AN INVESTIGATION TO DETERMINE THE EFFECT OF SHORT TERM LOW –DYE TAPING ON VERTICAL GROUND REACTION FORCES IN ASYMPTOMATIC PES PLANUS, CAVUS AND NORMAL FEET.

A dissertation presented to the Faculty of Health Services, Durban Institute of Technology, in partial fulfillment of the requirements for the Master's Degree in Technology: Chiropractic

By

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I, John Wayne Elphinstone, do hereby declare that the following dissertation represents my own work, both in conception and execution.

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DEDICATION

This work is dedicated to my family whose love and belief in me will never fail. You’re my inspiration to be a stronger and wiser man.

To Nicole whose fearless love and innate goodness always reminds me what it means to be alive.

I love you all.

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ABSTRACT

Low -Dye taping is a method commonly used in sport participation and normal daily activity (Harradine, Herrington and Wright, 2001). It has been indicated in support of injured structures, decreasing edema and protection against re-injury (Reid, 1992:232). Contrary to these beliefs, studies have shown that low -dye anti-pronatory control is lost after relatively short episodes of exercise (Ator et al., 1991 and Vicenzino et al., 1997). The variations in dynamic foot function with low -dye taping is not well understood, although taping of the foot in low-dye type method has been advocated by many authors (Brantingham et al., 1992, Ryan, 1995 and Chandler and Kibler, 1993).

It was the purpose of this study to investigate the maximum ground reaction force and percentage contact time within 10 demarcated regions of the foot in asymptomatic patient with pes planus, cavus and normal medial longitudinal arches at four time intervals over 24 hours. Having established its baseline function it may serve as point of reference for clinical trials that wish to determine the role of taping as part of the management of symptomatic feet.

This trial consisted of 60 participants with asymptomatic feet that were divided into three groups of 20. Participants were divided into three groups depending on their respective foot structures. To qualify for one of the three groups subjects had to either have flexible low, high or normal medial longitudinal arches.

Maximum ground reaction forces (GRF) and Percent contact time was obtained for each of the three groups and for each of four visits. GRF were obtained with the aid of a registered orthotist who has agreed to work with the researcher on this project using the RSscan International 1m footscan plate system (Appendix L). The data was interpreted and analyzed using the RSscan Clinical Version 7.08 software package.

All data was analyzed using the SPSS statistical software package. Univariate analysis of variance (one way ANOVA) was used to determine the interaction of variables within the set time periods. This method of analysis was also used to determine if any interaction existed between groups and variables in those groups. The Post- Hoc test was used to determine the location of significant values within each subset. The T-test was done to determine the effect of taping on different means at different time intervals.

There appears to be a definite trend towards a supinated foot position directly after taping. This is supported by the increased contact time and maximum force over metatarsals 4 and 5. The low-dye taping appears to be elevating metatarsals 2 and 3 and in the process restricting their motion. The taping technique appears to cause an initial foot contact that is less distinctive at the heel but is more widespread throughout the mid and frontfoot regions. Although these trends exist after one hour of taping there seems to be a gradual loss of these effects over time so that after 24 hours a definite regression can be observed. These findings may indicate a complete return to the pre- taped condition over a longer period of time.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction:

The foot is a highly specialized structure (Jahss 1991:31) designed to carry out three important functions: support, propulsion and shock absorption (Kleneman 1991:1). The main functions of the foot are to distribute ground reaction forces associated with heel strike and to allow the transfer of body weight for effective locomotion.

These tasks are achieved by the effects of soft tissue structures and complex articulations (Michaud, 1993:1). Thus according to Cailliet (1997) the normal foot should conform to the following criteria:

I. The foot must be pain free
II. The foot must exhibit normal muscle balance
III. The foot must have an absence of contractures
IV. The foot must have a central heel
V. The foot must have straight and mobile toes
VI. The foot must have three points of weight bearing

Further to this, the foot may be classified as being pes planus, pes cavus or normal, with respect to the medial longitudinal arch of the foot (Magee 1997).

In this respect pes planus, as defined by Dorland's Medical Dictionary (1997:638), is a condition in which one or more of the arches of the foot have flattened out. Michaud (1993:173) goes further to divide pes planus into four different categories based on the structural and functional causes for pes planus:

I. Convex pes valgus (congenital in nature)
II. Talipes calcaneovalgus (congenital in nature)
III. Peroneal spastic flat foot (congenital in nature)
IV. Hypermobile flat foot (Biomechanical in nature)

The hypermobile flat foot or flexible pes planus can be differentiated from the other forms of pes planus by extending the hallux or asking the patient to stand on his toes (Magee, 1997:458). This causes the plantar aponeurosis to tighten thereby re-establishing the arch of the foot (Brown, 1996). Flexible pes planus can be further categorized into first second and third degree based on the amount of navicular drop present (Magee, 1997:484).

Pes cavus consists of an excessively high medial longitudinal arch that causes the foot to be shorter and the metatarsal heads to make oblique contact with the ground. This type of foot structure often leads to metatarsalgia and callus formation under the metatarsal heads as well as claw toes (Cailliet, 1997).

Plantar fasciitis is often associated with biomechanical changes of the medial longitudinal arch. It has been found to be the fourth most common overuse injury of the lower limb (Leach, Seavey and Salter, 1986). It represents between 7% to 9% of all running injuries (Batt and Tanji, 1995) and 8.5 to10% of all presenting sports injuries (Pollard and So, 1999 and Batt and Tanji, 1995)

Much emphasis has been placed on the effect of pronation on the plantar fascia.

However, any condition causing excessive tension on the plantar fascia may be responsible for the development of clinical signs and symptoms in the foot (Batt and Tanji, 1995, Barret O'Malley, 1999). Conditions such as pes planus, pes cavus and tight Achilles tendons are some of the factors that may contribute to the increase in tension of the plantar fascia (Brown, 1996).

Various clinicians use strapping as a method to support the plantar fascia (Ambrosius and Kondracki, 1992). A common technique called low-dye taping has been used since the 1940's and was developed by Dr. Dye (Saxelby, Betts and Bygrave, 1997). Anecdotal evidence suggests its function to be restricting pronation as well as supporting the medial longitudinal arch during mid-stance of the gait cycle. (Tanner and Harvey, 1988, Brantingham et al., 1992 and Ryan, 1995). Lynch et al. (1998) in their study of conservative treatment of plantar fasciitis concluded that mechanical control of the foot with taping and orthoses was more effective than either anti-inflammatory drugs or therapy with heel cups.

Although taping of the foot using the low-dye type method has been advocated for plantar fasciitis (Brantingham et al., 1992, Chandler and Kibler, 1993 and Ryan, 1995) it's relevance with respect to ground reaction forces remains uncertain. The role of low-dye taping has for the most part been extrapolated from its use in strapping of the ankle (Reid 1992:233), where:

I. It provides post injury support and controls edema,
II. It prevents re-injury between treatments,
III. It decreases the chances of re-injury on return to activity,
IV. It provides stability when chronic instability is present, and
V. It protects the structure against injury when applied prophylactically.

With the clinical efficacy of low-dye taping clearly still in question, it makes sense to determine and evaluate its effect on the ground reaction forces of the asymptomatic foot. Having established its baseline function it may serve as point of reference for clinical trials that wish to determine the role of taping as part of the management of symptomatic feet.

1.2 Objectives of the Study:

1.2.1 Objective one:

The first objective of the study is to determine the extent of peak ground reaction forces in the asymptomatic foot with pes cavus, planus and normal medial longitudinal arches prior to taping.

1.2.2 Objective two:

This study will determine the effect low- dye taping has on ground reaction forces by doing measurements immediately after taping, 1hour and 24 hours after taping in the asymptomatic foot with pes cavus, planus and normal medial longitudinal arches respectively.

1.2.3 Objective three:

The third objective of the study is to determine the extent of percentage contact time in the asymptomatic foot with pes cavus, planus and normal medial longitudinal arches respectively.

1.2.4 Objective four:

This study will determine the effect low- dye taping has on percentage contact time by doing measurements immediately after taping, 1hour and 24 hours after taping in the asymptomatic foot with pes cavus, planus and normal medial longitudinal arches respectively.

CHAPTER TWO

A REVIEW OF RELATED LITTERATURE:

2.1 INTRODUCTION:

In this chapter follows a detailed discussion with regards to foot structure, taping, ground reaction forces and their relationship to the foot.
The information will be presented as follows:

i. The role of taping
ii. Review of the Anatomy and Biomechanics,
iii. Normal gait cycle.
iv. Pes planus, pes cavus and their effect on the gait cycle
v. Low -dye taping and related literature

This chapter contains literature relating to the structure, function and biomechanics of the foot as well as low -dye taping.

2.2 THE ROLE OF TAPING

Taping is used by therapists for its mechanical support, proprioceptive feedback and control of swelling and pain in the treatment and prevention of many injuries (Callaghan, 1997)

The role of plantar fascial taping is still slightly obscure and has for the most part been extrapolated from its use in strapping of the ankle, where:

I. It provides post injury support and controls oedema,
II. It prevents re-injury between treatments,
III. It decreases the chances of re-injury on return to activity,
IV. It provides stability when chronic instability is present, and
V. It protects the structure against injury when applied prophylactically (Reid 1992:233).

The main mechanisms of action is considered to be the ability to limit mechanical joint stability, prevention of the extremes of ankle motion while at the same time increasing the reaction time and proprioception of surrounding structures (Cordova, Ingersoll & Leblanc, 2000, Karlsson, 1993).

The mechanical support provided by taping has long been the primary indication application of this intervention, Perrin (1995) stated that tape should limit abnormal or excessive motion while supporting the underlying compromised structures. Karlsson (1993) found in his research of ankle taping that although taping cannot completely eliminate movement it does prevent excessive end of range movement and therefore added that it does play a role in increasing the mechanical stability of the ankle. Laughmann (1980) stated that the tape acts as an external ligament that is dependent on the tensile strength of the tape and its adhesive quality only at the origin and insertion of the tape. However it has been reported that the stabilising effect of tape is drastically decreased after excessive movement (Alt et al., 1999, Callaghan, 1997)

Perhaps the greatest contributions of the tape are to the proprioceptive feedback by stimulation of mechanoreceptors in the ligaments and capsules of the underlying articulation (Karlsson, 1993). This in turn shortens the reaction time of the supporting muscles. Robbins et al. (1995) in a randomized, crossed over, controlled comparative trial showed how proprioception in the taped ankle improves after exercise compared to the untapped ankle. Absolute mean estimate error increased 7% in the taped ankle compared to an increase of 39% in the untapped ankle. Robbins et al. (1995) also tested proprioception with athletic footwear and found that although the taped ankle performed better proprioception was greatly limited compared to the barefoot readings and therefore showed that proprioception generally is less when shod.

2.3 ANATOMY AND BIOMECHANICAL REVIEW:

The foot and ankle articulations, although so often described individually, function dynamically to distribute forces at the end of the lower kinematic chain (Abboud, 2002). Although movement at each individual joint seems insignificant the combinations of these articular movements is what guarantees us functional mobility (Abboud, 2002). For ease of understanding we will discuss only the anatomy relevant to the medial longitudinal arch and the changes associated with those structures.

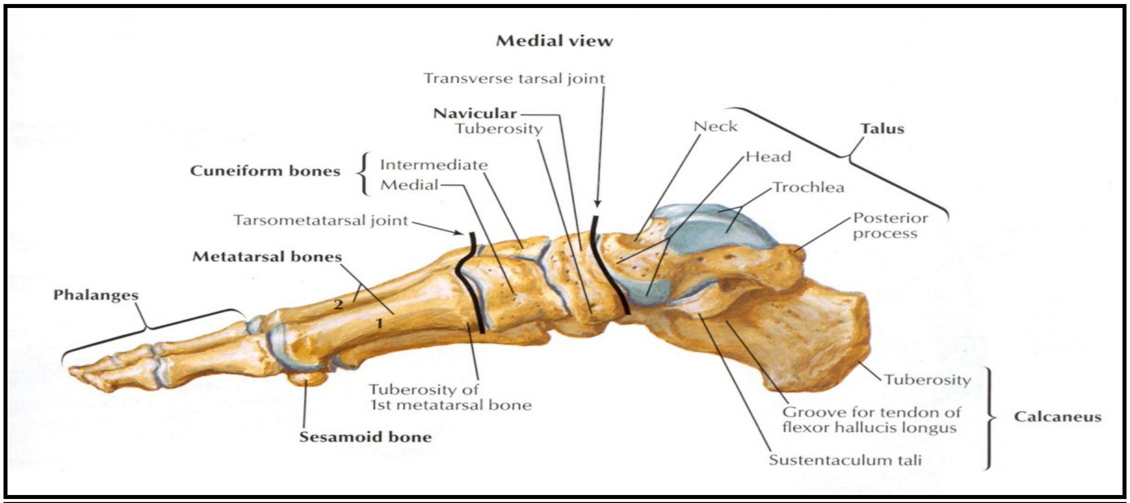


Figure 1: The right foot demonstrating the hind, mid and forefoot (Netter, 1999:489).

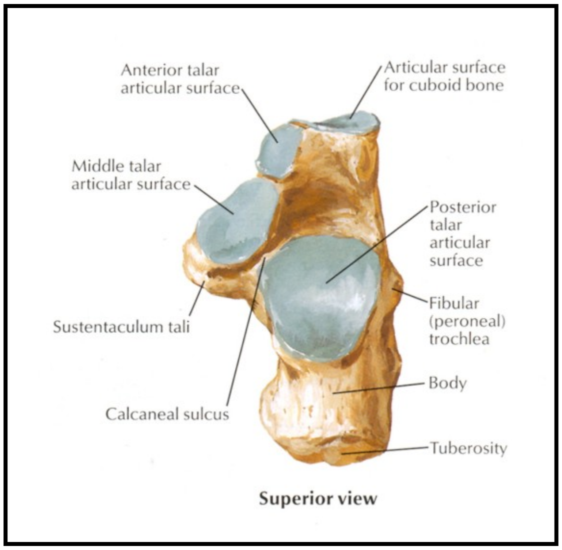
According to Magee (2001:446) the foot can be divided into three distinct regions (Refer to Figure 1):

I. Hindfoot, consisting of the tibia, fibula, talus and the calcaneus and functioning through the tibiofibular, talocrural and subtalar joints.
II. Midfoot, consisting of the calcaneus, navicular, cuboid and three cuneiform bones and the talocalcaneonavicular, cuneonavicular, cuboideonavicular, intercuneiform, cuneocuboid and calcaneocuboid articulations collectively known as the Chopart's joints.
III. Forefoot, consisting of the metatarsals, phalanges and some sesamoid bones. The main articulations are the intermetatarsal, tarsometatarsal, metatarsophalangeal and interphalangeal joints also collectively known as Lisfranc's joints.

The medial longitudinal arch stretches throughout these three regions (Norkin and Levangie, 1992:389). The osseous components of the medial longitudinal arch consist of the calcaneus, talus, navicular, as well as the three cuneiforms and metatarsals (Moore and Dalley, 1999:640)

Weight bearing supination is a combination of inversion, adduction and plantarflexion while pronation is defined as eversion, abduction and dorsiflexion (Cailliet 1997, Hunt et al., 2001, Abboud, 2002, McDonald and Tavener, 1999). Two of the main articulations involved with these motions are the subtalar and talocalcaneonavicular joints.

Figure 2: Superior view of the calcaneus and subtalar joint (Netter, 1999:490).



The subtalar joint is generally accepted to consist of three articulations between the talus and the calcaneus (Moore and Dalley, 1999:637, Michaud, 1993:9). The posterior facet formed by the talus and calcaneus is the largest of the three facets. The inferior surface of the talus is concave while the calcaneus has a convex superior surface (Refer to figure1 and figure 2). The two anterior facets are formed by two convex surfaces on the inferior surface of the neck of the talus that correspond to two anterior calcaneal concavities (Refer to figure 2) (Michaud 1993:9, Norkin and Levangie 1992:389). The tarsal canal runs obliquely between these two osseous structures and is formed by sulcus on the inferior surface of the talus and calcaneus (Refer to figure 2). Ligaments running in this tunnel divide the posterior from the middle and anterior facets, forming two distinct joint cavities. The anterior two articulations share one joint capsule with the talonavicular joint (Norkin and Levangie 1992:389).

The primary motions of the subtalar joints are inversion / eversion and abduction / adduction but these two motions do not occur independently of each other, rather the subtalar joint is said to have one degree of freedom namely pronation and supination (Abboud, 2002).

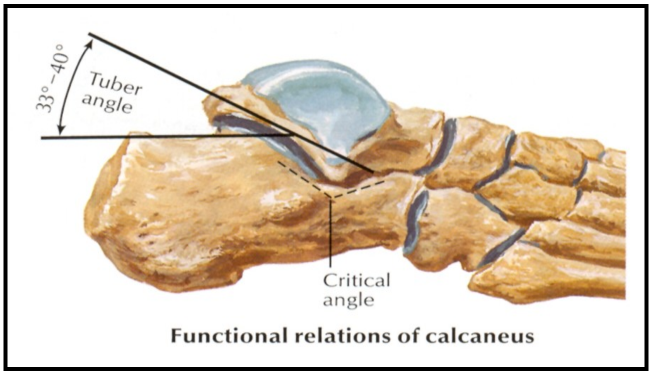


Figure 3: The subtalar and talocalcaneonavicular joints (Netter, 1999:490)

The talocalcaneonavicular (TCN) joint is a combination of the subtalar joints and talonavicular joint (Refer to figure 1 and figure 4). The talonavicular joint consists of the head of the talus articulating with the corresponding navicular articular facet. This surface is deepened and enlarged by the plantar calcaneonavicular ligament, deltoid ligament and the bifurcate ligaments. These ligaments connect the calcaneus to the navicular creating a joint with one degree of freedom, being supination and pronation (Norkin and Levangie 1992:390). This joint's function (TCN) is virtually identical to the subtalar joint, it is said to be the key to foot biomechanics from which the other articulations form an elastic unit. (Norkin and Levangie 1992:390)

Two other articulations, the talonavicular and calcaneocuboid joints combine as the transverse tarsal joint (Refer to figure 1 and figure 4). This joint forms the separation between the hindfoot and the midfoot. In contrast to the talonavicular joint described above, the calcaneocuboid joint allows very little motion due to complex concave and convex articulating surfaces (Norkin and Levangie 1992:391). Movement is therefore predominantly around a longitudinal axis of the foot which allow supination and pronation as their primary movements although inversion and eversion seem to predominate (Norkin and Levangie 1992:391). Due to its intimate relationship with the TCN joint, any motion at one joint would mean reciprocal movement in the others creating a dynamically moving complex of articulations (Norkin and Levangie 1992:391).

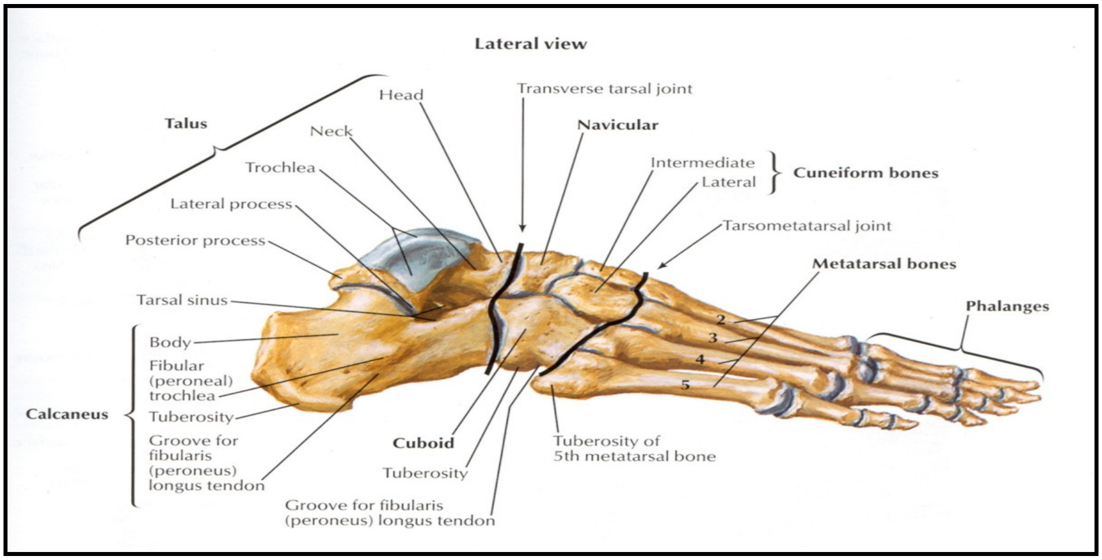


Figure 4: Lateral aspect of the foot showing the transverse tarsal joint (Netter, 1999:489).

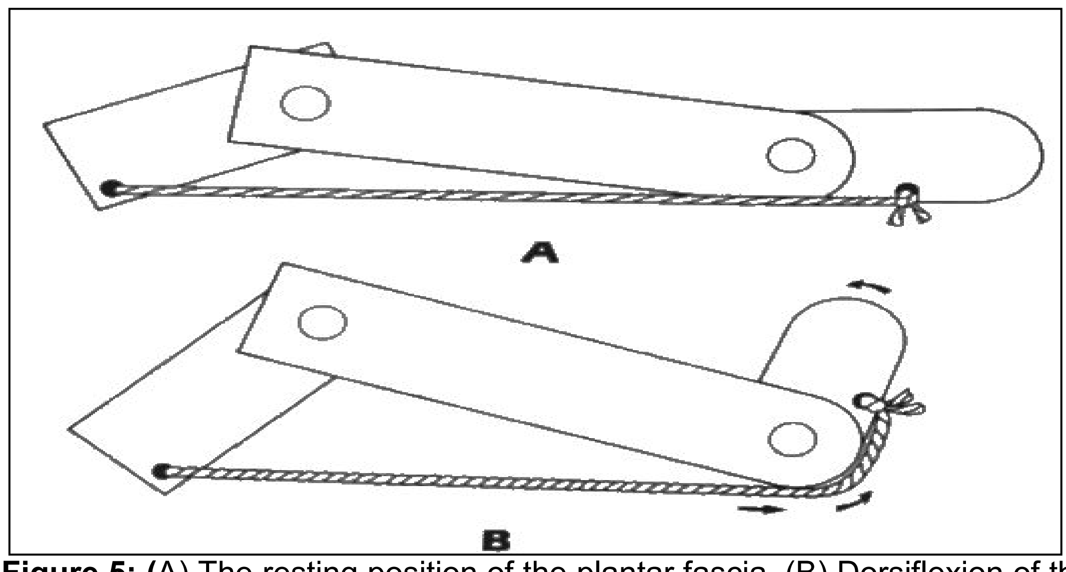


Figure 5: (A) The resting position of the plantar fascia. (B) Dorsiflexion of the first toe leads to tightening of the fascia and lifting of the arch. (www.orthoteers.co.uk/Nrujp~ij33lm/Orthfootmech.htm).

Passing over and maintaining these articulations are the soft tissue structures consisting of the ligaments and tendons of the foot. The plantar ligaments are of particular importance providing support whiles at the same time allowing slight mobility neccesary for shock absorbtion during the gait cycle (Norkin and Levangie 1992:391). The plantar ligaments consist of the the calcaneonavicular ligament, long plantar ligament, plantar fascia (aponeurosis) and short plantar ligaments (Moore and Dalley, 1999:586).

The plantar aponeurosis creates a bowstring effect in the foot (Refer to figure 5) (Reid, 1992:130, Brown, 1996). It enables the fibrous structure of the plantar aspect of the foot to enhance distribution of forces, support the articular components and enable a spring like action during the final aspects of gait also called the windlass mechanism (Soderberg 1996:313, Erdemir et al., 2004). This action can be readily seen by dorsiflexion of the great toe and is often used to differentiate between flexible and rigid pes planus (Magee, 1997:458)

The calcaneonavicular ligament, also called the spring ligament is a triangular structure passing from the sustentaculum tali to the posterioinferior surface of the navicular bone (Refer to figure 6). The long plantar ligament passes from the plantar surface of the calcaneus to the groove on the cuboid bone. Some of the fibres extend to the base of the middle three metatarsals thereby forming a tunnel for the peroneus longus muscle. The short plantar ligament, deep to the long plantar ligament, extends from the antero-inferior surface of the calcaneus to the inferior surface of the cuboid (Refer to figure 6) (Moore and Dalley, 1999:586).

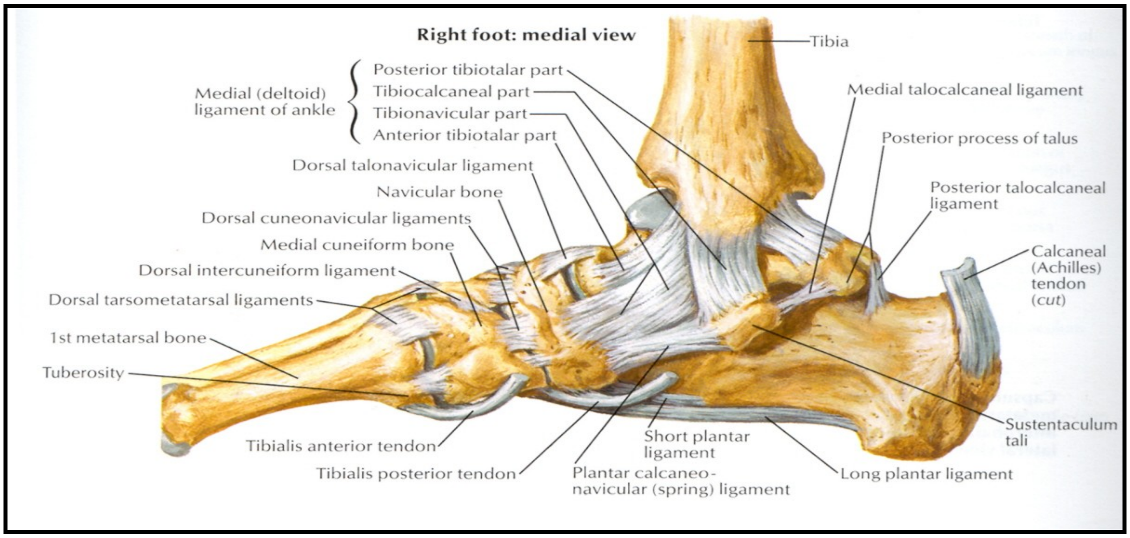


Figure 6: Ligaments supporting the articulations of the foot (Netter, 1999:491)

Although the gastrocnemius and soleus muscle (Figure 7), often referred to as the calf muscles or triceps surae, aren't directly related to the stability of the MLA. It acts via the achilles tendon attachment to the posterior surface of the calcaneus and ensures that hind-foot supination occurs during the gait cycle (Soderberg 1996:312, Moore and Dalley, 1999:586). This supination locks the talocalcaneonavicular (TCN) joint into a rigid lever, which will eventually lead to elevation of the heel and plantar arch if contraction continues (Soderberg 1996:325-326, Norkin and Levangie 1992 and Moore and Dalley, 1999:586).

Other muscles are more directly related the stability and function of the MLA. These include:

1. The tibialis posterior (Refer to figure 7) which pass behind the medial maleolus to anchor the navicular, calcaneus, cuneiforms, cuboids and base of the four metatarsals (Travell, and Simons, 1983:460). The main action of this muscle is primarily inversion and adduction while also giving a weak contribution to plantar flexion of the ankle (Travell, and Simons, 1983:460). Functionally it resists lateral valgus force of the ankle at early stance phase

and plays a significant role controlling functional pronation during gait and therefore also medial rotation of the leg (Norkin and Levangie, 1992, Travell, and Simons, 1983:460).

2. The Tibialis Anterior crosses the anterior surface of the tibia to attach to the medial plantar surface of the cuneiform and first metatarsal bones (Travell, and Simons, 1983:355). Dorsiflexion and supination is the main action of this muscle but has also been found to be vital in maintenance of balance during the stance phase of the gait cycle (Travell, and Simons, 1983:358-359).

3. The flexor digitorum longus (FDL) (Refer to figure 7) terminates in a tendon that passes over the flexor hallicus longus and joins the quadrates plantae muscle. It divides into four tendinous slips attaching each on its own to the distal phalynx of the terminal four toes (Travell, and Simons, 1983:490). FDL flexes the four lesser toes, which together with the flexor hallicus longus (FHL) causes clawing allowing the toes to grip the ground while walking (Travell, and Simons, 1983:491-492).

4. Flexor hallicus longus (Refer to figure 7) tendon passes deep to the flexor digitorum longus tendon and between the two heads of flexor hallicus brevis. It attaches to the terminal phalynx of the first toe (Travell, and Simons, 1983:490). The action produced by this muscle causes the hallux to be pressed against the ground to allow walking, together with FDL it supports the MLA during gait (Travell, and Simons, 1983:491-492)

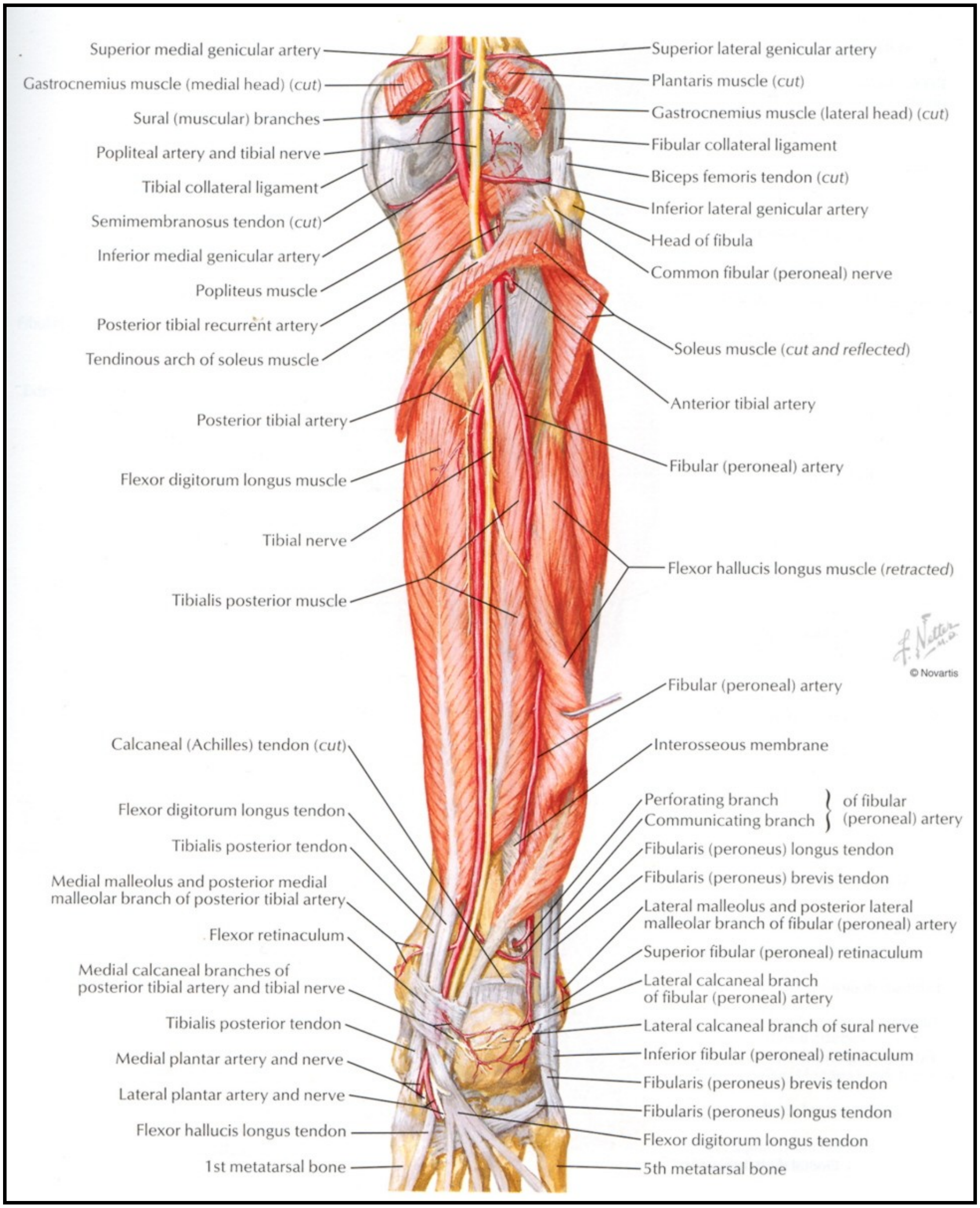
5. The Abductor hallicus (AH) covers the entrance to the plantar nerves and vessels (Travell, and Simons, 1983:504). Proximally it attaches to the medial calcaneal tuberosity, flexor retanaculum, plantar fascia and intermuscular septum of flexor digitorum brevis. Together with flexor hallicus brevis it attaches to the medial aspect of the base of the first toe (Travell, and Simons, 1983:504). The AH can flex and abduct the great toe. Although the AH and

flexor digitorum brevis (FDB) may contribute to static arch support in flatfooted individuals its activity is not required for normal foot arch maintenance rather their activity seems necessary where compensation is required in feet suffering with lax ligamentous and articular structures (Travell, and Simons, 1983:507-508)

6. The flexor digitorum brevis (FDB) covers the lateral plantar nerve and vessels. Proximaly it extends from the medial process of the anterior calcaneus, plantar fascia and adjacent intermuscular septa (Travell, and Simons, 1983:505). Distally it divides into four tendons that splits to allow passage for flexor digitorum longus after which it unites and then split again just before attaching to the middle phalynx. The FDB's role together with AH seems to be one of support in feet with biomechanical inadequacies; it does not seem to be active in normal feet. (Travell, and Simons, 1983:507-508)

When looking at the literature it can be reasoned that even a small deviation in anatomical structure will lead to significant alterations in the gait cycle. The gait cycle is unique in every individual but general trends can be distinguished to allow us to describe the normal gait cycle.

Figure 7: Muscles of the posterior leg (Netter, 1999:483)



2.4 THE NORMAL GAIT CYCLE

Due to the complexity of the gait cycle this discussion on gait patterns will be limited to the ankle and foot only due to its relevance in this study.

The human gait can be described as a translatory progression of the whole body due to coordinated rotatory movements of specific body segments (Norkin and Levangie, 1992:450). Although no two individuals share the exact same gait patterns the large majority of movements can be described in each individuals making disruption of this pattern easily identifiable (Norkin and Levangie, 1992:450).

The gait cycle represents the period between two identical events of the same limb, therefore from one event until the identical limb repeats the same action (Abboud, 2002). The gait cycle consist of two main phases, a swing phase consisting of 38 % of the gait cycle and a stance phase consisting of 62 % of the cycle (Jahss, 1982:400). A complete cycle is known as a stride while one step is considered the period between which the same event occurs in both limbs (Soderberg, 1997:412). Therefore the terms stride length and step distance is self-explanatory (Refer to figure 8) (Norkin and Levangie, 1992:388, Soderberg, 1997:412).

The stance and swing phase can further be broken down into sections. Multiple classifications exist but for the purposes of this study the more recent classifications of the Rancho Los Amigos (RLA) Medical Centre will be used, as they are more accurate in the breakdown of the phases (Figure 8) (Norkin and Levangie, 1992:450):

2.4.1 Stance Phase (Norkin and Levangie, 1992:388, Soderberg, 1997:413)

I. Initial contact: The point at which the extremity strikes the ground.
II. Loading response: From initial contact until contra lateral extremity is lifted
III. Midstance: Continues until body has moved over the supporting limb.
IV. Terminal stance: the period between midstance and initial contact of the contra lateral extremity or following heel off of the ipsilateral limb.
V. Preswing: period following heel off until the toe leaves the ground.

2.4.2 Swing Phase (Norkin and Levangie, 1992:388, Soderberg, 1997:413)

I. Initial swing: The end of preswing until the reference extremity has maximum knee flexion.
II. Midswing: The period between initial swing until the tibia is in a vertical position.
III. Terminal swing: The period between midswing and initial contact.

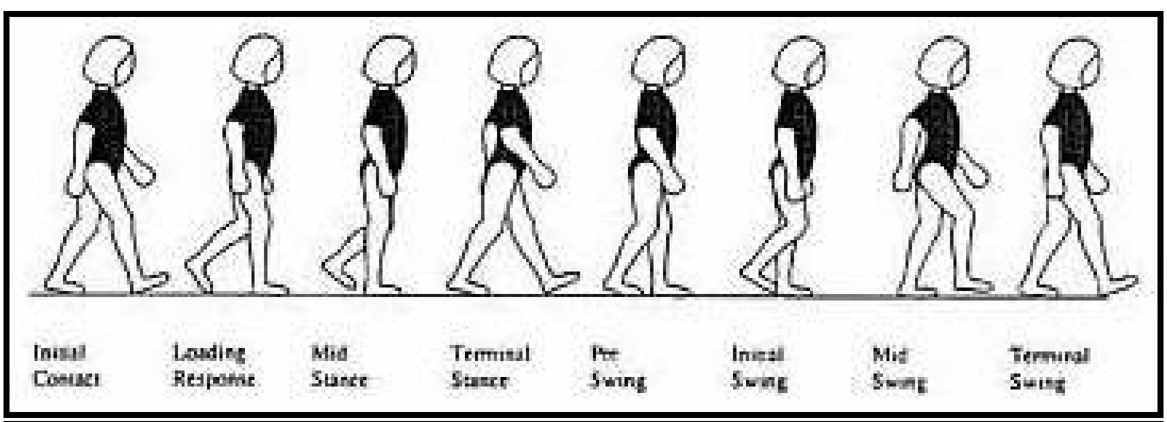


Figure 8: The Gait cycle also demonstrating stride length and step length. (http://www.childsdoc.org/images/99-1-motion2.jpg)

Table 1: Divisions of stance phase, ankle/foot motions and muscular actions (Norkin and Levangie, 1992:388, Soderberg, 1997:413).

Stance Phase	**Ankle/ Foot Motion**	**Muscular Action**
Initial contact to Midstance	• Plantarflexion: 0°-15° Calcaneal valgus movement • Neutral → Maximum subtalar pronation. • Transverse tarsal pronation	• Tib Ant, EDL, EHL → Eccentric contractions • Tib Post→ Eccentric contraction
Midstance	• Plantarflexion (15°) to Dorsiflexion (5°-10°) • Subtalar joint move to supination, neutral at midstance	• Triceps surae, plantar flexors→Eccentric contraction • Tib Post→ Concentric contraction
Midstance to Terminal stance	• Plantarflexion: 5°-0° Dorsiflexion • Toes 0°-30° extension • Supination subtalar joint	• Triceps surae→ Concentric contraction. • FHL, FHB, AH, Interoseii, Lumbricals→ Eccentric • Plantar flexors→ Concentric contraction
Preswing	• Ankle: Plantarflexion 0°-20°. • Toes: Extension 50°-60° • Subtalar: Maximum supination	• Triceps surae, Peroneii, FHL→ Concentric • AH, FDB, FHB, Interoseii Lumbricals→ Concentric • Plantar flexors→ Concentric

The calcaneus strikes the ground at initial contact and immediately moves into a valgus position allowing the subtalar joint to pronate (Norkin and Levangie, 1992:388). This functional pronation is essential for weight absorption and adaptation to the supporting surface. Pronation continues until the start of midstance (25% of stance phase), during this period tibialis posterior controls the movement towards pronation while the tibialis anterior controls the plantar flexion of the foot. In response to the functional pronation of the foot the tibia is forced to rotate medially (Norkin and Levangie, 1992:388, Soderberg, 1997:414).

By midstance the talus retreats back into its mortise and the foot moves from plantar flexion (15°) to dorsiflexion (20°) as the weight is transferred onto the weight-bearing limb (Soderberg, 1997:328-329, Abboud, 2002). Supination is initiated at the subtalar joint as midstance continues until the subtalar joint assumes its neutral position, at the end of midstance (Abboud, 2002). The triceps surae muscles control dorsiflexion while subtalar supination is brought about by concentric contraction of the tibialis posterior (Norkin and Levangie, 1992:388, Soderberg, 1997:313).

During terminal stance the weight is distributed throughout the front foot. The toes in response start to extend. The foot plantarflexes and the subtalar joint continue supinating whilst pulling the tibia into external rotation along with it. All the toe flexor muscles control the movement of the toes while tibialis posterior continues to supinate the foot and the peroneii muscles control its movements eccentrically (Norkin and Levangie, 1992:388, Soderberg, 1997:328-329).

Weight is further transferred onto the toes causing hyperextension at the metetarsophalageal joint (30°-50°) during preswing. The great toe or first digit is the last to bear weight and together with the heel allows the spring like action of the windlass mechanism (Refer to figure 4) (Soderberg, 1997:313). Supination continues throughout preswing reach a maximum while the foot actively is plantar flexed to produce forward propulsion (Soderberg, 1997:414)

The swing phase sees very little ankle motion with the ankle dorsiflexing 20° to return to neutral during the initial swing and midswing and remaining in that position until initial contact. The subtalar joint assumes a slight supinated position throughout the swing phase (Abboud, 2002).

Swing Phase	**Foot/ Ankle motion**	**Muscular action**
Initial and Midswing	• Ankle: Dorsiflexion to neutral (20°) • Subtalar: Supination	• Tib Ant, EDL, EHL→ Concentric Contraction
Terminal swing	• Neutral	• Tib Ant, EDL, EHL→ Isometric contraction.

Table 2: The Ankle/foot motion and related muscular action during the swing phase of the gait cycle (Abboud, 2002).

2.5 FLEXIBLE PES PLANUS AND PES CAVUS

Pes planus in the adolescent and adult result from the collapse of the medial longitudinal arches (Moore and Dally, 1999:642; Calliet, 1998). Continual stresses on the plantar ligaments specifically the calcaneonavicular ligament causes the ligaments to become abnormally stretched. The talus and navicular as a result slide medially and inferiority, becoming more prominent (Calleit, 1998). As a result the medial longitudinal arch is abnormally decreased and the forefoot deviates slightly laterally (Moore and Dalley, 1999:642). Although some muscular compensation have been thought to occur in asymptomatic patients with pes planus the extent and duration of this compensations is thought to be limited (Hunt and Smith, 2004).

Pes planus and the resultant hyperpronated position of the subtalar and transverse tarsal joints have been associated with a wide variety of conditions some of which include plantar fasciitis, metetarsal stress fractures and achilles tendinitis (Hunt et al., 2004).

Kwong et al. (1988) have shown that pronation creates an increase in the tensile stress at the plantar fascial insertion. Kibler et al. (1991) in his article proposed that tight posterior musculature and decreased range of motion may lead to valgus heel strike and push off causing a decreased mid- and hind foot supination and therefore a reduced push of and propulsive phase. This leads to increased load and stress placed on the musculature and ligamentous attachments and therefore poorer stress absorption and distribution resulting in functional hind foot pronation (Kibler et al., 1991). During continual running this places more tensile stress on the plantar fascia, which is at a disadvantage compared to the Achilles tendon (Kibler et al., 1991). He suggests that when coupled with other factors this biomechanical alteration may become pathological.

Ambrosias and Kondracki (1992) in their review of literature discussed the effect of abnormal joint mechanics on the foot and in particular the effect of prolonged pronation causing abnormal loading patterns throughout the foot. Other problems that commonly occur are functional limb length inequality, dorsiflexed first ray and hallux valgus due to excessive first ray supination (Norkin and Levangie 1992:388).

Pes planus may also lead to excessive medial rotation of the tibia on the talus, which in turn may cause multiple problems around the knee joint (Williams III, McClay, Hamill, 2001).

Less commonly but more ominous is the flexible pes cavus foot. Flexible pes cavus is a foot in which normal movements are decreased due to either tight soft tissue structures or hypomobile articulations leading to a rigid and pronounced medial longitudinal arch (Williams III, McClay and Hamill, 2001).

Like pes planus movement, or lack of movement, have compounding effects higher up the biomechanical chain specifically at the ankle and knee joints (Williams III, McClay, Hamill, 2001). The lack of subtalar and TCN joint motion prevents normal medial rotation of the tibia and therefore excessive stress is placed on the lateral knee structures. Furthermore the poor shock absorption and distribution in the foot places higher demands on the ankle joint, in particular, the lateral collateral ligaments of the ankle (Williams III, McClay and Hamill, 2001). The plantar aponeurosis remains slack and may in time become abnormally shortened (Norkin and Levangie, 1992:388)

2.6 LOW –DYE TAPING AND RELATED LITERATURE

Low- Dye taping, named after Dr. Ralph Dye, has been used for stabilizing the medial longitudinal arch and preventing it from collapse (Reid, 1992:198). Although different variations are now used in practice, one technique has been used frequently and is documented in literature to have a beneficial effect particularly in patients suffering with plantar fasciitis (Reid, 1992:198-199)

Low -Dye taping is a method commonly used in sport participation and normal daily activity (Harradine, Herrington and Wright, 2001). It is thought to function by restricting pronation as well as supports the medial longitudinal arch during mid-stance of the gait cycle and in so doing protects the plantar fascia by decreasing the stress along the plantar fascial plate (Tanner and Harvey, 1988, Brantingham et al., 1992 and Ryan, 1995). Taping has been indicated in support of the injured structure, decreasing oedema and protection against re-injury (Reid, 1992:232).

Hunt et al. (2004) evaluated the effectiveness of arch taping in controlling pain during ambulation, taping appeared effective in controlling pain and improving ambulation. Saxelby et al. (1997) reported benefits in plantar fascial symptoms over two days using low -dye taping. A study done by McCloskey (1992) assessed the effect upon foot function using mediolateral force readings from a kistler force plate. It was concluded that low -dye taping significantly altered the mediolateral force.

Contrary to these beliefs, studies have shown that low -dye anti-pronatory control is lost after relatively short episodes of exercise (Ator et al., 1991 and Vicenzino et al., 1997). Both studies found an initial reduction in pronation which was lost following the exercise. Harradine, Herrington and Wright (2001) assessed the effect of low -dye taping upon static pronatory control and dynamic hindfoot motion before and after walking. They found that taping initially reduced static pronation but that effects were lost after 30 minutes walking.

The variations in dynamic foot function with low -dye taping is not well understood, although taping of the foot in low-dye type method has been advocated by many authors (Brantingham et al., 1992, Ryan, 1995 and Chandler and Kibler, 1993).It's relevance in respect to ground reaction forces remains questionable and the efficacy of low dye taping is currently still under debate.

Most overuse injuries caused by excess pronation manifest during weight bearing activities such as standing, walking and running. The effectiveness of any taping technique in the treatment of these injuries depends upon its ability to prevent abnormal pronation for this period of time (Harradine, Herrington and Wright, 2001).

It is the purpose of this study to investigate the maximum ground reaction force and percentage contact time within 10 demarcated regions of the foot in asymptomatic patient with pes planus, cavus and normal medial longitudinal arches. Having established its baseline function it may serve as point of reference for clinical trials that wish to determine the role of taping as part of the management of symptomatic feet.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction:

In this chapter follows:

i. A detailed description of the study design,
ii. Discussions with regards to the intervention used,
iii. Discussion of methods used during the data collection,
iv. Description of the statistical analysis and testing.

A discussion of each sample group and their inclusion and exclusion criteria will also be given in this chapter.

3.2 Sampling Procedure:

This trial was designed as a quasi-experimental comparative trial, utilizing asymptomatic participants limited to those residing in the Kwazulu-Natal province.

A non-probability sampling technique was used to attract participants. There was no bias to race, religion or socio-economic standing:

1. Advertisements (Appendix F) were placed at the Durban Institute of Technology Chiropractic Day Clinic, Durban Institute of Technology Campus, local sports clubs, gyms, old age homes and local newspapers.
2. Advertising by word of mouth was also one of the methods used to attract participants to this study.

Interested participants were screened for suitability for this study by applying certain set questions; these questions could be employed telephonically or by direct contact with the prospective participant. These questions were structured in a manner that would insure a strong possibility of qualification for this specific trial. Details of these questions are listed in appendix G.

This trial consisted of 60 participants with asymptomatic feet that were divided into three groups of 20. Participants were divided into three groups depending on their respective foot structures. To qualify for one of the three groups subjects had to either have flexible low, high or normal medial longitudinal arches.

Group one consisted of participants with pes cavus (high medial longitudinal arch), group two consisted of participants with pes planus (low medial longitudinal arches) and group three consisted of participants with normal medial longitudinal arches.

Table 3: Representation of the three sub -divisions of the sample population.

Arch height	**Population**
Normal	20

High arch	20
Low arch	20
Total	**60**

Participants were classified into their respective groups using a line drawn from the plantar aspect of the first metetarsophalageal joint to the apex of the medial maleolus (Feiss Line) (Magee, 1997). The position of the navicular in relation to this line was used to determine their particular classification (Magee, 1997):

- ***Normal:*** The weight bearing navicular tuberosity remains along this line not dropping more than one third to the floor.
- ***Pes planus:*** The weight bearing navicular drops more than on third of the distance to the floor.
- ***Pes cavus:*** The weight bearing navicular should exhibit a position above this line or a normal navicular with a weight bearing leg heel alignment greater than 8 degrees in the varus position.

Measuring the extent of navicular drop is a common and satisfactory manner of determining severity pronation and hence pes planus (Vincenzino, 1997).

3.2.1 Inclusion and Exclusion Criteria:

Suitability for this study required that certain parameters be met. Participants were selected in such a manner as to apply maximum homogenicity. Once the interview indicated an eligible and willing participant for this study the participant was scheduled for a initial consultation with the researcher during which the researcher screened the individual for suitability for the study by applying a thorough history, physical and foot regional examination. No intervention or measurements were taken during the initial consultation. During this time the participant was also screened for relevant inclusion and exclusion criteria.

2.2.1.1 Exclusion criteria:

1. Participants suffering from systemic or local pathology for example gout or osteoarthritis were excluded from the study. Exclusions were based on findings obtained by taking a complete history as well as performing physical and regional examinations.

2. Any participant who was on any oral non-steroidal anti-inflammatory drug was required to participate in a 48 hour wash out period prior to entering the study (Poul et.al, 1993)

3. Participants were asked not to change their lifestyle, daily activities, and regular medication or exercise programs in any way to avoid being excluded from the study.

3.2.1.2 Inclusion criteria.

1. Participants were between the ages of 18-45 years. Participants under the age of 18 were not included in this study as they required parental consent, and would not have attained skeletal maturity. Selecting participants less than 45 eliminated those patients with degenerative joint diseases that could compromise the ability of the patient to adequately weight bear or render the foot as painful.

2. Participants that spent at least 3 but no more than 8 hours a day seated behind office desks. This prevented variations from occurring due to different participant occupations.

3. All participants received a letter (Appendix E) informing them about the study.

They then had to complete and sign an informed consent form in agreement that they understood the implication of the research (Appendix D).

4. All participants presented with a normal foot according to the following edited guidelines of Michaud (1997):
    1 The foot must be pain free,
    2 The foot must exhibit normal muscle balance,
    3 The foot must have an absence of contractures,
    4 The foot must have straight and mobile toes,
    5 The foot must have three points of weight bearing

3.3 Intervention:

The research project and the procedures were clearly explained to the participant (Appendix E), participants were also asked to complete an informed consent form to indicate their willingness to take part in this study.

Participants were informed with regards to which group they belonged to and all three the group received the same intervention in the form of modified low -dye taping. This taping technique is widely accepted and well documented in literature and was done as described by Reid (1992).

3.3.1 Modified Low- Dye strapping of the foot:

This taping procedure, as can be seen on the picture of appendix K, consists of a forefoot anchor over the metetarsophalageal joint. Three strips of tape are then taken in a teardrop manner around the calcaneus. All three strips of plaster have their origin at the base of the first metatarsal. Each one is passed around the calcaneus from its medial aspect to its termination at the base of the fifth metatarsal (Appendix K) (Reid 1992:199, Ryan 1995 and Batt and Tanji, 1995).

All taping was done using 38mm Rigid Leuko Sports tape Premium; this tape has been widely endorsed by various sports teams and widely used for its supportive functions during activity (www.sharksmart.co.za).

3.4 Measurements:

3.4.1 Location of the data:

This study included primary and secondary data

3.4.2 The primary data:

3.4.2.1 Objective data:

Dynamic ground reaction forces of the foot prior to and after taping.
Percentage time spent per region of the foot prior to and after taping.

3.4.2.2 Subjective data:

None was recorded in this study as the participants where asymptomatic

3.4.3 The secondary data:

Secondary data was collected using Journal articles, Textbooks and the Internet.

3.4.4 Measurement methods:

Maximum ground reaction forces (GRF) and Percent contact time was obtained for each of the three groups and for each of their four visits. GRF were obtained with the aid of a registered orthotist who has agreed to work with the researcher on this project using the RSscan International 1m footscan plate system (Appendix L). The data was interpreted and analysed using the RSscan Clinical Version 7.08 software package.

All three groups underwent the same procedure. Participants were required to walk unassisted and with their natural stride across a one-meter force platform (RSscan International footscan) whilst data was collected for each of the regions of the left foot. An average of three readings was calculated for each time interval.

This procedure took place four times:

1. Once prior to taping
2. Once immediately after taping
3. One hour after taping
4. 24 hours after taping

The taping was required to stay on the participant's feet for 24 hours and participants were instructed on how to deal with the tape. These instructions included:

1. To maintain their daily routine and activities.
2. Not to perform any unusual or compensatory activities that does not form part of their daily routine.
3. Participants were encouraged to keep the foot dry during bathing and were instructed to dry the tape with a blow dryer in the event of it getting wet.
4. Participants were instructed not to tamper with the tape.

Maximum ground reaction forces and percentage time spent per region for each of the 10 areas were calculated.

The 10 areas of calculation included:

1. Medial Heel
2. Lateral heel
3. Mid- foot
4. First metetarsal
5. Second metetarsal
6. Third metetarsal

7. Fourth metetarsal
8. Fifith metetarsal
9. Hallux
10. Toes 2-5

3.5 Statistical Analysis

All data was analyzed using the SPSS statistical software package(SPSS Inc., Marketing Department, 444 North Michigan Avenue, Chicago, Illinois, 606611).

Univariate analysis of variance (one way ANOVA) was used to determine the interaction of variables within the set time periods. This method of analysis was also used to determine if any interaction existed between groups and variables in those groups. The Post- Hoc test was used to determine the location of significant values within each subset. The T-test was done to determine the effect of taping on different means at different time intervals.
Frequency distribution was calculated for all the data and the Chi-Squared test was used in the comparison of data together with the Kriskal Walis test that was used in the comparison of the demographic data.
Repeated measures of variance were also tested within each group against time although they showed no statistical significance. Correlation statistics were run using a significance level of $p <= 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION:

4.1 Introduction:

This chapter contains detailed information related to the statistical methods used in the analysis of data and the relevant significant findings of that analysis.
The information will be presented as follows:

i. Discussion of statistical method,
ii. Description of demographic data,
iii. Analysis of percentage contact time and
iv. Analysis of maximum force

The discussion of the results will be carried out throughout this chapter for the comfort of the reader.

4.2 Discussion of statistical method:

All data was analyzed using the SPSS statistical software package (SPSS Inc., Marketing Department, 444 North Michigan Avenue, Chicago, Illinois, 606611).

Univariate analysis of variance (one way ANOVA) was used to determine the interaction of variables within the set time periods. This method of analysis was also used to determine if any interaction existed between groups and variables in those groups. The Post- Hoc test was used to determine the location of significant values within each subset. The T-test was done to determine the effect of taping on different means at different time intervals.
Frequency distribution was calculated for all the data and the Chi-Squared test was used in the comparison of data together with the Kruskal Wallis which was used in the comparison of some of the demographic data.

Repeated measures of variance were also tested within each group against time although they showed no statistical significance. Correlation statistics were run using a significance level of $p <= 0.05$.

Multiple comparisons were conducted of which none showed a significantly altered pattern between the three groups (neutral, pes planus and pes cavus). The results shown below only consist of the significant information gathered during the statistical process. For your convenience the remainders of the statistical test results are shown in appendix m.

4.2.1 Data layout and notation

Foot measurements (percentage contact time and maximum force) were obtained from each of 60 people:

- 20 with normal foot arches (n),
- 20 with low foot arches (l) and
- 20 with high foot arches (h)

These measurements were taken at each of 10 regions on the foot:

- The big toe (t1),
- The four smaller toes (t2),
- Metatarsal 1 to metatarsal 5 (m1 to m5),
- mid foot (mf), medial heel (mh) and
- Lateral heel (lh).

In order to determine the effectiveness of taping on a person's foot, these measurements were taken at 4 different times:

- Initially without taping (time 0),
- Immediately after taping (time 1),
- One hour after taping (time 2) and
- 24 hours after taping (time 3).

Contact time measurements at these 4 times will be denoted by:

- ct0 - Contact time prior to taping
- ct1 - Contact time immediately after taping
- ct2 - Contact time after 1 hour of taping
- ct3 - Contact time after 24 hours of taping

Maximum force measurements are denoted by:

- mf0 - Maximum force prior to taping
- mf1 - Maximum force immediately after taping
- mf2 - Maximum force one hour after taping
- mf3 - Maximum force after 24 hours of taping

The analysis also involves a summary of some basic demographic information.

4.3 Demographic Data:

Age:

Figure 9: Age frequency distributions for arch groups

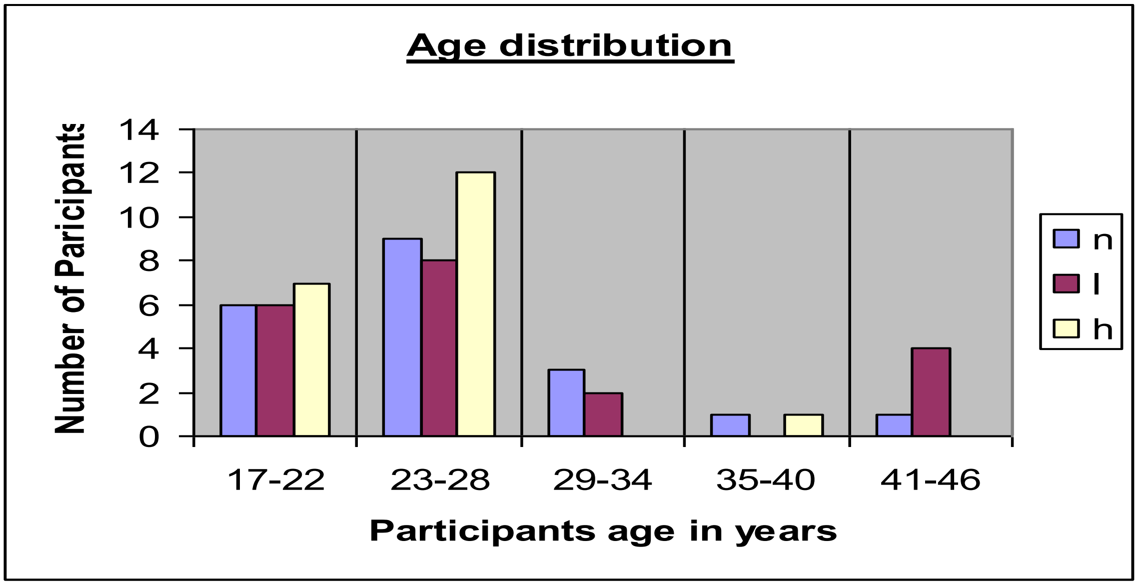
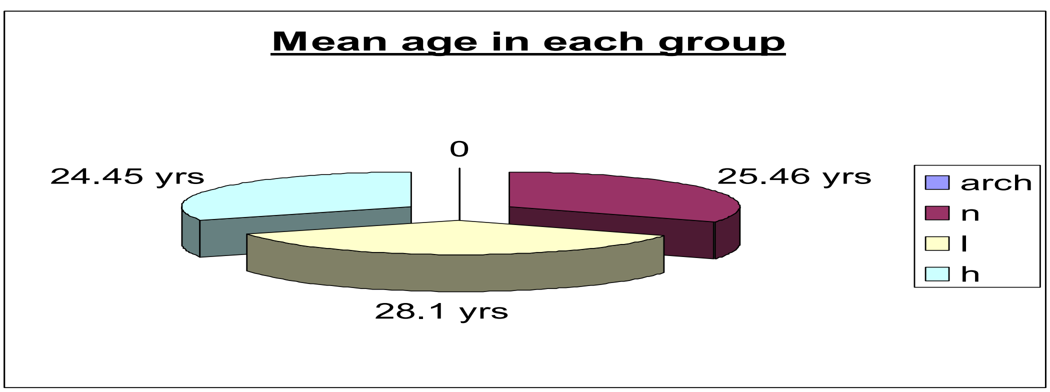


Figure 10: Means of ages for arch groups



The age of participants varied from 18 to 46 years of age as can be seen from Figure 9. Although a greater proportion of the participants seemed to occur in the subset of ages 23- 28 years, the mean age for all the groups were not significantly different (The Kruskal-Wallis test shows chi-square = 1.696 with a p-value of 0.428.). The three arch types seem to occur evenly throughout all age groups.

4.3.1 Heights:

Figure 11: Height frequency distributions for arch groups

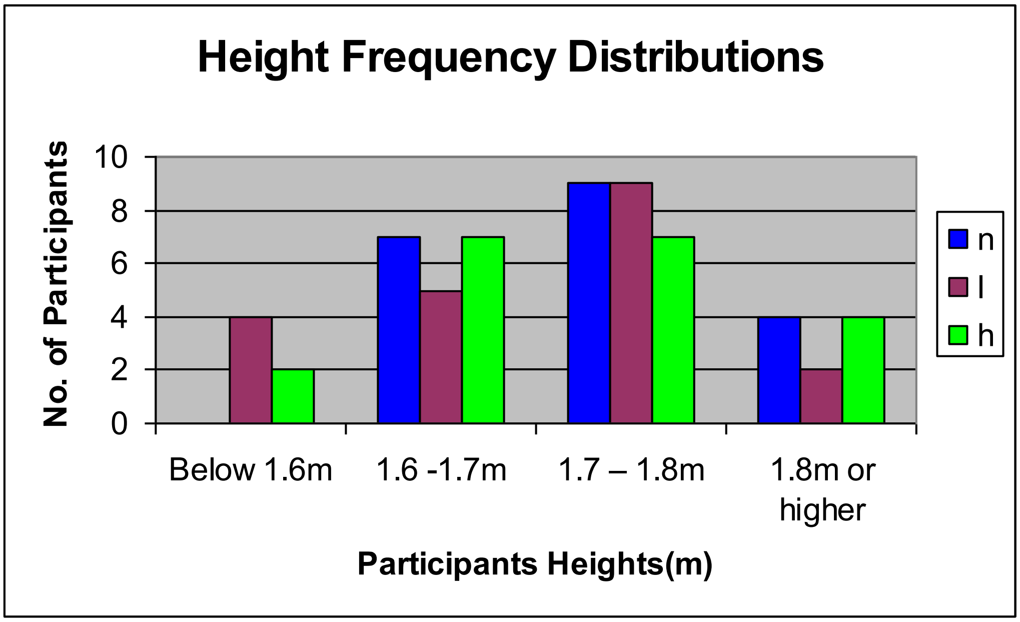


Table 4: Height frequency distributions for arch groups

Height grouping

Arch	Below 1.6m	1.6 - 1.7m	1.7 - 1.8m	1.8m or higher
N	0	7	9	4
L	4	5	9	2
H	2	7	7	4

Participants heights for the three arch groups were analyzed using the F -test that showed F = 0.571 with a p-value of 0.568. This meant that no group had a significant advantage in terms of height. The largest percentage of participants seemed to be between the height of 1,7-1,8m. The means of heights for each group is shown in table 5.

Table 5: Means and standard deviations of heights for arch groups

Arch	Mean	Standard deviation
N	1.7195m	0.0807
L	1.6885m	0.1091
H	1.712m	0.0951

4.3.2 Weight

Figure 12: Weight frequency distributions for arch groups

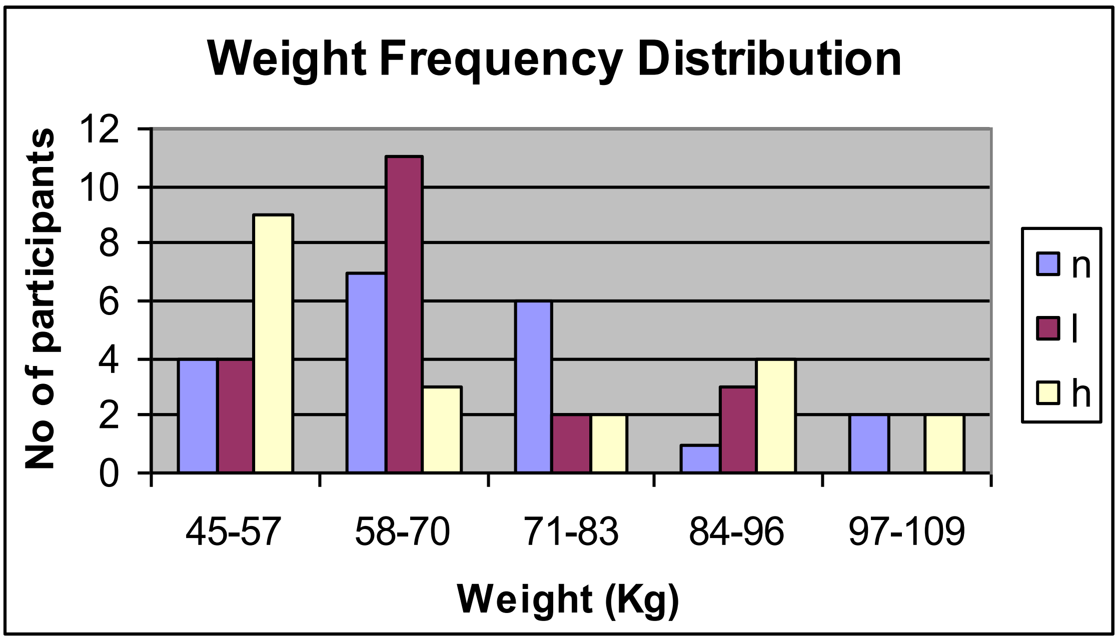


Table 6: Weight frequency distributions for arch groups

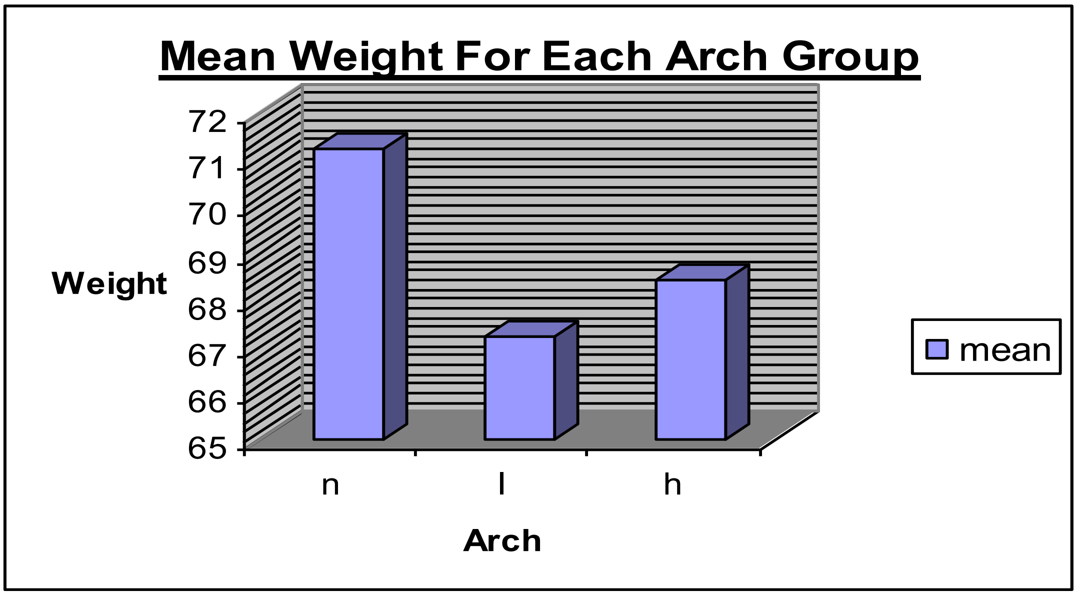
Weight group

Arch	45-57kg	58-70kg	71-83kg	84-96kg	97-109kg
N	4	7	6	1	2
L	4	11	2	3	0
H	9	3	2	4	2

Table 7: Means of weights for arch groups

Arch	Mean
N	71.2kg
L	67.175kg
H	68.4kg

Figure 12: Means of weight or arch groups



Frequency distributions for weight indicated that the neutral arches more frequently occurred between the weights of 58-70kg, the pes planus arches occurred more frequently between the weights of 58-70kg and that high arches were more common among individuals of weight 45-57kg. The weight means for the three arch groups were not significantly different and the Kruskal-Wallis test shows chi-square = 0.833 with a p-value of 0.659. (Refer to table 7 and figure 12)

4.3.3 Occupation:

Figure 13: Cross classification according to arch group and occupation

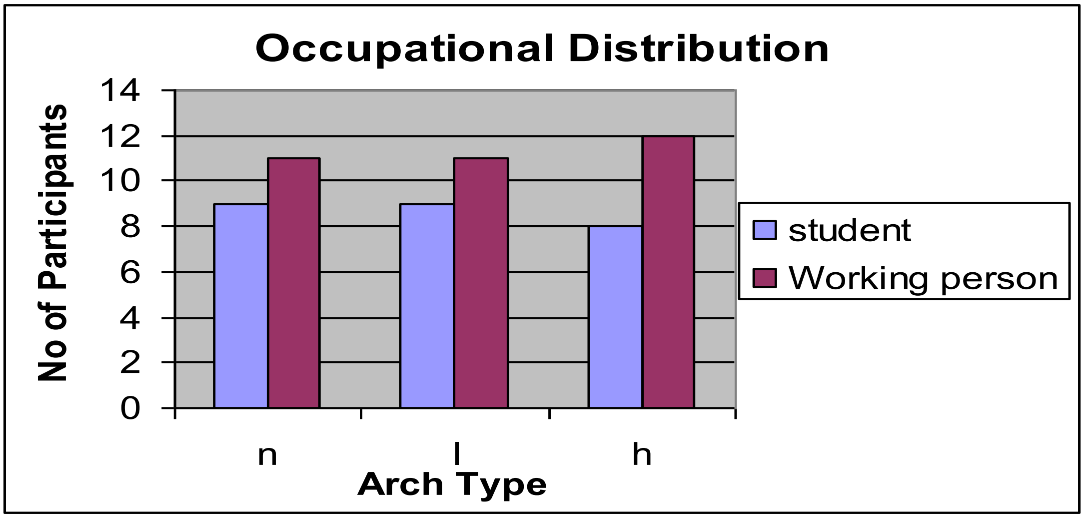


Table 8: Cross classification according to arch group and occupation

Arch	Student	Working person
N	9	11
L	9	11
H	8	12

A cross classification of occupations of participants showed an even spread throughout the three groups. The occupation patterns are the same for the 3 groups (chi-square = 0.136 with p-value = 0.934). This indicated that variances between readings due to occupational habits were limited during the course of the study (Refer to figure 13).

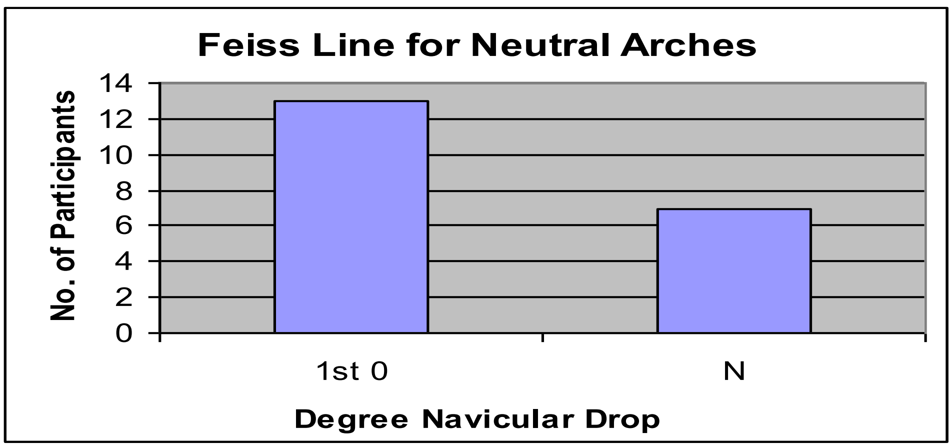
4.3.4 Feiss line:

4.3.4.1 Normal Arches

Table 9: Feiss line classification for normal arches

Feiss line	Number
1st ^{0}	13
N	7

Figure 14: Feiss line classification for normal arches



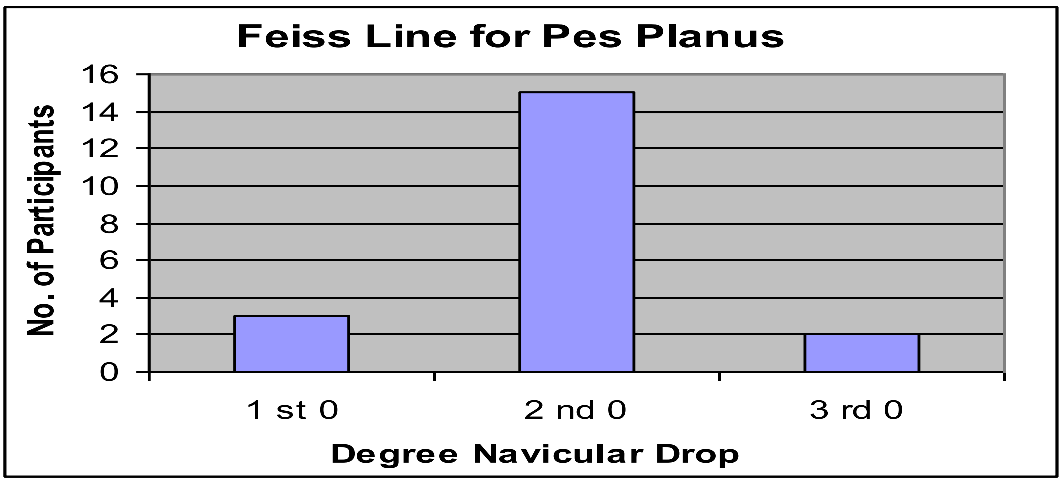
Feiss line readings in participants with normal arches showed that 13 (65%) participants presented with 1st degree navicular drop and 7 (35%) presented without any deviation of the navicular during weight bearing. The majority of pes planus participants presented with 2nd degree navicular drop with only 2 participants presenting with complete collapse of the navicular to the ground (Refer to table 10).

4.3.4.2 Low Arches

Table 10: Feiss line classification for low arches

Feiss line	Number
1 st ^{0}	3
2 nd ^{0}	15
3 rd ^{0}	2

Figure 15: Feiss line classification for low arches



4.3.4.2 High Arches

For high arches the Feiss line classification is N in all the cases.

4.3.5 Heel leg:

Table 11: Heel leg alignment degrees valgus

valgus ^{0}	2	4	5	6	8	9	10	12	13
number n	2	1	4	5	3	0	0	0	0
number l	0	2	2	1	1	2	8	2	2

Figure 16: Participants demonstrating a valgus heel leg alignment.

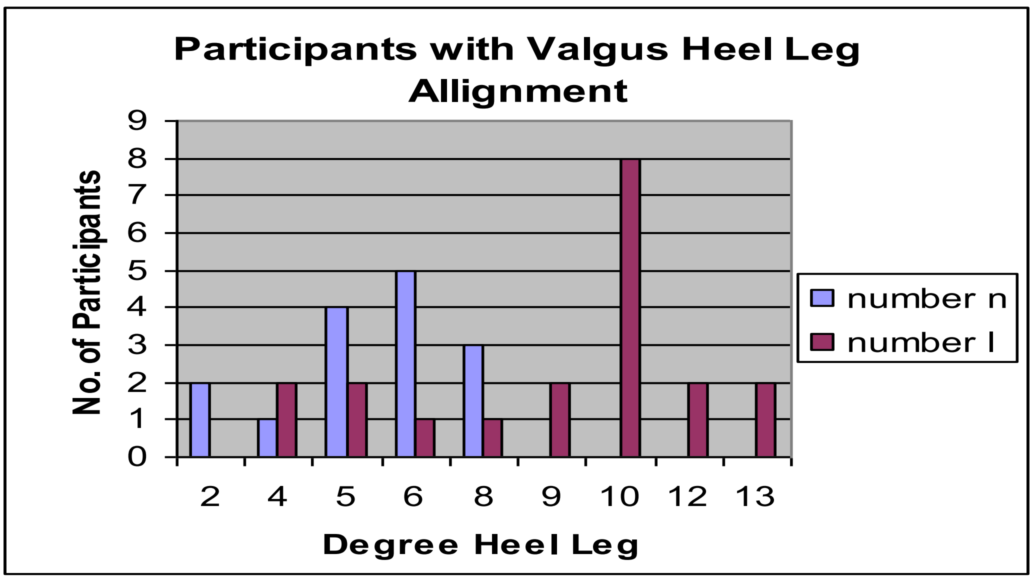
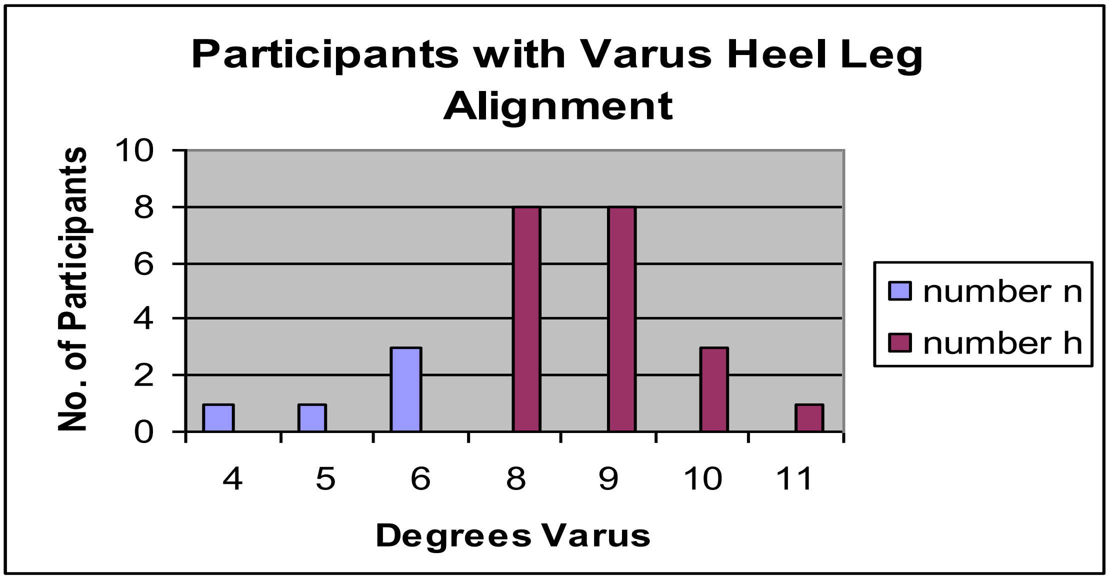


Table 12: Heel leg alignment degree varus

varus ^{0}	4	5	6	8	9	10	11
number n	1	1	3	0	0	0	0
number h	0	0	0	8	8	3	1

Figure 17: Participants demonstrating a varus heel leg alignment.



Subjects with normal arches have heel legs ranging from 8 degree valgus to 6 degree varus. Those with low arches had heel legs ranging from 4 to 13 degrees valgus and those with high arches from 8 to 11 degrees varus. The majority of participants with neutral arches (25%) presented with 6 degrees heel leg valgus while the majority pes planus participants (50%) presented with 10 degrees heel leg valgus. The majority of pes cavus participants (40%) evenly presented between 8 and 9 degrees varus (Refer to figure 16 and 17).

4.4 Analysis of Percentage Contact Time

4.4.1 Values of means across time

Percentage contact time denotes that percentage of stance phase for which a specific region (of the 10 regions) is in contact with the ground.

The percentage contact time means for the different types of arches and different regions as well as their ranks are shown in the tables below.

Table 13: Percentage contact time means for arches at different times

Time

Arch	0	1	2	3
H	60.3983 (1)	60.0900 (1)	62.2183 (1)	59.3650 (1)
L	58.2817 (2)	59.8950 (2)	59.9517 (2)	57.9850 (2)
N	55.5967 (3)	56.3700 (3)	55.3333 (3)	56.8550 (3)

The figure shown in brackets is the rank. Rank 1 indicates the largest mean, rank 2 the second largest mean and so on.

4.4.2 Patterns for different arches

The mean for high arches is consistently the highest (over the 4 time periods), for low arches consistently second highest and for normal arches consistently the lowest. When comparing means for the individual time periods, the following differences were found to be significant.

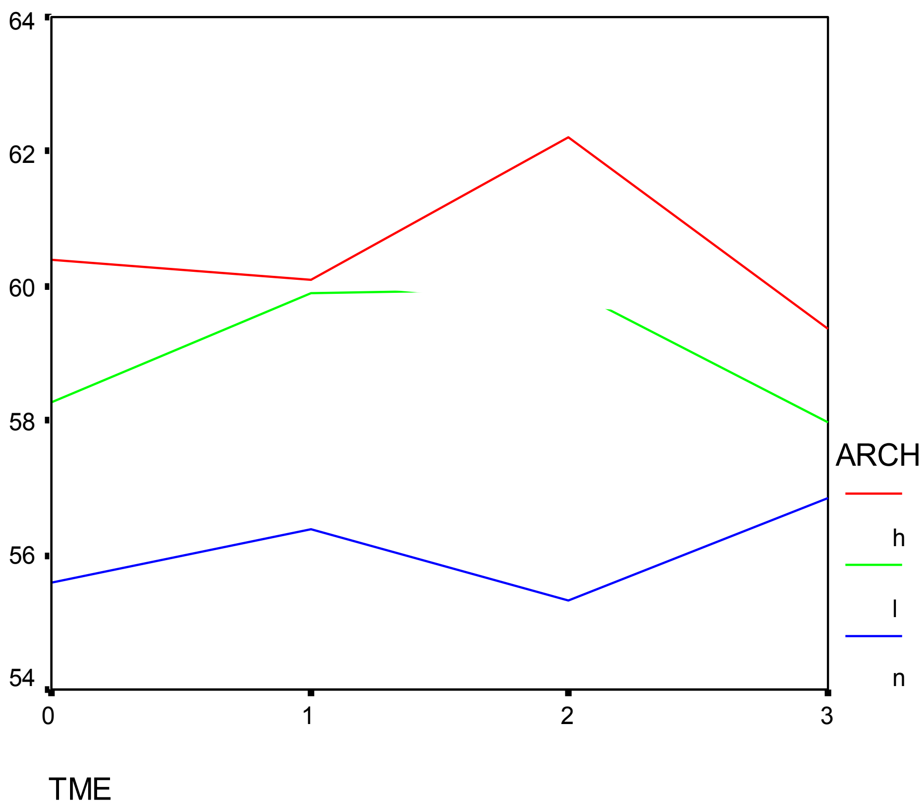
From the Figure 18 it can be seen that the difference between the contact time means for high and low arches is much smaller for time 1 (just after taping) than for the other 3 times (a difference of 0.195 for time 1 versus differences of 2.1166, 2.2666 and 1.38 for times 0, 2 and 3 respectively).

Table 14: Significant differences between means for individual time periods

Time	Significant differences
0	n < h
1	n < l , n < h
2	N < l , n < h
3	None

A plot of the means (mean ct) versus time (time) for the 3 arches is shown in figure 1 on the next page.

Figure 18: Plots of contact time means for arches at different times



TME refers to time.

Table 13 and figure 15 display certain definite trends.

When looking at Group h (pes cavus) we notice a high contact time as compared to the other two groups (60.3983%). It's possible that the high contact time is due to this type of foot structure being more rigid in nature than low arched foot structures (Norkin and Levangie, 1992:415). Due to this the ability of the foot to accommodate to the surface is decreased (Norkin and Levangie, 1992:415). It is possible that a larger amount of time is spent on the 10 regions because of a decrease in gradual weight transfer. At time period one we see very little change to this percent contact (60.0900%) but at time period 2 we observe a significant increase in contact time (62.2183%). It is possible that the taping technique lends itself to further rigidity at time period 2. A possible reason for this delay is that the natural rigidity of the foot resists the effect of the taping on the respective regions at time period 1 (Norkin and Levangie, 1992:415). At time period 3 (24hours) we note a decrease in contact time (59.3650%), this may be due to the inability of the tape to alter foot structure for long periods of time as documented by Vicenzino et al. (1997)and Harradine, Herrington and Wright, (2001.).

Looking at group l (pes planus) we observe a lower percent contact time within the ten regions (58.2817%).The reason for the contact time being greater than those exhibited by group n (Normal arches) is the effect the lowered arch of the midfoot will have on the contact surface. Due to the increased contact surface we have a larger percent contact time as compared to the normal aches. At time period 2 we have a similar effect as observed with group h. This could be due to either the mechanical rigidity of the tape limiting the normal gait and therefore increasing the relative contact times or due to the nature of the taping technique as the tape might come into contact with the ground. This effect is maintained through period 2. At period 3 we observe the highest percent contact time (57.9850%), this may be due to an alternate compensatory gait employed to deal with the weakening tape.

Group n (neutral arches) has the lowest percent contact time of all the time periods (55.5967) indicating a natural roll of the foot during the gait cycle. At time period 1 a similar increase in percent contact time occurs as with group I (56.3700%) this may be due to the mechanical effect of the tape on the arch of the foot. At time period 2 however this contact time is significantly decreased (55.3333%), this might indicate adaptation of a compensatory gait due to the tape. At time period 3 the contact time is once more increased (56.8550%), this might indicate a desire of the foot to return to its normal function due to failure of the tape (Vicenzino et al., 1997, Harradine, Herrington and Wright, 2001) but not completely achieving that aim and in the process adopting an altered gait pattern.

4.4.3 Patterns for different regions

Table 15: Percentage contact time means for regions at different times

	Time			
Region	0	1	2	3
m3	68.5000 (1)	65.3944 (3)	67.3000 (3)	68.2222 (2)
m4	68.3000 (2)	72.4556 (1)	73.4556 (1)	71.9889 (1)
m2	66.1333 (3)	61.2222 (4)	62.8444 (4)	63.1944 (4)
m5	61.3278 (4)	68.9000 (2)	69.6556 (2)	64.8944 (3)
m1	55.8444 (5)	59.0944 (5)	61.1500 (5)	59.4833 (5)
Mf	55.5444 (6)	56.5556 (7)	57.9111 (6)	57.5944 (6)
Hm	54.6556 (7)	57.5611 (6)	54.4611 (7)	53.3611 (7)
Hl	53.2111 (8)	56.4778 (8)	53.0500 (8)	51.5444 (8)
t2	48.7889 (9)	37.3333 (10)	43.3389(10)	42.8889(10)
t1	48.6167(10)	52.8556 (9)	48.5111 (9)	47.5111 (9)

The figure shown in brackets is the rank.

The following are clear from tables 15 and 16. The means for the 5 front foot regions (m1 to m5) are consistently the highest over the 4 time periods. The next highest is the mean for mid foot (mf) which is higher than that for both the heel regions (hl and hm) for times 0, 2 and 3. Only for time 1 is this mean slightly smaller than the mean for the medial heel (hm) region. The means for the two toe regions (t1 and t2) are consistently the lowest over the 4 time periods.

Table 16: Differences between percentage contact time means for successive time periods for each of the regions

	Difference			
Region	Ct1-ct0	ct2-ct1	ct3-ct2	Ct3-ct0
hl	3.2667	-3.4278	-1.5056	-1.6667
Hm	2.9055	-3.1	-1.1	-1.2945
m1	3.2500	2.0556	-1.6667	3.6389
m2	-4.9111	1.6222	0.35	-2.9389
m3	-3.1056	1.9056	0.9222	-0.2778
m4	4.1556	1	-1.4667	3.6889
m5	7.5722	0.7556	-4.7612	3.5666
Mf	1.0112	1.3555	-0.3167	2.05
t1	4.2389	-4.3445	-1	-1.1056
t2	-11.4556	6.0056	-0.45	-5.9

Shifts in contact percentage means over time:

Between times 0 (before taping) and 1 (just after taping) there is a shift in contact from the center of the front foot region towards the two sides. From table 15 it can be seen that the means for regions m2 and m3 (center of foot) decrease and those for regions m1, m4 and m5 (sides of foot) increase. This increase is larger on the outside of the foot (regions m4 and m5) than on the inside (region m1). There are indications that this trend is reversed as more and more time after taping elapses (means for m2 and m3 increase after time 1 and those for m1, m4 and m5 eventually decrease).

The two heel regions (hl and hm) show significant increases in the mean from time 0 to time 1 (for hl t = 4.193 with a p-value of 0.00004681, for hm t = 3.51 with a p-value of 0.000432597), but revert back to the pre-taping means after that i.e. they show decreases after time period 1.

Except for time period 0 (where the t1 and t2 means are approximately the same), the means for time period 1 (the big toe) are consistently higher than the corresponding ones for time period 2 (the 4 smaller toes). The big toe (region t1) shows a significant increase in contact from time period 0 to time period 1, while the 4 smaller toes (region t2) show a huge decrease over this period. The reason for this seems to be the shift in contact (after taping) towards the sides. The increase in contact for the big toe (which is on the inside of the foot) together with the increase in contact for region m1 (also on the inside of the foot) balances out with the increase in contact for m5 on the outside of foot) i.e. increase in m1+increase in t1 = 3.25 + 4.2389 = 7.4889 balances with increase in m5 = 7.5722. The increase in regions m4 and m5 from time period 0 to time period 1 results in a corresponding decrease in region t2. After time period 1 the mean for t1 returns to its value at time period 0 (before taping). During this period the mean for t2 also starts returning to its value at time period 0 but at a slower pace.

We can therefore extrapolate that the following relationships may exist with respect to percentage contact time in certain regions:

Metatarsal 2 and 3 appear to function as a unit. A high percent contact time exist before taping. At time period 1 there seems to be a drastic decrease in contact time that continues through to period 2. At time period 3 the percentage contact time appears to be approaching the initial reading. This trend may be due to the taping technique elevating metatarsal 2 and 3. This trend is supported by Saxelby, Betts and Bygrave (1997) who suggests that the elevated metatarsals could either be due to induced supination of the foot by the taping technique or due to the horizontal anchoring straps preventing the usual metatarsal spread on the floor during weight bearing. The increase in contact time at time period 3 may indicate eventual failure of the tape to maintain them in an elevated position.

Metatarsal 1, 4 and 5 also appear to follow a similar pattern. A rapid increase in contact time that is maintained through to time interval 2 is observed. This indicates a peripheral shift in contact of the foot with the ground. At time period 4 this effect is depleting and appears to be returning to a pre –taped condition. This may be explained in two ways:

a. The taping technique causes an alteration in the gait pattern of the foot by plantar flexing metatarsal 1 and fixing metatarsal 4 and 5 which are inherently more mobile. This causes greater contact with the peripheral aspects of the foot specifically the lateral aspects suggesting a shift towards a supinated foot position after taping (Saxelby, Betts and Bygrave, 1997). This effect of the tape can be seen to decrease at time interval 3 possibly due to failure of the tape (Vicenzino et al., 1997, Harradine, Herrington and Wright, 2001).

b. Due to the taping technique being primarily over these two regions it may be possible that the tape thickness itself had an influence in the contact time of the foot. This explanation however fails to clarify the clear trend towards the pre -taped condition seen at time interval 3.

The midfoot appears to be increasing the percent contact time throughout the 4 time periods. This could be due to the tape causing a less distinctive heel strike with a shift towards the lateral front and mid foot regions. This is supported by the findings at the medial and lateral heel regions which indicate an initial rise in contact followed by a gradual decrease which may indicate a shift of contact towards the mid and frontfoot. This effect seems to increase with time as the heel contact decrease.

The participants seem to have a rigid foot in response to the initial tape, after which we start to seeing a clear shift away from a large heel strike and a shift towards the peripheral aspects of the foot seen under metatarsals 1, 4 and 5.

4.4.4 Interaction:

There is no interaction between arches (n, l and h) and their regions for time periods 0, 1 and 3. The pattern appeared the same for all arch types. For time 2 there appears to be some interaction between these variables. The nature of this interaction can be seen from the means in the table below.

Table 17: Contact percentage means for different regions and arches at time 2

	Arch			
Region	Normal	Low	High	Overall
m4	69.9500 (1)	72.8667 (1)	77.5500 (1)	73.4556 (1)
m5	69.3167 (2)	67.9333 (2)	71.7167 (4)	69.6556 (2)
m3	62.8333 (3)	66.2000 (3)	72.8667 (2)	67.3000 (3)
m2	58.3500 (4)	63.1500 (5)	67.0333 (5)	62.8444 (4)
m1	55.4000 (5)	63.9500 (4)	64.1000 (6)	61.1500 (5)
Hm	52.8833 (6)	57.1670 (6)	52.7833 (7)	54.4611 (7)
Hl	51.9333 (7)	56.0667 (7)	51.1500 (8)	53.0500 (8)
Mf	47.4167 (8)	54.0333 (8)	72.2833 (3)	57.9111 (6)
t1	44.2500 (9)	50.4000 (9)	50.8833 (9)	48.5111 (9)
t2	41.0000(10)	47.2000 (10)	41.8167 (10)	43.3389 (10)

The figure shown in brackets is the rank.

From table 17 it can be seen that:

I. With the exception of region m5 (where the means are approximately equal) the region means for normal arches are all less than the corresponding ones for low arches (as is the case overall).

II. The ranks for normal and low arches follow the same pattern as the overall ranks except for mf where the rank is lower than overall (mean smaller) and hm and hl where the rank is higher than overall (means greater).

III. Region mf has a below average mean for normal and low arches, but an exceptionally large mean (14.3722 above overall mean) for high arches. This may indicate a substantial increase in mid foot contact as the participant alters his heel strike (refer to figure 13) and gait pattern to accommodate to the tape.

The findings above suggest that after 1 hour of taping the mid foot region has a higher than average percentage contact in participants with high arches and the heel regions have a higher than average contact for participants with normal and low arches.

4.5 Analysis of Maximum Force

4.5.1 Values of means across time

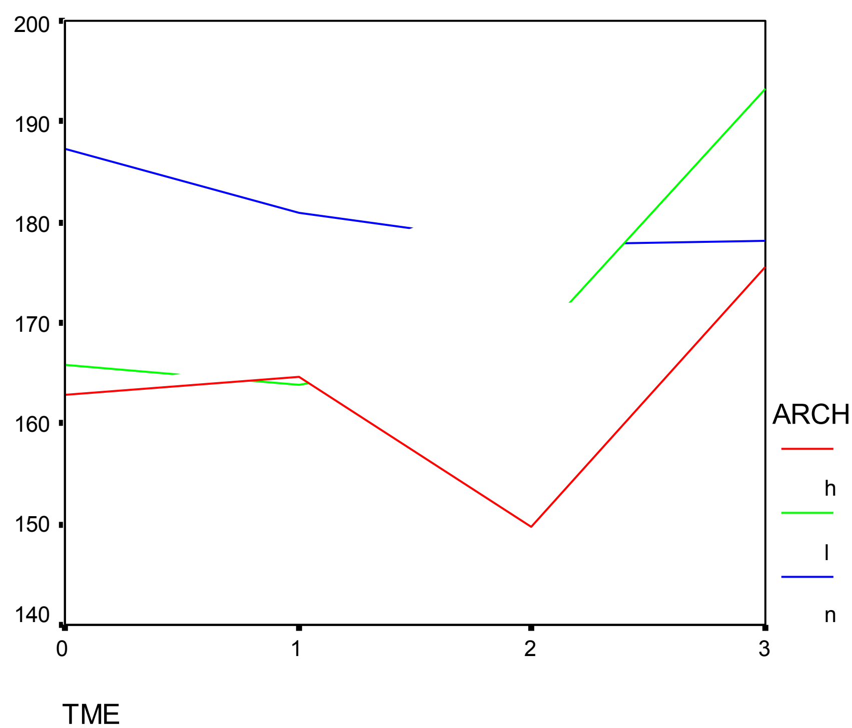
The maximum force means for the different types of arches and different regions as well as their ranks are shown in the tables below

Table 18: Maximum force means for arches at different times

	Time			
Arch	0	1	2	3
N	187.3087 (1)	180.9127 (1)	177.7825 (1)	178.1688 (3)
L	165.8480 (2)	163.8600 (3)	167.7305 (2)	193.2077 (1)
H	162.8572 (3)	164.5632 (2)	149.6850 (3)	175.6123 (2)

The figure shown in brackets is the rank.

Figure 19: Plots of maximum force means for arches at different time



4.5.2 Patterns for different arches

From the above plot the following can be seen:

I. The maximum force mean for normal arches shows a slight downward trend over time.
II. The maximum force mean for low and high arches show an upward trend over the 24 hour period. The rate of increase in maximum force appears to be slightly greater for low arches than for high arches.
III. Initially (before taping, just after taping and 1 hour after taping) the maximum force mean for normal arches is higher than those for high and low arches. As time goes by the means for low and high arches catch up with that for normal arches. At time 3 (24 hours after taping) the mean for low arches is higher than that for normal arches and the mean for high arch just about the same as that for normal arches.

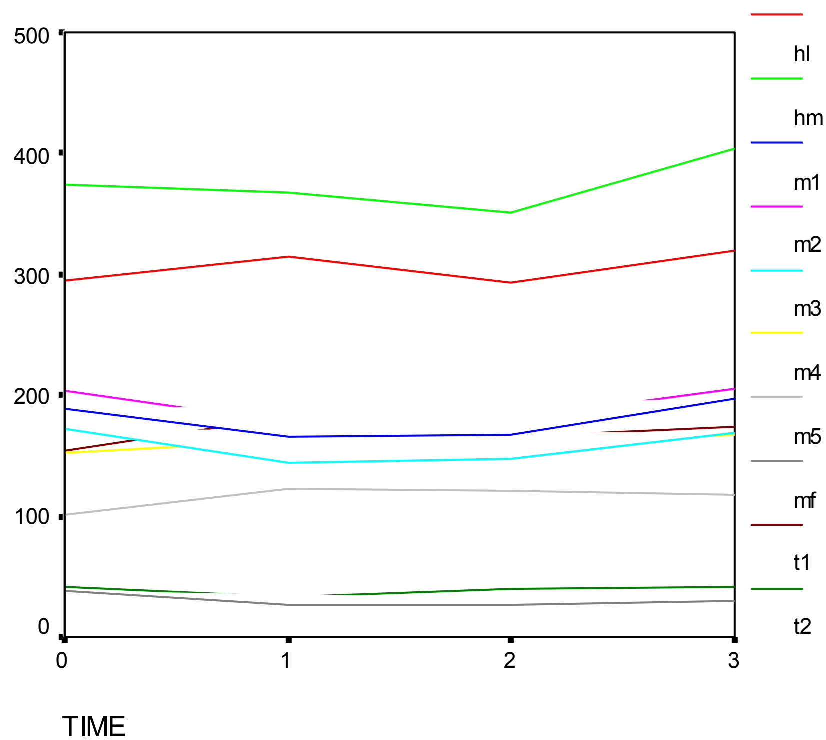
4.5.3 Patterns for different regions

<u>Table 19:</u> Maximum force means for regions at different times

Region	0	1	2	3
hm	374.1250 (1)	368.3156 (1)	350.6544 (1)	403.6644 (1)
Hl	294.1306 (2)	315.3944 (2)	292.3017 (2)	318.7900 (2)
m2	204.3561 (3)	177.3244 (4)	179.7622 (3)	204.6156 (3)
m1	188.6594 (4)	164.9811 (5)	166.7106 (4)	197.6883 (4)
m3	172.2472 (5)	144.7467 (7)	146.8817 (7)	169.0789 (6)
t1	154.1472 (6)	181.8706 (3)	165.0039 (5)	173.9161 (5)
m4	152.3017 (7)	162.8378 (6)	160.4006 (6)	166.6294 (7)
m5	100.3089 (8)	123.2389 (8)	121.4817 (8)	118.1089 (8)
t2	40.9061 (9)	32.4167 (9)	40.3211 (9)	41.3678 (9)
Mf	38.8639 (10)	26.6600 (10)	27.1422 (10)	29.4367 (10)

The figure shown in brackets is the rank.

Figure 20: Plots of maximum force means for regions at different times



Throughout the 4 time periods the largest maximum force is in the heel region (hm and hl) and the smallest are the mid foot, small toes and outside front foot regions (mf, t2 and m5).

Both heel regions and the outside foot region (m5) show a slightly upward trend over time. The mean maximum force for the small toes region stays the same over time, while that for the mid foot region decreases over time.

Of the remaining 5 regions that occupy ranks 3 to 7 regions t1 and m4 show slight increases over time, while regions m1, m2 and m3 stay the same over time.

4.5.3.1 Differences:

<u>Table 20:</u> Differences between maximum force means for successive time periods for each of the regions

Region	Ct1-ct0	Ct2-ct1	ct3-ct2	ct3-ct0
Hl	21.2638	-23.0932	26.4883	24.6589
Hm	-5.8094	-17.6612	53.01	29.5394
m1	-23.6783	1.7295	30.9777	9.0289
m2	-27.0317	2.4378	24.8534	0.2595
m3	-27.5005	2.135	22.1972	-3.1683
m4	10.5361	-2.4372	6.2288	14.3277
m5	22.93	-1.7572	-3.3728	17.8
Mf	-12.2039	0.4822	2.2945	-9.4272
t1	27.7254	-16.8667	8.9122	19.7709
t2	-8.4894	7.9044	1.0467	0.4617

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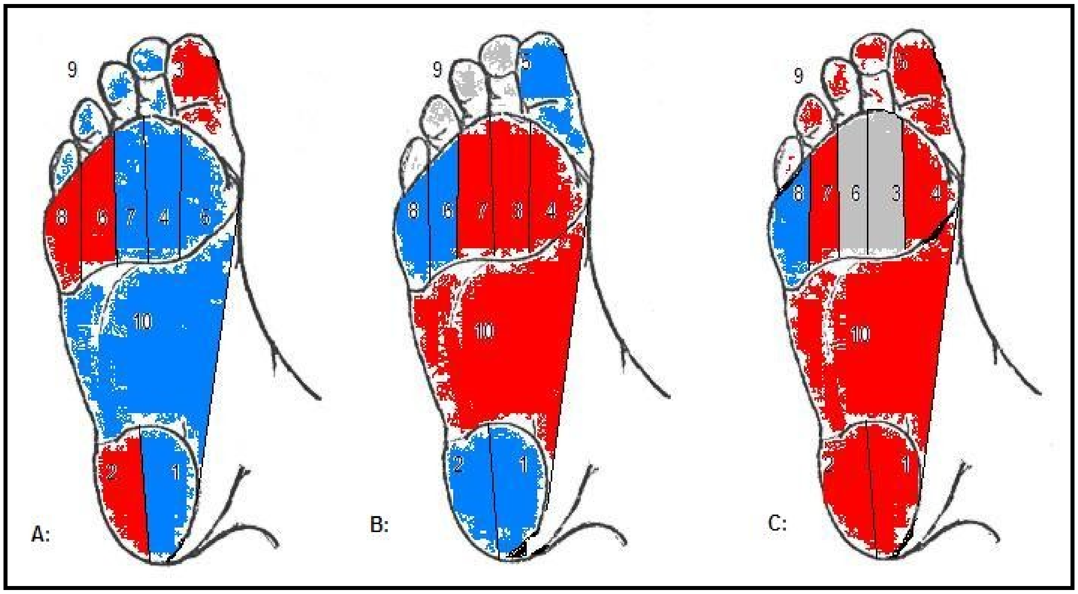
Prior to taping the maximum ground reaction forces appear to be over the two heel regions and metatarsals 1 and 2. The toe 1 region has a high maximum force (154.3017) compared to toe 2-5 (40,9061). These values suggest a distribution of force throughout the foot to be similar as those documented in the literature (Norkin and Levangie, 1992:466).

Period 1 shows a drastic change in force along the lateral aspect of the foot. The lateral heel, metatarsal 4, 5 and toe one all increase their maximum force immediately after taping. This is counterbalanced by decreased values throughout the front foot and midfoot regions. The areas of metatarsal 2 and 3 are especially decreased in the front foot indicating that the taping technique may cause an elevation in the transverse arch of the foot which is n agreement with the findings of percent contact time. Toe one has a high increase in maximum force indicating that the tape might force a larger degree of toe off in the final stages of the gait cycle. These findings are in agreement Hunt, et al. (2004) who states that low dye method may increase the windlass mechanism at toe off

Figure 21: A: Indicates changes between period 0 and 1. B: indicates changes beween period 1 and 2. B: indicates changes between period 2 and 3.
Blue → Decrease in maximum force. Red→ increase in maximum force.
Gray→ Minimal change. Number indicates their rankings in maximum force.



Period 2 (1hour) shows a slightly different pattern. Maximum force at the lateral and medial heel areas decrease drastically. This may indicate a shift of force toward the front foot and midfoot areas as compared to previous trend. This is substantiated by a increase of maximum midfoot force (0.4822) and a increase in force of metatarsal 1, 2 and 3. The decrease in maximum force of metatarsal 4 and 5 may either be due to toe 2-5 bearing a greater amount of force or due to metatarsal 1-3 increasing their weight bearing capacity but this is not greatly significant.

Period 3 (24hours) shows an incomplete attempt to return to the normal force transfer across the foot. There is a substantial return of maximum force at heel strike indicating a return of emphasis to hindfoot contact. Midfoot maximum force is further increased together with maximum forces across metatarsals 1, 2, 3 and

4. Metatarsal 1 and 2 bear the greatest maximum force of all the metatarsal and have an increase of 30.997 and 24.8534 respectively indicating a shift towards the pre -taped foot measurements and the medial aspect of the front foot. This can further be seen be the gain in maximum force of the first toe at toe off.

Failure of the tape to maintain the foot in its original position is a plausible explanation for the regression of maximum forces towards the pre –taped foot measurements and is substantiated by the literature (Vicenzino et al., 1997, Harradine, Herrington and Wright, 2001). Ator et al. (1991) suggests that this failure of the maintain the foot for long periods of time could be due to a loss of tensile strength of the tape or due to decreased adhesion to the skin.

4.6 Relationship Between Percentage Contact Time and Maximum Force

There appears to be a moderate linear relationship between the difference between the time 1and time 0 values for percentage contact time and maximum force for some of the regions. The correlations between the differences for the 2 variables for the different regions are given in the table below.

Table 13: Correlations between percentage contact time and maximum force differences for the different regions

Region	m1	m2	m3	m4	m5	hl	hm	t1	t2	mf
Correlation	0.481	0.601	0.611	0.522	0.332	0.136	0.149	0.603	0.17	-0.02

The moderately high positive correlations are in the front foot regions m1 to m4 and big toe region. The correlations imply that in these regions the differences move together i.e. as the one difference increases (decreases), so does the other one.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions:

1. This research has shown that with the exception of period 2, where pes cavus presented with a significantly higher contact time in the midfoot, there is no clear distinction between maximum force and percent contact time within the three groups namely pes cavus, pes planus and normal arches.

2. The distribution of maximum force in the three groups were similar throughout al the time periods(immediately after taping, one hour after taping and 24 hours after taping):

   I. Prior to taping the maximum ground reaction forces appear to be over the two heel regions and metatarsals 1 and 2. The toe 1 region has a high maximum force compared to toe 2-5. These values suggest a distribution of force throughout the foot to be similar as those documented in the literature (Norkin and Levangie, 1992:466).

   II. Immediately after taping there seemed to be a shift of maximum force away from the hindfoot and towards the lateral aspect of the frontfoot (metatarsal 4 and 5) with a decrease of maximum force over metatarsal 2 and 3 and a decrease of maximum force at metatarsal 1. This could be due to the transverse anchoring and securing straps elevating the metatarsals. This is supported by Saxelby, Betts and Bygrave, (1997) who suggests that these findings could be an indication of decreased pronation of the foot.

   III. A the trend towards front foot maximum force is seen again at 1 hour after taping with a decrease in heel maximum force, a greater maximum force at the midfoot and at the metatarsals 1, 2 and 3. This may indicate a loss of tensile strength or adhesive properties of the tape (Vicenzino et al, 1997; and Harradine, Herrington and Wright, 2001).

IV. The changes seen at the 24 hours reading suggests an incomplete return to the maximum forces seen prior to the initial taping (as evident at the increase in force of the heel strike as well as the mid foot increasing in maximum force but still remaining far from its high force value and the maximum force at metatarsal 3 remaining unchanged). This indicates some restriction from the taping in this region. Metatarsal 1 and 4 compensates for this deficiency by having increased maximum force values.

3. The distribution of percent contact time in the three groups were similar throughout al the time periods(immediately after taping, one hour after taping and 24 hours after taping):

I. Percent contact time increase in metatarsal 4, 5, and metatarsal one indicating a shift of contact from the center of the foot to the peripheral structures. The increased contact of the heel regions support Hunt et al (2004) in their theory of calcaneal sagital restriction by the swing like strap around the heel. An increased contact time at toe 1 and deceased contact at toe 2-5 indicate a larger degree of toe off.

II. The readings at time period two indicates a slight increase of contact at metatarsal 2 and 3. The remainder of the metatarsals and the midfoot increase in contact time while both the heel regions undergo a drastic decrease in contact. This may indicate a further shift to the front and midfoot regions.

III. Twenty four hours after the employment of the tape there seems to be a trend to returning to the pre –taped contact time readings. Metatarsal 2 and 3 increase their contact while metatarsal 4 and 5 decrease their contact with the ground. The midfoot region seems to decrease contact time slightly together with metatarsal 1 and the first toe. These findings seem to support the theory of limited use of adhesive taping as stated by Vicenzino et al, (1997) and Harradine, Herrington and Wright, (2001).

In summation there appears to be a definite trend towards a supinated foot position directly after taping. This is supported by the increased contact time and maximum force over metatarsals 4 and 5. The low-dye taping appears to be elevating metatarsals 2 and 3 and in the process restricting their motion. The taping technique appears to cause an initial foot contact that is less distinctive at the heel but is more widespread throughout the mid and frontfoot regions. Although these trends exist after one hour of taping there seems to be a gradual loss of these effects over time so that after 24 hours a definite regression can be observed. These findings may indicate a complete return to the pre- taped condition over a longer period of time.

5.2 Recommendations:

I. Since our findings indicate that a similar pattern of percent contact time and maximum force exist between the three groups a more accurate result may have been achieved by focusing on one type of arch only.

II. Greater accuracy could have been attained in the classification of the arch by types. It's the author's suggestion to use either x -ray findings or the arch ratio (Williams III. Et al, 2004) in studies where distinction between arched feet will be made.

III. A more homogeneous sample group could have been attained by only accepting individuals within a certain weight category and limiting the participants to one specific type of activity or group e.g. hockey, rugby or cricket players.

IV. Greater measurement accuracy can be attained through fixing the speed with which the participant walks across the platform and by increasing the plate length from 1m to 2m in order to measure the effect on both feet.

V. If this study is to be repeated a greater number of measurements with a shorter time interval (e.g. measurement every half an hour) should be done. This will document the changes of the tape over time more accurately.

VI. In future studies a method should be devised to ensure a standardization of taping tension when it is applied. Although care was taken to repeat the taping procedure in the most identical manner it is not known whether taping tension varied significantly between participants and whether that might have had an effect on the outcome of the study.

VII. A similar study investigating the effect of taping on patients with foot disorders would be useful to further increase our knowledge of the effect of low –dye taping.

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