[1)]	Right[2)]
12.2433	4.9907

1 Estimate of carry-over effect (left) = (-0.2607–1.5380) – (-6.0540 – 7.9880) = 12.2433

2 Estimate of carry-over effect (right) = (-0.9673 – 1.37) – (-3.0773 – 4.2507) = 4.9907

When testing for carry-over effects for the two sides simultaneously F = 2.102 with a p-value of 0.1418. This means that the carry-over effects are simultaneously equal to zero for the two sides (left and right). When testing the carry-over effect for the 2 sides separately F = 4.297 with a p-value of 0.047 for the left hand side and F = 1.166 with a p-value of 0.289 for the right hand side. This means that on the left hand side the carry-over effect of treatment B is greater than that of treatment A, while this is not the case on the right hand side.

2.2 Test for equal treatment effects given equal carry-over effects

The estimates of these effects can be obtained from table 5.

Table 7 – Estimates of treatment effects (dorsiflexion observations)

Side	
Left[1)]	Right[2)]
-0.6567	-0.7707

1 Estimate of period effect (left) = (-0.2607 – 7.988) – (-1.538 – 6.054) = -0.6567

2 Estimate of period effect (right) = (-0.9673 – 4.2507) – (-1.37 – 3.0773) = -0.7707

The test statistic F = 0.09 with a p-value of 0.9115 is not significant. This means that the treatment effects (of treatments A and B) are simultaneously equal to zero for the two sides (left and right). This translating into the fact that the two treatments, although causing an improvement in Maximum Weight-Bearing Dorsiflexion in both ankles, were equally effective.

2.3 <u>**Test for equal treatment effects for period 1**</u>

When testing the hypothesis that the mean improvements of the two sides (left and right) are the same for both treatments at the end of period 1, F = 1.533 with a p-value of 0.234. This means that treatments are equally effective on both ankles jointly at the end of period 1. When testing the treatment effect for the ankles separately, there was some evidence that treatment B is more effective than treatment A on the right ankle (F = 3.170 with a p-value of 0.086).

2.4 <u>**Test for equal period effects**</u>

Since the carry-over effects are simultaneously equal to zero, the hypothesis that the period effects are simultaneously equal to zero for the ankles on both sides (left and right) can be tested.

The estimates of these effects can be obtained from table 5 and are shown in table 7.

Table 7 – Estimates of period effects (dorsiflexion observations)

Side	
Left[1)]	Right[2)]
3.2113	1.5761

1 Estimate of period effect (left) = (-0.2607 – 6.054) – (-1.538 – 7.988) = 3.2113

2 Estimate of period effect (right) = (-0.9673 – 3.0773) – (-1.37 – 4.2507) = 1.5761

The test statistic F = 1.35 with a p-value of 0.2757 is not significant. This means that there is no improvement in the dorsiflexion as a result of performing the second treatment after the first one.

3 PLANTARFLEXION OBSERVATIONS:

The values of the means of the plantar flexion observations are shown in the table below.

Table 8 – Means of plantar flexion observations for both sides for different periods and groups

Group	Sequence	Means			
		L1	R1	L2	R2
1	A then B	2.5133	4.7333	5.8000	6.6467
2	B then A	5.5900	5.6733	6.3567	9.1400

3.1 **Test for equal carry-over effects**

The estimates of these effects can be obtained from table 8 and are shown in the table below.

Table 9 – Estimates of carry-over effects (plantar flexion observations)

Side

Left[1)]	Right[2)]
-3.6334	-3.4336

1 Estimate of carry-over effect (left) = (2.5133 + 5.8) – (5.59 + 6.3567) = -3.6334

2 Estimate of carry-over effect (right) = (4.7333 + 6.6467) – (5.6733 + 9.14) = -3.4333

F = 0.18 with a p-value of 0.8367. This means that the carry-over effects are simultaneously equal to zero for the two sides (left and right).

3.2 Test for equal treatment effects given equal carry-over effects

The estimates of these effects can be obtained from table 8.

Table 10 – Estimates of treatment effects (plantar flexion observations)

Side

Left[1)]	Right[2)]
-2.52	1.5533

1 Estimate of period effect (left) = (2.5133 + 6.3567) – (5.59 + 5.8) = -2.52

2 Estimate of period effect (right) = (4.7333 + 9.14) – (6.6467 + 5.6733) = 1.5533

The test statistic F = 2.04 with a p-value of 0.15 is not significant. This means that the treatment effects (of treatments A and B) are simultaneously equal to zero for the two sides (left and right).

3.3 Test for equal treatment effects for period 1

When testing the hypothesis that the mean improvements of the two sides (left and right) are the same for both treatments at the end of period 1, neither the test for both ankles jointly nor the tests for the ankles separately show significant results. Therefore it can be concluded that the treatments effects do not differ at the end of period 1.

3.4 Test for equal period effects

Since the carry-over effects are simultaneously equal to zero, the hypothesis that the period effects are simultaneously equal to zero for the ankles on both sides (left and right) can be tested. The estimates of these effects can be obtained from table 8 and are shown in table 11.

Table 11 – Estimates of period effects (plantar flexion observations)

Side	
Left[1)]	Right[2)]
- 4.0534	-5.3801

1 Estimate of period effect (left) = (2.5133 + 5.59) – (5.8 + 6.3567) = - 4.0534

2 Estimate of period effect (right) = (4.7333 + 5.6733) – (6.6467 + 9.14) = - 5.3801

The test statistic F = 1.92 with a p-value of 0.1663 is not significant. This means that there is no improvement in the plantar flexion as a result of performing the second treatment after the first one. When testing the two sides separately, none show significant period effects.

4 GONIOMETER DORSIFLEXION OBSERVATIONS:

The values of the means of the goniometer dorsiflexion observations are shown in the table below.

Table 12 – Means of goniometer dorsiflexion observations for sides for different periods and groups

Group	Sequence	Means			
		L1	R1	L2	R2
1	A then B	7.3333	5.6667	10.3333	9.6667
2	B then A	6	10	10.3333	13

4.1 Test for equal carry-over effects

The estimates of these effects can be obtained from table 12 and are shown in the table below.

Table 13 – Estimates of carry-over effects (goniometer dorsiflexion observations)

Side	
Left[1)]	Right[2)]
1.3333	-7.6667

1 Estimate of carry-over effect (left) = (7.3333 + 10.3333) – (6 + 10.3333) = 1.3333

2 Estimate of carry-over effect (right) = (5.6667 + 9.6667) – (10 + 13) = -7.6667

F = 1.02 with a p-value of 0.3724. This means that the carry-over effects are simultaneously equal to zero for the two sides (left and right).This means that there is no carry-over effect of either of the treatments given in period one into period two, thus allowing the two treatments to be analysed individually: for each period and separately from each other.

4.2 **Test for equal treatment effects given equal carry-over effects**

The estimates of these effects can be obtained from table 12.

Table 14 – Estimates of treatment effects (goniometer dorsiflexion observations)

Side	
Left[1)]	Right[2)]
1.3333	-1

1 Estimate of period effect (left) = (7.3333 + 10.3333) – (10.3333 + 6) = 1.3333

2 Estimate of period effect (right) = (5.6667 + 13) – (10 + 9.6667) = -1

The test statistic F = 0.24 with a p-value of 0.785 is not significant. This means that the treatment effects (of treatments A and B) are simultaneously equal to zero for the two sides (left and right). Meaning that there is no difference in the effectiveness of the two treatments, in terms of the improvements noted in the Goniometer readings taken.

4.3 **Test for equal treatment effects for period 1**

When testing the hypothesis that the mean improvements of the two sides (left and right) are the same for both treatments at the end of period 1, neither the test for both ankles jointly nor the tests for the ankles separately show significant results. Therefore it can be concluded that the treatments effects do not differ at the end of period 1.

4.4 Test for equal period effects

Since the carry-over effects are simultaneously equal to zero, the hypothesis that the period effects are simultaneously equal to zero for the ankles on both sides (left and right) can be tested. The estimates of these effects can be obtained from table 12 and are shown in table 15.

Table 15 – Estimates of period effects (goniometer dorsiflexion observations)

Side	
Left[1)]	Right[2)]
-7.3333	7

1 Estimate of period effect (left) = (7.3333 + 6) – (10.3333 x 2) = -7.3333

2 Estimate of period effect (right) = (5.6667 + 10) – (9.6667 + 13) = 7

The test statistic F = 6.54 with a p-value of 0.0048 is significant. This means that there is a significant improvement in dorsiflexion (it is higher) on at least one of the sides by performing the second treatment after the first one.

When testing for a period effect for the two sides separately, F = 8.164 with a p-value of 0. 008 (left-hand side) and F = 7.622 with a p-value 0.010 (right hand side). This means that there is a significant improvement in dorsiflexion on both sides by performing the second treatment after the first one.

4B GONIOMETER PLANTARFLEXION OBSERVATIONS:

The values of the means of the goniometer plantarflexion observations are shown in the table below.

Table 16 – Means of goniometer plantarflexion observations for both sides for different periods and groups

Group	Sequence	Means			
		L1	R1	L2	R2
1	A then B	6.3333	5	8.3333	6.6667
2	B then A	12.8667	12.3333	16.6667	17

4B 1 Test for equal carry-over effects

The estimates of these effects can be obtained from table 16 and are shown in the table below.

Table 17 – Estimates of carry-over effects (goniometer plantar flexion observations)

Side	
Left[1)]	Right[2)]
-14.8667	-17.6667

1 Estimate of carry-over effect (left) = (6.3333+8.3333)–(12.8667+16.6667) = -14.8667

2 Estimate of carry-over effect (right) = (5 + 6.6667) – (12.3333 + 17) = -17.6667

F = 4.26 with a p-value of 0.0.0247. This means that the carry-over effects are simultaneously less than zero on both sides. This means that there is an improvement in condition on both sides in period 2 as a result of the effect of the treatments administered in period 1.

4B 2 Test for equal period 1 treatment effects given significant carry-over effects

Since the carry-over effects were significant, only tests for equal period 1 treatment effects will be performed.

The estimates of these effects can be obtained from table 16.

Table 18 – Estimates of period 1 treatment effects (goniometer plantarflexion observations)

Side	
Left[1)]	Right[2)]
-6.5334	-7.3333

1 Estimate of period effect (left) = 6.3333 – 12.8667 = -6.5334

2 Estimate of period effect (right) = 5 – 12.3333 = -7.3333

F = 3.4074 with a p-value of 0.0479 is significant and indicates that treatment B is better than treatment A on both sides.

5 ROCKER BOARD EXERCISES:

The values of the means of the rocker board exercise observations are shown in the table below.

Table 19 – Means of rocker board exercise observations for different periods and groups (R01 being the difference between period one and baseline, R02 being the difference between period two and baseline).

Group	Sequence	Means	
		RO1	RO2
1	A then B	83.2	143.7333
2	B then A	114.8667	128.3333

5.1 Test for treatment effects

From table 19 it can be seen that the treatment effect is given by

(83.2 + 128.3333) – (114.8667 + 142.7333) = -46.0667.

F = 35.61 with a p-value < 0.0001 is highly significant. This means that treatment B (administered initially to group two and then to group one) yields a far greater improvement in score than treatment A (initially given to group one and then group two after four weeks).

5.2 Test for period effects

From table 19 it can be seen that the period effect is given by

(83.2 + 114.8667) – (143.7333 + 128.3333) = -74.

F = 88.68 with a p-value < 0.0001 is highly significant. This means that the treatment in period 2 in addition to the period 1 treatment results in a significant improvement in the score.

This may be explained by the following statements: Active and passive exercises are used to increase range of motion and strength, and to reduce pain and adhesions or scar tissue formation in undesirable locations (Hammer, 1991: 278). In PNFT, the stronger body parts are used to assist the weaker body parts to improve function, thus PNFT is an excellent adjunct to the therapeutic strengthening program (Hammer, 1991:279).

6 ROMBERG TEST FOR BALANCE:

For each of the 3 periods when readings were made, the subjects were classified as having no balance problem (negative classification) or a balance problem on one or both sides. All cases where subjects had a baseline classification of negative and remained negative for the next two periods were ignored for the purpose of assessing the various effects. The reason for this is that these classifications did not change and therefore gave no information on any effects, except that the subject's condition was not getting worse. Six of the group 1 and 10 of the group 2 subjects were in this category. The table below summarizes the period 1 and period 2 conditions of the 14 subjects (9 from group 1 and 5 from group 2) who had a balance problem at baseline.

Table 20 – Period 1 and period 2 conditions of subjects with balance problem at baseline

Group	Period 1		Period 2	
	Number negative	Number problem	Number negative	Number problem
1(A then B)	5	4	8	1
2(B then A)	4	1	5	0

Comments on counts shown in table 20 :

1) The treatment (A or B) over the 2 periods is definitely successful. Of the 14 subjects with balance problems at baseline, only the subject with the worst condition at baseline (wobbly left and right) still had a slight problem at the end of period 2. The p-value (probability of 13 or more subjects recovering by chance from a balance problem) associated with this figure is 0.0009.

2) The proportions (percentages) of subjects that improved (from problem to negative) at the end of period 1 are 5/9 (55.56%) for group 1(which, at this stage, had received only treatment A {PNFT's}) and 4/5 (80%) for group 2 (which, at this stage, had received only treatment B {Proprioceptive Training - Active Rocker Board Exercises}). This would seem to suggest that treatment B is better than treatment A. This may be the case, but the sample size (14 subjects) is too small to verify this (Fisher's exact test shows a p-value of 0.378).

3) The period 2 treatment in addition to the period 1 treatment seems to result in an improvement in condition (only 1 of the 5 subjects who still had a problem at the end of period 1 still had a problem at the end of period 2). Unfortunately the sample size (5 subjects) is too small to yield a significant p-value (p-value = 0.1875).

7 ASSESSMENT OF THE FEET AND ANKLES FOR ANY FIXATIONS PRESENT:

7.1 Talocrural (upper ankle joint)

The inversion (inward turn) and eversion (outward turn) patterns were the same on both feet and were therefore considered as one entity. For each of the 3 periods (baseline, period 1 and period 2) the number of fixations (0, 1 or 2) was recorded for each group.

The results (fixation sequences for the 3 periods) are shown in the table below.

Table 21 – Talocrural fixations sequences for each group in each period

Grp	Sequence														
1	001	120	211	201	202	221	210	210	212	211	220	210	211	110	202
2	211	200	202	222	222	211	221	011	211	211	211	210	100	111	210

A sequence of 221 refers to 2 fixations at baseline, 2 at period 1 and 1 at period

7.2 Subtalar (lower ankle joint)

The varus (inward turn) and valgus (outwards turn) were not quite the same on both feet and were therefore considered separately. For each of the 3 periods (baseline, period 1 and period 2) the number of fixations (0, 1 or 2) for the varus and valgus was recorded for each group. The results (fixation sequences for the 3 periods) are shown in the table below.

Table 22 – Subtalar varus and valgus fixations sequences for each group in each period

(a) varus

Grp Sequence

1	200	100	100	120	101	020	100	200	111	110	100	100	200	200	210
2	001	011	110	200	100	000	200	110	220	200	100	110	200	100	200

(b) valgus

Grp Sequence

1	200	100	000	120	101	220	100	200	111	110	000	200	000	200	210
2	001	010	110	200	100	000	200	110	220	200	100	110	100	100	200

7.3 Analysis of ankle joints fixations for groups and periods

Baseline to period 1 :

The number of fixations at baseline and period 1 (first two numbers of the triplets in table 22) were recorded and a frequency distribution (table of counts) obtained for each group at each of the joints.

Table 23 – Frequency distributions of number of fixations at baseline and period 1 for each group at each of the joints

(a) Talocrural

	00	01	02	10	11	12	20	21	22
Group 1	1	0	0	0	1	1	3	7	2
Group 2	0	1	0	1	1	0	2	7	3

(b) Subtalar - varus

	00	01	02	10	11	12	20	21	22
Group 1	0	0	1	6	2	1	4	1	0
Group 2	2	1	0	3	3	0	5	0	1

(c) Subtalar - valgus

	00	01	02	10	11	12	20	21	22
Group 1	3	0	0	3	2	1	4	1	1
Group 2	2	1	0	4	3	0	4	0	1

Period 1 to period 2 :

The number of fixations at period 1 and period 2 (second and third numbers of the triplets in table 22) were recorded and a frequency distribution (table of counts) obtained for each group at each of the joints.

Table 24 – Frequency distributions of number of fixations at period 1 and period 2 for each group at each of the joints

(a) Talocrural

	00	01	02	10	11	12	20	21	22
Group 1	0	2	2	4	3	1	2	1	0
Group 2	2	0	1	2	7	0	0	1	2

(b) Subtalar - varus

	00	01	02	10	11	12	20	21	22
Group 1	9	1	0	2	1	0	2	0	0
Group 2	9	1	0	3	1	0	1	0	0

(c) Subtalar - valgus

	00	01	02	10	11	12	20	21	22
Group 1	9	1	0	2	1	0	2	0	0
Group 2	9	1	0	4	0	0	1	0	0

Table 25 shows the code for referring to each of the 12 cases shown in tables 23 and 24.

Table 25 – Codes for referring to cases

Code	Case
0	Talocrural, baseline & period 1 for group 1
1	Talocrural, baseline & period 1 for group 2
2	Talocrural, period 1 & period 2 for group 1
3	Talocrural, period 1 & period 2 for group 2

4	Subtalar varus, baseline & period 1 for group 1
5	Subtalar varus, baseline & period 1 for group 2
6	Subtalar varus, period 1& period 2 for group 1
7	Subtalar varus, period 1& period 2 for group 2
8	Subtalar valgus, baseline & period 1 for group 1
9	Subtalar valgus, baseline & period 1 for group 2
10	Subtalar valgus, period 1 & period 2 for group 1
11	Subtalar valgus, period 1 & period 2 for group 2

The frequency distributions of differences between two successive periods for the different cases are summarized in table 26.

Table 26 – Frequency distributions of differences between successive periods for different cases

Difference	Case codes									
	0	1	2	3	4	5	6	7	8	9
-2	3	2	2	0	4	5	2	1	4	4
-1	7	8	5	3	7	3	2	3	4	4
0	4	4	3	11	2	6	10	10	6	6
1	1	1	3	0	1	1	1	1	1	1
2	0	0	2	1	1	0	0	0	0	0
mean	-0.8*	-0.73*	-0.13	-0.07	-0.8*	-0.8*	-0.33	-0.27	-0.73*	-0.73*

Difference Case codes

	10	11
-2	2	1
-1	2	4
0	10	9
1	1	1
2	0	0
mean	-0.33	-0.33

For each of the 12 variables in table 26 the hypothesis that the mean difference is 0 was tested versus an alternative hypothesis of a mean difference of less than 0. For the cases marked with an asterisk (*) there was a significant reduction in the mean number of foot fixations.

These cases are talocrural (baseline to period 1 for both groups), subtalar varus (baseline to period 1 for both groups) and subtalar valgus (baseline to period 1 for both groups). This means that there was a significant improvement (for both treatments) from baseline to period 1 for both the ankle joints, but no significant improvement from period 1 to period 2.

Two sample t-tests were also carried out to compare the differences for the two groups for each case (case 0 versus case 1, case 2 versus case 3, case 4 versus case 5, case 6 versus case 7, case 8 versus case 9, case 10 versus case 11). In none of these tests were the means significantly different for the 2 groups. This means that there was no difference between the two treatments in terms of reducing the number of fixations at the feet.

The following other fixations were also observed in the ankle joints :

Talocrural plantar flexion left hand side and talocrural dorsiflexion left hand side. These fixations disappeared after the period 1 treatments.

Other fixations

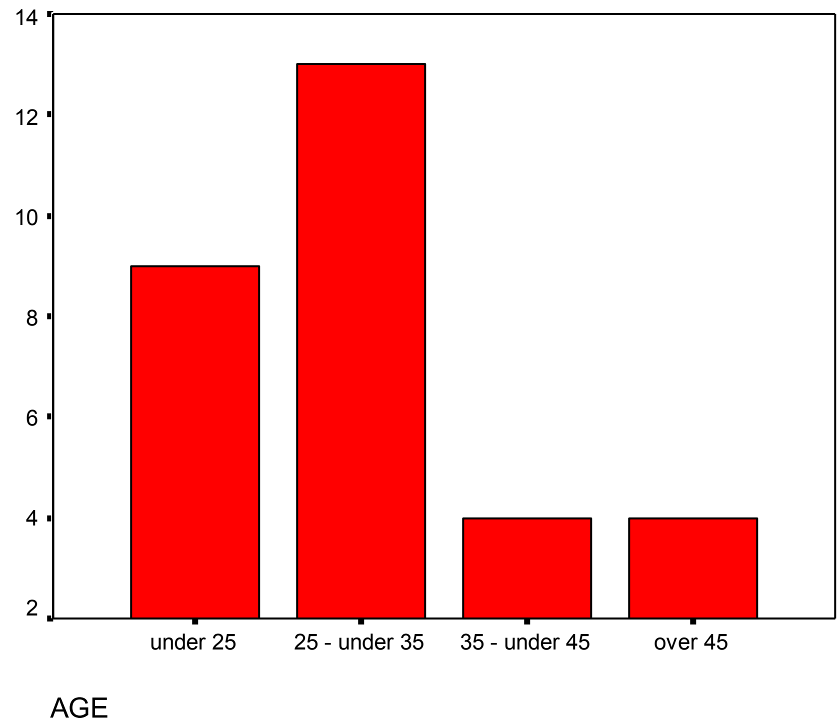
The following other fixations were observed in group 2 at baseline :

First ray plantarflexion on the left-hand side and fifth ray plantarflexion and dorsiflexion on the left-hand side (all twice) and first ray dorsiflexion on the left-hand side (once). These fixations disappeared after the period 1 treatments.

DEMOGRAPHICS:

10.1 Age

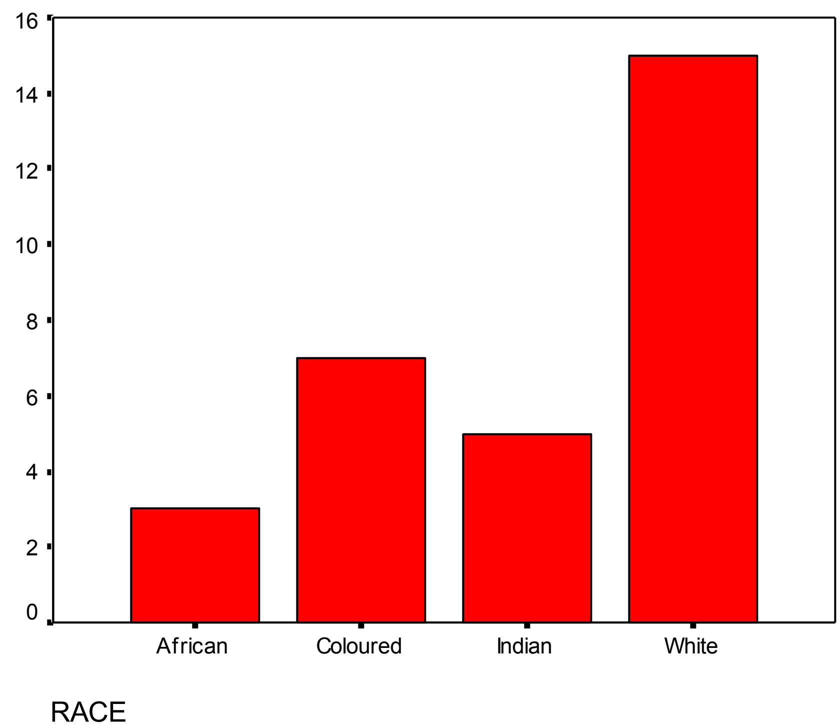
Figure 1 – Bar Chart of ages



The above bar chart demonstrates the age distribution of participants who were included in the study. One can clearly see that the majority of the participants, twenty two out of thirty, were under the age of thirty-five. Furthermore, nine of these were under the age of twenty five years. The largest number of participants, being thirteen were in the age bracket of twenty-five to thirty-five. There were an equal number of participants in both the thirty-five to forty-five age group and the over forty-five group, being four. The first thirty people to present to the clinic and fill all the necessary criteria were included in the study.

10.2 Race Distribution

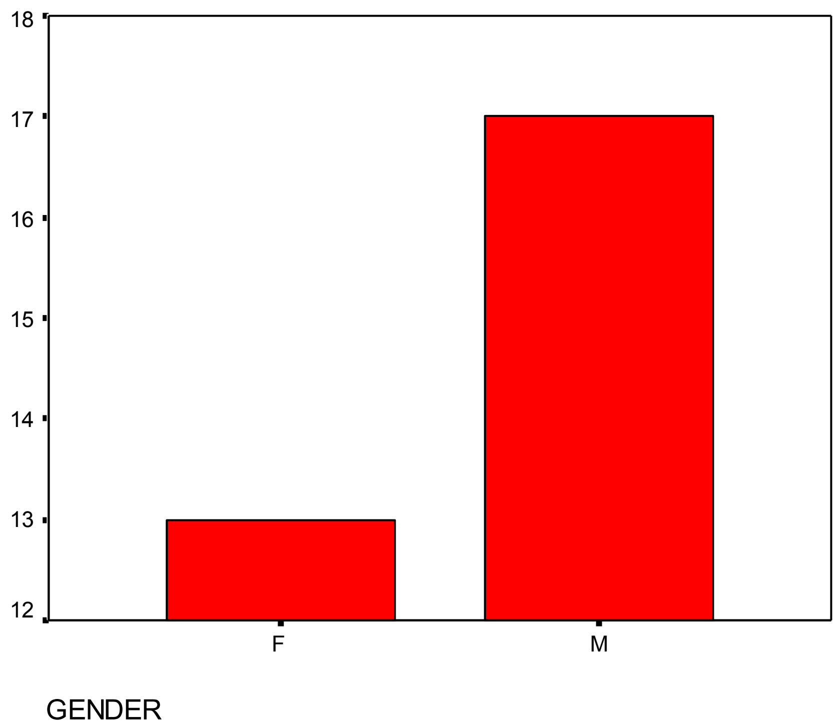
Figure 2 – Bar Chart of Race Distribution



This bar chart demonstrates the race distribution of participants who were involved in the study. The first thirty people to present to the clinic and fulfil all the necessary criteria were included in the study. It can clearly be seen that the majority of participants, being half of the total included in the study, were Caucasian. The next notable figure was that of seven coloured participants. The third largest group was that of the Indian participants, of which there were five. The smallest group was that of the African participants as there were only three participants in this group.

10.3 Gender Statistics

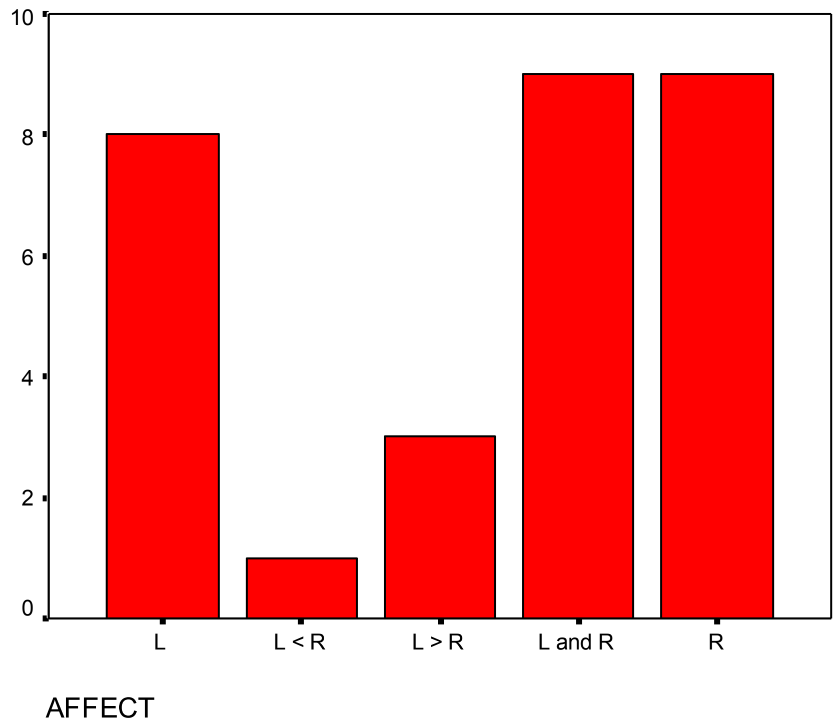
Figure 3 – Bar Chart of Gender Spread in Study



The above bar chart distinctly shows the gender distribution of the participants which were included in the study, meaning those who presented to the clinic and met all the necessary criteria. It can be seen that out of thirty participants, seventeen were male and only thirteen were female.

10.4 Statistics of which ankles were affected by sprains

Figure 4 – Bar Chart of which ankles were affected by sprains



This bar chart shows whether both ankles, or either one in particular, were more commonly affected. One can see that, with reference to the participants in this study, the left and right ankles were affected in nine out of thirty participants. This number was equalled by the number of participants who reported their right ankle only was affected. This value is more than that of eight participants, whose left ankle only was affected, leading one to believe that the right ankle is more commonly affected than the left, other than when both ankles are involved. Where both ankles were affected, three people reported that the left ankle was more seriously affected, one that the right was. The remaining five out of nine reported no difference between the two ankles.

CHAPTER FIVE – DISCUSSION:

1) Experiment and data layout:

Thirty (30) participants, each of whom had sprain in either one or both ankles for at least 6 weeks, were randomly subdivided into two groups of 15 each (hereafter referred to as groups 1 and 2). For the first 4 weeks of the experiment: the group 1 participants were treated by means of facilitated stretches (PNFT's - hereafter referred to as treatment A) and those in group 2 were treated by means of active exercises (hereafter referred to as treatment B). After 4 weeks the treatments for the two groups were reversed i.e. group 1 received treatment B and group 2 received treatment A. The participants received treatment on 10 occasions i.e. they made 10 visits.

The following measurements / information were recorded at (i) the first visit before any treatment was administered (hereafter referred to as **baseline** measurements / information), (ii) the 6 th visit (after 4 weeks) before any treatment was administered i.e. before reversing the treatments (hereafter referred to as **period 1** measurements / information) and (iii) the 10 th (last) visit before any treatment was administered (hereafter referred to as **period 2** measurements / information):

1) Algometer readings in both ankles (left and right) that measured the tolerance to pain.
2) Goniometer readings (in degrees) that measured the range of motion upwards (dorsiflexion) and downwards (plantarflexion) in both ankles.
3) Dorsiflexion readings (in degrees) that measured the extent to which each leg could be bent at the knee before the ankle hurt. (Maximum Weight Bearing Value)
4) Plantarflexion readings (on a digital scale) that measured the pressure that could be put on each foot when pushing against a scale.
5) A total score (out of 730) based on 5 different rocker board exercises.
6) A test for balance (Romberg's test) where a subject was classified as being negative (no problem with balance) or having a problem on one or both of the sides (left, right).
7) Assessment of feet for any fixations that were present.

Specific analysis of variables considered in the study:

Treatment A being Proprioceptive Neuromuscular Facilitation Techniques (PNFT's) first administered to Group One Participants. Treatment B being Active Rocker - Board exercises given first to Participants in Group Two.

1) ALGOMETER READINGS:

The carry-over effects for the algometer readings were found to be simultaneously equal to zero for the two sides (left and right). This was determined by applying a specific formula to the values in Table 1 (the Means of the Algometer readings for both Groups at Period 1 and 2), the estimates of which are shown in Table 2. After calculation it was determined that there is no carry over effect of either treatment from period one into period two, therefore making it possible to compare the effectiveness of each treatment at each period individually.

In Table 3, the estimates of treatment effects on algometer readings were determined and following a specific calculation it was shown that: the treatment effects were simultaneously equal to zero for the two sides (Left and Right). The mean improvements of the two sides were the same for both treatments at the end of period one i.e.: both treatments were equally effective at this stage.

When testing for period effects, as shown in Table 4, The test statistic $F = 20.57$ with a p-value <0.0001 was concluded to be highly significant. This means there was a significant improvement in pain tolerance, on at least one of the sides, by performing the second treatment after the first one.

This could be due to a number of factors: 1) That participants had, at the end of period two, been in the rehabilitation programme for an extended period of eight weeks and that this in itself could explain the participant's improvement in response as compared to when they had only received four weeks of rehabilitation. Brostrom (Reid, 1992: 247), stressed the need of at least twenty weeks for good healing and the need for continued protection during activities. According to Reid (1992: 242): Stage five, the final stage of rehabilitation, may be reached as early as two to three weeks, but it usually takes longer. This period is used to return the athlete to full activity. 2) That the participants responded, to an even greater degree, to the combination of the two treatments as opposed to either one individually. Stretching exercise is useful in facilitating the relaxation of muscles, thereby reducing unnecessary muscle tone, increasing joint mobility, and restoring optimal neurological patterning (Haldeman, 1992: 453, 529, 537). Proprioceptive training is aimed at treating existing proprioceptive deficits and restoring ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al. 1999) and re-educating the proprioceptors and golgi tendon organs in the musculature, via weight bearing activities, co-ordination exercises and balance (wobble boards) (Thompson et al. 1991: 41) These strength gains are an important component of enhancing proprioception (Kawaguchi, 2003). It can be assumed, that the restoration of normal muscle length and neuromuscular feedback loops as well as the afferent input from the proprioceptors and golgi tendon organs will result in a reduction in pain perceived by the patient and objectively measured by the researcher. 3) Perhaps the participants became accustomed to the Algometer, over the three visits when these readings were taken, and hence their tolerance of the pressure applied at the ankle seemed to improve with successive measurements.

When testing period effects for each side separately it was noted that: there was a significant improvement in pain tolerance on both sides, by performing the second treatment after the first one. There seemed to be a larger improvement in pain tolerance on the right-hand side, (as compared to the left) by performing the second treatment after the first, this was not the case after the first period.

The inter-subject recording and comparison of the algometer readings, in this study, were potentially affected by:

- The Pain Threshold of the various subjects
- Sensitivity of the subjects
- BMI of the subjects
- Psychosocial background of the subjects
- The use of inter-patient comparisons decreases the sensitivity and reliability of the algometer as patients respond uniquely to the algometer initially and at subsequent visits.

Achilles contracture / tightness and insidiously increasing pain and stiffness in the region of the Achilles tendon can also be a long term complication of chronic ankle sprains and can predispose patients to further sprain if not rehabilitated correctly and returned to it's normal length and functioning (Baker and Todd, 1965; Reid, 1992). This is the reasoning behind taking an Algometer reading at the insertion of the Achilles Tendon. A reduction in the pain readings in this region was regarded as confirmation that the tendon was correctly rehabilitated and returned to it's normal length and functioning, this improvement was assumed to be as a result of the overall rehabilitation of the ankle joint.

Contraction of the scar tissue, as a result of the remodelling phase of the natural history of ankle sprains, may limit motion and cause pain so gentle stretching of the Achilles, surrounding muscles, ligaments and tendons is necessary throughout the healing process (Reid, 1992:77).

Although reasoning is given above for algometer readings at the Achilles tendon insertion in chronic ankle sprains: it is suggested by the researcher that the algometer readings, in future studies on chronic ankle sprains, be taken rather at the lateral ankle than at the insertion of the Achilles tendon. This recommendation is made due to the fact that the majority of participants in this particular study complained of pain and discomfort at the lateral ankle and none of the same symptoms at the Achilles region. All the participants however, had some degree of pain and tenderness upon the application of the algometer to the Achilles insertion and with rehabilitation of the ankle complex these readings were greatly reduced.

The difficulties encountered when using this apparatus for pain pressure threshold readings can be partly ameliorated by averaging the lowest two of three readings if they are in reasonable agreement (Travell, Simons and Simons, 1999:28). In this particular study, an attempt was made to minimise any incorrect readings being considered, in order to achieve this: three readings were taken on each ankle and the average value over the three was the value included in the statistics for analysis.

The algometer is a preferred tool when measuring and monitoring the improvement of a specific individual. It is however not the tool of choice in research, such as this study, where individuals are being compared.

2) MAXIMUM WEIGHT BEARING DORSIFLEXION (DORSIFLEXION OBSERVATIONS)

The carry-over effect, for these particular readings, was analysed using the values in Table 5 (The means of dorsiflexion observations for both sides). The estimates of these carry-over effects are shown in Table 6. The carry-over effects were shown after calculation to be simultaneously equal to zero for the two sides (Left and Right). There was some, non-significant, evidence of a carry-over effect of treatment B compared to treatment A on the left-hand side, which was not evident on the right-hand side.

The estimates of treatment effects on dorsiflexion observations are demonstrated in Table 7. With calculation it was determined that the treatment effects were simultaneously equal to zero for the two sides (Left and Right).

When testing for treatment effects at the end of period one, it was shown that the treatments were equally effective on both ankles at that stage.

When testing the treatment effect for the ankles separately, there was some evidence that treatment B was more effective than treatment A on the Right ankle.

In testing for equal period effects, the estimates of which are shown in Table 7, the test statistic F = 1.35 with a p-value of 0.2757 was proven to be insignificant. This means that there was no improvement in the dorsiflexion observations as a result of performing the second treatment after the first one.

Some subjects with shortened calf muscles may have movement limitation in dorsiflexion before the extreme of the articular range of motion has been reached (Kaikkonen et al. 1994:469). Therefore one must consider that the limitation of movement recorded at the ankle joint may be as the result of tightened surrounding muscles, ligaments and tendons and not necessarily as the result of joint restriction. If this is the case, one expects that with stretching of these structures and restoration of normal muscle length and functioning that the range of motion at the ankle joint should improve.

Vegso (1995: 476, 477) and Juehring and Weinert (2000: 200) state that stretching exercises done on a regular basis may help improve the tensile strength and elasticity of ligaments and fascia. This is reinforced by the following: if a sustained stretch to these shortened structures is done on a regular basis and the increase in length is maintained, then it is possible to regain full range of movement (Kerr et al. 1998:51). Heel cord stretching is suggested as an important part of both rehabilitation and prevention of ankle sprains (Coker, 1991:2418). This is reiterated by Baker and Todd (1995:67) who claim that Achilles tendon stretching should be one of the components included in a rehabilitation program. The following statement adds to the support for the use of treatment A, i.e. PNFT's to increase the range of motion at the ankle joint : Range of motion is emphasised using a wedge board and the calf stretch position should be used frequently (Reid, 1992:240; Prentice, 1994:443).

Proprioceptive training (Active Rocker Board exercises) can be used for restoration of multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al. 2003) and the patient's range of motion at the ankle should be progressed, within a protected stress level, by making use of the stabilisation device, the wobble/balance board (Kawaguchi, 1999; McGrew et al. 2003). These statements reinforce the importance of the Active Rocker Board exercises, which are a form of Proprioceptive Training, in the rehabilitation of chronic ankle sprains, especially in the restoration of range of movement and flexibility at the ankle joint.

Upon examining the results of this particular study, it is noted that treatment A (the PNFT's) results in an improvement in range of motion at the ankle joint however, this effect is shown to be equal to that of the Active Rocker Board exercises, for the left ankle, at the end of period one. There is some suggestion that Treatment B (Active exercises) may be more effective, in this regard, on the right ankle at the end of period one. There is no improvement in dorsiflexion noted, bilaterally, as the result of performing the second treatment after the first one.

3) PLANTARFLEXION OBSERVATIONS (STRENGTH READINGS WITH DIGITAL SCALE)

The means of the Plantarflexion observations are depicted in Table 8, and the estimates of the carry-over effects based on these values are shown in Table 9.

In calculating the actual carry-over effects it was proven that the effects were simultaneously equal to zero for both sides (Left and Right). Meaning that there was no carry-over effect of either treatment from period one to period two. Therefore, the two treatments could be individually analysed, at each period, separately from each other.

In testing for equal treatment effects, the estimate values of the effects are shown in Table 10. On calculation it was demonstrated that the treatment effects were simultaneously equal to zero for the two sides (Left and Right). Therefore, it was determined that there was no difference between the effect of the two treatments on plantarflexion strength.

When testing for equal treatment effects at period one, neither the test for both ankles together, nor the tests for the ankles separately showed any significant results. Therefore, it was concluded that the treatment effects do not differ at the end of period one in terms of improvement in plantarflexion strength.

In examining for equal period effects, the estimate values determined from Table 8 are shown in Table 11. After applying a specific calculation to these values, there was no evidence of improvement in the plantarflexion strength as the result of performing the second treatment after the first one. This finding was confirmed when testing the two sides separately, as neither showed significant period effects.

Patients obtain proper strength and balance through proprioceptive training with a stabilisation device, such as a balance board (McGrew et al. 2003) and the emphasis on proprioceptive work using balance boards is an excellent method of strengthening (Reid, 1992: 243). PT treats existing proprioceptive deficits and restores ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al.1999), allowing for increased strengthening of the triceps surae as indicated by Reid (1992:240) and supported by Calliet (1997); Kawaguchi (1999) and McGrew et al. (2003).

PNF stretching has been found to help strengthen the muscles that are contracted, and therefore is a good therapeutic tool for increasing active and passive flexibility (Appleton, 2003). It has also been documented to be a valuable tool for restoring normal movement patterns, strength, endurance and ultimately full function (McAtee, 1993). The physiological basis of PNF is based on the stretch reflex, which results in the stimulation of golgi tendon and muscle spindles. The resulting impulses to the brain lead to contraction and relaxation of the muscle. Injury leads to a delay in muscle spindle and golgi tendon stimulation with resulting muscle weakness. PNF is responsible for re-educating the motor units, which are lost due to injury (www.angelfire.com. Proprioceptive neuromuscular facilitation).

After examining the results obtained in the above tests, one can conclude that the following is true: Although the ankle is unstable in plantarflexion, appropriate training and conditioning strengthens the joint in this position (Moore, 1992: 487-490). The fact that there is no difference between the two treatments at the end of period one or two, suggests that the appropriate training (Active Rocker Board Exercises) and conditioning (PNFT's) at the ankle are equally effective and necessary in the stabilisation and strengthening of the ankle joint.

Although a thorough literature review was conducted, evidence supporting this method of muscle strength measurement was not found, therefore the reliability and validity of these readings is questionable.

A shoulder support was supplied to prevent pressure being transmitted into the bed instead of onto the scale. Despite this, there were large discrepancies between participant's readings and therefore the researcher concluded that this means of assessing muscle strength at the ankle joint was not reliable. Another means of measuring plantarflexion strength at the ankle needs to be found, which would yield more reliable results, thus ensuring correct and accurate assessment of the values obtained.

The reviewed literature stated manual muscle testing (in the form of resisted isometric testing) as the accepted method for testing muscle strength and function, or when necessary and practical, the use of isokinetic machines such as the CYBEX are used (Donatelli, 1990:217; Andrews and Harrelson, 1991:47, 48; Prentice, 1994:263; O'Sullivan and Schmitz, 1994:118, 120).

4) GONIOMETER DORSIFLEXION OBSERVATIONS

Table 12 shows the means of the goniometer dorsiflexion observations and the estimates of these effects are shown in Table 13. Specific calculation of these values, in order to determine whether there were any carry-over effects, showed that the carry-over effects were simultaneously equal to zero for both sides (Left and Right). This means that there were no carry-over effects of either treatment from period one to period two.

Tests for equal treatment effects, based on the estimate values shown in Table 14, revealed that the treatment effects of Treatment A and B were simultaneously equal to zero for both sides (Left and Right). Meaning that the treatments were equally effective in improving goniometer dorsiflexion values.

In testing for equal treatment effects for period one: neither the test for both ankles together, nor the tests for the ankles separately showed any significant results. Therefore, it was concluded that the treatment effects do not differ at the end of period one with regards to goniometer dorsiflexion observations.

The test for equal period effects was applied to the estimate values shown in Table 15. The test statistic, as a result of this specific test, of F = 6.54 with a p-value of 0.0048 is deemed to be significant. This means that there was a significant improvement in Dorsiflexion on at least one of the sides, by performing the second treatment after the first one.

This could be due to the fact that 1) the participants had, at the end of period two, been in the rehabilitation programme for an extended period of eight weeks and that this in itself could explain the participant's improvement in response as compared to when they had only received four weeks of rehabilitation. Brostrom (Reid, 1992: 247), stressed the need of at least twenty weeks for good healing and the need for continued protection during activities. According to Reid (1992: 242): Stage five, the final stage of rehabilitation, may be reached as early as two to three weeks, but it usually takes longer.

2) The participants had a greater response to a combination of the two treatments compared to each one separately. It has been suggested that occasionally some subjects with shortened calf muscles may have movement limitation in dorsiflexion before the extreme of the articular range of motion has been reached (Kaikkonen et al.1994: 469). By applying a sustained stretch to these shortened structures for some minutes can encourage lengthening or "creep" of the tissues. Provided this is done on a regular basis and the increase in length is maintained, then it is possible to regain full range of movement (Kerr et al. 1998: 51). This is reinforced by Vegso (1995: 476, 477) and Jeuhring and Weinert (2000: 200) who state that stretching exercises done on a regular basis may help improve the tensile strength and elasticity of ligaments and fascia (Coker, 1991: 2418). PNFT's have been shown to be "one of the fastest and

most effective ways known to increase static and passive flexibility" (Prentice, 1988: 164; Appleton, 2003). The patient's range of motion at the ankle should be progressed, within a protected stress level, by making use of the stabilisation device, the wobble/balance board (Kawaguchi, 1999; McGrew et al. 2003). Proprioceptive training can be used for multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al.2003).

3) At the end of period one the participants already had a reduction in the articular limitation at the ankle joint, as the result of the first treatment (regardless of which treatment was administered in this period, as both treatments have been documented and proven to cause improvements in range of motion at the ankle complex. This is in addition to the fact that with every assessment of the feet and ankles, there is a simultaneous mobilisation of these areas. Manipulation is defined in the New Standard Dictionary of the English language as an "examination or treatment by the hands". This definition gives ample argument for using the term joint manipulation to include any manual technique applied to a joint in dysfunction that moves the two surfaces in relation to one another. Included in this definition is joint mobilization, which is a slow passive movement imparted to an articular surface (Edmond, 1993: 1). One can maximise the available range of motion with adjustment and mobilisations of the forefoot and ankle complex, within capable limits. The use of a general mobilisation technique of the forefoot is useful in establishing the normal biomechanics (Clinical Biomechanics V Notes DIT). What most people do not seem to realise is that

passive movement treatment can achieve desired changes which other forms of physiotherapy cannot (Maitland, 1991: 12).

When testing for a period effect for the two sides separately, the results were that: F = 8.164 with a p-value of 0.008 (Left-hand side) and F = 7.622 with a p-value of 0.010 (Right-hand side). This means that there was a significant improvement in Dorsiflexion on both sides, by performing the second treatment after the first one.

Some subjects with shortened calf muscles may have movement limitation in dorsiflexion before the extreme of the articular range of motion has been reached (Kaikkonen et al. 1994:469). Therefore one must consider that the limitation of movement recorded at the ankle joint may be as the result of tightened surrounding muscles, ligaments and tendons and not necessarily as the result of joint restriction. If this is the case, one expects that with stretching of these structures and restoration of normal muscle length and functioning that the range of motion at the ankle joint should improve.

Vegso (1995: 476, 477) and Juehring and Weinert (2000: 200) state that stretching exercises done on a regular basis may help improve the tensile strength and elasticity of ligaments and fascia. This is reinforced by the following: if a sustained stretch to these shortened structures is done on a regular basis and the increase in length is maintained, then it is possible to regain full range of movement (Kerr et al. 1998:51). Heel cord stretching is suggested as an important part of both rehabilitation and prevention of ankle sprains (Coker, 1991:2418). This is reiterated by Baker and Todd (1995:67) who claim that Achilles tendon stretching should be one of the components included in a rehabilitation program.

The patient's range of motion at the ankle should be progressed, within a protected stress level, by making use of the stabilisation device, the wobble/balance board (Kawaguchi, 1999; McGrew et al. 2003). Proprioception training (Active Rocker Board exercises) can be used for restoration of multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al. 2003). The use of Active Rocker Board exercises for the restoration of range of motion and flexibility at the ankle joint, in this particular research, was based on these statements.

Upon assessing the results of this particular study, it was noted that there is no difference at the end of period one between treatment A and B. There is however, improvement in the range of motion at the ankle joint in both groups and therefore it can be concluded that although treatment A is not more effective than treatment B the above is true: that stretching shortened calf muscles and the surrounding structures does have a positive effect on the range of motion measured at the ankle joint, especially into dorsiflexion. One can also conclude that the following is true of the treatment B (Active Rocker Board exercises): that these exercises do in fact improve multi-axial range of motion and flexibility at the ankle joint.

4B GONIOMETER PLANTARFLEXION OBSERVATIONS

The means of the goniometer plantarflexion observations are included in Table 16 and the estimates of the carry-over effects are shown in Table 17. When specific testing for carry-over effects of both treatments was performed: it was found that the carry-over effects were simultaneously less than zero on both sides. This means that there was an improvement in condition on both sides, in period two, as a result of the effect of the treatment administered in period one. This result is true, regardless of which treatment was given in period one and which given in period two.

The test for equal treatment effects is different in this instance to that previously used as there is significant carry-over of the effect of the treatments given in period one into period two. Due to this fact, only tests for equal period one treatment effects were performed. The estimates of these effects are shown in Table 18.

After calculation, F = 3.4074 with a p-value of 0.0479 was a significant result, indicating that treatment B was better than treatment A on both sides, at the end of period one. Unfortunately the significant carry-over effect prevents one from separating the individual effects of each treatment and each period from each other, therefore it was impossible to determine and analyse the effect of each treatment individually in period two.

These carry-over effects make a comparison of the two treatment results in period two impossible, as well as a comparison between periods one and two, this means that an incomplete assessment is carried out on the results obtained. Perhaps, to avoid carry-over effects of the treatments given in period one: 1) one could have two different sample groups that are separate from each other and whose results can be compared in both periods or 2) another means of possibly avoiding carry-over effects is to: lengthen the gap between treatments given to participants.

PNF stretching has been found to help strengthen the muscles that are contracted, and therefore is a good therapeutic tool for increasing active and passive flexibility (Appleton, 2003). It has also been documented to be a valuable tool for restoring normal movement patterns, strength, endurance and ultimately full function (McAtee, 1993). PNFT's have been shown to be "one of the fastest and most effective ways known to increase static and passive flexibility" (Prentice, 1994:164; Appleton, 2003).

Proprioception training (Active Rocker Board exercises) can be used for restoration of balance (i.e.: needing to improve proprioception) (Kuligowski et al. 1999), multi-axial range of motion and flexibility at the ankle joint (Calliet,1997; Kawaguchi,1999; McGrew et al. 2003). This gives a possible explanation for the results obtained in this particular study.

When assessing the specific results obtained in this study, the conclusion reached is that: although there was an improvement in the plantarflexion available at the ankle joint as the result of treatment A (PNFT's), this was shown to be far less effective than treatment B (Active Rocker Board exercises) bilaterally, at the end of period one. Due to the significant carry-over effects from period one to period two, only period one effects were considered and assessed.

Reliability of the goniometer has been tested by various people and the following concluded : "Joint motion measured by Goniometry should differ by at least 5 degrees before a real increase or decrease in joint motion has occurred" (Boone et al. in Kerr et al. 1998). Johnson and Gross (1997:255) concluded that this means of measuring ankle dorsiflexion showed high intra-examiner reliability. Validity of the goniometer has also been tested (Gogia et al. in Kerr et al. 1998) and it was noted that: there was good agreement between the Universal Goniometer measurements and X-Ray findings, this showed that there was a high degree of validity to the goniometer readings taken.

In future studies conducted on the rehabilitation of chronic ankle sprains: it is suggested, by the researcher that the Digital Inclinometer be used to measure the amount of dorsiflexion and plantarflexion available at the ankle joint. This apparatus records, digitally, the amount of movement at the joint to the nearest degree and therefore can give more accurate results than the hand-held goniometer. The researcher also believes that the Digital Inclinometer would remove any researcher bias from the readings taken and would therefore result in more accurate and reliable readings being recorded.

5) ROCKER BOARD EXERCISES

The means of the rocker board exercise observations are shown in Table 19. When testing for treatment effects, the result of $F = 35.61$ with a p-value <0.0001 is highly significant. This means that treatment B yielded a far greater improvement than treatment A, in terms of the total score obtained for exercises successfully completed on the Rocker Board.

Proprioception training (PT) treats existing proprioceptive deficits and restores ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al. 1999) allowing for increased strengthening of the triceps surae as indicated by Reid (1992: 240) and supported by Calliet (1997), Kawaguchi (1999) and McGrew et al.(2003). PT also allows the patient to improve their sense of where his or her body part is in space and helps with the restoration of balance (Cooper et al. 1998; Kuligowski et al. 1999), multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al. 2003). These strength gains are an important component of enhancing proprioception (Kawaguchi, 1999).There is therefore an overall improvement, of the ankle joint movement, strength and sense of balance with treatment B and these statements give the necessary reasoning behind the effectiveness of the PT in comparison to PNFT, in terms of the scores obtained on the Rocker Board. This result is enforced by the opinion of Reid (1992: 252), that the strengthening component is largely responsible for the overall functional improvement.

When assessing the two treatments, with regards to the retraining of the golgi tendon organs at the ankle joint complex, one needs to keep in mind that: Active contraction of the muscle fibres will cause a greater firing rate than a passive stretch because active contraction is more effective in elongating the tendon and deforming the golgi tendon organs (Kerr et al. 1998: 128, 129). As the person is able to bear more weight on their ankle, there should be a corresponding increase in the use of closed-chain activities, which more closely simulate functional activities for all the joints of the lower extremity (Kawaguchi, 1999). The Active Rocker Board exercises are an excellent example of these prescribed activities.

It is also suggested that, the participants in the group receiving treatment B are on the Rocker Board regularly with relatively small gaps between sessions, whereas those receiving treatment A have large gaps between sessions on the Rocker Board. This could contribute to the fact that those getting treatment B at any one time are more successful, than those getting treatment A at the same period, in terms of their total scores obtained for the Rocker Board exercises.

When testing for period effects the following result was found: $F = 88.68$ with a p-value of <0.0001 this too, is a significant result. This means that the treatment in period two, in addition to the treatment in period one, results in a significant improvement in the total score attained for successfully completing the exercises on the Rocker Board. This is true, regardless of which treatment was given in period one and which in period two.

Proprioceptive neuromuscular facilitation techniques (PNFT) (Treatment A) have been recommended for increasing strength, flexibility and range of motion as PNFT have been shown to be “one of the fastest and most effective ways known to increase static and passive flexibility” (Prentice, 1994: 164; Appleton, 2003). The physiological basis of PNF is based on the stretch reflex, which results in the stimulation of golgi tendon and muscle spindles. The resulting impulses to the brain lead to contraction and relaxation of the muscle. Injury leads to a delay in muscle spindle and golgi tendon stimulation with resulting muscle weakness. PNF is responsible for re-educating the motor units, which are lost due to injury (www.angelfire.com. Proprioceptive neuromuscular facilitation). These effects can clearly be seen when one examines the total scores attained by participants for exercises successfully completed on the Rocker Board. These scores are shown to improve, even when the only form of treatment given to the participants is that of heat and hold-relax PNFT’s.

In contrast to this, proprioception training (PT) (Treatment B) has proven to be equally effective and important in ankle rehabilitation (Thomson et al.1991: 41). PT treats existing proprioceptive deficits and restores ankle joint stability, presumably by retraining altered afferent neuromuscular pathways (Kuligowski et al.1999) allowing for increased strengthening of the triceps surae as indicated by Reid (1992:240) and supported by Calliet (1997), Kawaguchi (1999) and McGrew (2003). PT can also be used for restoration of balance (Cooper et al.1998, Kuligowski et al. 1999), multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999; McGrew et al. 2003). With proprioceptive exercises the patient retrains the ankle and decreases the chances of re-spraining this joint (Cooper and Sammarco, 1998:367).

The sequence of rehabilitation of any contracture, decreased range of motion (flexibility) of a joint, and muscle strength and function has been focused on the improvement of strength prior to proprioception (Calliet, 1997; Flemister et al. 1998; Buhler et al. 2002). However according to McGrew et al. (2003) and supported by Oloff (1994); Vegso (1995); Calliet (1997); Kawaguchi (1999) and Buhler et al. (2002), this is a common mistake in rehabilitation and focus should lie in obtaining a functional range of motion (increased flexibility) and proprioceptive ability and strength will follow with normalisation of the relationship of the anatomical structures.

The results, in this particular study show two things: firstly, that the sequencing of the ankle joint rehabilitation programme (specific to these readings) is not as important as previously believed; and secondly that the above is in fact true, that proprioceptive ability and strength of the ankle follow after normalisation of the relationship of the anatomical structures, as the result of flexibility training.

The results of the tests for treatment effects, show that the Active Rocker Board exercises (Treatment B) improved the participant's overall scores in follow-up sessions to a greater degree than PNFT's (Treatment A) i.e. that treatment B is more effective than treatment A for these readings. However, both treatments are shown to have had a positive effect on the participant's scores, strength, range of motion and flexibility at the ankle joint.

The results of the tests for period effects, show that regardless of the order in which the treatments are administered, having both treatment components included in the rehabilitation programme has a far greater effect on the improvement of the participant's scores, which are determined by the successful completion of specific tasks on the Rocker Board, than either treatment alone.

6) <u>ROMBERG'S TEST FOR BALANCE</u>

For this specific test: all cases where subjects had a baseline classification of negative and remained negative for the next two periods were ignored for the purpose of assessing the various effects. The reason for this is that these classifications did not change and therefore gave no information on any effects, except that the participant's condition was not deteriorating.

Table 20 summarises the period one and two conditions for the fourteen participants included in the testing (Nine from Group One and Five from Group Two) i.e. those that had a balance problem at baseline. It was shown that at the end of period one: five out of the participants in group one had negative Romberg's tests and the remaining four in this group still had problems with balance. For those participants in group two it was shown that four of the participants with initial balance problems now had negative tests and only one person in this group had a residual balance problem. At the end of period two eight out of nine participants in group one, with initial balance problems, now had negative Romberg tests and all five participants in group two, with balance deficiencies initially, also had negative Romberg tests.

The following comments were made regarding the results after an analysis of Table 20:

1) The treatment (A or B) over the two periods was definitely successful. Of the fourteen participants with balance problems at baseline, only the participant with the worst condition at baseline (wobbly left and right) still had a slight problem at the end of period two.
2) The proportions (percentages) of participants that improved at the end of period one are five out of nine (55.56%) for Group one and four out of five (80%) for Group two. This suggests that treatment B was more effective than treatment A. This may have been true, but the sample size (14

participants) was too small to verify this (Fischer's exact test shows a p-value of 0.378).

3) The period two treatment in addition to the period one treatment seemed to result in a further improvement in condition, with only one of the five participants who still had a balance problem at the end of period one, with a problem at the end of period two. Unfortunately, the sample size of five participants (those with a residual balance problem at the end of period one) was too small to yield a significant p-value (p-value of 0.1875).

One can make a comparison between the results of the Romberg Tests and those attained in the Rocker Board Assessments, as the Active exercises are known to treat existing proprioceptive deficits and retrain the ankle proprioceptors and hence should have a positive effect on the participants sense of balance. Point one showed that both treatments A and B were successful in addressing the participants sense of balance over the two periods. This proved to be true for the Rocker Board exercises as well. Point two suggested that treatment B (PT in the form of The Active Rocker Board exercises) was more effective than treatment A (PNFT's) in terms of the participants sense of balance, however the sample size was too small to reach a definitive conclusion. In an assessment of the total scores attained by the participants in the Rocker Board exercises, the same conclusion was reached: that treatment B was in fact more effective, in improving the participants scores on the Rocker Board. Obviously this translates to an improvement in the participants sense of balance, as well as increased range of motion and strength at the ankle complex. Point three showed the benefit of both treatment components as compared to either one alone in the improvement of participants sense of balance, as measured by the Romberg's test, this corresponds to a similar finding in the Active Rocker Board exercise results, being that the two treatments together are definitely more effective as a combination than either one alone. The correlations between these two specific sets of results are what was expected, and they therefore support all the previous literature in terms of Proprioception Training and its effect on the improvement of participants' sense of balance.

One must also keep in mind that Romberg's test is not exclusive for one particular finding and as a result there may be a lack of sensitivity associated with this test. In hysteria, there can often be a false Romberg and unsteadiness is exaggerated by extreme swaying at the hips rather than at the ankles. It would be advantageous to watch closely for an occasional fall even though this type of patient will seldom injure himself. Elderly persons will often fear closing their eyes and this must also be taken into account (Arnold,1979). Unilateral vestibular disease may and can simulate cerebellar involvement (Arnold, 1979). In ataxia due to loss of positional sense, vision compensates for sensory loss. Patient stands fairly well with their eyes open but loses balance when they are closed, a positive Romberg sign. In cerebellar ataxia, the patient has difficulty standing with their feet together whether their eyes are open or closed (Bates,) In 1965 Freeman et al. (in Reid, 1992:252), used a modified Rhomberg test to define the possible association of a proprioceptive deficit in patients with functional instability. They postulated that significant ligament damage would damage sensory nerve endings and produce a situation where there was inadequate biofeedback from the joint. Of those individuals with functional instability, 34 percent had a positive test that was dramatically reduced to 7 percent with therapy.

The nerves associated with proprioception are sensory in nature, sending information from these mechanoreceptors to the brain allowing us to know the location of one body part in relation to another, the degree of joint flexibility, the degree of muscle contraction and tendon stress, and the head and body position in movement, providing us with a conscious awareness of body position and movement known as the kinaesthetic sense (predictive nature with regards to the maintenance of balance) (Adragna et al. 1990:553). This statement highlights the need for Neuromuscular Feedback Techniques so that these mechanoreceptors and sensory nerves can function optimally, allowing the brain to know the location of one body part in relation to another so that we may be coordinated and have a good sense of balance.

Instability undoubtedly occurs because of loss of proprioception at the ankle following an ankle sprain (Calliet, 1997:211) and unconscious proprioception modulates muscle function and initiates reflex stabilisation (Prentice, 1994:119) and

Therefore the objectives of proprioceptive training are to refine joint sense awareness in order to initiate this muscle reflex stabilisation to prevent re-injury (Prentice, 1994:128). Articular structures also have a significant sensory function that plays a role in dynamic joint stability, chronic injury and rehabilitation training (Prentice, 1994:119). Simply restoring mechanical restraints or strengthening the associated muscles neglects the co-ordinated neuromuscular controlling mechanism required for joint stability during the sudden changes in joint position common to sports and daily activities (Prentice, 1994:118). This statement demonstrates the limited effectiveness of the Active Rocker Board training exercises, and highlights the need for integration of Proprioceptive Neuromuscular Feedback Techniques as part of a complete rehabilitation program.

The inability to maintain postural equilibrium correlated with functional instability but not with mechanical instability (Nawoczenski et al. 1985 in Reid, 1992:252).

The above results could also be interpreted to indicate peroneal muscle weakness instead of inadequate feedback. Indeed, improvement in all these parameters after therapy correlate well with improved strength (Reid, 1992:252). These findings support the necessity for Proprioceptive Training (Active Rocker Board exercises) as well as Neuromuscular Feedback Techniques in the rehabilitation of chronic ankle sprains.

Rehabilitation programs often neglect the proprioceptive training, which can make a difference in the patient's outcome after treatment (Oloff, 1994:247). If the evidence of ligament mechanoreceptor importance is valid, more effort should be made to substitute for their function once this function is disrupted by trauma. The introduction of significant amounts of proprioceptive training in rehabilitation programs following ligament injury or surgery is essential (Reid, 1992: 77). In most cases the ankle does not have the ability to stabilise the increase in mobility and therefore one needs to re-establish proprioceptive integrity to the ankle musculature (Buhler et al. 2002: 8-15).

Proprioceptive exercises, using a tilt-board, are initiated to rehabilitate and retrain the damaged mechanoreceptors in the joint capsule and accompanying ligaments thereby improving proprioception at these joints (Donatelli, 1990:222, 223). Proprioception training (PT), which is also used to re-educate the proprioceptors and golgi tendon organs in musculature, via weight bearing activities, co-ordination exercises and balance (wobble boards) (Thomson et al.1991: 41), allows the patient to improve their sense of where his or her body part is in space and helps with restoration of balance (i.e. needing to improve proprioception) (Cooper et al.1998; Kuligowski, 1999). These active exercises should be considered early and performed with or without resistance (Calliet, 1997:152).

Patients progress through a series of specific exercises which strengthen the ankle and retrain the sense of balance and proprioception at the ankle joint (Prentice, 1994:444), treating existing proprioceptive deficits and restoring ankle joint stability, presumably by retraining afferent neuromuscular pathways (Kuligowski et al. 1999). There is also a learning curve that demonstrates some improvement with training (Reid, 1992: 252), these statements further support the suggestion that proprioceptive training is effective in improving one's sense of balance which is demonstrated by means of the results obtained in this study.

Both treatments A and B were shown, via the results obtained, to be effective in improving the patient's sense of balance and it was suggested that treatment B (the Active Rocker Board exercises) was more effective than treatment A but the sample size was too small to confirm this notion.

7) ASSESSMENT OF FEET FOR ANY FIXATIONS PRESENT

In the Talocrural Joint assessments, the inversion and eversion fixation patterns were the same for both feet and therefore were considered as a single entity. The results (fixation sequences for the three periods are shown in Table 21).
In the Subtalar Joint assessments it was shown that the patterns for varus and valgus fixations were not the same for both feet and therefore these were

regarded as separate entities. The fixation sequences for the three periods are depicted in Table 22a and b.

From Baseline to period one:

The number of fixations at these stages were recorded and tabulated in order for a frequency distribution to be determined for each group, at each of the joints. The results are shown in Table 23a, b and c.

From period one to period two:

The same procedure was followed for this period difference as for the baseline to period one values, and the frequency distribution of fixations for both groups, at each of the joints is depicted in Table 24a, b and c.

To simplify the assessment of all these fixations a coding system was developed and this is demonstrated in Table 25. The frequency distributions of the differences between the two successive periods for the different cases are summarised in Table 26.

For the cases marked with an asterisk (*) there was a significant reduction in the mean number of foot fixations. These cases are the Talocrural (baseline to period one for both groups), Subtalar Varus (baseline to period one for both groups) and Subtalar Valgus (baseline to period one for both groups). This means that there was a significant improvement (for both treatments) from baseline to period one for both the ankle joints, but no significant difference from period one to period two in either ankle, regardless of which treatment was given in period two.

Two sample t tests were carried out to compare the differences for the two groups for each case: in none of these tests were the means of the two groups proven to be significantly different. Therefore both treatments were shown to be equally effective in reducing the number of foot fixations.

Mobilisation is a passive movement performed in such a way that at all times they are within the control of the patient so he can prevent the movement if he so chooses, an example of this is distraction which is used as an examination test movement as well as a treatment, likewise is compression (Maitland, 1999: 9). Mobilisation techniques to stretch have three other roles: 1) slow passive movement to retain range of motion, 2) stretching to increase otherwise normal range of motion, therefore increasing mobility, 3) stretching to lengthen contracted or fibrosed muscle tissue (Maitland, 1999: 10).

One can maximise the available range of motion with mobilisations of the forefoot and ankle complex, within capable limits. General mobilisations of the forefoot are also useful in establishing the normal biomechanics. The treatment works around changing of muscular/tendinous pathologies that are correctable, by means of stretching, mobilisation and light manipulation of all lesions that present (Clinical Biomechanics V notes DIT).

Both treatments caused a mobilisation directly or indirectly of the ankle complex and thus had an equal effect on reducing the fixations present at the ankle without manipulation. What most people do not seem to realize is that passive movement treatment can achieve desired changes which other forms of physiotherapy cannot (a) achieving the maximum attainable range of motion and muscle length (b) achieving the best results from the effects of pain inhibition. Also it may be the only way of clearing a protective muscle spasm (Maitland, 1991: 12). Mobilization of the joints and related tissues occurs in the passive range. This range brings the joint just up to the elastic barrier and not beyond (Hammer, 1991: 197). Freeman (Reid, 1992:247) suggested that a comparison of surgery versus early mobilization (in ankle sprains) had similar results in terms of stability, and that the overall return to activity and employment was more rapid among the nonoperative group. Freeman concluded that mobilisation was the treatment of choice, regardless of the severity of the injury. Treatment works around changing of the muscular/tendinous pathologies that are correctable, by means of stretching, mobilisation and light manipulation of all the lesions that present (Clinical Biomechanics v notes DIT). One must also keep in mind when performing an assessment manipulation: Each technique is both an evaluative technique and a treatment technique (Edmond, 1993: 13).

<u>The following additional fixations were observed at the ankle joints:</u> A Talocrural Plantarflexion fixation and a Talocrural Dorsiflexion fixation, both being on the Left-hand side. These fixations both disappeared after the period one treatments.

The following fixations were also noted in group two at the baseline measurements: Two Fifth ray Plantarflexion fixations and two Fifth ray Dorsiflexion fixations, all four being on the left-hand side. Two First ray Plantarflexion fixations and one First ray Dorsiflexion fixation were noted, these also being on the left-hand side. These fixations all disappeared after the period one treatments.

Continuing symptoms following a sprained ankle such as pain, swelling, a feeling of instability, crepitus, weakness and decreased range of motion or functional instability and stiffness can be as a result of incomplete or absent rehabilitation. It can be concluded that unless properly rehabilitated these complications such as chronic functional instability, synovitis, tendinitis, weakness and stiffness of the involved joint may arise (Baker and Todd, 1995).

The main causes of these symptoms are instability, joint stiffness due to a loss of fibular and subtalar joint motion, tight sensitive scar tissue and incomplete rehabilitation (Reid, 1992:250).

Subtalar stiffness and loss of motion easily ensues from post-traumatic oedema, particularly when cast immobilisation has been the treatment of choice. Failure to restore this subtalar motion throws increasing stress on the talocrural joint during all cutting and turning movements, gradually contributing to further stretching of already lengthened ligaments(Coker, 1991:2433; Reid, 1992:251-252). Due to the obvious effects that a restriction of movement, at the subtalar and talocrural joints, have on the ankle it was necessary to assess these joints initially and it was hypothesised that the restrictions would become reduced as a result of the rehabilitation program. After examining the results this seems to have been the case (even without the classic chiropractic manipulation).

Manipulation is defined in the New Standard Dictionary of the English language as an "examination or treatment by the hands". This definition gives ample argument for using the terms joint manipulation to include any manual technique applied to a joint in dysfunction that moves the two surfaces in relation to one another. Included in this definition is joint manipulation in the more narrow sense – joint mobilisation, which is a slow passive movement imparted to an articular surface (Edmond, 1993: 1). When performing an assessment manipulation the clinician should keep the following in mind: each technique is both an evaluative technique and a treatment technique (Edmond, 1993: 13). Manipulation cane be divided into the following categories: 1) Mobilisation, 2) manipulation.

Mobilisation is a passive movement performed in such a way that at all times they are within the control of the patient so he can prevent the movement if he so chooses (Maitland, 1999: 9).

In the event of articular limitation or early contracture, the foot must be mobilised: this passive motion can be accomplished by a therapist, relative or the patient themselves (Calliet, 1997: 152). This mobilisation of the foot can effectively be achieved by means of the patient participating in Active Rocker Board exercises or via the application of PNFT's to the ankle musculature.

Proprioceptive Neuromuscular Feedback Techniques (PNFT's) have been recommended for increasing strength, flexibility and range of motion (Prentice, 1994: 164; Appleton, 2003). They are a combination of passive and isometric stretching in order to achieve maximum static flexibility (Appleton, 2003) and usually employ the use of a partner to provide resistance against the isometric contraction, and then later to passively take the joint through its increased range of motion (Appleton, 2003).

Stretching exercise is useful in facilitating the relaxation of the muscles, thereby reducing unnecessary muscle tone, increasing joint mobility, and restoring optimal neurological patterning (Haldeman, 1992: 453, 529, 537) and heel-cord stretching exercises are standard (Calliet, 1997: 152).

Proprioception training (Active Rocker Board exercises) can be used for the restoration of multi-axial range of motion and flexibility at the ankle joint (Calliet, 1997; Kawaguchi, 1999 and McGrew et al. 2003). This statement suggests that proprioception training can also have an effect on the reduction of fixations at the ankle joint, as the result of increasing the ankle's range of motion and flexibility. In completing the specified weight-bearing exercises on the Rocker Board, the participants moved both ankles through the full possible range of motion, thus improving the range of motion and flexibility at the ankle joints and in the surrounding structures. This directly and indirectly caused the restoration of normal length and functioning of the soft tissue structures at the ankle and thus facilitated the resumption of the ankle joints to their normal positions i.e. reduced the fixations initially present.

This is however, a situation where the cause and effect relationship is not clear: the reduction of ankle fixations results in normal movement at the ankle and thus reduces symptoms, but the rehabilitation of the ankle musculature and surrounding structures releases the joints, so they may return to their normal positions thus also reducing symptoms experienced.

8) ASSESSMENT OF DEMOGRAPHIC MAKE-UP IN THIS STUDY

The ankle sprain is probably the single most common injury in sport (Garrick and Requa, 1988; Oloff, 1994:243; Kawaguchi, 1999) and recurrent ankle sprains are, according to Greenman (1996:552) equally common in both the "weekend warrior" and the high level athlete (i.e. recreational or competitive) with runners and joggers especially being more prone to injury, due to repetitive use of extremities and alterations in training schedules and shoe wear (Calliet, 1997; Cooper and Sammarco 1998; Austin, 2002; Hammer, 2002; Smith et al. 2002 and McGrew et al. 2003).

In the demographics one should also consider the activity levels of the participants, especially in this particular study, as the amount and type of exercise each person is involved in has an effect on their predisposition to injury and affects their recovery time, it also determines the extent of rehabilitation needed.

Out of the thirty participants: Thirteen people exercised five times a week or more (seven of these being female and six male), two exercised four times a week (one female and one male), six people exercised three times a week (two being female and four being male), four twice a week (one being a female and three males) and two people exercised once a week (one female and one male), there was one participant who only exercised once every two months (male) and three participants didn't exercise at all (two females and one male).

In further assessment of these values, the following was noted: 53.846%of the female participants exercised five times a week or more; 15.384 % of the females exercised three times a week, with the same percentage not exercising at all and 7.692 % of females exercised once, twice and four times a week.

In an assessment of the exercise patterns of the males, the following was noted: 35.294 % of the males exercised five times a week or more; 23.529 % exercised three times a week; 17.647 % of the male participants exercised twice a week and 5.882 % of the males exercised four times a week, once a week, once in two months and not at all. An interesting finding was, that although the females included in this particular study seemed to exercise more than the males, their incidence of chronic ankle sprains was lower.

The variety of sports in which the participants were involved was noted, and assessed according to the number of participants involved in any particular type of sport. There were seven males who played rugby/touch rugby, an equal number went to gym and were runners. There were four participants who played soccer, two who cycled and one who played golf. One participant played action netball, one was involved in jujitsu and one was a kite boarder. This result suggests that frequency of exercise does affect the prevalence of ankle sprains, and that in fact those athletes who are more competitive and train more regularly are shown to be at a higher risk of developing chronic ankle sprains. Chronic ankle sprain may occur during such activities as ballet, where poor postural habits and insufficient strength of the muscles controlling the subtalar joint can lead to gradual stretching of the ligaments. In some sports, e.g. football or soccer, the constant stresses and forces around the ankle can lead to chronic bone and joint changes (Reid, 1992: 222). Generally, athletes that train more regularly and vigorously than others are susceptible to overuse syndromes, ligamentous laxity and the tendency to push themselves past pain and discomfort, they often tend to return to sport too soon, especially in team sports or high levels of competition leading to unresolved injuries and further complications. As the result of continuous training and competing, athletes may place a greater stress on some structures than those structures can stand. This extra stress superimposed on an over-use situation will result in symptoms (Maitland, 1991: 12).

The classic presentation of chronic ankle sprains is in the 18-65 year old male recreational or competitive athlete involved in ballistic sports activities as well as running and jogging sports where changes in direction and speed are made quickly (Reid, 1992; Oloff, 1994).

During the comparison between the literature survey and the analysis of the particular findings of this study, in terms of the demographics involved, the following patterns were identified: The majority of participants presenting with chronic ankle sprains were male (seventeen males, being 56.6 %, and thirteen females, being 43.3 %), most of these males were in the twenty-five to thirty-five year old age group (43.3 %), fewer were included in the other age groups, being: 9 % in the under 25yr group; and 13.3 % of participants falling into both the 35-45yr group and the over 45yr group. All of the male participants were between the ages of nineteen and sixty-two, and 35.294 % of them exercised five times a week or more with decreasing percentages involved as frequency of exercise decreased.

One can compare these results to those in the classic presentation of chronic ankle sprains (as determined from the literature survey) and see that the only area where the results differed was with regards to whether the athletes were competitive or recreational. The results therefore show a strong correlation, in terms of the demographics, between this study and the classic chronic ankle sprain presentation. In this case there was a discrepancy in results between those who exercised five times a week or more and those who exercised once a week or not at all.

One can also compare the demographic make-up of this study to other studies conducted at the Durban Institute of Technology.

The following was noted, in three such studies:

1) Research into grade one and two ankle sprains by D. Coetzer in 1999 Age (70 % of participants were in the 15-25 group; 13.3 % were in the 26-35yr group; 13.3 % were in the 36-45yr group and 3.3 % were in the 46-55yr group). Gender (63.3 % of participants were male and 36.7 % female). Race (70 % of participants were Caucasian; 16.7 % were Black; 10 % were Indian and 3.3 % were Coloured).
2) Research into acute grade one and two ankle sprains by S.Bellingham in 2001: Age (53.3 % of participants were in the 15-24yr group; 36.7 % were in the 25-34yr group; 6.7 % were in the 35-44yr group; 0 % were in the 45-54yr group and 3.3 % were in the 55-65yr group). Gender (63.3 % of participants were male and 36.6 % were female). Race (60 % of participants were Caucasian; 6.7 % were a combination of Coloured and Indian participants and 33.3 % were Black participants).
3) In a similar study conducted by J. Gaymans into Achilles Tendonitis, similar demographics were found, in terms of Race and Gender distribution however the Age groups affected were significantly different: Age (12 % of participants were in the 15-24yr group; 25 % were in the 25-

34yr group; 18 % were in the 35-44yr group; 40 % were in the 45-54yr group and 5 % were in the 55-65yr group). Gender (63 % of participants were male and 37 % female). Race (65 % of participants were Caucasian; 27.5 % were Indian; 7.5 % were Coloured and 0 % were Black).

In an evaluation of the demographics , with regards specifically to the ankles affected by chronic ankle sprains, the following was noted and questioned: eight out of the thirty participants reported that their left ankle was involved, however nine participants claimed their right was affected. This result leads one to believe that the right ankle is more commonly affected than the left, other than when both ankles are affected (in this study: nine participants). One can assume that these findings are in some way related to ankle dominance, however, unfortunately no substantiating references were found and therefore a definitive conclusion cannot, as yet, be made. In this particular study the focus was not on the predominance of left or right ankle sprains and therefore testing for ankle dominance was not carried out. In future this could be included in the initial assessment of participants with ankle sprains by observing which ankle the participant favours and takes off from when running or jumping. This measurement could explain the demographics of why one ankle seems to be more commonly affected as well as giving an explanation for the effectiveness of the ankle rehabilitation treatment. One assumes that the majority of people are right ankle dominant, although as previously stated no references were found to confirm this notion The participant has, previously, relied on the dominant ankle to take more of their body weight, and has also used this ankle for pushing off in climbing stairs, running and jumping: therefore one can assume that the proprioception and strength at this ankle are more developed. As a result: the participant is more confident on, and favours this ankle. It is therefore expected that: the dominant ankle would respond to a greater degree and in a shorter time period to the rehabilitation programme, as the participants would perhaps push themselves harder in the exercises and stretches on this side.

CHAPTER SIX – CONCLUSIONS AND RECOMMENDATIONS:

Conclusion:

This research has shown that in most instances: the sequencing of the rehabilitation programme is irrelevant, but that both components (The Proprioceptive Neuromuscular Feedback Techniques: Hold-relax stretching Technique and Proprioceptive Training: Active Rocker Board Exercises) are vital in the management and rehabilitation of chronic ankle sprains, with treatment B proving to be slightly more effective than treatment A in certain instances.

1) The two treatments are shown to be equally effective in terms of the Algometer readings at the end of period one, and further improvement, in both groups, was noted with the addition of the second phase of the programme (More so on the right ankle) regardless of the order in which the treatments were administered. This can possibly be related to right ankle dominance in the majority of people (this is an assumption for which, unfortunately, no references were found). Based on this assumption: it is expected that the proprioception and strength as well as neuromuscular feedback loops are more developed in the dominant ankle, therefore contributing to the fact that the dominant ankle (right) responded to a greater degree and in a shorter time period than the left, to the

rehabilitation programme.(this is further explored at the end of this chapter when assessing the demographics of the ankles affected by chronic ankle sprains).

2) Both treatments are also concluded to be equally effective in the restoration of Strength in the Ankle Plantarflexors at the end of period one. The results show that there is no benefit, in terms of plantarflexion strength, in performing the second portion of the rehabilitation programme as no further improvements are noted after period one (regardless of which treatment was administered in period one and which in period two).

3) The treatment effects of both components (PT and PNFT) are also shown to be equal at the end of period one with regards to the improvement in Goniometer Dorsiflexion readings. There is an additional significant degree of improvement noted, in this specific range of motion (in both ankles), when adding the second portion of the rehabilitation to the first in both groups. These findings suggest that the sequencing of the rehabilitation program, with regards to the Goniometer Dorsiflexion readings, is irrelevant as long as both components are included. This is demonstrated by the fact that, despite both groups showing an improvement at the end of period one, both groups showed even further improvement as a result of the combination of the two treatments.

4) The effectiveness of both treatments was found, in the reduction of Fixations at the Talocrural and Subtalar joints of the ankles, to be equal and significant. There was no notable difference between: the reduction of fixations at the end of period one, or two for both groups. Any fixations at the feet other than those at the Talocrural and Subtalar joints: were shown to disappear after the period one

treatments, regardless of the group in which the participants were placed. This result is possibly due to the direct and indirect mobilisations that occur at the ankle joint complex, simultaneously and as the result of: the PNFT's and the Active Rocker Board exercises.

All periarticular tissue, including the muscles, tendons and fascia, are affected by the joint manipulation techniques (Edmond, 1993: 3). General forefoot mobilisations of the forefoot are useful in establishing the normal biomechanics (Clinical Biomechanics V notes DIT). Manipulation and mobilisation of the foot and ankle joints often helps to decrease reflex muscle spasm and reduce swelling of due to increased motion (Clinical Biomechanics V notes DIT). When performing an assessment manipulation the clinician should keep the following in mind: each technique is both an evaluative technique and a treatment technique (Edmond, 1993: 13).

In the following reading assessments however, it was shown that there is a definite difference in the effectiveness of the two treatments: with Treatment B (Active Rocker Board exercises) being proven to be more effective than treatment A.

a) In the Maximum Weight Bearing Dorsiflexion assessment, it was demonstrated that: at the end of period one Treatment B (Active Rocker Board exercises) was more effective than treatment A (PNFT's) on the right ankle. There was no further improvement shown after phase two of the rehabilitation programme, in either group. Therefore both treatments are assumed to have been equal in terms of treatment effects in period two.

b) In the Goniometer Plantarflexion observations it was noted that at the end of period one: treatment B (Active Rocker Board exercises) was once again proven to be more effective than treatment A (PNFT). Due to significant carry-over effects of the two treatments from period one into period two: only period one effects were evaluated, therefore the effectiveness of either treatment in period two was impossible to determine.

c) The same result was shown to be true for period one of the Active Rocker Board exercise scores, with treatment B being the more effective treatment. Here however, there was a significant improvement noted in the participant's scores with the addition of the second phase of the rehabilitation programme, regardless of the sequencing of the treatments.

d) When examining the results for the Romberg's test for sense of balance, the following was demonstrated: treatment A and B were definitely successful in the restoration of proprioception and balance. The proportions of participants that improved from baseline to period one suggested that treatment B was again more effective, but the sample size was too small to make any definite conclusions. The addition of phase two of the rehabilitation programme also resulted in further improvement in the values obtained in both groups, however this sample size was also too small to come to any definite conclusions.

A possible reason for the greater improvements in balance with treatment B is that: treatment B (Active Rocker Board Exercises) is a training programme for the proprioceptors at the ankle joint. Treatment A (the PNFT's) also addresses the proprioceptors at the ankle but are more instrumental in establishing normal neuromuscular feedback loops than developing and further educating these specific receptors. Therefore, treatment B had a far greater effect on the sense of balance of the participants. It has been noted by Buhler et al. (2002) that once you relax a muscle it functions normally. Stretching exercise is useful in facilitating the relaxation of muscles, thereby reducing unnecessary muscle tone, increasing joint mobility, and restoring optimal neurological patterning (Haldeman, 1992: 453, 529, 537). PNFT's have been documented to be a valuable tool for restoring normal movement patterns, strength, endurance and ultimately full function (McAtee, 1993). Proprioception training (PT), in contrast to PNFT's, is used to re-educate the proprioceptors and golgi tendon organs in musculature, via weight bearing activities, co-ordination exercises and balance (wobble) boards (Thomson et al. 1991:41). These strength gains are an important component of enhancing proprioception (Kawaguchi, 1999). These closed chain exercises are more functional as they involve weight bearing activities, which are important, as the majority of daily activities involve a closed kinetic chain system (Prentice, 1994: 98, 100).

The overall conclusion that can be drawn from the above results is that although both treatments were shown to be equally effective in certain readings, treatment

B (Proprioception Training - Active Rocker Board exercises) was shown to be more effective than treatment A (Proprioceptive Neuromuscular Feedback Techniques – hold-relax stretching Technique) in four out of the eight objective readings. The sequencing however, of the two treatments in the rehabilitation programme was proven to be irrelevant as long as both components are included in the rehabilitation of chronic ankle sprains.

Recommendations:

1) In performing the literature review, it became that obvious that there is a discrepancy as to whether muscle stretching should be performed before or after heating. In this particular study the muscles were heated for approximately ten to fifteen seconds prior to stretching. It would be interesting to note whether the results of the stretching differ significantly when the muscles are heated afterwards as opposed to before stretching.

This difference of opinion and reasoning behind the discrepancy is highlighted in the following statements:

a) Warming up muscles before use increases the circulation to the muscles and their tendons, allowing extensibility and adequate blood flow. Failure to do so may precipitate minor tears and hence the onset of inflammation (Reid, 1992:277). There is also a higher friction force in muscles when they are cold (Reid, 1992:98) and a regimen of heat, activity, stretching exercises and a cool - down period with the respective muscles on a stretch is useful (Reid, 1992: 98, 99).

b) Post treatment muscle soreness is markedly reduced by applying a hot pack for a few minutes immediately after spray and stretch (Travell, Simons and Simons, 1992: 138).

Chronic soft tissue swelling responds best to heat, compression, and carefully progressed motion (Reid, 1992: 232). The following question can be raised, whether not heating the musculature at all would have a potentiating effect on the stretching therapy, or whether this would have a negative effect on the outcome of this treatment? (a) Heat may have distinct advantages for the treatment of sub-acute and chronic swelling (Reid, 1992:229). (b)The application of a heat pack to the involved muscle groups for approximately fifteen seconds warms the muscles and thereby enhances the stretch of the muscles (Reid, 1992: 98, 559). The reasoning for the use of heat and the effects that it has on the musculature are included above. It can therefore be concluded that although the omission of heat from the treatment would isolate the effect of the stretching technique itself: it would increase the risk of muscle and surrounding tissue damage, and have a negative effect on the outcome of treatment, (PNFT's) as the full extensibility of the tissues would most probably not be reached, as well as the fact that there would be a residual deficiency in the circulation to the ankle complex.

2) It has been documented, in the literature that: The most important post-stretch procedure is to have the patient actively perform three FULL cycles

of the range of motion that fully lengthens and fully shortens every muscle that was treated. This encourages the patient to use those muscles throughout the full normal range in ordinary daily activities (Travell, Simons and Simons, 1992:137).

This procedure was followed for every participant in this study after the PNFT hold-relax stretching technique. It would be interesting to compare two groups, in terms of the effectiveness of the stretching programme: where one group followed this protocol and the other did not.

3) The assessment of invertor and evertor muscle strength and the comparative ratios should be a possible measurement in future studies of this nature, so as to determine the effectiveness of the rehabilitation programme and the participant's readiness to return to sport or daily activities. As they would, according to Reid (1992:242), have completed stage five of the rehabilitation programme.
4) It is suggested, by the researcher, that a more accurate and unbiased tool be used to measure range of motion at the ankle joint than the hand-held goniometer. Past research has shown this tool to be highly reliable and the same positioning etc was used for every participant, with all possible steps being taken to reduce researcher bias and error; the results obtained in this study in terms of the range of motion at the ankle were also backed-up by the assessment of the ankle with other supportive tests. However there is still believed, by the researcher, to be a significant

effect of researcher bias and possible incorrect measurements with the goniometer. The tool which is suggested, by the researcher, to be used in future studies is the digital inclinometer. This tool gives an accurate reading in degrees of the amount of dorsiflexion and plantarflexion available at the ankle joint and is believed to reduce researcher bias and possible error in measurement resulting in more accurate readings for analysis.

5) It was found, in this study, that it was extremely difficult to coordinate the researcher's times with those of the patients. A plan of the frequency and the amount of time between treatments was devised. However, it was more difficult than initially believed to adhere to this plan. The patients, although coming to weekly visits, did not always come in on the same day of the week, this was unavoidable as business meetings cropped up, cars broke down etc. Due to the fact that there were thirty participants in this study and on any given week a large percentage of these participants required two follow-up treatments, the researcher's time and resources were also limited. This resulted in: difficulties guaranteeing the availability of clinic rooms and the researcher herself for specific time periods, obviously also having an impact on the times when participants could be treated. It would be an interesting study if this same rehabilitation programme was run with the time between treatments being equal for each participant and between the participants, this would give an equal period of recovery after every treatment: whereas this was not always the

case in this study, especially in the weeks when the participants had two follow-ups, where sometimes there was only a day's recovery between treatments.

6) In this particular study, the researcher did not give specifications for the Active Rocker Board exercises, as the main objective of these exercises was for the participants to remain on the Board for the duration of these exercises and to complete as many of the stipulated tasks as possible. This meant that participants could use their arms to steady themselves, rock the board as much as they were comfortable with, and stand in any position they preferred – meaning there were no rules about how far apart the feet should be or whether the feet should face straight forwards or if some degree of toeing in or out were allowed etc. In future studies of this nature it is recommended, by the researcher, that guidelines with regards to these above issues should be formulated and enforced as they would ensure a greater amount of reliability and uniformity between participants, and for individual performance monitoring at subsequent treatments.

7) Another suggestion, with regards to the Rocker Board , is that the surface of the Board be covered with a non-slip material. It was found, despite the rubber covering of the Board's surface : that participants failed to complete some routines of the exercises due to the fact that their feet were slipping on the Board and not as the result of poor proprioception, strength, range of motion or flexibility at the ankle joint.

8) This study should be repeated with a much larger sample size, as was demonstrated by the results: when a few participants are excluded from some measurements, for whatever reason, the sample groups become too small to make any definite conclusions.
9) There should also be a follow-up for the participants in a study such as this one, one month later, to assess whether: with the participants returning to their lives without the programme, the effects of the rehabilitation programme are sustained or lost.

CHAPTER SEVEN - REFERENCES AND APPENDICES:

REFERENCES:

Abraham,L.D;Etugre,B.R.1986.In The American Journal of Physical Medicine: Gains in range of ankle dorsiflexion using three popular stretching techniques.65(4)189-96(accessed 2003 via Pubmed)

Adragna, P.J; Schmidt, R; Solomon, E. 1990. Human Anatomy and Physiology. Second Edition. Saunders College Publishing, USA.

Akdogan,S;Bayar,K;Erbahceci,F;Sener,G;Ulger,O.G;Yigiter,K.2002.In The Prosthetic Orthopaedic Journal: A comparison of traditional prosthetic training versus proprioceptive neuromuscular facilitation resistive gait training with Trans-femoral amputees.26(3)213-7(accessed 2003 via Pubmed)

Anderson, B and Burke, E.R. 1991. Scientific Medical and Practical Aspects of Stretching. Clinics in Sports Medicine 10 (1) pg 63-85.

Andrews, J.R and Harrelson, G.L.1991. Physical Rehabilitation of the Injured Athlete. WB Saunders Company.

Appleton, B, 2003 Stretching and Flexibility-Types of Stretching. www.shinyo.co.uk/information/Flexibilty/stretching.6 html (accessed 2003).

Arnold, L.E. 1979. Chiropractic Procedural Examination. Seminole Publishing, Inc. Florida, USA.

Austin, W.M. 2002. Chiropractic Health for Recreational Runners. Journal of the American Chiropractic Association. May. Pg 32-36.

Baker, C.L. and Todd, J.L.1995. Intervening in acute ankle sprain and chronic instability. The Journal of Musculoskeletal Medicine. July: 51-68.

Bassewitz, H.L and Shapiro, M.S. 1997. Persistent Pain after ankle sprain: targeting the causes. The Physician and Sports medicine (online) 25 (12) http://www.physsportsmed.com/issues/1997/12dec/shapiro (accessed July 2004)

Baumhauer, J.F.; Dr Giovanni, B.F.; Voloshin, I.2002.Plantar heel pain: Making a difficult diagnosis. Journal of Musculoskeletal Medicine.19: 373-376.

Bickley, L.S. 1999. Bates' Guide to Physical Examination and History Taking – Seventh Edition. Lippincott, Williams and Wilkins, USA.

Blanke,D;Sady,S.P;Wortman,M.1982.In Physical Medical Rehabilitation: Flexibility training: ballistic, static, or proprioceptive neuromuscular facilitation. 63(6)261-3(accessed 2003 via Pubmed)

Blokker.C;Carter,T.R;Fowler,P.J.1992.In:The American Journal of Sports Medicine Functional postoperative treatment of Achilles tendon repair. 20 (4)459-62.(accessed 2003 via Pubmed)

Buhler, C; Hammer, W.I; West, H.2002.The Chiropractic take on Tendonitis. Journal of American Chiropractic Association.39 (3): 8-15.

Calliet, R.1997. Foot and Ankle pain. USA:FA Davis Company. pg 136-137, 152-153, 189, 211-213.

Chaitow, L. and DeLany, J.W., 2002. Clinical Application of Neuromuscular Techniques. Volume 2 – The Lower Body. Churchill Livingston, Elsevier Science Limited, Edinburgh, Scotland. Pp 598. ISBN 0443 06284 6.

Chazan, I.M. 1998. Achilles Tendinitis Part 1: Anatomy, Histology, Classification, Etiology and Pathomechanics. Journal of Manual and Manipulative Therapy. 6 (2) 63-69.

Chazan, I.M.1998. Achilles Tendinitis Part 2 : Clinical Examination, Differential Diagnoses and Approach to Management. Journal of Manual and Manipulative Therapy. 6 (2) 70-77.

Coker, T.P.1991. Sports injuries to the Foot and Ankle. In: Jahss, M.H. Disorders of the Foot and Ankle: Medical and Surgical Management.2nd edition. Philadelphia: W.B. Saunders Company. pg 2415-2445.

Comas, A.J. 1977. Neuromuscular Function and Disorders. Chapel River Press. England.

Cooper, P.S., Sammarco, G.J.1998. Foot and Ankle Manual. USA: Williams and Wilkins. pg 107-109, 331-333, 366-367.

Dallal, G.E. The Computer-Aided analysis of crossover studies.(http://www.tufts.edu/-gdallal/crossovr.htm. Accessed 14/09/2004).

Donatelli, R.1990.The Biomechanics of the Foot and Ankle. FA Davis Company. USA.

Edmond, S.L. 1993. Manipulation and Mobilization: Extremity and Spinal Techniques. Mosby-Year Book, Inc. pg 1-13.

Eils,E;Rosenbaum,D.2001.A Multistation Proprioceptive exercise programme in patients with ankle instability.(accessed via Pubmed 2003)

Fischer, A.A. 1986. Pressure Threshold Meter: It's use for quantification of tender spots. Archives of Physical and Medical Rehabilitation, 67: 36-38.

Flemister, S; Stephens, H.M.1998. In: The Foot and Ankle Manual. USA. Williams and Wilkins.

Garrick, J.G.1977.The Frequency of injury, Mechanism of injury and Epidemiology of Ankle Sprains. The American Journal of Sports Medicine, 5(6):241-242.

Garrick, J.G. and Requa, R.K.1988.The epidemiology of Foot and Ankle Injuries in Sports. Clinics in Sports Medicine, 7(1):29-36

Gatterman, M.I.1990.Chiropractic Management of Spine Related Disorders. Baltimore, Maryland: Williams and Wilkens.437p.

Grand, L.S and Ordet, S.M.1992. Dynamics of Clinical Rehabilitative Exercise. USA. Williams and Wilkins. pg 98, 110-112.

Greenman, P.E. 1996. Principles of Manual Medicine. Second Edition. Williams and Wilkins, Baltimore.

Grender, J.M and Johnson,W.D. 1993. Analysis of crossover designs with multivariate response. Statistics in Medicine. Vol12 pg 69-89.

Grender, J.M and Johnson, W.D. 1992. Using the GLM Procedure to analyse multivariate response in crossover designs. Proceedings of 17th Annual SAS Users Group International Conference, Honolulu, Hawaii. April pg 1355-1360.

Haldeman, S. 1992. Principles and Practice of Chiropractic. Appleton and Lange, Conneticut. Pg 453, 529, 537.

Hammer, W.I. 1991. Functional Soft Tissue Examination and Treatment by Manual Methods. Aspen Publishers, Inc. pg 278-279.

Jonson, S.R and Gross, M.T. 1997. Interexaminer reliability, Intraexaminer reliability and mean values for Nine lower extremity skeletal measures in Healthy naval midshipmen. Journal of Orthopaedic and Sports Physical therapy, 25 (4): 253-263.

Juerrhing, D. and Weinert, D.2000. Physical Rehabilitation. In: Gardner, S and Mosby, J.S., Chiropractic Secrets. Philadelphia: Hanley and Belfus Inc. pg 195-203.

Kaikkonen, A.; Kannus, P and Jarvinen, M., 1994. A Performance Test Protocol and Scoring Scale for the evaluation of Ankle Injuries. The American Journal of Sports Medicine. 22(4): 462-469.

Kawaguchi, J., 1999. Ankle: Proprioceptive exercises balance rehabilitation. In: Bio-Mechanics Rehabilitation Supplement. (http:/www.coachr.org/ankleproprio.htm)

Kerr, K., Lockwood, J; Pitt-Brooke, J; Reid, H., 1998. Rehabilitation of Movement: Forces resisting and assisting movement. England: WB Saunders Company Limited. pg 201, 202-203, 205-206, 240.

Kibler, D. 2001. Get a Little Balance in Your Life. http:/www.getrolling.com/orbit/balance.html. (accessed 26/02/2004).

Klaure, K and Speck ,M.1998.In The American Journal of Sports Medicine: Early full weight bearing and functional treatment after surgical repair of acute Achilles tendon rupture.26(6)789-93.(accessed via Pubmed in 2003)

Kuligowski,L;Lephart,S.M;Rozzi,S.L;Sterner,R.1999.In The Journal of Orthopaedic Sports Physical Therapy: Balance Training for persons with functionally unstable ankles.29(8)478-86(accessed via Pubmed 2003)

Mack, R.P. 1982. Ankle Injuries in Athletics. Clinics in Sports Medicine, 1 (1):71-84.

Magee, D.J. 1992. Orthopaedic Physical Assessment. Second Edition. WB Saunders Company, USA.

Maitland, G.D. 1999. Peripheral manipulation – Third Edition. Butterworth-Heinemann Ltd. Pg 9-12.

McAtee, R.E. 1993.Facilitated Stretching. Human Kinetics Publishers, Illinois.

McGrew, C.A; Schenck, R.C., 2003. Ankle Sprain 20 Clinical pearls. Journal of Musculoskeletal Medicine.20: 34-40.

Oloff, L., 1994. Musculoskeletal Disorders of the Lower Extremity. USA.WB Saunders.

O'Sullivan, S.B and Schmidt, T.J.1994. Physical Rehabilitation: Assessment and Treatment. FA Davis Company. USA.

Prentice, W.E., 1994. Rehabilitation Techniques in Sports Medicine. 2nd edition. USA. Mosby-Year Book, Inc. pg 164.

Reid, D.C., 1992. Sports Injury Assessment and Rehabilitation. USA: Churchill Livingstone Inc. pg 22.

Reider, B. 1999. The Orthopaedic Physical Examination. WB Saunders Company, USA.

Smith, A.M and Teasdall, R. 2002. Managing Tendon disorders of the Foot and Ankle. The Journal of Musculoskeletal Medicine. May 2002 pg 196-202.

Thomson, A; Skinner, A; Piercy, J., 1991. Tidy's Physiotherapy. 12th edition. Oxford: Butterworth-Heinemann.

Travell, J, Simons, D.G and Simons, L.S., 1992. The Myofascial Pain and Dysfunction: The Trigger Point Manual. The Lower Extremities. USA. Williams and Wilkins. pg 406, 412, 439-446.

Tropp, H; Askling, C and Gillquist, J. 1985. Prevention of Ankle Sprains. The American Journal of Sports Medicine 13 (4) 259-262.

Vegso, J.J., 1995. Principles of Stretching, In: Torg, J.S and Shepard, R.J.. Current Therapy in Sports Medicine. 3rd edition. St Louis: Mosby-Year Book Inc. pg 476-478.

Wilkinson, A. 1992. Stretching the Truth. A review of literature on muscle stretching. Australian Physiotherapy 38(4) : 283-285.

LIST OF APPENDICES: