THE EFFECTS OF OSTEOPATHIC MANIPULATIVE TREATMENT ON THE PLANTAR PRESSURE DISTRIBUTION WITHIN A POPULATION WITH FLEXIBLE FLAT FOOT

PAUL LORENC

THESIS PRESENTED TO THE INTERNATIONAL JURY, TORONTO, ONTARIO

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ACKNOWLEDGEMENTS

The study was carried out under the supervision of my thesis advisor Orazio Carbonara, DO (MP), RMT, who, through his assistance and valuable comments made this work possible. I wish to express my gratitude to all the people who in different ways made this work possible, in particular the following people:

- Ron Davis and Dr. Kim Ross for their skillful assistance in connecting me with the appropriate professionals.

- Chris Bogle and Joanna Cousineau for editing and revising the thesis.

- Dave Soave for his skillful assistance in data collection and statistical analysis.

- To my secretary Margaret for taking the TOG gait scan measurements and arranging all the appointments for the study.

- To all my wonderful professors and the administrative staff at the Canadian College of Osteopathy of Toronto for their patience and support during my studies.

- Brad McCutcheon, the Principal of the CCO for his valuable comments, support and encouragement.

- All the subjects who volunteered to participate in the study.

Finally, I would like to thank my beloved wife Marta and our children Olivia, Philip and Isabella who had patience and gave me encouragement, valuable comments, and everlasting support. I deeply appreciate their continuous understanding and encouragement from the bottom of my heart. This thesis paper is dedicated to them.
THESIS ADVISOR

Orazio Carbonara, DO (MP), RMT, Canada.
HYPOTHESIS

Standard osteopathic manipulative treatment improves the distribution of plantar pressure in individuals assessed with flexible flat foot pronation by bringing significance to the dynamic values of The Orthotic Group gait scan.
Abstract: The objective of this study is to identify the influence of osteopathic manipulative procedures (OM procedures) on improving the abnormalities in the distribution of plantar pressure that are known to exist among individuals presenting with “flexible flat foot.”

Method: Population of 34 subjects who met the enrollment criteria participated in this within-subject design research study. All subjects signed an informed consent and case history form approved by the Canadian College of Osteopathy located in Toronto. This research is a two-phase (controlled and experimental phase) quantitative within-subject design study conducted in a private osteopathic clinic. The type of osteopathic manipulation used in this research study is 14 standardized osteopathic manipulative procedures applied to each patient within the experimental phase. During the controlled phase the subjects did not receive any treatment. The methodology used in this study reports on procedures, tests, osteopathic manipulative procedures, and subject selection criteria of the study. The distribution of plantar pressure during this study was measured with The Orthotic Group (TOG) gait scan pressure platform prior to, and at the end of each phase, each participant’s feet were scanned 3 times in total. The subjects were assessed by the researching osteopath to confirm their condition of “flexible flat foot pronation” using Brody’s (1982) navicular drop test as a composite measure of excessive foot pronation (Mueller, Host & Norton, 1993, pp. 199; Allen, Ward & Glasoe, 2000, p. 403).

The Hypothesis that was being tested attempted to prove that three standard osteopathic manipulative procedures treatments, applied to the foot and lower leg,
produced a significant impact in the distribution of plantar pressure in individuals with “flexible flat foot” during dynamic phase of the gait. Individuals in the experimental phase showed greater improvement in the distribution of plantar pressure, relative to individuals in the control phase who did not receive any treatment at all. Pressure parameters were captured and collected using the TOG gait scan pedal pressure platform system. Collected measurements included impulse percentage values at 4 foot landmarks (medial heel, lateral heel, and 1st and 2nd metatarsals) that were later analyzed. The data comparison was done for both phases of the study.

**Results:** Standardized OM procedures performed on the feet and lower extremities of the subjects produced small differences on the effects of plantar pressure distribution, as compared with the placebo effect during the controlled phase, and determined by the data impulse percentage values collected using multiple dynamic TOG scans. One-way ANOVA’s were used to make between-visit comparisons on each of the outcome measurements. Post hoc comparisons were conducted between the three visits when the corresponding ANOVA warranted (Holm’s method of p value adjustment was used). Only m1 scores were found to change significantly between the second and final visit (left foot: mean change (SD) = 4.1(6.1), P value = 0.0011). No other measures changed significantly throughout the study period.

**Conclusion:** The data collected demonstrates that there was a significant effect on the values of the left foot and no significant effects on the other foot or tested landmarks. Further investigations are needed to fully elucidate the role of OM procedures on plantar pressure distribution within a population with flexible flat foot.
**SOMMAIRE**

**Objectif/But :** L’objectif de cette étude vise à établir l’influence des techniques de manipulation ostéopathique sur l’amélioration des anomalies relevées dans la distribution des pressions plantaires courantes chez les personnes qui présentent un « pied plat statique souple ».

**Méthode :** Une population de 34 sujets répondant aux critères de sélection ont participé à cet essai croisé dans-sujet. Tous les participants ont signé un formulaire de consentement éclairé et d’observation médicale approuvé par le *Canadian College of Osteopathy* situé à Toronto.

Cette étude croisée quantitative en deux phases (contrôlée et expérimentale) a été réalisée dans une clinique d’ostéopathie privée. Aux fins de l’étude, chaque patient participant à la phase expérimentale a subi 14 traitements par manipulation ostéopathique normalisés. Les patients du groupe de contrôle n’ont reçu aucun traitement. La méthodologie appliquée dans cette étude rend compte des méthodes, essais, traitements par manipulation ostéopathique, critères de sélection des participants et autres facteurs intervenant dans cette étude. La distribution des pressions plantaires a été mesurée au cours de l’étude au moyen du système de balayage The Orthotic Group avant et à la fin de chaque phase témoin; les pieds de chaque participant étant passés au lecteur optique à trois reprises au total.


On a ainsi vérifié l’hypothèse voulant que trois traitements standards par manipulation ostéopathique administrés au pied au à la jambe inférieure exerçaient une incidence notable sur la distribution des pressions plantaires chez les personnes qui présentent un « pied plat statique souple » pendant la phase dynamique de la démarche. On a observé une plus grande amélioration de la distribution des pressions plantaires chez les
personnes ayant participé à la phase expérimentale que chez les membres du groupe de contrôle n’ayant reçu aucun traitement.

Les paramètres de pression ont été recueillis et compilés au moyen d’un système de balayage TOG faisant appel à une plate-forme de pression. Les données recueillies englobent le pourcentage d’impulsions au niveau de 4 points-repères du pied (point médian du talon, côté du talon, et 1er et 2e métatarsiens), et ont par la suite fait l’objet d’une analyse. Une comparaison des données a été réalisée pour les deux phases de l’étude.

**Résultats** : Les manipulations ostéopathiques normalisées appliquées aux pieds et aux membres inférieurs ont produit de légères différences en termes d’effets sur la distribution des pressions plantaires, comparativement au groupe placebo de la phase de contrôle et selon les données d’impulsion (en pourcentage) recueillies au moyen de multiples balayages TOG dynamiques.

Des analyses de variance à un critère de classification ont été utilisées afin d’effectuer des comparaisons entre chaque visite, pour chacune des mesures relevées. Par ailleurs, des comparaisons post-hoc ont également été réalisées entre les trois visites lorsque les analyses de variation correspondantes le justifiaient (la méthode de rajustement des valeurs prédictives de Holm a été préconisée).

Seul les résultats m1 semblent avoir varié considérablement entre la deuxième et la dernière visite (pied gauche : variation moyenne (SD) = 4,1(6,1), valeur P = 0,0011). Aucune autre mesure n’a considérablement changé au cours de la période d’étude.

**Conclusion** : Les données recueillies démontrent une variation notable des valeurs au niveau du pied gauche et aucun effet significatif au niveau de l’autre pied ou des points de repère étudiés. D’autres travaux de recherche sont nécessaires afin d’approfondir le rôle des manipulations ostéopathiques sur la distribution des pressions plantaires au sein de la population de patients présentant un pied plat souple.
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1 CHAPTER ONE: INTRODUCTION
INTRODUCTION

1.1 GENERAL OBJECTIVE OF THE RESEARCH

The motivation for this study came about due to daily observations and treatments given to patients’ feet during the practice of Osteopathy and Pedorthics. Feet are important structures that form the base for our body; and a somatic dysfunction like “flexible flat foot” causes disarrangement in the bony alignment and plantar pressure distribution, and therefore merits investigation by an osteopathic professional. The practice of Osteopathy is a system of diagnosis and treatment for a wide range of musculoskeletal ailments. It predominantly works with the structure and function of the body, and is based on the principle that the health of an individual depends on proper physiological and anatomical function of the joints, muscles, ligaments and connective tissue.

In order for the body to function properly the foot structure must also function properly. Flexible flat foot is characterized by a collapsed medial longitudinal arch as well as increased plantar pressure and weight on the inner side of the foot. This behavior contributes to poorly functioning sub-talar joint biomechanics, and as a result the position of the foot significantly affects the lower extremities including: the tibia, knee joint, and the sacroiliac joints through improper biomechanics which can lead to chronic problems over time (McPoil & Knecht, 1985).

Osteopaths work to restore the body’s state of balance, where possible, with the use of manipulative treatments. The purpose of this study was to investigate changes in plantar pressure distribution in subjects who took part in this experiment and also to create a database collection tool using osteopathic manipulative procedures (OM procedures) design. The researcher has proposed in this study to test the hypothesis through a specified set of osteopathic manipulative procedures performed to the foot and lower extremity.
The aim of this within-subject experimental research study is to contribute to osteopathic knowledge by investigating the problems concerning the nature of somatic dysfunction (flexible flat foot) and its OM procedures treatment. This study assessed the immediate effects of using 14 standardized osteopathic manipulative procedures on plantar pressure distribution within a population with flexible flat foot.

This study used osteopathic manipulative procedures (OM procedures) treatment as an independent variable; therefore an OM procedure research design style will be employed in this research paper. This type of research design gives information on the specific OM procedure and its effectiveness on the plantar pressure distribution within a population with flexible flat foot. This research paper investigated the usefulness of osteopathic manipulative procedures on the overpronated foot.

The main target of this study was to test and prove the hypothesis, which says that standard osteopathic manipulative procedures treatment improves the distribution of plantar pressure in individuals assessed with flexible flat foot pronation by bringing significance to the dynamic values of The Orthotic Group gait scan.

This statistical research reveals that individuals in the experimental phase showed a significant statistical difference between visits in the distribution of plantar pressure on the left foot for the metatarsal 1 (m1 scores p=0.0013) but, there was no significant statistical effect on the right foot between follow-up visits in this phase to show statistical significance.
Zhu, Wertsch, Harris, Loftsgaarden & Price (1991) stated that a poorly functioning foot is vulnerable to tissue damage in places of repetitive and increased pressures. Increased pressure can lead to the development of an ulcer and other chronic foot conditions.

The foot is the first contact point of our body with the ground; its complex make-up provides support during standing and walking. Due to the proper output that comes from the muscles, fascia and mechanoreceptors, it can adapt to ever-changing terrain and speed. (Soames, 1985).

Nachbauer & Nigg (1992) found that low-arched feet absorb more energy during walking or running than high arched feet, as a result a flat foot can result in high numbers of metatarsal stress fractures. A low arch usually develops when plantar vault weakness sets in and the arch loses its elastic shock-absorber quality. Muscular and ligamentous weakness, as well as biomechanical overpronated function of the subtalar joint (often caused by genetics) are the major causes for flat feet to develop.

Menz (1998) agrees with Nachbauer et al. (1992) about low arch tendencies for developing chronic degenerations, and as a result flat footed individuals are prone to a large range pathologies including: Morton’s neuroma, plantar fasciitis, hallux abducto valgus, and heel spurs.

From an osteopathic point of view, a flexible flat foot can be a complex somatic dysfunction with a number of symptoms and different degrees of deformity and disability that, when in use cannot adequately absorb or efficiently redistribute the reactive ground forces that it is receiving. There are several types of flat foot; but all have one characteristic in common, that
is partial or complete loss of the medial longitudinal arch. Flexible flat foot represents one of the most common types of flat foot. The term “flexible” indicates that while the arch collapses and the foot is flat when standing (weight-bearing), the arch returns when not standing (no weight-bearing). Flexible flat foot develops early during childhood or adolescence and gets worse with age and increased weight. As the deformity progresses the foot is prone to lose its arch height, and the soft tissues (tendons, ligaments, and fascia) become overstretched and, that adaptive state can lead to inflammation (http://www.foothealthfacts.org/footankleinfo/flatfoot.htm, 2006).

Rigid flat foot is a condition where the sole of the foot is rigidly flat even when a person is not standing. Other flat foot conditions are various forms of tarsal coalition, which develop between two or more bones on the medial aspect of the foot (Wikipedia, http://en.wikipedia.org/wiki/Flat_feet, 2006).

Zhang, Bates & Dufek (2000) report that the accumulation of high impact forces during contact with the ground by the flat foot may pose a problem and cause disarray in the foot and lower extremities, resulting in injuries.

According to Michaud (1997), overpronation of the subtalar joint is a problem that is prevalent in our society and affects about 67% of the population. Overpronation causes themidtarsal and intertarsal joints to be unstable; resulting in propulsion by the lower extremity to be relatively inefficient, because the foot is unable to produce enough force on the ground.
Druelle (1992) discusses the foot and the role it plays as the base of the human body. Its main function is to support, balance, sense and walk as well as to absorb and transmit the reactive ground forces. When a healthy foot loses its proper arch height it becomes flat; then the foot exists in a compromised environment with mechanisms that malfunction due to misaligned bones as well as overstretched muscles and ligaments. The forces that the flat foot receives is not locally absorbed and move up along the lower extremities, affecting neighboring structures such as the interosseous membrane, knees, hips, pelvis and lumbar spine. All three arches of the foot and its plantar vault provide the base of support and are the means through which the forces are transmitted and absorbed.

A flexible flat foot lacks the ability to control and adequately absorb reacting ground forces, mainly due to its faulty biomechanics; this can lead to injury, altered performance and other problems along the kinetic chain. Excessive foot pronation and related high-impact forces have been associated with numerous lower extremities ailments; in particular, medial tibial stress syndrome, metatarsal stress fractures, plantar fasciitis, heel spur, patellofemoral syndrome and anterior cruciate ligament tears. The key to injury prevention in the foot and lower extremities is the ability to control and sufficiently absorb dynamic forces at the level of the foot (Hargrave, Garcia, Gansneder & Szultz, 2003).

Druelle (1992) discussed the complexity of the foot as well as its ability to transform weight and distribute pressure along the kinetic chain. Feet are strategically important because they are the place where the two forces meet: the ascending and descending forces. These forces are present in the foot during motion relative to gravity and reactive ground forces. Feet are also the place where the passage from the vertical to the horizontal forces starts.
This study tests the somatic dysfunction (flexible flat foot) and the changes that occurred to participants in the experimental phase before and after OM procedures treatment. The primary objective of this study is to show improvement in the plantar pressure distribution in the flexible flat foot. The secondary objective is to establish the connection between the OM procedures used in this study and the improvement of the tested somatic dysfunction and to bring significance to the plantar pressure distribution during walking in the experimental phase of this study. Therefore, this study aims to show the potential relationship between this somatic dysfunction and the proposed OM procedures; with the intention that the principles, tools and methodologies used in this study may provide a basis for future research in this area and an approach for potential clinical applications. It is assumed that any contribution by this study to the advancement of Osteopathy occurs through the safety and efficacy of the proposed OM procedures, thus serving to establish their effectiveness. The OM procedures seek to demonstrate how to facilitate the desired change in the somatic dysfunction.

There has not yet been any similar osteopathic manipulative procedure study done that would investigate the influence of standardized osteopathic manipulative treatments on the plantar pressure distribution within the population with flexible flat foot; as a result this study can be considered a brand new area of research. The literature reviewed in chapter two covers other related areas of osteopathic and non-osteopathic research on both the feet and the lower extremities and their relative effectiveness in clinical practice.

Foot pressure parameters during this study were captured and collected by The Orthotic Group gait scan pedal pressure system developed by The Orthotic Group, Markham, Ontario, Canada. Collected measurements included impulse percentage values at four foot landmarks.
(medial heel, lateral heel, 1\textsuperscript{st} and 2\textsuperscript{nd} metatarsals), which were later analyzed and compared by a statistician. The data comparison and analysis examined both the controlled and experimental phases of the study.
CHAPTER TWO: LITERATURE REVIEW

2

CHAPTER TWO: LITERATURE REVIEW
LITERATURE REVIEW

2.1 INTERNET SOURCES

Key Words Searched: Plantar pressure, pressure distribution, flat foot, foot types, gait, osteopathy, pronation.

Search Engines Used:

- Google scholar
- Google.ca, Medscape.com
- Pub Med Central.nih.gov
- Sciencedirect.com
- Jaoa.org/cgi/content
- Jn.physiology.org/cgi/content
- Woundsresearch.com/article
- Elsevier.com/locate/Journal of biomechanics
- Medline

2.2 FLEXIBLE FLAT FOOT and SOMATIC DYSFUNCTION

Burns (1945) reported that somatic dysfunction is a term that involves the musculoskeletal system and the disease process. Somatic dysfunction may include structural, visceral and psychological components. The diagnosis of somatic dysfunction is based on changes in tissue texture, joint motion and bony alignment as well as the presence of pain. The flexible flat foot is an example of somatic dysfunction that
produces degenerative changes if not altered through OMT. The four cardinal signs of somatic dysfunction are summarized by using the acronym “TART.”

T - Refers to tissue texture change/abnormality

A - Refers to asymmetry

R - Refers to range of motion restriction

T - Refers to tenderness

Kelso (1981) wrote that the osteopathic profession was founded on the premise that the somatic system plays an important role in health and disease.

The role of somatic dysfunction in personal health needs attention.

We need to recognize the broader implications of the influence of somatic dysfunction on health and to avoid the attitude that finding and treating somatic dysfunction is the only concern of the osteopathic profession.

Somatic dysfunction should be identified for its influence on health.

Manipulative treatment should be described for its influence on health status. (Kelso, 1981, p. 193)

Korr (1986) contributed the idea that the entire nervous system, from the most complex (being the brain) to a peripheral one, is involved in somatic dysfunction and every time OMT is used in the treatment of foot disorders. Clinical case studies indicate
that somatic dysfunction and OMT as a treatment is a powerful factor in how the brain translates information to the musculoskeletal system by coordinating its functions, perception and personality. According to Korr (1986) OMT or OM procedures performed on the foot affect the nervous system in its entity due to the responsive afferent and efferent pathway interconnection via the spinal cord.

Flexible flat foot is an example of a somatic dysfunction that not only affects the human body locally but the person and their posture. Pratt (1951) in his review paper revealed that “pronation syndrome” is closely associated with flexible flat foot and can be found in the posture of at least 75% of the population.

Burns (1945) reported that an osteopathic treatment requires knowledge, and its application must be supported with the proper knowledge about anatomy. Precise methods suitable for the correction of any given joint or myofascial lesion must be used throughout the course of treatment to produce a therapeutic effect on the patient’s body. Every step ought to be planned with relation to structural and anatomical factors, such as the direction of the articular surfaces, articular ligaments, muscles, leverage and force used. Burns stated that the results of such treatment have placed Osteopathy in a most important and enviable position in North America. The correction of somatic dysfunction has led to a great number of recoveries in all kinds of diseases, and to recoveries that would have been impossible without the use of osteopathic manipulation. Osteopaths must then identify and treat somatic dysfunctions and remove the antagonizing elements that the body is dealing with.
Patterson (2001) wrote that clinical research is a relatively young area of research design that has evolved in the last 40 years. Health professionals in manipulative practices claim that utilizing manipulative therapy on a specific area of the body to treat somatic dysfunction can be very effective and beneficial in achieving improvement to the area of the body that requires treatment.

According to Louisa Burns (1994-95) the strongest evidence in supporting osteopathic principles occurs when OMT or OM procedures can be linked to the somatic dysfunction that the patient experiences.

Dr. Korr (1986) states that, as Osteopaths, our main responsibilities are to observe and recognize the somatic dysfunction that a patient experiences and to support those mechanisms while removing all possible impediments to healing. The osteopath recognizes that it is the patients, who get well, not the osteopathic treatment that makes them well, because the improvement comes from the patients themselves.

This research study follows the suggested guidelines and design recommended in Dr. Patterson’s paper “Foundation for Osteopathic Medical Research” (Patterson, 2001) and the format proposed by the Osteopathic research literature publication.

2.3 PRONATION SYNDROME

Proper postural mechanics is closely related to patient wellbeing and walking. In their clinics most practitioners can quite easily identify various postural problems including: anterior or posterior posture or leg length discrepancy, related to rotoscoliosis.
Unfortunately, certain type of posture problems, which should be equally important are quite often neglected by health practitioners. The type of posture problem described by Dr. Pratt (1951) as “the pronation syndrome,” and its degree of changes can be detected in at least 75% of individuals who share the following characteristics: protruded lower abdomen, depressed chest, anteriorly displaced neck, and round shoulders. During postural assessment the following characteristics are also seen: increase in antero/posterior spinal curves, signs of thickening and tightness in the lumbodorsal and cervicodorsal fascia, and everted feet pointed out and with knees in valgus. This type of posture if not reduced and changed through treatment and home care, poses the potential danger of resulting in chronic degenerative changes. In order to correct the “pronation syndrome” it is necessary to discover the mechanism by which it was produced. According to Pratt (1951), the primary factor in the formation of this type of posture problem is an increase in ante flexion of the sacrum, producing an anterior/inferior tilt on the pelvis and an increase in lumbosacral curve. Hyperextension of the lumbar spine takes the iliopsoas muscle compartment into a relaxed sate, causing the femur/thigh to rotate medially, which sequentially continues down the lower extremities and causes torsion.

Since the foot is in a closed kinetic chain position, torsion continues down to the foot affecting the talus and moving it into an antero/medial position. As the internal rotation continues on the talus against fixed points, the navicular and cuniforms are displaced into antero/medial rotation creating gapping of their joints. The cuboid bone rotates into an antero/medial direction around its axis. Calcaneus forced by the talus on the sustantaculum tali moves into an antero/lateral position, and creates medial convexity
on the Achilles tendon. The pronated foot position causes improper balancing of the peroneals producing strain. In an attempt to reduce the impact and the constant internal/rotation strain on the lower extremities externally an individual will rotate their feet and legs. Pratt (1951) continues his investigation into the mechanism of the production of pronation syndrome by asking the following questions: “What causes the increased lordosis of the lumbar spine?” and “Why is so common?”

Evidence into the effectiveness of manual therapies has been recently revealed through the team of American Osteopaths and Canadian Chiropractors. They have adapted a version of a grading system developed by the US Preventive Service Task Force and a study risk of bias tool as a basis for clinical guidelines. Their conclusions were predicated on widely accepted evidence-base guidelines. In their summary they were able to classify which conditions could be significantly helped and which ones were inconclusive. Manipulation/mobilization was both effective treatments for several lower extremity conditions (Bronfort, Haas, Evans, Leininger & Triano, 2010).

A review lead by Brantingham, Globe, Pollard, Hicks, Korporal & Hoskin (2009) concluded that there is significant evidence to support the use of manipulative therapy of the ankle and foot combined with exercise therapy. The same researchers found insufficient evidence of the same approach in the treatment of plantar fasciitis, metatarsalgia, and hallux limitus/hallux abducto valgus.
2.4 INFLUENCE OF OMT and OTHER FOOT MANIPULATION

Foot manipulation is a very old form of treatment that has been used in clinics by foot specialists and Osteopaths. The manipulative foot treatments used by many different practitioners today was developed by A.T. Still in the 1890s. There are many opinions as to how joint manipulation works but they fall short of explaining exactly why or how they work and what in the process is alleviating patient’s pain. There are many direct and indirect forms of foot manipulations, some of which include: high velocity techniques, low velocity techniques, myofascial release, counter-strain, trigger point, cranial and muscle energy (http://www. Chiropodyonline.co.uk/footman.htm).

Dr. Korr (1986) acknowledges in his paper that osteopathic manipulative treatment is a transaction between two unique individuals, and is achieved through the mutual influence of their personalities and perceptions on both participants.

Dr. Wells et al. (1999) performed successful standard osteopathic manipulative treatments for patients with Parkinson’s disease on gait performance. The data collected showed that after a single standardized OMT session there were immediate results on a Parkinsonian gait. The results included: increase in stride length, increase in cadence, and speed of walking, as well as an increase in velocity in the upper extremities. The study gave evidence that osteopathic manipulation treatments may be considered as an effective treatment in the management of movement deficiencies in Parkinson’s patients.

Anderson et al. (2003) utilized osteopathic joint manipulation on ankle joint to affect its range of motion. Only a few studies looked into the effects of manipulation on
ankle range of motion. They used a single high-velocity, low amplitude of thrust osteopathic manipulation delivered to the talo-crural joint for study subjects with former lateral ligament sprain. The study proved no improvement in dorsiflexion range of motion in participated population.

A case study done by Alm & Lockwood (2010) investigated the effects of osteopathic manipulative treatments on plantar fasciitis. The main cause of plantar fasciitis is by over-pronation of the foot, which is related to faulty biomechanics. The OMT consisted of myofascial release and Dr. Still’s techniques performed to sacrum. Ligamentous articular counter-strain on the piriformis bilaterally, ilium and ankle muscle energy, and counter-strain on the calcaneus. The patient received 3 OMT in total; a reduction in foot pain was noted and complete resolution of the problem was achieved.

Dr. Lopez-Rodriguez, Fernandez de-las-Penas, Alburquerque-Sendin, Rodriguez-Blanco & Palomeque-del-Cerro (2007) conducted a study into the immediate effects of talocrural joint manipulation on stabilometric and baropodometric outcomes in patients with grade 2 ankle sprain injuries. The administering of talocrural foot manipulation was helpful in load redistribution at the level of the foot as compared with a placebo treatment.

French researchers under the leadership of J. Vaillant,Vuillerme, Janvey, Louis, Braujou, Juvin et al. (2007) investigated the effect of a therapeutic manipulation of the feet and ankles on postural control during quiet standing in aged adults. They were able to show that the manipulation of the feet and ankles allows the elderly patients to partially adjust for the negative effect caused by the loss of eyesight.
2.5 HISTORY OF PLANTAR PRESSURE MEASUREMENT TECHNIQUES

Through the work of the pioneers Beely (Cited in Elftman 1934) & Elftman (1934), the measurement methods used to analyze foot loading forces and its plantar pressure distribution, have advanced considerably over the last decade and have become an important diagnostic tool in gait assessment.

Beely (Cited in Elftman 1934) used a thin sack to measure the plantar pressure distribution. In his method he used a sack filled with plaster of Paris, he expected that the sack filled with plaster of Paris would compress by the area of the patients’ foot that carries the greatest weight. Unfortunately his design was unsuccessful in measuring plantar pressure distribution; it only captured the shape of the patient foot (Lord, 1981).

As a result of Elfman’s (1934) continued interest in plantar pressure measurement, a tool called a Barograph was developed, which allowed for direct observation of pressure distribution under the foot. That device comprised of black rubber platform positioned on top of glass flood-lit from underneath. A white fluid was inserted between the platform and the glass to enhance the image. Areas of the image with greater and darker dots represented areas where greater pressure was present. Elfman’s barograph was an important step in advancing plantar pressure measurement technology, and became useful in clinical settings.

Dr. Morton (1930) was another pioneer who developed a device to measure plantar pressure distribution called the Kinetograph or Morton’s device. This system
formed the basis for other future developments; it utilized the elastic properties of rubber and its ability to convert pressure into a proportional deformation (Lord, 1981).

Hertzberg (1955) reported using a Pedobarograph similar to Elfman’s (1934) but used a different optical solution. The device comprised of a flat optically clear mat lit along two opposing edges. A thin foam rubber sheet was used on top of the mat that was able to deform after contact with the patient’s foot. Upon the contact of the sheet with the mat the light must move away from the plate to illuminate the surface beneath the sheet. A video-camera was used to capture the direct Pedobarogram and the data was displayed on the monitor. A black and white intensity modulated footprint was displayed as the result of the plantar pressure of the patient standing on top of the sheet that was forced to flatten.

The desire to understand the quantitative and qualitative pressures under the human foot during gait was the determining factor for the development of measurement technology (Ralph, Lunsford & Greenfield, 1990).

During the last 50 years a number of new technologies have developed to measure the plantar pressure distribution during the static and dynamic phase of gait. Currently, plantar pressure measurement devices have become a very useful clinical and research tool in gait analysis (Sneyers et al., 1995).

As Hughes, Kriss & Klenerman (1987) have stated over the past century many professionals in a clinical have come to utilize the art of pressure measurement technology to measure the pressure distribution under the foot. There are currently three
commercially available systems that can be compared, they are: The Harris mat, the Dynapod and the Pedobarograph. In the 1980s the Dynapod was considered the best and most precise system available. Many methods have been developed but few have proven to be as accurate and the focus should be made to develop more accurate pressure technologies.

Sneyers et al. (1995) & Lord (1981) reported that a new way of evaluating the foot and its function through the use of a force plate. A force plate is able to collect the vertical and horizontal forces of the ground reaction force. A force plate captures static and dynamic data during a single step of the gait cycle. There is a marked limitation in analyzing the pressure of the foot this way, because the data collected is not specific to a particular location on the foot. Most modern force plates are electronic, although mechanical devices are still in use.

Morton’s (1930) technological principle was used as the basis to develop other systems in the plantar pressure measurement industry. His technology used a method called the printing technique, which offered a useful and simple measuring process to record the highest pressure under the foot during walking.

The most commonly used assessment tool in the foot profession today is the pressure platform system or in-shoe system. Recent developments in technology have been able to allow for an accurate assessment device to collect the pressure produced under the foot during gait. This allows for the collection of information about the kinetic aspect of the foot when static or during gait. The patient either steps with bare feet on the surface of the mat or has a thin sole-like transducer insert in their shoe. The software
collects pressure information from the anatomical landmarks on the plantar aspect of the foot, and provides the researcher with the timing of pressure build up at each level. Such technological systems are beneficial in that they provide real-time measurements of the gait (Bryant, Tinely & Cole, 2004; De Cock, Willems, Witrouw, Vanreenterghem & De Clercq, 2005; Duffin, Kidd, Chan & Donaghue, 2003; Fuller, Schroeder & Edwards, 2001; Lord, 1981).

2.6 CURRENT PLANTAR PRESSURE MEASUREMENT TECHNIQUES

Plantar pressure measurement has become an important research tool in today’s clinics where gait analysis is used. A wide spectrum of methods to collect and analyze plantar pressure distribution information is available. This allows a practitioner/osteopath to collect valuable information about the function of the foot during the distribution of pressure between the sole of the foot and the ground. The measurement of plantar pressure distribution under the foot can serve as a solid record to monitor patients’ progress and the effectiveness of therapeutic application. It can be used as a tool to collect the data and compare it with pre and post treatment results (Hughes et al., 1987; Lord, 1981; Karki, Lekkala, Kaistila, Laine, Maenpaa & Kuokkanen, 2009).

Soames (1985) asserts that each technique has provided unique insight into the structure and biomechanics of the foot. Many researchers have devised methods to record and analyze the foot function; one of these methods is a technique that records the vertical forces distributed under the foot using a force plate. This particular method provides the researcher with following information:
• The contact time of the foot initially with the plate

• How long the foot remained on the plate

• How much pressure the foot produced while it was on the plate

Sneyers et al. (1995) maintain that that evaluation of the foot function and its alignment should be done when the subject is experiencing an overuse injury. In her study of athletes she assessed the plantar pressure pattern using pressure-measuring insoles. Peak pressure and impulses were calculated for different anatomical foot locations. There was more weight load in the medial part of the heel in the pes planus group as compared with the normal group.

As reported by Gefen, Itzchak & Arcan (2000), even though the foot plays a critical role in the body’s function, quantitative kinematic and dynamic analysis during gait is in its infancy. In their study they developed a system of experimental and numerical tools, to analyze the three-dimensional foot and its behavior during gait. They state that direct measurements of the stress distribution within the foot in vivo during gait are not feasible, so, the use of a model, subjected to muscle and structural loading, and to ground constraints, is the only choice to carry out such a project.

Yarnitzky, Yizhar & Gefen (2005) make us aware that there is no technology currently available to provide real-time data on internal deformations and stresses in the plantar soft tissues during gait analysis. They proposed a method that couples analytical modeling of the foot with a finite element analysis of the heel and metatarsal head
regions in the plantar pad. This method enables the visual and quantitative analysis of
time-dependent deep soft tissue deformations/stresses during the stance of gait.

Knowledge of the forces acting under the foot is important in the assessment of
various foot pathologies and abnormal foot biomechanics. These measures have been
utilized in determining the success of surgical foot procedures (Bryant, Tineley & Cole,
2005), the influence of foot type (high versus low arch) on pressure (Burns, Crosbie,
Hunt & Potter, 2005), the areas of the foot that may be susceptible to diabetic ulcers
(Duffin, Kidd, Chan & Donaghue, 2003), and the effect of conditions such as ankle
equines on plantar pressures (Lavery, Armstrong & Boulton, 2002). Pressure
measurement has also been used to evaluate the effectiveness of footwear (Burnfield,
Few, Mohamed & Perry, 2004), and to provide diagnostic information for foot orthotics
(Claisse, Binning & Porter, 2004; Nigg, Stergiou, Cole, Stefanyslyn, Mundermann &
Humble, 2003; Redmond, Lumb & Landorf, 2003). Recently, due to the intervention of a
pedal pressure analysis system, functional foot types have been also recognized (De
Cock, Willems, Witvrouw, Vanreenterghem & De Clercq, 2005).

Lord (1981) and Gefen (2007) discussed various available technologies in their
research to measure plantar pressure and the techniques used to collect the data. Currently
several measurement systems utilize a wide variety of technologies that are available for
both research and clinical purpose.

There are three main approaches to measuring the process of plantar pressure distribution
under the foot:
• Between a bare foot and the diagnostic device

• Between the sole of the shoe and the ground

• Between the plantar surface of the foot and the shoe insole

Each of these diagnostic methods has its strengths and weaknesses with crossover information in certain areas of the measurement.

Hughes, Clark, Linge & Klenerman (1993) acknowledge that currently professionals utilize a wide variety of methods to process plantar pressure distribution data. They calculated that there are approximately 40 different types of pressure systems available. Most of those systems have sensors inside the shoe which are placed under a specific area of the foot.

Clinical research that measures plantar pressure distribution uses various types of sensors in the measuring devices, for example:

• Capacitive sensors that have electrically charged plates which are separated by an insulating elastic layer which has a deforming ability when pressure is acting on it. These receptors are used in a technology developed by Novel Co. in its EMED foot pressure platform, the Pliance sitting pressure mat, and the Pedar insole system (Nicol & Henning, 1976; Gefen, 2007; Gefen, 2007).

• Resistive sensors measure the resistance of conductive foam encapsulated between 2 electrodes. The electric current through the resistive sensor increases as
the conductive layer deforms under the pressure. The receptors are used in the TOG pressure system manufactured by The Orthotic Group Lab in Markham, Ontario, Canada. An outcome measure device used in this research study (Ross, et al., 2007; Rose, Feiwell & Cracchiolo, 1992; Gefen, 2007).

- Piezo-electric sensors are made of a semiconductor material that acts as force or pressure sensing resistors in an electric circuit. When the sensors are unloaded its resistance is very high, and when force is applied the resistance decreases. They are employed by Tekscan Co. in its FlexiForce sensors, Paromed CO. (Munich, Germany), in its Parotec in-shoe system, and Sensor Products CO. (Madison, NJ) in its Tactilus sitting mat (Henning, Cavanagh, Albert & MacMillan, 1982; Gefen, 2007).


Gefen (2007) states that all the different types of sensors are characterized by following characteristic: special resolution, sampling frequency, accuracy, sensitivity and ease of calibration.

- Special resolution refers to the number of sensors per unit area. The more sensors per unit area the more accurate the data collection is.
Sampling frequency refers to the number of pressure distribution samples, measured by individual sensor each second. It is adequate to sample with a speed of 50 Hz to process walking data.

Accuracy of sensors refers to the error in pressure measurements in relation to the real pressure that is applied.

Sensitivity applies to the ability of the sensors to pick up very low pressure.

Calibration refers to the process whereby the magnitude of the output signal of the sensor is related to the magnitude of the actual pressure acting on the sensor. (Gefen, 2007, p. 3)

Cavanagh, Hewitt & Perry (1992) report that capacitive and force sensitive resistor transducers are the common plantar pressure measuring technologies used today.

2.7 BAREFOOT PLANTAR PRESSURE MEASUREMENT

Cobb & Claremont (1995) make us aware that there are several methods available to measure plantar pressure distribution between the bare foot and the pressure platform.

Lord (1981) listed four main types of plantar pressure measuring methods:

- Foot printing technique
- Optical system
- Force plate and load cells
Insoles and pressure pads

The bare foot to ground measurement is relevant in diagnostic issues pre and post treatment, i.e. during Youngswick surgery procedure for Hallux Limitus (Bryant et al., 2004).

There are two components of foot loading that can be collected using barefoot plantar pressure measurement: vertical and horizontal. The ground reaction force during walking is the force applied by the body towards the ground and its greatest component is the vertical component of foot loading. The horizontal component during ground reaction forces is smaller than the vertical one (Jacob, 2001; Lord, 1981).

Most current techniques utilized in plantar pressure measurement methods performed in clinics today measure the vertical component of ground reaction forces acting on the foot during walking. Vertical components relate to gravity forces and the horizontal components deals with shear forces that occur on the surface of the skin and that aspect is yet not well analyzed (Soames, 1985).

Morton (1930) used the printing technique, which unfortunately only gave him the highest pressure distribution information under the foot during walking.

The pedobarograph system utilizes the optic techniques to process the barefoot measurements and provide a better level of resolution comparing to the printing techniques. As a result pedobarographs systems have been used widely in static (Minns (1982) and dynamic studies. Quaney, Meyer, Cornwall & MaPoil (1995).
A comparative study between the pedobarograph and EMED pressure systems were obtained to compare the peak pressure and peak force. All 21 individuals walked barefoot over both systems using two-step protocols. Peak plantar pressure and plantar force was measured under the heel, mid-foot, 1st metatarsal and the entire foot with both pressure devices. EMED demonstrated larger peak pressure values under the mid-foot and 1st metatarsal. The pedobarograph produced larger peak pressure values under the heel and the entire foot. Consequently, the pedobarograph system produced significantly higher peak vertical forces under the heel and mid-foot when compared with the EMED system. Peak vertical forces in both cases were lower under the 1st metatarsal and entire foot (Quaney et al., 1995).

Ross & Karolidis (2007) report about a barefoot to ground contact pressure device system developed by The Orthotic Group Lab that is used by clinics and was used in this study to collect the dynamic data as a useful diagnostic and assessment tool to collect plantar pressure distribution during standing and walking.

Plantar pressure measuring devices are designed to capture the highly loaded pressure areas underneath the foot during standing and walking. Pressure processing devices vary in respect to the sensor configuration and its multiple applications. Devices to process foot pressure are classified as pressure distribution platforms (barefoot to ground) and in-shoe systems. Pressure distribution platforms are able to measure static and dynamic components of gait and are utilized in static or dynamic studies. The pressure platforms are composed of thousands of sensors sitting tightly together and forming a matrix that is embedded in the floor of the device. The use of pressure platforms are therefore limited
to the clinics where gait is evaluated. The downfall for the plantar pressure platforms is that they measure only the interaction between the foot and the platform or ground (Gefen, 2007).

One of the downsides of the barefoot to ground method for taking the pressure data is that subjects quite often need to take a few walking trials to learn the proper targeting of the foot onto the pressure platform (Duckworth, Betts, Franks & Burk, 1982).

Lord (1981) states that the pressure distribution collected from beneath the foot during the measurement using the pressure platform can be useful in revealing information about the structure and function of the foot and the postural control of the whole body. The idea of being able to quantify the pedal plantar pressure during the dynamic or static phase of the gait can be well utilized in treatment as Hughes, Kriss and Kleerman (1987) have reported. The data received from pedal pressure could provide a firm record of the progress and effectiveness of the treatment.

2.8 IN-SHOE PRESSURE MEASUREMENT

In-shoe pressure processing devices are widely used in research and in clinical settings. The main providers of in-shoe technology are: the Research Foot software, the Tekscan Co., Boston, USA, and the Novel Co. in Munich, Germany. Both systems provide a visualization system for the data received from the testing by means of color-coded diagrams. High pressure areas are marked by using red or yellow and regions of low pressure by using blue or green color (Gefen, 2007).
In-shoe techniques utilize two different methods; the first design involves utilizing a thin discrete sensor inside the shoe distributed under specific anatomical landmarks of the foot called transducers, and the second design by using a matrix-insole technique, where the transducers are hidden inside a thin flexible insole. The in-shoe insoles are able to measure multiple gait cycles and they allow for the calculation of more robust statistical data whereas the force plate is limited to only one step at the time (Lord, 1981).

However, these small discrete in-shoe transducers can introduce an error since they are dependent on the accuracy of the positioning under the proper anatomical landmark (Cavanagh et al., 1992; Somaes, 1985).

Unfortunately the insole technique also has its negative aspects: the issue of cross talking between elements, repeatability between the elements within and between insoles, errors coming from bending forces, temperature and difficulty with calibration and wear and tear. Cavanagh et al. (1992), Cob et al. (1995).
2.9 FACTORS AFFECTING PLANTAR PRESSURE DISTRIBUTION

A. STRUCTURAL FACTORS

The following literature discusses several parameters related to plantar pressure distribution under the foot.

Increased metatarsal pressure during walking poises a significant risk factor to develop calluses and ulcer in diabetic population. Reduction in fat pad thickness predicts the development of foot ulcer and is a serious contributor for increase in peak plantar pressure under the metatarsal heads (Gefen, 2007; Duckworth, Boutton, Betts, Franks & Ward, 1985; Abouaesha, Van Schie, Griffths, Young & Boulton, 2001).

In their research Zhu et al. (1991) discuss about pressure variation factors including foot structure, pressure loading patterns, and body weight. The variations in pressure distribution among subjects display the uniqueness of foot function during gait.

A flat foot alters the plantar loading patterns when compared to a normal foot during walking. Significant differences between foot types exist in the contact area in the medial midfoot and maximum force and peak pressure in the lateral forefoot. The maximum and peak pressure greatly decreased in subjects with flat feet (Chuckpaiwong, Nunley, Mall & Queen, 2008).

There are only two studies that looked into the relationship between arch height index and foot pressure distribution. Patients with low arch height and body mass are linked to having a higher tendency for increased plantar pressure under the medial side of
the foot. Pressure can be defined as force by area; therefore it can be speculated that feet with a higher arch index and a smaller foot size may have higher plantar pressure than individuals with a lower arch index and greater total contact area (Van Schie & Boulton, 2000).

A study performed by Cavanagh, Morag, Boulton, Young, Deffner et al. (1997) focused on a predictive model of foot regional peak pressure using radiographic pictures and optical pedobarographs. The data captured radiographically was able to show a variance of 35% in peak plantar pressure under the heel and 1st metatarsal head during walking. They also developed the hypothesis that the two main factors in the prediction of plantar pressure are compressed soft tissue thickness and height of the medial longitudinal arch.

The association of limited joint mobility at the subtalar and first metatarsophalangeal joint is a related factor in abnormally high plantar pressure (Viswanathan, Snehalatha, Senna & Ramachandran, 2002).

Other structural factors that can influence the pressure distribution under the foot are: short 1st metatarsal and relative metatarsal length (Rothbart, 2002; Morton, 1935), bony prominences (Duckworth et al., 1985), and the embryological formation of the foot and its arches (Bareither, 1995).
B. FUNCTIONAL FACTORS

In addition to the structural factors, there are a number of other functional factors which relate to plantar pressure distribution under the foot. Subjects with a high foot approach velocity while walking exhibit increased peak plantar pressure under the heel area. Also, subjects who move their feet in high speed during dorsiflexion cause increased pressure at the first metatarsal during the push-off phase of gait, which, in turn, increases the pressure under the hallux, thus engaging the gastrocnemius muscle into high activity. The predictive model developed during this study was able to establish a 50% relationship in the variance in peak pressure with respect to structure and function of the foot (Morag & Cavanagh, 1999).

A review of the literature about overpronated feet reveals that excessive foot pronation has been the leading cause of lower extremity injuries. The ability of the flexible flat foot to control and adequately dampen the ascending and descending impact forces during walking is diminished. As a result, conditions such as medial tibial stress syndrome, metatarsal area stress fracture, plantar fasciitis, patella femoral syndrome and anterior cruciate ligament injuries can be linked directly to foot overpronation (Hargrave, Garcia, Gansneder & Szultz, 2003).

Sensory feedbacks from the receptors beneath the skin’s surface play a significant role in the regulation and redistribution of plantar pressure. A relationship was established that showed peak plantar pressure was higher in areas with normal skin sensitivity and lower in areas with decreased sensation (Nurse & Nigg, 2001).
Brand (1988) reveals the role of decreased sensation and increased repetitive mechanical pressure as the leading cause of plantar tissue breakdown in metatarsal ulcers in the diabetic population. Most diabetic patients suffer from peripheral sensory neuropathy, meaning that their ability to respond to good or bad stimuli is diminished or lost. The foot undergoes atrophy in the plantar muscle because of motor neuropathy. Atrophied intrinsic foot muscles cause instability of the metatarsophalangeal joints and produce anterior displacement of the fat pad from underneath the metatarsal heads.

C. METHODOLOGICAL FACTORS

Gefen (2007) in his paper goes over the number of variables that affect peak plantar pressure data; the list includes: special resolution, sampling frequency, accuracy, sensitivity and ease of calibration.

The size of the transducers used to collect the data must match the size of the measured anatomical landmark. Failure to do so can lead to reading errors, since plantar pressure systems that use large sizes of transducers in their devices will give data about the peak plantar pressure distribution that is higher than in reality. Consequently, a transducer that is too big for the measured landmark will yield a lower reading than the actual pressure. Therefore, the spatial resolution, which refers to the number of transducers used per unit of area, must be improved. It is necessary for the sensor size to be 5mm x 5mm or less in order to avoid misleading data of the peak pressure values (Lord, 1997).
Peak plantar pressure results can be affected through a sampling frequency of the measuring device. If the sampling rate of the device is low, the accuracy in collecting data from the heel will be low, because the plantar peak pressure is also low. Such clinical analysis can lead to the misinterpretation of peak pressure when the patient is walking faster. A clinically sufficient sampling rate for plantar pressure processing during walking is 50 HZ and above (Gefen, 2007).

Other methodological factors affecting the plantar pressure distribution is the data collection technique (one step, two steps and mid-gait techniques). This technique has been revealed to be more reliable since it produced patterns that were consistent with the average gait (McPoil, Cornwall, Dupuis & Cornwall, 1999).

In his study, Rogers (1985) did a comparison between the pressure recorded from the 1st step and the mid-gait step. The findings showed that the peak pressure for the heel and metatarsal heads were on an average 34% and 4.7% lower (respectively) during the 1st step than during step two and mid-gait.

Wearing, Urry, Smeathers & Battistutta (1999) determined that protocol for contact time is one of the most important factors in peak pressure measurements. They showed that the two steps and then hitting the mat protocol resulted in increased stance period time values, when compared to the mid-gait protocol. The reason for the difference is in the speed of walking; there is a slower velocity during the first and last steps of gait.
Other factors affecting plantar pressure measurements include: stride length, walking strategies, and visual targeting.

After an investigation of gait protocols, it is recommended that a consistent stride length be employed by the research subjects in order to collect accurate and consistent plantar pressure values (Harrison & Folland, 1997).

Muller, Sinacore, Hoogstrate & Daly (1994) came to the conclusion that walking strategies play an important role in the prediction of peak pressure, for example the hip walking pattern produces a 27% decrease in forefoot peak plantar pressure and a 24% increase in heel peak plantar pressure as compared with normal walking.

A small effect in peak plantar pressure has also been produced through visual targeting. Visual targeting may produce an unnatural stride and speed which can affect the plantar pressure values (Harrison et al., 1997).

D. INFLUENCE OF FOOTWEAR

The main purpose for wearing footwear is to redistribute the bodies’ weight over a wider area of the foot and to increase foot contact time (Soames, 1985).

There is consensus between researchers that the feet of western population are deformed due to the constant use of footwear. Feet consist of many joints and flexible tissues, and can be morphologically affected by wearing very tight or binding footwear. Other cases where foot deformation was observed are the wearing of tight rock climbing shoes, and the same shoes being worn every day (D’ Aout & Aerts, 2008).
A study lead by Praet, Willem & Louwerens (2002) investigated the influence of three different shoe designs on plantar pressure in neuropathic foot. They found the following results.

They used three shoe categories:

A. Over the counter, leather shoes which appeal to most females.

B. Semi-orthopedic shoes with extra depth, commonly prescribed by diabetic doctors.

C. Custom made rocker sole design shoes with soft leather and soft EVA insoles.

They used an in-shoe insole system with a sample frequency of 500 HZ to measure the peak plantar pressure.

The best results in plantar pressure reduction were achieved by shoe category C – custom-made rocker shoes. This type of shoe significantly lowered the pressure underneath the central forefoot to an acceptable level. Their study confirmed former research in this field lead, by Frykberg, Bailey, Matz, Panthel & Ruesch (2002), that rocker sole shoes were able to reduce by 35%-65% the pressure from underneath the heel and the central metatarsal heads in diabetic patients (Praet et al., 2002).

Grundy, Tosh, Mcleish & Smith (1975) linked rigidity of the sole of shoes and as the resulting increased contact time to increased peak pressure under the metatarsal area. Rigid soles move the center of foot pressure in a rapid manner towards the forefoot.
Flexible soles of regular shoes increase the total area of foot contact during the stance phase of gait and move the center of pressure from the 1st and 2nd metatarsal heads and toes to the center of the shoe. Both Oxford-type shoes with leather soles and running shoes significantly reduce pressure under the second metatarsal. Running shoes decrease pressure under every aspect of the foot, but Oxford-style shoes did not reduce pressure under the foot anywhere except under the 2nd metatarsal.

A study lead by Lavery, Vella, Fieischli, Armstrong & Lavery (1997) investigated the influence of therapeutic, comfort and athletic shoes with and without viscoelastic insoles on plantar pressure distribution in a diabetic population. The results of the study showed that all tested shoes, when used in conjunction with the viscoelastic insoles, were able to reduce the mean peak planar pressure better then the counterpart. The comparison for plantar pressure reduction was done under the common ulcer sites (under hallux, first metatarsal, and lesser metatarsals). The best results in pressure reduction under the first and lesser metatarsals were achieved when using the comfort shoes with the viscoelastic insoles. In their summary they state that therapeutic shoes (both comfort and athletic) and insoles have been widely used as a positive treatment to decrease foot pressures, increase cushioning and reduce tissue destruction in diabetic feet that are susceptible to constant repetitive high pressures. They conclude that there are significant differences in pressure reduction based on shoe type and the use of therapeutic insoles.

A case study lead by Kastenbauer, Sokol, Auinger & Irsigler (1997) compared the influence of pressure reduction in specially designed running shoes and custom-made soft insoles placed in a shoe with extra depth. The greatest plantar pressure reduction was
achieved by custom-made orthotics with a 50% reduction in pressure under the metatarsal heads and a 47% reduction in specially designed runners.

Soamaes & Clark (1985) discussed the relationship of heel height increasing plantar pressure under the metatarsal heads, and decreasing under the lateral metatarsal heads. In contrast, low heeled shoes move the pressure to the heel area and central area of the foot. They are not recommended for people with flat feet since they create more pressure on the inside of the foot during walking.

E. INFLUENCE OF CUSTOM-MADE ORTHOTICS

As the previous literature review suggests the ground reaction forces are the result of walking and moving activities; they produce stress and pressure under the plantar aspect of the flat foot.

Custom-made orthotics are medical devices which, when worn with proper shoes, are able to affect biomechanics during gait and pressure distribution by gently realigning and decreasing hypermobility in the foot. Orthotics have been demonstrated to be effective in the management of many foot conditions, either related to illness (diabetes) or due to biomechanical reasons (plantar fasciitis, metatarsalgia) (Michaud, 1997).

There is continued research that aims to investigate the effectiveness of custom-made orthotics, also known as insoles, in plantar pressure distribution in both healthy subjects and subjects with neuropathic foot problems (Gefen, 2007).
The effectiveness of custom-made orthotics for redistributing pressure during walking in both diabetic and non-diabetic individuals has been examined and compared during a study lead by Tsung, Zhang & Wong (2004). They compared three different support systems, which consisted of shoe only, flat insoles and three types of contoured insoles. The best result in decreasing the plantar pressure was achieved using the contoured insoles when the subtalar joint impression was taken in a semi-weight bearing state. The insole was able to significantly reduce local peak pressure under the 2\textsuperscript{nd} and 3\textsuperscript{rd} metatarsal heads. Conformation of these changes was registered through the F-scan in-shoe system when patients were tested during walking. The authors are in agreement that custom-made orthotics were able to significantly decrease plantar pressure, not only in diabetic individuals, but also in a healthy population (Tsung et al., 2004; Bus, Ulbrecht & Cavanagh, 2004; Zequera, Stephan & Paul, 2007; Lott, Hastings, Commean, Smith & Mueller, 2006).

2.10 RELIABILITY OF PLANTAR PRESSURE MEASUREMENT

Cavanagh & Ulbrect (1994) concluded in their research that different developed plantar measurement modalities can produce different results. A vast number of variables can affect the outcome of plantar pressure measurements; they can depend on the developed technology, special resolution, sampling frequency, accuracy, sensitivity and ease of calibration.

Wearing et al (1999) in their review on pressure devices technology found that the timing values were the most consistent, while peak plantar pressure and pressure time integrals were the least consistent values.
According to Gefen (2007) a low sample frequency and the incorrect size of sensors can lead to less accurate peak pressure values.

Dr. Ross & Karolidis (2006) & (2007) investigated the reliability of the TOG gait scan in their research and came to the conclusion that the majority of measurements made by this plantar pressure system show a good level reliability. The areas where the system showed poor reliability were the 1st and 5th metatarsal heads. They further report that:

*The fact that most of the measurements showed good reliability would suggest that the variability at 1st and 5th metatarsal heads is the result of subject variability rather than variability in the systems ability to measure pressure in these regions of the foot.*

(Ross et al., 2007, p. 3)

A similar study done on the F-Scan system found that most measurements showed a fair to good reliability, however, some regions showed poor reliability (Ahroni, Boyko & Forsberg, 1998).

A gait scan appears to provide results that are at least as good as an F-Scan and perhaps better for some anatomical landmark areas. The dependent variable used to collect the outcome measures in this osteopathic research study is a TOG gait scan pressure platform. A TOG gait scan offers the most up-to-date gait assessment technology available and is currently used by chiropractors, chiropodists, podiatrists, pedorthists and other health practitioners.

The TOG gait scan is a computerized assessment tool that is utilized in clinical offices to do the following data collection:
• Biomechanical foot function assessment data

• Plantar pressure analysis data

• Evaluation of orthotic efficacy

As the patient stands or walks across the Gait Scan pressure plate, 4,096 tiny sensors scan the plantar surface with a sampling frequency 300 times per second to determine the exact pattern of weight distribution throughout the stride. This diagnostic tool has been engineered to assist with the assessment and diagnosis of foot biomechanics. The TOG scan system measures the distribution of pressure throughout a patient’s foot during each step, identifying high and low pressure areas and gait abnormalities. The system is able to record timing, peak plantar pressures and impulse percentage of the following areas of the foot including the medial heel, lateral heel, mid-foot, metatarsals 1-5, the hallux and the toes 2-5. The gait scan allows for the viewing of plantar pressure of the foot in 2D or 3D. It also shows values that indicate which area of the foot receives the most amount of pressure over a given time (The Orthotic Group, 2006).

Hughes et al (1987) compared three commercially available pressure systems by which healthy subjects’ feet were scanned. Their results suggest that the type of equipment used in the practice or hospital will mainly depend on the funds available. They compared the Harris mat, Dynapod and pedobarograph. The Dynapod was the best measurement device due to its accuracy, special resolution and clear numeric printout. The peak plantar pressure and plantar pressure timing pattern showed, for the most part,
comparable distribution values, but with recognizable differences located in certain areas of the foot.

Lastly the differences in reliability could be subject-related rather than system-related. The greater the differences between the parameters developed for the measurement systems the higher the probability that the reliability in plantar pressure measurements will be inaccurate (Quaney et al., 1995).

2.11 PLANTAR PRESSURE DISTRIBUTION IN WALKING AND RUNNING RESEARCH STUDIES

According to the research literature on pressure measurements reliability, there are many examples of individual variability in peak plantar pressure, but for the most part the reported results from most studies are quite consistent for pressure values and pressure patterns.

In Soames’ (1985) reports about the phases of gait, he points out that the highest peak pressure during walking occurs under the heel, forefoot and 1st metatarsal area during early and late stance respectively, while the lowest peak pressure occurs under the midfoot and lateral metatarsals.

Brand (1988) hypothesized in his study that a shuffling gait pattern increases the period of flat foot load and the area of weight bearing, and thus results in lower peak plantar pressures under the forefoot than during normal walking patterns. The study also
gave evidence that pressure distribution patterns during shuffling were quite different from those assessed during normal walking.

Zhu et al. (1991) confirmed Brands’ (1988) findings about the effect of a shuffling gait pattern on foot pressure distribution during walking. The testing involved 10 male subjects without known musculoskeletal or neuromuscular impairments. They used a portable, insole-measurement based system, capable of recording plantar pressure.

Several authors have investigated the effects of walking patterns on the reduction of plantar pressure under the foot. Reduction of abnormal high peak plantar pressures, and the decrease in mechanical stress that leads to tissue breakdown during walking, has been the main focus in prevention and treatment diabetes (Karki et al., 2009).

Gefen (2007), in his publication, reports that foot pressure measurements are able to uncover the highly loaded areas of the foot during the static and dynamic phases of the gait. These devices decrease the chance of injury by taking positive steps in altering patient behavior.

Based on Hessert, Vyas, Leach, Hu, Lipsitz & Novak’s (2005) studies, it has now become clear that foot pressure distribution differences between young and elderly groups were assigned to calcaneus and hallux regions and to the medial side of the foot. Aging affects the dynamics of pressure distribution under the foot during normal walking; the main contributors are age-related structural and physiological changes in the bones of the foot and ligaments. Elderly people tend to favor their weight on the lateral side of the foot during the stance phase of the gait, which causes instability issues during
walking. The pressure under the medial foot is reduced in the elderly mainly due to anatomical foot structure, soft tissue thickness and arch height, producing a lower propulsion throughout heel strike and push off phases. Gait review points to a decreased stride length, reduced step force and increased variability in gait parameters. These results suggest that lateral foot pressure and decreased propulsion in elderly people affects their efficiency during walking, balancing, forward acceleration, and terrain adaptation.

Pedal pressure measurement systems are able to determine the increased and potentially risky loaded regions in the foot during static and dynamic activities. An example of this is the increased load under the 1st metatarsal head and the medial heel in people with overpronated feet which is commonly called flat feet (Gefen, 2007; Yarnitzky, Yizhar & Gefen, 2005).

The plantar pressure distribution during the push-off phase of walking was measured with the EMED-SF4 system in 42 healthy subjects. The results showed that the 1st toe and area under the 2nd metatarsal head exhibited the highest pressures (Hayafune, Hayafune & Jacob, 1999).

Wrobel, Connolly & Beach (2004) outline a relationship between static and dynamic foot measurements and pressure analysis. Their studies document that the associations between static and functional measures of joint function in the foot and ankle.
In his recent study Gefen (2003) evaluated a computational model of the foot structure in the standing position that was performed to check for stress distribution patterns in plantar soft tissue under the metatarsal area between a simulated diabetic and normal foot. The results showed that the maximum tension stress concentration was four times higher than in a normal foot under the 1st metatarsal head and almost eight times the normal under the 2nd metatarsal head. The tension stress concentration was four times greater. They also confirmed the experimental data collected over the last 20 years, that the pathological process in a diabetic foot occurs predominantly in deeper tissue layers first and not only on the skin surface. The most prominent tissues where the tissue distraction occurs are the medial metatarsals.

Hsi, Kang & Lai (2004) report high pressure under the 2nd metatarsal head but according to them it has not been reported in the research study. They measured the plantar pressure in 72 healthy people during walking using small transducers located under the second to fourth metatarsal heads. Data from the study was analyzed using special statistics. The results showed that the distribution parameters of plantar pressure were inversely correlated to peak pressure and in addition decreased proportionally from the 2nd to the 4th metatarsal heads and were different from the 1st metatarsal head.

Reinschmidt, Nigg & Hamilton (1994) performed a comparison study where they looked into the influence of activity on plantar pressure distribution in 11 subjects. The measurements with the pressure platform were done before and after a 30 minute run. The results from the study suggest that the 30 minute run did not affect the plantar
pressure distribution in the foot. Only one small statistical change (<3%) was reported in the forefoot related to the maximal force in the forefoot.

A brand new study lead by Stolwijk, Duysens, Louwerens & Keijzers (2010) brings a different light onto the aspect of plantar pressure change after long distance walking. They based the results on 62 subjects who took part in a four consecutive day long-distance study. Pre and post measurements were done and compared with baseline measurement taken two days before the long distance study. The final results showed that there was a short-term adjustment that took place after long distance walking. There was a significant decrease in toe loading, and an increase in loading on metatarsal heads 3-5, during all stages of walking. Contact time increased and a significant change in the center of pressure in a posterior direction was also reported. These results indicate that the long distance walking creates a lesser roll-off pattern during walking, mainly due to increased heel loading, and decreased loading on the toes.

2.12 INFLUENCE OF WALKING SPEED ON FOOT LOADING FORCES

Speed is the outcome of a number of steps taken and its length over a time period. A study lead by Zhu et al. (1991) confirmed that slower speed seen in shuffling walking resulted in lower peak plantar pressure compared to normal walking. Plantar pressure is the product of force acting over an area. Gait is a dynamic process; pressure variations in the study were analyzed and observed during a normal and shuffling gait. A
shuffling gait characterized by short steps and slow speed and increases the foot contact area which relates to weight bearing, resulting in a decrease in peak plantar pressure. Although a shuffling gait significantly decreases the plantar peak pressure and is recommended as a form of therapy to diabetic patients, it causes premature muscle fatigue and is inefficient for walking (Zhu et al., 1991).

Other studies have shown that walking speed reduces vertical reacting ground forces and is proportional to the increase or decrease of speed (Zhu, Wertsch, Harris & Alba, 1995; Simkin, 1981; Cook, Farrell & Care, 1997).

Hughes, Pratt, Linge, Clark & Klemerman (1991) report that walking speed has an effect on the loading forces the foot receives including peak pressure, and weight bearing contact time. It can be said that total peak plantar pressure proportionally increases with the increase in walking speed. During fast walking the pressure increases almost in the entire foot region with the exception of the lateral borderer and the fifth toe area.

Zhu et al. (1995) in a follow up study found that peak plantar pressure did not decrease under the lateral forefoot area after an increase of walking speed.

A study lead by Ivanenko, Grasso, Macellari & Lacquaniti (2002) on ground contact forces in simulated reduced conditions, studied the changes in vertical contact forces, lower limb kinematics, and electromyographic activity at different speed and gravitational loads. They reported that changing the body weight mass between 0% and 95% caused drastic changes in kinetic parameters, including the peak vertical force, and a
change in amplitude of the electromyographic activity of all the lower leg muscles. In both cases an increase in speed was related to an increase of peak plantar pressure and muscle activity.

2.13 INFLUENCE OF WALKING SYMMETRY

According to Michaud (1997) a healthy gait shows symmetrical lower leg and foot activity including foot loading patterns, cadence, speed, base width, step length, side to side motion, pelvic tilt and displacement.

For the most part researchers who examined walking symmetry within healthy individuals agree that subjects maintain high degree of symmetry in their gait pattern; they showed consistent loading patterns with no change in vertical force, and pressure-time integrals between left and right foot. Only two areas out of the four measured (forefoot and rearfoot) showed significant differences in peak plantar pressure. Healthy subjects usually met most of the ideal determinants of the gait cycle. By doing so the most energy-efficient method of walking is achieved, with constant velocity and smooth transfer of center of mass from one point to another (VanZant, McPoil & Cornwall, 2001).

Wells et al. (1999) in their study on Parkinson patients’ report about pathology which affects the central nervous system and produces asymmetry in gait including: stride length, cadence, propulsion, and speed.
Herzog, Nigg, Read & Olsson (1989) found that parameters of ground reaction forces acting in the medio-lateral direction exhibit a wide range of asymmetries, potentially due to a high percentage of variability along the axis of rotation for subtalar joint. During the study they formulated a symmetry index for 34 gait variables, taken from trials. A significantly high percentage of variables was found for variables with a magnitude close to zero, and variables that were found in quite different instances during the gait.

A study lead by Kim & Eng (2002) investigated two issues related to gait symmetry:

1. Whether symmetry in temporal-distance is accompanied by symmetry in kinetic measures during a self-paced gait.

2. Symmetry on gait speed in a population after a stroke.

The study revealed that gait speed was correlated with the symmetry of temporal measures and ground reacting forces. A second finding revealed symmetry in ground reacting forces was correlated with symmetry in temporal but not with distance measures of gait.

A study performed by Sau Lai (2008) on hemiplegic patients revealed that there is no benefit in using a walking stick or quadripod to achieve symmetrical gait pattern. On the contrary, aided walking decreased speed, and was found to have no effect on any of the temporal symmetry values when compared with no aid while walking.
Furthermore asymmetric gait reveals natural habitual differences between each leg during the gait cycle. This is due to the individual contribution coming from each leg, exercising a complex but well controlled action (Sadeghi, Allard, Prince & Labelle, 2000).

Another walking pattern that can be used in the reduction of forefoot plantar pressures is the “step to gait” walking pattern. During this study data from 10 healthy subjects were analyzed, they were instructed to shorten their step on the uninvolved side of the leg, in such a way that the step would end next to and not beyond the involved leg. A significant plantar pressure reduction was reported under the forefoot (53%) but with increase in pressure under the heel area (14%) (Drerup, Szczepaniak & Wetz, 2008; Kwon & Mueller, 2001).

2.14 INFLUENCE OF LOWER LEG FRACTURE

Fractures of the lower leg and foot are often associated with soft tissue damage and neurological impairment of intrinsic foot and lower leg muscle. Instability issues are known to result as a result of improper healing of the affected bone. Improper muscular engagement can restrict the ability to walk. A significant limb weight bearing asymmetry in plantar pressure distribution was found among evaluated patients who had surgery to correct an ankle fracture. Furthermore a tibial fracture with associated soft tissue damage may cause a significant impairment and be a factor in gait asymmetry and uneven foot loading (Becker, Rosenbaum, Kriese, Gerngross & Claes, 1995).
Stress fractures are common in runners; they often affect 2\textsuperscript{nd} metatarsal head and are more prevalent in women than in men. Queen, Abbey, Chuckpaiwong & Nunley (2009) used data from 15 healthy men and women to create plantar pressure baseline and 9 women with a history of stress fractures in the 2\textsuperscript{nd}/3\textsuperscript{rd} metatarsal area. Their study revealed that women with fractures demonstrated a decrease in contact area and a significant increase of force under the middle of the forefoot where such a change did not occur in the control groups.
CHAPTER THREE: OSTEOPATHIC JUSTIFICATION
OSTEOPATHIC JUSTIFICATION

3.1 BIOMECHANICS AND ANATOMY OF THE FOOT

The ground reaction forces (GRF) during gait cycle is the force applied by the body towards the ground. There are two components of GRF; the vertical component of GRF is the largest and it accounts for the acceleration of the body’s centre of mass in the vertical direction during walking, and the horizontal shear forces, determinant of skin stresses (Jacob, 2001).

Lord (1981) in her review reveals that literature has not provided any substantial reviews related to horizontal shear forces, the smaller component of GRF.

Seegmiller & McCaw (2003) state that the subtalar joint receives vertical GRF, which needs to be absorbed at the foot and ankle level as soon as it’s acting on it otherwise chronic dysfunctions can set in.

Also Kirby (2000) is in agreement with Seegmiller et al. (2003) that the vertical GRF the foot receives must be absorbed and reduced at the subtalar joint level; if not, the forces travel up the kinetic chain with great speed causing numerous chronic degenerative changes such as shin splints, peroneal weakness, knee, hip, pelvic tilts, hyperlordosis and lumbar-sacral dysfunctions as well as the “pronation syndrome” posture reported by Pratt (1951). The subtalar joint is the main pedal joint, which allows triplanar motion between the foot and lower extremity, thus normal subtalar joint function is necessary for normal foot and lower extremity function.
Druelle (1992) reports that descending forces, which are associated with weight and gravity, travel down the spine, and at the level of L5 divide into two directions, one towards iliac crest and the second towards the hip joints. The ascending forces travel in the opposite direction, they run up along the lower limbs towards the hips and then they split into two forces travelling towards the symphysis pubis and the ilio-sacral articulation where they are absorbed and balanced. Improper balancing of these two forces affects the sacroiliac joints and produces lesions. If the origin of somatic dysfunction comes from the descending force, this will affect the sacrum and produce sacro-iliac somatic dysfunction. If the origin of the dysfunction comes from the ascending force, this will affect the ilium and produce ilio-sacral somatic dysfunction.

Kirby (2000) compares the foot to an engineering marvel, which allows humans to walk while constantly being subjected to impact forces coming from the ground; these forces are called the ground reaction forces. The foot interacts with the rest of the body to absorb and redistribute the GRF throughout the skeletal framework. In addition the foot also receives a large degree of rotational and gravitational forces, which occur during movement. A healthy foot handles GRF through efficiently working a network of muscles, joints and ligaments whereby the impulses to accelerate or decelerate are analyzed. The largest amplitude of GRF occurs when the foot makes the weight bearing contact with the ground and these forces are in vertical plane. The transverse or horizontal GRF (run antero-posterior and medio-lateral) are considerably smaller then the vertical components of GRF.
Seegmiller & McCaw (2003) found that if the foot has faulty biomechanics it will not function properly, and it will not be able to dampen the ground reaction forces efficiently, so the pressure distribution in the plantar aspect of the foot will be unequally distributed. This behavior leads to compensations, and due to the body’s constant attempt to reach optimal function, the body may adapt to these structural and functional stresses.

Jacob (2001) investigated the forces that act along the tendons and joints of the 1st and 2nd metatarsal bones of the forefoot. High forces were found to be present along the flexor tendons of the heavily loaded first ray that is supporting the longitudinal arch of the foot. The second metatarsal is also subject to high bending movements with an acting force that amounts to about 45% of the body weight. The flexor hallucis longus and brevis tendons exert about 52% and 36% of the body weight, respectively. The peroneus longus exerts more than 58% of the body weight. According to the researching author the total force that the first metatarsal head receives amounts to 119% of the body weight. The second metatarsal is subjected to increased bending movement of about 45% of the body weight.

As Druelle (1992) reports the foot serves as the base of support for humans and allows an individual to express themselves through movement. A normally functioning foot is able to transform and minimize the ascending and descending forces that are related to gravity and GRF. The mobility of the foot is essential for a properly functioning lower kinetic chain involving the knee, hip, sacrum, pelvis and lumbar spine. In summary, he reveals that the “normal foot operates in a triangular base-like an inversed sacrum and in rhythmic conjunction with the sacrum” (Druelle, 1992, p. 9).
Clinicians and biomechanical engineers have studied the foot and ankle complex extensively during the last century. They came to realize that the proper alignment of the foot is an important aspect for shock absorption during the initial contact of the heel with the ground and stabilizes the foot during the propulsion phase (Sneyers et al., 1995).

What has now become clear is that the foot and ankle are quite complex and yet they use simple hinge joints for their motion. The axes are positioned in an oblique manner to each other, causing uniaxial triplanar motions (Oatis, 1988).

Michaud (1997) states that the human foot is composed of 28 bones, 55 joints, 20 muscles and over 100 ligaments holding everything together and forming a specialized functional unit that is capable of adapting efficiently to various terrain changes, dampening the ground reaction forces and the forces the body is receiving from above.
Figure 1  Dorsal aspect of the foot.
There are many ways of viewing the structure of the foot operating as a whole and even the structure does not apply directly to description of the longitudinal arches, the concept is similar and acts as a setting for the arches. According to Druelle (1992) feet can be divided into three mutually functioning zones that have a physiological resemblance with the cranial region.

- The cephalic zone: includes the talus and round calcaneus, which resembles the occiput.

- The caudal zone: includes the cuneiforms and metatarsals, this is a very mobile area that resembles the facial bones (frontal, sphenoid, and maxilla).

- The rhythmic zone: located between the cephalic and caudal zones, and houses some of the most important bones from the osteopathic point of view: the cuboid and navicular. The cuboid resembles in its function the ethmoid and is related to cranial respiration and lemniscate.

The rhythmic zone works in synchrony with respiration, and the lemniscate, which is the notion of change and balance point between the cephalic and caudal zones (Druelle, 1992; Magoun, 1976).
Figure 2  The subtalar joint axes of rotation:
Top view - sagittal plane (inversion and eversion occurs around that axis),
Bottom view - transverse plane (adduction/abduction occurs around that axis).
(McPoil & Knecht, 1985, p.70)
Figure 3  The midtarsal joint axes of rotation: oblique midtarsal axis allows large amounts of dorsiflexion/plantarflexion, abduction/adduction and the longitudinal axis allows small amounts of inversion and eversion.
(McPoil & Knecht 1985, p. 71)
Figure 4  Axes of midtarsal joints in relation to subtalar joint position. 
Lines represent the planes (sagittal and transverse) of the two midtarsal joint axes, pronation 
view A - planes of the midtarsal joint axes are parallel, view N and B - when the midtarsal joint 
axes move towards neutral and supination (B) the planes of the axes converge. 
(McPoil & Knecht 1985, p. 71)

Kapandji (1987) found the joints of the foot to be complex; he divided them into 
two main groups: the intertarsal and the tarsometatarsal joints. The lists of important 
joints are:

- The subtalar joint (triplanar motion occurs here - pronation and 
supination)

- The midtarsal (Chopart’s joint) (1st ray-Dorsiflexion and inversion or 
plantarflexion and eversion, 2nd, 3rd, 4th ray produce dorsiflexion and 
plantar flexion, 5th ray produces pronation and supination).

- Tarsometatarsal joint (Lisfrank’s joint)
• The cubonavicular and cuneonavicular joint (inversion and eversion occur here).

• The metatarsophalangeal and interphalangeal joints are less important than those joints listed above, but the metatarsophalangeal joint of the big toe is critical during walking.

The foot can be divided into two regions: the sensorial and the structural. The sensorial is located on the inside of the foot and consists of talus, navicular, three cuneiforms and first three metatarsals and works with GRF, gravity and balance. The outside of the foot, consisting of the calcaneus, cuboid and 4th and 5th metatarsals, is considered to be more structural and it is this part that is adapting an individual’s weight to the ground and is used during propulsion. Each foot has three arches: medial, lateral longitudinal arch and transverse arch. Their role is to support the foot and to blend the elements of the foot joints, ligaments and muscles into a unified system (Druelle, 1992).

Kapandji (1987) describes the medial longitudinal arch as being composed of the calcaneus, talus – its key bone, navicular, three cuneiforms, three medial metatarsals and its digits. This area is considered to be a more adaptive part of the foot and acts as a shock absorber necessary for flexibility during gait. The lateral arch is considered to be more structural and is composed of the calcaneus, cuboid and 4th and 5th metatarsals. The transverse arch is located in the anterior part of the foot and runs from side to side. It runs from the first metatarsal to the head of the 5th metatarsal. This arch is relatively flat and rests on the ground via the soft tissues.
As Nordin & Frankel (1989) state, the function of the plantar fascia is complex. It is attached to the calcaneus and it spans towards the tarsals and metatarsophalangeal joints to insert into the proximal phalanges. It prevents the medial longitudinal arch from collapsing by virtue of its anatomical orientation and tensile strength. The mechanism of “windlass effect” causes the plantar fascia of the foot to tighten while elevating the arch. The passive function of the fascia complements the active function of the muscles in standing and walking.

Gefen (2003) in his study elaborates on the plantar fascia’s elastic properties and its role during initial weight bearing activities. His study utilized two experimental procedures to concurrently record the shearing forces in the plantar fascia and the vertical forces collected during the contact phase of walking. The plantar fascia functions to support the medial and lateral longitudinal arches as well as to cushion the stress received from the initial contact through the process of deformation. The intensity and stress in the plantar fascia increases during the second half of the contact phase of the gait, when the person’s weight is moved towards the forefoot.

It has become obvious as stated by Elveru, Rothstein, Lamb and Riddle (1988) that the most strategic joint in the foot is the subtalar joint articulation formed by the talus and the calcaneus via three articulations. This joint moves in a triplanar motion and has an oblique axis thus allowing for pronation and supination of the foot.

Kirby (2000) reports about the subtalar joint that is directly and indirectly responsible for shock absorption and pressure distribution in the foot. He also reports that the function of the foot and the lower extremities are biomechanically integrated through
the musculoskeletal system. Interestingly, one of the osteopathic tenets is that when “the body is working as a functional unit” that unit is interrelated and if the foot, for example, is not working properly, that state will have a pronounced impact on the structures above the foot and will cause adaptive changes.

Oatis (1988) writes that the subtalar joint consists of the calcaneus and the talus and is able to move in a triplanar motion, allowing for pronation and supination. These motions are pure rotations around the subtalar joint oblique axis resulting in the same final position as three individual rotations in the cardinal planes. During pronation the foot moves in dorsiflexion, abduction and eversion and during supination it moves in plantarflexion, adduction, and inversion.

Kirby (2000) states that during relaxed standing each foot supports 50% of the person’s body weight. Ideally, the body’s center of mass should be located between the feet. Individuals with normal feet will contract the gastrocnemius muscles and extrinsic muscles of the foot to keep their equilibrium and stay well balanced. Structural deformities can cause medial drift of the subtalar joint axis in the medial position causing medial translation and leading to overpronation.

Mann (1982) reports that the subtalar joint functions as an oblique axes that translates the transverse rotation that occurs in the tibia. If the subtalar joint is not properly aligned, very serious pathologies could result, since the foot will not be in a planti-grade position.
In a recent study Kirby (2000) describes the subtalar joint as a hinge, with an axis running downward, posteriorly and laterally, producing a triplanar motion of pronation and supination respectively. Motion of the subtalar joint occurs within an oblique axis that lays 42 degrees to the transverse plane and 23 degrees to the sagittal plane. According to Kirby (2000), during pronation of the subtalar joint the calcaneus moves posteriorly, superiorly and laterally under the talus. Thus, the head of the talus moves anteriorly, inferiorly and medially.

Lower Limb: Ankle and Foot

Description of the Anatomy of the foot listed below is sourced from: Moore, 1985.

Ankle Joint (Talocrural Joint)

- Uniaxial, synovial, hinge type joint
- Articulation between tibia (medial malleolus), fibula (lateral malleolus), and talus
  - Distal ends of tibia and fibula form a mortise
  - Trochlea of talus fits into mortise
  - Malleoli grip talus
- Movements
  - Dorsiflexion
    - Produced by muscles of anterior compartment of leg
    - Limited by triceps surae
    - More stable when dorsiflexed
o Plantarflexion - produced by muscles of the posterior compartment of leg

o Some rotation, abduction, and adduction of joint possible in plantar flexion

- Capsule
  o Thin
  o Supported by strong collateral ligament
  o Attached to the tibia and the malleoli superiorly, and the talus inferiorly

- Ligaments:
  o Lateral consists of three parts
    - Anterior talofibular - from lateral malleolus to neck of talus
    - Posterior talofibular - from malleolar fossa to lateral tubercle of talus
    - Calcaneofibular - from tip of lateral malleolus to lateral calcaneus
  o Medial or deltoid
    - Strong ligament
    - Originates on medial malleolus
    - Fibers can be identified as
      - Anterior and posterior tibiotalar
      - Tibionavicular
      - Tibiocalcaneal

- Blood supply: malleolar branches of fibular, anterior and posterior tibial arteries
- Nerve supply: Tibial nerve and deep fibular nerve (a branch of the common fibular)

**Bones of the foot**

- 28 in number
- Tarsal bones (7)
  - Talus
    - Has head, neck, body with trochlea, posterior, and lateral processes
    - Articulates with fibula, calcaneus, and navicular
    - Has no muscular attachments
    - Head rests on lateral projection of calcaneus - sustentaculum tali
    - Wider anteriorly making the ankle more stable in dorsiflexion
  - Calcaneus
    - Largest and strongest bone
    - Posterior prominence - calcaneal tuberosity - with medial, lateral, and anterior tubercles
    - Articulates with the talus and cuboid
    - Transmits body weight from talus to ground
    - Lateral projection - sustentaculum tali - supports talar head
  - Navicular
    - Flattened bone with inferomedial tuberosity
• Located between talar head and three cuneiform bones
  o Cuboid
    ▪ Inferolateral groove for tendon of peroneus longus
    ▪ Most lateral bone in distal row of tarsals
  o Cuneiform (3)
    ▪ Medial, intermediate and lateral
    ▪ Each articulates with navicular posteriorly and base of related metatarsal anteriorly
    ▪ Lateral articulates with cuboid
• Metatarsals (5)
  o Have base (proximal), body, and head (distal)
  o Bases articulate with cuneiform and cuboid bones
  o Head articulate with proximal phalanges
  o Medial and lateral sesamoid bones on plantar surface of first metatarsal in plantar ligament
• Phalanges (14)
  o Great toe (hallux) has two - proximal and distal
  o Other toes have three - proximal middle and distal
  o Each consists of proximal base, body, and distal head
Joints of the foot

- Important intertarsal joints
  - Where inversion and eversion occur
  - Subtalar
    - Synovial joint with where talus rests on calcaneus
    - Fibrous capsule supported by talocalcaneal ligaments
  - Transverse tarsal, composed of
    - Calcaneocuboid joint
    - Talonavicular joint
- Other joints where slight movement occurs
  - Talocalcaneal
  - Tarsometatarsal
  - Metatarsophalangeal (MTP)
  - Interphalangeal: proximal and distal (PIP and DIP)

Arches of the foot

- Tarsal and metatarsal bones are arranged in longitudinal and transverse arches
- Bony arches maintained by
  - Interlocking bones
  - Plantar ligaments
  - Plantar aponeurosis
CHAPTER THREE: OSTEOPATHIC JUSTIFICATION

- Action of plantar muscles

- Functions
  - Shock absorbers for body weight
  - Distribute body weight
  - Make foot adaptable to changes in surface

- Longitudinal arch composed of medial and lateral arches

- Medial longitudinal arch
  - Higher arch than lateral
  - Composed of calcaneus, talus, navicular, three cuneiforms, three medial metatarsals
  - Talar head is the keystone
  - Strengthened by muscles and ligaments
    - Tibialis posterior tendon and attachments
    - Peroneus longus tendon
    - Flexor hallucis longus
    - Abductor hallucis longus
    - Plantar ligaments

- Lateral longitudinal arch
  - Flatter than medial
  - Rests on the ground when standing
  - Composed of calcaneus, cuboid, and lateral two metatarsal
Supported by 3 muscles:

- Peroneus brevis
- Peroneus longus
- Abductor digiti minimi

- Transverse arch – relatively flat, rests on the ground via soft tissues
  - Formed by cuboid, cuneiforms, bases of metatarsals

Supported by 3 muscles

- Peroneus longus
- Adductor hallucis
- Tibialis posterior
Figure 5  The longitudinal arches of the foot.  
(Beal, 1951, p. 98)
Ligaments of the foot

- All foot bones are united by plantar and dorsal ligaments
- Plantar calcaneonavicular ligament
  - Also called spring ligament
  - From sustentaculum tali to navicular
  - Maintains longitudinal arch of foot
- Long plantar ligament
  - From plantar surface of calcaneus to cuboid
  - Maintains foot arches
- Plantar calcaneocuboid ligament
  - Also called short plantar ligament
  - Deep to the long plantar ligament
  - From inferior surface of calcaneus to inferior surface of cuboid.

Muscles of the posterior Leg and Foot

Superficial layer

- Gastrocnemius - plantarflexes the ankle joint, and assists in flexion of the knee joint
- Soleus - Plantarflexes the ankle and stabilizes the leg over the foot
- Plantaris - Assists the gastrocnemius
Deep layer

- Popliteus - unlocks and flexes the knee.
- Flexor hallucis longus - flexes great toe, and weakly plantarflexes the ankle
- Flexor digitorum longus - flexes lateral four toes
- Tibialis posterior - plantarflexes the ankle and inverts the foot

Muscles of the anterolateral Leg and Foot

- Extensor digitorum brevis
- Tibialis anterior - dorsiflexes the ankle and inverts the foot
- Extensor hallucis brevis
- Assist extensor digitorum longus in extending toes
- Peroneus longus - Everts the foot and plantarflexes the ankle
- Peroneus brevis - Everts the foot and plantarflexes the ankle
- Peroneus Tertius - Dorsiflexes the ankle and aids in the interosseous membrane
Fascia of the foot

- Deep fascia on dorsum of foot
  - Thin on dorsum
  - Continuous with inferior extensor retinaculum
  - Over lateral and posterior aspects it is continuous with plantar fascia

- Deep fascia of plantar surface of foot
  - Central condensation of plantar fascia forms plantar aponeurosis
  - Arises from calcaneus

- Functions of plantar fascia
  - Holds foot together
  - Protects sole of foot from injury
  - Supports longitudinal arches

(Moore, 1985)
Figure 6  Plantar fascia of the foot.

According to Kapandji (1987) inversion and eversion of the foot are limited by two factors:

- Contact with bony surfaces
- The ligamentous system of the posterior tarsus
- The powerful yet stretchable tendons and fascia

Moore (1985) reports that the ankle joint is very stable during dorsiflexion and is supported by strong ligaments and tendons that cross down on the joint and tightly bind it together. Its stability is greatest in dorsiflexion due to the position of the trochlea of the talus, which fits the mortise tightly. The ankle joint is unstable during plantar flexion.
OSTEOPATHIC JUSTIFICATION

3.2 ASSESSMENT AND MECHANISM OF FLEXIBLE FLAT FOOT

According to Michaud (1997), about 67% of the total population has overpronation of the subtalar joint, which makes them prone to develop flat feet.

Dr. Pratt (1951), an Osteopath, reveals that “the pronation syndrome” type of posture can be detected in at least 75% of individuals and it has the following characteristics: protruded lower abdomen, depressed chest, anteriorly displaced neck, round shoulders and flat feet turned out.

Dr. Rothbar (2002) reports that in adaptations resulting from overpronated feet, the posture shifts forward and the body’s center of gravity moves to the inside of the medial malleolus. The knee becomes hyperextended, the pelvis unlevels producing a functional leg length discrepancy, the shoulders become rounded, and the head is displaced anteriorly in relation to the spine. The body is adapting to the strain and deformation patterns that occur in overpronated/flat foot, by means of chronic pain.

A study by Sneyers et al. (1995) found that in the case of high or low foot arch, the function of the subtalar and midtarsal joints are significantly impaired and prone to injuries. Nachbauer et al.’s (1992) research found similar findings about low arched feet suggesting that low-arched feet absorb a large amount of energy while walking, which results in metatarsal stress fractures.
The main principle of OMT for mechanical disorders of the foot is to restore normal healthy function. Proper diagnosis of the mechanical nature of the disorder must be done and treatment through specific manipulative procedures applied to the foot (Beal, 1951).

Bolga & Malone (2004) report that pronation does not necessarily lead to lower extremity problems. They write that Cornwall found that difficulties result when the joints of the foot are in constant function beyond its end range. This can lead to ligament stress and muscle lengthening. These structures are easily fatigued and work much harder in an attempt to control excess foot motion.
Sneyers et al. (1995) make us aware that proper foot alignment plays significant role in good shock absorption which begins at the initial contact point and continues throughout the push-off phase of gait.

Flat foot, pes planus and pes plantarvalgus are synonymously used to describe a flat foot. Flat foot can be a complex disorder, with many symptoms and degrees of deformities. There are many types of flat foot, but all have a common characteristic of having partial or complete loss of the medial longitudinal arch. Flexible flat foot is one of the most common types of flat foot. The term “flexible” refers to the flat position of the
foot when weight bearing, then the arch springs back when weight is removed. It usually occurs in both feet and increases throughout adulthood. As the bony prominences are becoming more obvious, the soft tissues of the arch stretch or tear and can become inflamed leading to plantar fasciitis or other foot dysfunctions (www.FootPhysicians.com, 2005).

Therefore people with flexible flat feet can often exhibit the following symptoms:

- Heel, arch, ankle, and knee pain
- Poor proprioreception
- Shin splints
- Fatigue and weak muscles/legs
- Anterior cruciate ligament injury
- Metatarsal stress fracture


Over the last century, health care practitioners have been developing numerous methods to assess the subtalar joint neutral position. Elveru et al. (1988) found that the subtalar joint neutral position is the position in which the foot is neither pronated nor supinated. That neutral position of the subtalar joint serves as a point of reference for other lower extremity measurements. The American Academy of Orthopaedic Surgeons
manual states that the subtalar joint’s neutral position is where the longitudinal midline of
the leg and heel are parallel. He says this method is clinically not useful, because it does
not take into consideration anatomical differences between the sizes of patients’ feet
(Elveru et al., 1988).

According to Elveru et al. (1988) the subtalar joint neutral position should have
following be characteristic

Their method must meet the following conditions:

1. If the Patient is prone, the forefoot is then passively pronated and the ankle
taken into dorsiflexion until soft end-field is felt.

2. The talar head cannot be palpated and is extending equally at the medial
and lateral borders of the talonavicular joint.

They indicated that this method has a logical construct and is producing a good
intratested reliability and has good clinical validity and reproducibility.

Another measurement used as an assessment test is the navicular drop test, which
was developed by Brody (1982) to measure foot pronation in runners. The measurement
of the navicular drop can be defined as the distance between the navicular tuberosity to
the final weight bearing position of the navicular in a relaxed stance. This test can be
considered a composite measure of pronation because the rear foot and forefoot
abnormalities can affect it. To document reliable data from the navicular drop test a small
ruler or card that is marked can be utilized (Menz, 1998).
Mueller, Host & Norton (1993) used Brody’s (1982) method to estimate the amount of pronation in a patient’s foot during their research. In their summary they state that a navicular drop greater than 10 mm is considered abnormal, and may contribute to foot pathology. Though measurements may vary if smaller sizes of feet are evaluated then a smaller navicular drop is considered valid.

Dahle, Mueller, Delitto & Diamond (1991) report that when feet do not function properly, everything they support is in danger of working harder. Therefore a foot that overpronates and has a faulty foot alignment may cause pain in other parts of the body, i.e., if the foot is overpronated, the leg, the knee and the back will not function properly; it will produce disturbances and the poor function of all the structures along the kinetic chain.

Kirby (2000) points out that an overpronated subtalar joint will not provide sufficient shock absorption to dissipate the ground reaction forces and also the gravity forces. Inadequate subtalar joint pronation during heel strike can lead to injuries and dysfunctions in the lower extremities.

Dahle et al. (1991) list the following criteria, which would classify the foot as excessively pronated. The foot has to present with three mandatory criteria (items 1-3) and two elective criteria (items 4-5).

1. The calcaneus must be everted.

2. A medial soft tissue bulge must be present around the talonavicular joint.
3. The medial longitudinal arch height must be low.

4. The forefoot must be abducted in respect to the rearfoot at the tarsal joint.

5. The lower extremity must be in excessive internal rotation.

He reports that proper biomechanics and alignment of the foot are dependent on the integrity of the ligaments and the collective work of the muscles.

Kapandji (1987) points out that the progress and eventual collapse of the plantar vault is due to the weakness of the muscles and the ligaments, he lists the peroneus longus and tibialis posterior as the main contributors in the process of the foot becoming flat.
Figure 8  The effect of pronation on lower extremities and the foot.
(Pratt, 1951, p. 113)
OSTEOPATHIC JUSTIFICATION

3.3 GAIT ANALYSIS OVERVIEW

Direct evidence now is available that lesion free joint mobility and correct muscle recruitment force increase walking activity. Proper shock absorption and alignment are an important element of an efficient gait. Ridged or lax joint motion and altered muscle force may be one of the contributors in the increase of ground reaction forces and lead to foot and lower leg related problems (Bogey, 2009).

Bolga et al. (2004) point to the functions of the foot as: propulsion, adaptation to uneven terrain, shock absorption and support of the body. During walking, many forces are stressing the medial longitudinal arch and without proper mechanisms that control the fascia of the foot we could not walk in efficient manner. The body weight in the static foot is equally divided between the heel and metatarsals. The metatarsals have six weight bearing positions, the two seasamoid and the heads of metatarsals 2-5.

During relaxed standing the foot is splayed and there is a tendency for the foot to rest in a pronated position. It is the counteracted action by the upward rotation of the first cuniform and first metatarsal, as a result of the pressure on the ground, which allows the foot to stay in plantigrade state. When the foot starts to move forward the weight moves to the outside of the foot with the help of the muscles and ligamentous recruitments.

In the process of walking the heel contacts the ground first, then the body’s weight moves forward on the outer aspect of the foot around the head of fifth metatarsal.
It then continues across the ball of the foot towards the head of the first metatarsal. That is the final step when the foot pushes off causing the forward spring of the leg. The main locations of motion in the foot are the following articulations: the talo-navicular, the calcaneo-cuboid, and the talo-calcanean. These joints are concerned with inversion and pronation motions (Beal, 1951).

![Figure 9](image.png)

**Figure 9**  Weight distribution during walking. (Beal, 1951, p. 99)

Michaud (1997) reports that a single stride cycle lasts approximately 1 second and it is divided into stance phase and swing phase, which normally occupy 62% and 38% of the gait respectively.
Stance phase is further divided into the following major events:

- Contact phase - begins at heel strike and ends at full forefoot load (FFL)
- Midstance phase - begins at FFL and ends at the heel lift

Propulsion phase - time from heel off to toe off Swing phase consists of:

- Initial swing
- Mid-swing
- Terminal swing

The primary function of the foot and ankle during swing phase is to reach enough dorsiflexion to clear the forefoot off the ground.
The Orthotic Group development team (2007) found that when the subtalar joint returns to its neutral position at about 50 to 55% of stance phase, the midtarsal joint is able to lock up the forefoot into a rigid lever that can be effectively used for the propulsive period. The ideal timing for midtarsal locking is between 70 to 80% of the stance phase.

Michaud (1997) reports about the major joint events that occur in the human body during a single gait cycle.

- Hip joint flexes and extends once per cycle and its maximum flexion occurs in swing phase and, its maximum extension is reached before the end of the stance phase.

- Knee joints show two flexion and extension peaks during each cycle.
• Ankle joints are neutral at heel strike and then the plantar flexes to bring the forefoot to the ground.

• During the swing phase the ankle moves back into dorsiflexion and stays there until the forefoot clears the ground. The neutral position is then kept until another heel strikes.

Based on Reid’s (2009) paper regarding gait analysis it is evident that foot pronation should be viewed as a whole body movement, since it affects muscles and structures located not only in the foot area. The function of the foot and lower extremities can be described as a chain reaction that occurs along the lateral kinetic chain. The kinetic chain operates as an independent operation of muscles, fascia, nervous system and joints.

Figure 11  Open kinetic chain motion of subtalar joint. B - supination, A – pronation. There is no foot contact with the ground.  
(McPoil et al., 1985, p. 70)
Figure 12  Closed kinetic chain motion of subtalar joint. B – supination A- pronation. The line under the foot indicates that the foot is in contact with the ground. (McPoil et al., 1985, p. 70)

According to Reid (2009) these components of the musculoskeletal system must work together to allow for the proper movement motion at the foot to occur. Imbalance or deficiency in one of these systems might result in a faulty recruitment pattern and increased demand on other muscles. Movement is not a singular event that occurs in one cardinal body plane. It is quite a complex undertaking where synergists, stabilizers and antagonists all work together to achieve the desired effect. When the foot pronates it is dominated by deceleration or muscular force reduction activities that come from the following muscles: gluteus medius, gluteus maximus, vastus lateralis, biceps femoris, gastrocnemius, peroneus longus, soleus, and Achilles tendon. Supination is dominated by an acceleration or muscular force provided through these muscles: tensor fascia latae, rectus femoris, vastus lateralis, iliotibial band, tibialis anterior and extensor digitorum longus. Deceleration of muscle function during pronation is termed eccentric muscle function or lengthening muscle contraction.

On the other hand, during supination concentric muscle function or shortening of the muscle takes place. There is a time when eccentric and concentric muscle functions
occur at the same time during gait cycle. Deceleration may occur at one joint or joints i.e., when the foot meets the ground during walking, and simultaneously a joint will produce acceleration of movement, towards supination, to create a strong base to push forward. Once the leg is completing pushing off on another side, the propulsive leg needs to stiffen up to accelerate leg and body movement to continue to move forwards. This chain of muscular events reaches all the way to the upper body. A classic example of injury in poorly controlled foot pronation is Achilles tendinitis. This injury occurs when someone suddenly increases his or her level of training, or has flat/overpronated feet. The main cause of this injury is associated with the gluteus maximus if an athlete is running or the gluteus medius if walking. The functions of the gluteals are evident, during heel strike and into full forefoot load:

- Decelerate hip flexion and internal rotation

- Decelerate tibial internal rotation via its insertion into ilio tibial band

- Concentrically accelerates hip extension and external rotation to extend the hip, knee and ankle

Weak gluteus maximus or medius muscles are quite often prevalent in office workers and truck drivers. These muscles cannot control lower extremity pronation effectively. This creates additional tension on the calf muscle. The gastrocnemius and soleus both eccentrically control pronation at the foot and ankle. These muscles become overloaded and are not able to control their motion. This situation causes the lower extremity to stay in an overpronated position too long, which stresses and overloads the
Achilles tendon leading to inflammation. Insufficient force output by the muscles in the flexible flat foot may be the result of disuse, trauma, disease, or impaired motor function. Proper muscle force is necessary in the movement of the ankle/foot complex (Kapandji, 1987; Reid, 2009).

There are a number of muscles that are responsible for proper foot movement during walking. Most of these muscles have very long tendons that attach into the foot and play a role in generating intrinsic stresses; they are located in the lower leg and their action is the movement of plantarflexion and dorsiflexion. The main muscles that are associated with the foot movement are: tibialis anterior, extensor hallusis longus, extensor digitorum longus, triceps surae, tibialis posterior, flexor hallucis longus, flexor digitorum longus, peroneus longus and brevis, and the abductor hallucis (Gefen et al., 2000).

Michaud (1997) says, that in order for the body to minimize muscular strain during gait shock absorption, surface adaptation, and forward acceleration of the center of mass must take place. The body also must possess the following determinants for a smooth and coordinated gait:
Pelvic rotation, pelvic tilt, knee flexion and extension during stance phase, hip, knee, and ankle interaction, lateral pelvic displacement and lateral and vertical center of mass displacement (Michaud, 1997).

Figure 13  Pronation and the kinetic chain.
(Reid, 2009, p. 11)
OSTEOPATHIC JUSTIFICATION

3.4 EMBRYOLOGY OF THE FOOT

Bernhardt (1988) reports that the embryological development of the human body changes in complexity from lower to higher. The prenatal period is divided into two stages of development, embryonic and second fetal. The embryonic phase takes 8 weeks of development, and the fetal from week 9 to week 38. The embryonic phase occurs with a very fast speed of development. During this time all the main external and internal structures and organs are forming and in the fetal phase only further growth and tissue differentiation takes place. The foot and ankle are forming during week 3 of embryonic development (Bareither, 1995).

Sadler (2004) noted that the third week of embryonic life is characterized by the gastrulation process; it is the time when the 3 germ layers (ectoderm, mesoderm and endoderm) are formed. In the further development these three germ layers will give rise to specific tissues and organs. The ectoderm layer forms the foundation for the organs and systems that are responsible for the outside functions of our body. These systems are: central nervous system, peripheral nervous system, and sensory epithelium of ear, nose, eye, skin, hair, nails, pituitary, mammary, and sweat glands, and the enamel of teeth. The mesodermal germ layer consists of three sublayers: paraxial, intermediate and lateral. The paraxial mesoderm forms somitomeres and the beginning to the mesenchyme of the head and differentiates into somites in occipital and caudal segments. Somites give rise to myotomes, sclerotomes and dermatomes, which are the supporting tissue of the body.
Bareither (1995) reports that day 19 is the beginning of the central nervous system. During days 23-25 of the embryo life, the formation and closure of the anterior neuropore and the formation of the wolffian ridge occurs; it is a thickening along the ventral margin of the embryo between the fourth and twenty-sixth spinal segments. In the next phase of development, the upper and lower limbs will arise from the wolffian ridge.

The upper limb buds are present a couple of days sooner than the lower limb buds. The lower limb buds become visible as the elevations of the ventrolateral body wall during the fourth week of embryo life (Bernhardt, 1988).

The lower limb buds form around day 28 on the ventrolateral aspect of the embryo and opposite to the first lumbar to the first sacral somites and spinal nerves. The muscle of the lower limb is of somitic mesoderm origin and the tendons and chondrogenic tissues are derived from somatic mesoderm. During day 32 the blood vessels are present in the lower limb buds, the main vessel now, the axial artery branches into two and forms the irregular sinusoidal plexus. Blood vessels appear prior to nerves in embryo development of the lower limb. Lower limb buds lengthen as the process of proliferation of the epical ectoderm takes place. Due to blood supply, bony ossification occurs at this time, beginning first with the calcaneus, navicular, cuboid, cuniforms, metatarsals and phalanges.

An embryo’s lower limb buds differentiate into thigh, leg and foot region by day 37. These three parts are located perpendicular to the trunk. The limb buds flatten to form handplates and footplates. During this time the lumbosacral plexus are being formed and
four major nerves merge distally to innervate the lower limb. The axial artery, after it passes the tibial nerve, creates a plexus called the plantar rete (Bareither, 1995).

Bernhardt (1988) contributed to this subject by reporting that the foot develops first in supinated position and it changes its position as fetal development continues. Around day 44 of embryo life the digital rays are visible in the footplate but the digits are still in a mitten-like structure. Toes are formed around day 47 of embryo life. The lower leg muscles, the soleus and the gastrocnemius are becoming more distinct and visible. The lower limb buds rotate 90 degrees around their long axis, but in the opposite direction to each other; this takes place in the 7th week. The limb buds are facing each other and the femur is in an abducted position, with toes touching each other. The transverse arch forms during this week and subtalar joints are being formed due to migration of the calcaneus from parallel to plantar position in relation with talus. Tibia and fibula meets the talus to form the ankle joint. The process of chondrification of tibia and other bones begins at this time. During week 12-26, the external hip rotators and hamstring muscles start to contract, bringing the lower limbs into a folded position. At the start of week 16 the feet cross at the ankles and the toes are not touching. Feet still stay in an inverted position until the 7th month but they start to change from being extremely inverted to being less inverted. The obliquity of the neck of the talus decreases from a range of 35-75 degrees in the fetus to 12-32 degrees in an adult, reducing forefoot varus. It is very common to see 5 degrees of forefoot varus at birth and as much as 22 degrees of calcaneus varus in relation to tibia (Bernhardt, 1988).
According to Bernhardt (1988) during postnatal development, the process of calcaneal correction to assume more perpendicular position continues. Usually calcaneus assumes 3 degrees of varus or perpendicular position during maturity. Ossification occurs at a slow pace in the feet; the initial ossification takes place in the phalanges and metatarsals during the embryo’s week 9, and then between weeks 20-24. The calcaneus ossifies first as part of the tarsal bone at around the 5th/6th month of fetal life, followed by the talus during the 8th month. All the other ossification centers in the tarsal area appear after birth during week 3 for the cuboid, 4-20 months for the lateral cuneiforms, 2 years for the medial cuneiform, 3 years for middle cuneiform, and 2-5 years of age for the navicular. The newborn foot is very flexible; it has normal plantar flexion and as much as 45 degrees of dorsiflexion, which is related to prenatal position. The adduction of the forefoot is greater than abduction, it decreases with maturation, so that the first metatarsal adducts relative to the others. Foot length at birth is 7 to 10 cm. The width of the foot at birth is one-half its lengths and one-third its length in the adult. The foot grows proportionally to the whole body, not to the lower extremities.

Bernhardt (1988) also looked at the final ossification process in the ankle-foot complex, which takes place later than most of the other bones in the human body. This phase allows for prolonged growth and in some cases foot deformities. The adult foot has well-defined angular relationships. The axis of the talocrural joint runs diagonal, down and lateral to correspond to the lateral rotation of the tibia. Load can have an effect on tissue growth and maturation. The tissue responds to load and depends on the degree of change. A light increase of load might have no effect or may only slow the growth of bone tissue, while large load increases may result in the halt of endochondral growth or
cause endochondral reabsorption. Increased load increases bone density and thickens and strengthens the collagen fibers but damages the cartilage.

Rothbart (2002) makes us aware of the normal ontogenetic development within the lower limb bud, and the two possible aberrations during fetal developments that can occur in the developing footplate, which are:

- Clubfoot deformity - when calcaneus head fails to unwind and,

- Rothbart foot structure - when talar head fails to unwind.
OSTEOPATHIC JUSTIFICATION

3.5 OSTEOPATHIC PRINCIPLES IN RELATION TO THE HYPOTHESIS

It is quite evident that all the osteopathic tenets must be properly considered and applied during the study by the researching Osteopath, it also needs to be stressed that every part of the body is in communication with all other parts and that any small change in the lower extremities and the foot can produce adaptive changes in other body parts; therefore the entire body is affected as a result of these changes. Because of this, it is up to the Osteopath to properly evaluate, recognize and address these ailments during OM procedure treatment.

According to Michael Paterson, PH.D, OMT and OM procedures research design types are valuable and valid. Both types are necessary and essential and must be recognized and appreciated (Patterson, 2001). In another paper Dr. Patterson reiterates one of the osteopathic principles that research on the effectiveness and mechanism of osteopathic manipulation must recognize the importance and centrality of the patient in achieving healing (Patterson, 2007).

The foot plays an important role in human movement, and it is a strategic connection between the top of the human body and the ground and is an area were the GRF begin and if not absorbed by the soft tissues and joints can affect structures at a distance; therefore attention needs to be given during osteopathic assessment and treatment (Gefen et al., 2000).
Sneyers (1995) reveals that good alignment of the foot is a vital element for adequate shock absorption and pressure distribution during the gait cycle. Osteopaths on a daily basis in their clinics assess the proper alignment of joints and their mobility and vitality. It is necessary to include the foot and look into its biomechanics in every OMT because of its importance.

Korr (1987) relates the first osteopathic principle “the body is a unit” to the notion that every part of the body is in tight arrangement within each other, and a disturbance to that set up produces adaptation within the area and in the body as a whole.

_The person is the environment in which parts exist and operate. Every quality and circumstance of the person’s life influences the quality of function of every cell, tissue, organ, and system._

(Korr, 1987, pp. 514/106)

The body consists of many parts, which are interconnected in function and structure. The musculoskeletal system, through its fascial and muscular components, is acting together to minimize the stress resulting from gravity, and the vertical and horizontal reacting ground forces (RGF) the foot receives when it meets the ground.

The flexible flat foot is altered by its environment due to the changes that occur in muscle function and its position within the soft tissues and joints. Since the foot is the foundation of our body, any alteration in the structure or function of any one area of the foot influences the integrated function of the network as a whole (Sneyers et al, 1995).
The largest of all body systems is the musculoskeletal system, which is also metabolically the most demanding system. In order to meet its optimal requirements, it must be accommodative in its behavior that varies from movement to movement, according to the environment and circumstances. This behavior is the constant changing patterns of muscular contractions and relaxation that occur in a flexible flat foot. The musculoskeletal system is therefore the major source of perturbation and of constant challenge to the homeostatic mechanisms of the body. The musculoskeletal system has a great demand for energy consumption; its continued demands upon other systems for fuel, cellular reproduction, and waste and heat removal are high and require a large amount of the body’s resources. Somatic dysfunction can often develop in the foot and lower extremities, partly due to the compressive forces of gravity. Somatic dysfunction concerning the feet may impede function of other systems and areas. It is therefore necessary to decrease the negative impact that this dysfunction has on quality or pathology of the foot and other organs and systems (Korr, 1987).

The musculoskeletal system, including muscles of the feet and lower extremities, receives the greatest number of efferent impulses from the central nervous system coming via the ventral root of the spinal cord and then feeding into the muscles that perform the CNS motor processes. The muscular system is also responsible for the sensory input that comes from many reporting (myofascial and articular components) stations to the spinal cord via the dorsal root. This sensorial input is important to the moment-to-moment control and fine adjustment of posture and foot dynamics. Proprioreceptors are sensory end organs located in the musculoskeletal system including the foot and lower extremities. These end organs are able to signal physical change in the musculoskeletal
system related to muscle length, tension, pressure, joint motion and position. The Ruffini endings located around joint capsules and ligaments report joint position and velocity of motion as well as force. The golgi tendon located in the musculotendinous junction receptors perceives tension. Muscle spindles located in the muscle belly record changes in length and stretch. Muscle spindles have 2 types of fibers: intrafusal and extrafusal. The intrafusal fibers are innervated by gamma motor fibers originating in the ventral horn. The extrafusal fibers are innervated by alpha motor neurons and are small in size. Dr. Korr proposes that in the lesioned area the gain in the spindles has been turned up on one or more of the muscles. According to the hypothesis, the OM procedures proposed in this paper aim to stretch or realign joint or myofascial components, which contributes to a more normal muscle spindle-gain setting that results in the relaxation of the structures (Korr, 1975).

The musculoskeletal system in the feet receives rich efferent and afferent input via the central nervous system and through the large vascular and lymphatic system assures the exchange and delivery of blood into the foot. Its key role is to maintain health and proper function. Proper flow is important for the foot, supplying nutrients for cellular respiration and removing metabolic debris. Therefore, it is important to rely on another osteopathic principle: “the role of the artery is absolute.” This statement leads me to the rotational forces and faulty foot alignment that is present in a flexible flat foot and impedes the flow of blood and lymph, leaving the area at risk for compensations and adaptations which alter the foot function and pressure distribution (Korr, 1991).
As Korr continues in “Proprioreceptors and somatic dysfunction,” the muscular system receives the greatest number of impulses from the central nervous system coming through the ventral root of the spinal cord and then feeding into the foot muscles that perform the motor processes. The muscular system is also responsible for the sensory input that comes to the spinal cord via the dorsal root. This sensorial input comes from many places in the myofascial and articular components of the foot, which are very important to the moment-to-moment control and fine adjustment of posture and dynamics (Korr, 1975).

The vascular and lymphatic system assures the exchange and delivery of blood into the foot and lower extremities. Its aim is to maintain health through the nourishment of foot tissues and allowing for proper function of its components. Proper flow is important for the foot and supplies nutrients for cellular respiration and removing metabolic debris. Therefore it is important to speak about another osteopathic principle “the role of the artery is absolute.” This statement leads the author to the rotational forces in faulty foot alignment seen in a flexible flat foot, where the calcaneus, talus, navicular and cuneiforms are frequently seen in lesioned positions. This environment results in blood and lymph flow restriction, since compensations and adaptations will alter the foot function and pressure distribution.

The endocrine system is interconnected through its hormonal canals that can act reactively to many of the stressors that someone with flat feet experiences. This is prevalent and results when a flat foot occurs and the vascular and lymph vessels become overstretched medially and compressed laterally. In normal circumstances this system is
able to speed responsiveness to alter the length and flexibility of the tissues and articulations in response to function, environment and other circumstances (DiGiovanna & Schiowitz, 1997).
CHAPTER FOUR: METHODOLOGY
METHODOLOGY

4.1 RESEARCH DESIGN

This research is a two-phase quantitative within-subject design study divided into controlled and experimental phases, conducted in a private clinic. It took the researching osteopath 7 months to complete the entire research study. All 34 research participants were assessed for the somatic dysfunction “flexible flat foot” by the investigating researcher using Brody’s navicular drop test. Brody’s navicular drop test took into account the height of the medial longitudinal arch and the rear foot and forefoot relationship.

*Navicular drop is a clinical measure of foot pronation, defined as the change in height of the navicular bone when the foot moves from subtalar neutral to a relaxed weightbearing stance.*

*(Allen et al., 2000, p. 403)*

The deciding factor and general criteria for enrolment into this study was Brody’s navicular drop test where the drop in medial longitudinal arch had to be 10 mm or higher (Danoff, 2005, p. 1; Mueller et al., 1993, p. 199).

Mc Poil, Cornwall, Medoff, Vicenzino, Forsberg & Hilts’s (2008) research reveals that the navicular drop test is widely used as a clinical method and might be the most valid and reliable measurement available to assess the degree of foot pronation available to clinicians today.
Danoff (2005) reports that Mueller et al. (1993) and Allen et al. (2000) respectively, suggest that the navicular drop test measurement has good intrarater and interrater reliability and therefore can be used as a standard tool to evaluate foot pronation.

The objective of this study was to identify the effectiveness of the proposed OM procedures treatment on a population with flexible flat feet and to investigate the changes on plantar pressure distribution within those individuals. The participants volunteered for five visits, each visit was 30 minutes in length, with the exception of 5th visit which was only five minutes long.

It took each individual 12 weeks to complete the two phase quantitative within-subject design study. The controlled phase was six weeks long and the experimental phase was six weeks long. This two phase quantitative design study was advocated to evaluate the benefits of OM procedures on improving the distribution of plantar pressure in individuals diagnosed with “flexible flat foot” pronation. Pre-test and post-test dynamic foot scans measurements were performed using The Orthotic Group pressure platform (Appendix D).

A total of three dynamic foot scans were collected and the data was analyzed at the end of the study by the osteopath a statistician. Other collected data included the navicular drop test used as a general screening for flat feet. All collected data was used at the end of the study for statistical analysis.
Data from barefoot contact with the pressure platform was collected by using the TOG pressure platform three times during the entire study (during visit 1, 2 and 5). Information about plantar pressure parameters (the impulse percentage value) was collected from each foot using TOG pressure platform system. This research study collected only the impulse percentage plantar pressure values from 4 specific foot landmarks which are commonly examined during assessment of overpronated or flat footed individuals. The impulse percentage provides values that indicate which areas of the foot experience the most amount of pressure over a given time. A common indication for flat foot in the forefoot area is increased impulse percentage values under 1st and 2nd metatarsals, and for the heel area increased impulse percentage values under the medial heel. These four collected and later analyzed landmark levels were: medial heel, lateral heel, and 1st and 2nd metatarsals. The data from these four landmarks was blinded since the researching osteopath’s secretary was collecting it. She was instructed in the proper use of the TOG gait scan equipment and performed all three foot scan measurements on the participating subjects.

Subjects were familiar with the dynamic TOG gait scan procedures, since they were instructed to do pre-trials to establish a starting point to ensure that the foot would land on the platform in the center.

The dynamic scan was recorded individually for each foot. The bare footed patient faced the TOG pressure plate and took exactly three steps before stepping onto the pressure plate and three steps after it. They walked with a loose natural stride and stepped
as close to the center of the plate as possible. Participants were given a chance to take another scan if the original scan was not properly done.

This type of study allows a single osteopath to look into the causes of a somatic dysfunction (flexible flat foot) and its origin, and to affect the lower extremity and feet during the choice of appropriate treatment, keeping in mind that the patient is the center of healing and that element is what is promoted during the osteopathic clinical research.

During this study, this researcher abided by the current human subject regulations for research design studies. The main ethical considerations during this research study were: subjects’ safety, confidentiality, informed consent and the absence of monetary incentive.

The lay-out of the visits was as following:

The quantitative research began with the control phase, during which no OM procedure treatment or any other intervention was administered to the subjects. This phase was six weeks long.

Visit #1 - Start of Control phase - 6 weeks long.

Order of events for Visit #1- All volunteered subjects signed the written consent form (Appendix A) and the confidential case history form (Appendix B). Brody’s navicular drop test to measure the degree of pronation (Appendix H) was performed by the researching osteopath and after the screening assessment protocol (Appendix C) was completed. All forms used in the study were previously approved by the Canadian
College of Osteopathy. Also foot scan #1 was taken during this session using The Orthotic Group pressure platform to create a baseline for plantar pressure distribution.

This within-study design type of research is an example of an easy and inexpensive method that does not require a large number of participating subjects and may be used as a research design by a single osteopath (Keating, Seville, Meeker, Lonczak, Quitoriano, Dydo & Leibel, 1985).

**Visit #2** - End of control phase and beginning of the experimental phase - six weeks long. During this phase participants received 3 – 30 minute treatments, which consisted of 14 prearranged OM procedures given in the same order to both feet of each participant. The order of events for this visit was as following: Dynamic foot scan #2 was taken using TOG pressure platform and the first OM procedures treatment performed. The data from the 2nd dynamic foot scan was collected and saved on the computer for statistical analysis and used when the study ended. All 34 participants received three proposed OM procedures treatments in total during this experimental phase.

**Visit #3** - two weeks interval from visit #2.

Subjects received OM procedure treatment #2.

**Visit #4** - Two weeks interval from visit #3.

Subjects received OM procedure treatment #3.
Visit # 5 - Two weeks interval from visit #4.

Subjects received 3rd dynamic foot scan. The data from the four proposed landmarks was collected and saved on the computer for statistical analysis at the end of the entire study.

4.2 SUBJECTS

A population of 34 participants, who were assessed with “flexible flat foot” somatic dysfunction, participated in the study. They had the following demographics: 16 males and 18 females between the ages of 30 and 50, mean age and (SD) 42.9 (4.8), the height - mean and (SD) 67, 3 inches, (3.2). The mean and (SD) value for weight 161.9 lbs (44.5).

Two participants dropped out due to their scheduling problems, leaving 34 subjects for analysis.

All subjects had to meet the inclusion and exclusion criteria in order to qualify into the study.

INCLUSION CRITERIA

- Age 30-50 years

- Male and female participants

- Individuals suffering from “flexible flat foot” pronation as determined by the assessment
• Written consent forms provided prior to study-related assessment or procedures

• Participants who wear any type of custom orthotics

• Subjects that previously have been seen by the researching Osteopath, or other Osteopaths

**EXCLUSION CRITERIA**

• Acute ankle sprain

• Facture or surgery to foot or lower extremities within the last year

• Balance and neuropathic problems, e.g. history of head injury, inner ear dysfunction

• Systemic conditions, i.e. rheumatoid arthritis, fibromyalgia, diabetes, neuropathies or other connective tissues conditions

• Anatomically shorter leg > than 1 cm

• Upper or lower motor neuron lesions

• Patients who are using antidepressant drugs

• Menopausal

• Previous occurrence of plantar warts
• Surgery of abdomen or lesser pelvic organs

• Must not receive any other type of manual treatment during the research study

• Artificial joints in lower extremities or hips

4.3 DEPENDENT VARIABLES

The dependent variables, also known as “outcome measures,” were used to evaluate whether the experimental OM procedures were effective and resulted in the improvement of plantar pressure distribution as stated in the hypothesis of this paper. This research study used a highly developed (and proven for validity and reliability) technology called the TOG gait scan, which is able to quantify the subtle pressure changes in the feet which are anticipated in the hypothesis (Ross et al., 2006 & 2007).

The TOG gait scan is able to track time and pressure throughout the step-cycle for 10 landmarks on the foot. These landmarks are: (T1) hallux, (T2-5) 2-5 toes, (M1) 1st metatarsal head, (M2) 2nd metatarsal head, (M3) 3rd metatarsal head, (M4) 4th metatarsal head, (M5) 5th metatarsal head, (MF) mid-foot, (HM) medial heel, (HL) lateral heel. The information obtained from the scan provides the percentage and time values that are placed on the graph and table (TOG, 2006).

This study compared the impulse percentage variable between both phases (controlled and experimental) as the only aspect of dynamic data to be analyzed by the statistician. This outcome variable was evaluated at 4 levels for each participant to
compare changes following both the control and treatment phases: (HM) medial heel, (HL) lateral heel, (M1) 1st metatarsal, and (M2) second metatarsal.

4.4 INDEPENDENT VARIABLES

The independent variables refer to the OM procedures used during the experimental phase of the study that influenced the plantar pressure distribution as proposed in the thesis. During the experimental phase of this study, 34 participants received 3 – 30 minute long osteopathic manipulative procedure treatments whereas during the control phase individuals did not receive any kind of treatment at all. It was also impossible to blind the study subjects to OM procedures treatment since all participants were familiar with osteopathic treatment.

The osteopathic manipulative procedures treatment used during the experimental phase consisted of: 14 prearranged osteopathic manipulative procedure techniques applied to each individual during visit # 2, 3 and 4 in the same order. Each foot always received exactly the same OM procedures treatment.

Although the proposed set up of treatment is not entirely consistent with the osteopathic principles of treatment, for experimental reasons this way of arrangement is deemed to be necessary to maintain a uniform treatment protocol. Fourteen prearranged OM procedure techniques were created as a means of treatment for improvement of the plantar pressure distribution within the study subjects who have flexible flat feet.

A sequence of OM procedures was developed to correct the structural lesions or restrictions that flexible foot has and to assist in the resumption of proper physiological
function. The study was concerned with the following elements: position, motion and vitality of the foot and lower leg. During the application of the OM procedures treatment every step was planned with relation to anatomical and physiological factors like the direction of the articular surface, ligamentous and muscle suppleness and the amount of thrust during manipulation. Throughout the application of the OM procedures treatment the researching osteopath asked himself the following questions:

1. Where was the lesion localized?
2. Where does the motion need to be introduced?
3. How can the position of the patient be used to the osteopath’s advantage?
4. How much force needs to be applied?

The correction of somatic dysfunctions, including structural lesion, led the Osteopathic profession into achieving greater numbers of recoveries in all kinds of diseases. This study therefore gives some insight into the treatment of flexible flat foot where chosen articulation can change the pressure distribution from incorrect to correct.

The researching osteopath was aware that there is a considerable difference between each patient in the presence or absence of the lesions he proposed to treat in this uniform approach by doing 14 OM procedures. If during the testing, which was done at the beginning of visit 2, 3 and 4, no lesion was identified, and the researching osteopath still administered the technique at any level by treating it more as a restriction. The less mobile area in the restriction concept was treated.
The methodology used during visits 2, 3 and 4 consisted of the application of 14 OM procedures techniques, given in exactly the following order and number to both feet.

During visit 2, 3 and 4 all 34 subjects that participated in experimental phase of this study were assessed for lesions or restriction in both feet before OM procedure was performed.

This succession of events took place during visit 2, 3 and 4. Only visit #2 had the component of the dynamic foot scan, component B was part of visit 2, 3 and 4.

A- Subjects were greeted and asked to remove their shoes and socks for dynamic foot scan #2. Patients walked bare foot exactly three steps before hitting the mat and three steps after. A dynamic foot scan for both feet was done. Method of taking the scan was blinded to the researched-osteopath since his secretary took this and all subsequent scans.

B- Subjects were asked to come to a treatment room and lie supine or prone on electric osteopathic table. The researching osteopath started to perform the 14 prearranged OM procedures, but before applying it a test of the joint or area of tissue was done for direction of lesion. If no lesion was present the most rigid/restricted joint or area was treated. Each of the 3 OM procedures treatments was 30 minutes long. Before the patient left the clinic the next visit was arranged.

The list of 14 OM procedures was as follows:

1. Myofascial interosseous membrane release (lower leg).
2. Proximal Tibio-fibular joint correction (Ant or Post).

3. Distal Tibio-fibula joint correction (Ant or Post).


5. Compaction/Decompaaction of Talocrural Joint.

6. Talocrural joint osteo-articular adjustment (Ant or Post).

7. Subtalar joint compaction/decompaction correction.

8. Talonavicular osteo-articular adjustment (superior or inferior glide).

9. Calcaneo-cuboid osteo-articular adjustment (superior or inferior glide).

10. Navicular osteo-articular adjustment (externally or internally rotated).

11. Cuboid osteo-articular (low or high).

12. PRM for naviculo-cuboid joint.

13. Cuniforms osteo-articular adjustment (superior or inferior glide).


All 14 OM procedures techniques used in the experimental phase and its full description are located in Appendix G.
CHAPTER FIVE: STATISTICAL ANALYSIS
STATISTICAL ANALYSIS

5.1 METHOD

Demographic information was summarized for the study sample including gender, age, height and weight. A one way repeated measures analysis of variance (ANOVA) was conducted for each of the 8 outcome measures [Impulse percentage for left foot: medial heel, lateral heel, metatarsal 1, metatarsal 2, and right foot: medial heel (mh), lateral heel (lh), metatarsal 1 (m1), metatarsal 2 (m2)] with “foot scan” (foot scan 1/foot scan 2/foot scan 3) as the factor. Post hoc t-testing using Holm’s method of p-value adjustment was used for pair-wise comparisons of GAIT score impulse percentage for the three foot scans when the corresponding ANOVA was found to be significant. Since 8 ANOVAs are required, the standard for statistical significance in any one of the analyses (ANOVA or post hoc multiple comparisons) is set at 0.05/8 = 0.00625.

5.2 RESULTS

34 subjects (18 females and 16 males) entered and completed the study. The average age of study participants was 42.9 years (standard deviation = 4.8 years). Demographic information from the sample is summarized in Table 1.

Navicular Drop test measurements are considered the best clinical method to screen for the degree of pronation. These tests were performed twice for both the left and right foot, in sitting and standing positions, and are described in mm in Table 2.
A summary of the gait measurements (impulse percentage) for the 8 tested landmarks (4 for the right foot and 4 for the left foot) are presented in Table 3, they were collected over 3 dynamic foot scans using TOG pressure platform.

Graphical representation of the mean impulse percentage (including standard deviation bars) through each foot scan at each location on each foot can be found in Figures 1.2.1 through 1.2.8.

Results from the 8 separate one-way repeated measures ANOVAs (four locations on each foot) on the gait measurements were as follows:

*Note: Differences between foot scan 1 and 2 indicate a change in impulse percentage during the control period. Differences between foot scan 2 and 3 indicate a change during the experimental period that included 3 OM procedure treatments given to 34 study subjects over a period of 6 weeks with 2 weeks interval between treatments.

There was no significant difference between foot scans (1, 2 or 3) for the medial heel (mh), lateral heel (lh) or second metatarsal (m2) scores on the left foot (P values for the main effect of the foot scan in the ANOVA models were 0.16, 0.17 and 0.85 for those sites respectively).

There was, however, a significant effect of the OM procedures treatment during the experimental phase of the research on the first metatarsal (m1) scores on the left foot (p=0.0013). Post hoc testing suggests a significantly lower mean score on the 3rd and final foot scan [mean (SD) = 19.8(7.6)] when compared to the second foot scan [mean
(SD) = 24.0(9.7)] indicating a change potentially due to the OM procedure treatment phase (P value=0.0011 - obtained by Holm’s method of p value adjustment for paired t tests). See Figure 1.2.3 for a graphical depiction of this change in GAIT score between foot scan 1, 2 and 3 at the first metatarsal on the left foot (Table 3).

There was no significant difference between foot scans (1, 2 or 3) for impulse percentage at the medial heel (mh), lateral heel (lh), first metatarsal (m1) or second metatarsal (m2) on the right foot (P values for the main effect of foot scans in the ANOVA models were 0.15, 0.15, 0.37 and 0.17 respectively).

Although statistical significance (p value < 0.00625) was not achieved when comparing the means of the GAIT measurement between the second and third foot scans of the first metatarsal on the right foot, it is evident that the mean score did, in fact, decrease between these two foot scans as it did in the left foot.

In summary variation in scores related to impulse percentage value and follow-ups for foot scans indicates that collected data for the right and the left foot didn’t create a very significant statistical effect. However, according to Table 2 in the statistical analysis chapter, positive changes exist in pressure distribution under measured landmarks and between follow-up foot scans, which benefits the patient. The right foot (four measured points – mh, lh, m, m2) scores were: P value for the main effect of foot scans were 0.15, 0.15, 0.37 and 0.17. Please refer to Table 2 - Gait Measurements; Mean (SD) to see these changes between foot scans and left foot verses right foot.
These differences between the second and third foot scan indicate a change due, potentially in part, to the 3 OM procedures treatments that participants received. Outside of this finding within the first metatarsal, no other variability between foot scans at any of the other landmarks were found that would have proposed P value and statistical significance. But there were some positive variability in impulse % between foot scans 2 and 3 at lateral heel on the left foot, and medial heel, metatarsal 1 & metatarsal 2 (Table 3).

According to the results of the statistical analysis, we rejected the null hypothesis that there would be no change in the m1 impulse of the left foot (Holm’s adjusted P value = 0.0011). The pressure measuring equipment was a self-calibrating device intended to deliver accurate measurement every time a foot scan was taken.

**Table 1.** Demographics - the mean and standard deviation (SD) of age, height and weight of the subjects

<table>
<thead>
<tr>
<th>34 Participants</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>42.9 (4.8)</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>67.3 (3.2)</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>161.9 (44.5)</td>
</tr>
</tbody>
</table>
Table 2. Summary of Navicular Drop (ND) measurements - taken twice for right and left foot to assess for degree of foot pronation in millimeters. Mean and standard deviation (SD).

<table>
<thead>
<tr>
<th></th>
<th>Time1</th>
<th>Time2</th>
<th>Mean value from both tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Foot ND Drop (mm)</td>
<td>11.1 (2.5)</td>
<td>11.4 (2.6)</td>
<td>11.25 mm</td>
</tr>
<tr>
<td>Light Foot ND Drop (mm)</td>
<td>11.8 (2.6)</td>
<td>11.7 (2.7)</td>
<td>11.75 mm</td>
</tr>
</tbody>
</table>
Table 3. Gait Measurements; Mean (SD - Standard Deviation) - Impulse % values for each tested landmark in left and right foot. Numbers for each landmark indicate fluctuation in percentage impulse values over the 3 foot scans.

<table>
<thead>
<tr>
<th>The 4 tested landmarks</th>
<th>Foot Scan #1 Baseline Impulse % and (SD)</th>
<th>Foot Scan #2 First Visit Impulse % and (SD)</th>
<th>FootScan #3 Fifth &amp; Final Visit Impulse % and (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left Foot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle heel (mh)</td>
<td>54.0 % (3.2)</td>
<td>51.6 % (8.7)</td>
<td>53.3 % (3.3)</td>
</tr>
<tr>
<td>Lateral heel (lh)</td>
<td>46.0 % (3.2)</td>
<td>46.9 % (2.8)</td>
<td>46.7 % (3.3)</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; metatarsal (m1)</td>
<td>20.8% (8.6)</td>
<td><strong>24.0 % (9.7)</strong>*</td>
<td><strong>19.8 % (7.6)</strong>*</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; metatarsal (m2)</td>
<td>26.2 % (3.6)</td>
<td>25.9 % (3.9)</td>
<td>26.2 % (3.8)</td>
</tr>
<tr>
<td><strong>Right Foot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle heel (mh)</td>
<td>53.5% (2.9)</td>
<td>52.8 % (3.3)</td>
<td>52.5 % (3.2)</td>
</tr>
<tr>
<td>Lateral heel (lh)</td>
<td>46.5 % (2.9)</td>
<td>47.2 % (3.3)</td>
<td>47.5 % (3.2)</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; metatarsal (m1)</td>
<td>20.4 % (7.6)</td>
<td>20.6 % (10.3)</td>
<td>18.7 % (9.1)</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; metatarsal (m2)</td>
<td>25.6 % (4.3)</td>
<td>25.2 % (4.4)</td>
<td>24.5 % (4.3)</td>
</tr>
</tbody>
</table>

*Results from post hoc t-testing using Holm’s method of p value adjustment indicate a significant difference between foot scan 2 and 3 at the first metatarsal on the left foot.
Graph 1.2.1  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on left medial heel (mh). Vertical axis represents the variations in the impulse % value. Horizontal axis represents the # of foot scans performed during the study.
Graph 1.2.2  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on left lateral heel (lh). Vertical axis represents the variations in the impulse % value - Horizontal axis represents - the # of foot scans performed during the study.
**Graph 1.2.3**  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on left first metatarsal (m1). Vertical axis represents the variations in the impulse % value - Horizontal axis represents the # of foot scans performed during the study.
Graph 1.2.4  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on left second metatarsal (m2) Vertical axis represents the variations in the impulse % value - Horizontal axis represents the # of foot scans performed during the study.
**Graph 1.2.5** Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on right medial heel (mh) Vertical axis represents the variations in the impulse% value - Horizontal axis represents the # of foot scans performed during the study.
Graph 1.2.6  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on right lateral heel (lh) Vertical axis represents the variations in the impulse% value - Horizontal axis represents the # of foot scans performed during the study.
Graph 1.2.7  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on right first metatarsal (m1) Vertical bar represents the variations in the impulse% value - Horizontal bar represents the # of foot scans performed during the study.
Graph 1.2.8  Mean plot with standard deviation (SD) bars for Gait measurements (impulse %) on right second metatarsal (m2) Vertical axis represents the variations in the impulse% value - Horizontal axis represents the # of foot scans performed during the study.
6  CHAPTER SIX: DISCUSSION
DISCUSSION

6.1 INTRODUCTION

This chapter discusses various aspects of the thesis in relation to the accumulated data. It also looks at how it relates to the data. The data and the hypothesis support the osteopathic justifications.

This study investigated the somatic dysfunction (flexible flat foot) and the changes that occurred in subjects in the experimental phase before and after an OM procedures treatment. It needs to be emphasized that postural changes related to flexible flat foot if not treated can lead to chronic degenerative changes in subjects.

6.2 SAMPLE SIZE AND CHARACTERISTICS

Thirty four volunteers were used in the study. All subjects in the study had a flexible flat foot and need to meet the inclusion and exclusion criteria as stated in the methodology chapter. It was also determined that it was not possible to blind all the 34 participants to an OMT sham-treatment during the controlled phase because the subjects were familiar with osteopathic treatments. Most of the subjects had has some form of osteopathic treatment in the past.

In this study a navicular drop (ND) test was used to screen participants for the degree of overpronation. Brody’s navicular drop test was used during this study as the only clinical measurement qualifying subjects to enroll because it has been previously reported by other authors to have good intratester reliability and to be effective in
classifying overpronation (Mueller et al., 1993; Danoff, 2005; Allen et al., 2000; McPoil et al., 2008).

As recommended by Menz (1998) and Danoff (2005) two measurements for each foot were taken as the proper choice for reliable and accurate data. The mean score for the navicular drop test during this study was as follows: Left foot- 11.75 millimeters, Right foot – 11.25 millimeters. This indicates that the mean value for the navicular drop test was higher in the left foot. This finding suggests that most participants had their left medial longitudinal arch slightly lower than the right foot.

The (ND) test takes into consideration the rear foot and forefoot relationships therefore it gives a realistic measure of the height variation of the medial longitudinal arch in tested participants,

McPoil, Cornwall, Medoff, Vicenzino, Forsberg & Hilts’ (2008) research reports that the navicular drop test is widely used as a clinical method and might be the most valid and reliable measurement available to assess the degree of foot pronation available to clinicians today.

This study also found that using a student ruler to measure navicular drop test values, as reported by Mueller et al. (1993) was a good clinical substitution to other expensive measuring equipment like the Metrecom.

The past literature evidence reports that the greatest movement in the subtalar joint occurs in the vertical antero-posterior direction and therefore can be
measured well using a student ruler. The advantage of using a Metrecom to measure navicular drop is that it can be measured on all three planes. Nevertheless the findings in this study are in agreement with” Mueller et al.” (1993) which stated that a simple ruler is able to give reliable results in navicular drop test measurements.

The use of the TOG pressure platform to take dynamic scans was easy and smooth due to its abilities to self calibrate.

6.3 OBJECTIVE OF STUDY

The primary objective of this study was to show improvement in the plantar pressure distribution in a population with flat feet. The second objective was to establish the connection between the proposed OM procedures and the improvement of the tested somatic dysfunction. Therefore, to address this somatic dysfunction, (flexible flat foot) the study used a specific sequence of OM manipulative procedures (total of 1) that were administered to left and right feet and the left and right lower legs. One of the intentions of this research study was to investigate whether the proposed hypothesis “Standard osteopathic manipulative treatment improves the distribution of plantar pressure in individuals assessed with flexible flat foot pronation by braining significance to the dynamic values of The Orthotic Group gait scan” could be proven through the planned research design and suggested local methodology.

Dr. Kelso (1988) states that the primary purpose of OMT research is to prove that the osteopathic palpatory diagnosis and manipulative treatment can add to person’s health and public well being.
The previous literature review confirms that very limited work has been done by the osteopathic and other related health professions on the subject of manipulative treatments and its effect on the plantar pressure distribution of flat feet. To date there has not yet been any osteopathic research performed on flat feet either locally or globally.

Anderson at el (2003) reports that a limited amount of research exists that investigated the effects of joint manipulation on lower extremities including the foot. Furthermore they report that those few studies that examined the effects of joint manipulation brought conflicting results.

The reason for limited literature availability on similar research topics is that the approach of osteopaths to treating somatic dysfunction is a global approach rather than local approach.

A local rather than global methodology was chosen in this research. This was done to show that in any profession where manipulative techniques are used it is important to show the results of local versus a global approach to treatment. This information can only add to the profession as a whole and encourage a stronger foundation from which to build our profession upon.

6.4 OVERALL ANALYSIS

The information obtained during this research proved in part the tested hypothesis that Osteopathic manipulative treatment improves the distribution of plantar pressure in individuals assessed with flexible flat foot pronation. This was proven by bringing significant changes to the dynamic values of the Orthotic Group gait scan.
Statistical analysis showed evidence of the efficacy of OM procedures on a flexible flat foot when comparing foot scan #2 and foot scan #3 (final foot scan). There was also a brief statistical comparison done between foot scan #1 and foot scan #2 for left and right foot which included four tested landmarks for each foot.

This chapter will look at the changes that took place in the pressure distribution measured by its mean impulse percentage value in the left and right foot and the possible reasons for these changes.

6.4.1 LEFT FOOT, FIRST METATARSAL, COMPARISON BETWEEN SCAN #1 AND SCAN #2

If the findings of the metatarsals 1 (m1) scores on the left foot are compared between foot scan #1 being 20.8 mean impulse % and (8.6) (SD) against the foot scan #2 being 24.0 mean impulse % and (9.7) (SD), then we can see the impulse % value increased during the second foot scan. It should be noted that during this controlled phase no OM procedures treatment was given.

6.4.2 LEFT FOOT, FIRST METATARSAL, COMPARISON BETWEEN SCAN #2 AND SCAN #3

The statistical analysis showed a significant effect of OM procedures treatments on the first metatarsal (m1) scores on the left foot (p=0.0013) during the experimental phase of the research. Post hoc testing suggests a significantly lower mean score on the final foot scan [mean impulse % and (SD) = 19.8 (7.6) when compared to the second foot scan (mean impulse % and (SD) = 24.0 (9.7)] indicating most likely that a change
occurred due to the 3 OM procedures treatments performed during the experimental phase (p value = 0.0011 obtained by Holm’s method of p value adjustment for paired t tests). Graph 1.2.3 shows a graphical depiction of this change in GAIT score between foot scan 1, 2 and 3 at the first metatarsal on the left foot.

The statistical significance of the M1 on the left foot has been reached due to the following reasons:

According to Jacob (2001) increased pressure has been noted under the 1st metatarsal and its tendons (tibialis posterior and peroneus longus muscles) in individuals with flexible flat foot. These individuals have more pressure under the M1 than the rest of the population with neutral medial longitudinal arches. The M1 is made to receive the greatest amount of pressure during the push phase of gait cycle when compared to metatarsals 2-5. This is due to its size, location and function. Flexible flat foot alters the biomechanics and can produce metatarsal stress fractures. Due to its location and function in the foot the M1 has an increased number of proprioceptors that are the sensory end organs located in muscles, tendons and ligaments of the dorsal and plantar aspect of the first metatarsal bone. This makes the M1 a unique bone in the foot.

Proprioceptive contribution in M1 comes from 10 muscles located in the lower leg (on dorsal aspect – direct contribution from extensor hallucis longus, and extensor hallucis brevis, and indirect contribution from dorsal interossei. On the plantar aspect – direct contribution comes from tibialis anterior and peroneus longus, and indirect contribution from tibialis posterior, flexor hallucis longus and brevis, adductor hallucis and adductor hallucis longus). These muscles insert directly to M1 or its neighbors.
There function is to signal about physical changes in the musculoskeletal tissues, therefore it is able to serve as the sensorial part of the foot which is also mobile and adaptive.

Areas of somatic dysfunction where adaptive changes occur tend to react in a positive way when OMT is used. An example of this is osteoarticular adjustments or myofascial techniques.

One of the OM procedures used during this research study was the Interosseous membrane release technique which was applied to the lower leg. This technique releases tension and improves neuro-vascular facilitation in the five extrinsic muscles of the foot (arising in the leg area) that insert on the plantar aspect of the foot. Primarily affected is the tibialis posterior muscle that sends some fibers of insertion onto the plantar surface of six of the seven tarsal bones together with the peroneus longus they are responsible for holding up the medial longitudinal arch. The interosseous membrane release technique affects the musculoskeletal system by releasing disturbances caused by increased ground reacting forces that act on flexible flat feet.

Other reasons for the significant change to M1 are due to corrections to the sensory input from the musculoskeletal system of the lower leg and foot.

OM techniques also improved the function of M1 and enabled it to reach statistical significance. These techniques included OA to the talonavicular joint to correct the inferior glide, OA to the navicular to correct the internal rotation, OA to the
cuneiforms to correct the inferior glide and the use of a lemniscates maneuver to integrate the metatarsals.

Another finding of the study was that the mean value of navicular drop test for both tests was lower for the left foot than the right. This would suggest that the side with the lower arch height tends to respond better to OM procedures.

Due to the statistical significance that resulted with the first metatarsal on the left foot, the null hypothesis that there would be no significant changes to the dynamic values of the TOG gait scan was rejected. This change occurred in the left and it was in the M1 percentage impulse (Holm’s adjusted P value = 0.0011).

6.4.3 LEFT FOOT, SECOND METATARSAL, COMPARING FOOT SCAN #1 AND SCAN #2

This section compares the findings between foot scan #1 and foot scan #2 for the second metatarsal on the left foot.

If the findings of the metatarsal 2 (m2) scores on the left foot are compared between foot scan #1 – mean impulse % 26.2 and (SD) 3.6 against foot scan #2 – mean impulse % 25.9 and (SD) 3.9; the findings show that the mean and (SD) increased.
6.4.4 LEFT FOOT, SECOND METATARSAL, COMPARING FOOT SCAN #2
AND SCAN #3

This section compares the finding between foot scan #2 and foot scan #3 for the
second metatarsal on the left foot.

This was the experimental phase of the study during which the OM procedures
treatment were administered. Findings through the statistical analysis showed no affect
between foot scan #2 and foot scan #3 on the second metatarsal (m2). The value of the
mean impulse % and (SD) increased during foot scan #3 – mean impulse % 2.6.2 and
(3.8); while compared with foot scan #2 – mean impulse % 25.9 and (3.9). OM
procedures treatment was not able to bring positive changes to the impulse % values for
(m2) on the left foot. A slight increase in impulse percentage score was noticed during
the final foot scan.

This may be due to the fact that the base of M2 receives one of the branches of
tibialis posterior which is responsible for plantar flexion and inversion of the foot.
Indirect insertions that may affect M2 on the middle phalanx are the flexor digitorum
brevis and the distal phalanx by flexor digitorum longus. The interosseous membrane
release did not have an effect on M2.
6.4.5 LEFT FOOT, MEDIAL HEEL, COMPARING FOOT SCAN #1 AND SCAN #2

This section will compare foot scan #1 against the foot scan #2 on the left foot for the medial heel (mh).

In comparing foot scan #1 with foot scan #2 it is found that scan 1 has a 54.0 mean impulse % and 3.2 (SD) versus foot scan #2 being 51.6 mean impulse % (8.7) (SD), one can see that the impulse % value is lower during the second foot scan. It must be noted that during this controlled phase no OM procedure treatment was given. The score represents a decrease in the impulse % during foot scan #2 regardless of the lack of intervention.

6.4.6 LEFT FOOT, MEDIAL HEEL, COMPARING FOOT SCAN #2 AND SCAN #3

This section will compare foot scan #2 against the foot scan #3 on the left foot for the medial heel (mh).

Findings through the statistical analysis showed no effect between foot scan #2 and foot scan #3 on the medial heel (mh). The value of the mean impulse % increased during foot scan #3 – mean impulse % 53.3 and (SD) 3.3 compared with foot scan #2 – mean impulse % 51.6 and (SD) 8.7. The possible lack of positive results of the MH and LH (as shown later) were due to the choice of local OM procedure treatment versus global, since the calcaneus receives direct contribution from three muscles of the lower leg. These muscles are the plantaris, soleus and gastrocnemius which ascend past the
knee. In order to affect pressure distribution the knee and pelvis need to be assessed and treated.

6.4.7 LEFT FOOT, LATERAL HEEL, COMPARING FOOT SCAN #1 AND SCAN #2

This section will compare the foot scan #1 against foot scan #2 on the left foot for the lateral heel (lh).

In comparing the findings of the (lh) scores of the left foot with foot scan #1 – 46.0 mean impulse % and 3.2 (SD) against foot scan #2 – 46.9 mean impulse % and (2.8) (SD) it is seen that the impulse % value is slightly higher in the second foot scan. This was during the controlled phase and no OM procedures treatment was given. The score represents a mild increase in the impulse % during foot scan #2 regardless of the lack of intervention.

6.4.8 LEFT FOOT, LATERAL HEEL, COMPARING FOOT SCAN #2 AND SCAN #3

This section will compare the foot scan # 2 against foot scan # 3 (final scan) on left foot for the lateral heel (lh).

Findings through the statistical analysis showed small effect between foot scan #2 and foot scan #3 on the lateral heel (lh). The value of the mean impulse % decreased during foot scan #3 – mean impulse % 46.7 and (SD) 3.3 compared with foot scan #2 –
mean impulse % 46.9 and (SD) 2.8. This indicates that OM procedure administered during experimental phase produced small effect by changing the plantar pressure distribution under the lateral heel on left foot.

6.4.9 RIGHT FOOT, FIRST METATARSAL, COMPARING FOOT SCAN #1 AND SCAN #2

This section will compare the foot scan #1 against foot scan #2 for the metatarsal 1 (m1) on the right foot.

Findings of the first metatarsal scores of the right foot are compared between foot scan #1 – 20.4 mean impulse % and (7.6) (SD) with foot scan #2 – 20.6 mean impulse % and (10.3) (SD) showed a small increase in impulse % value during the controlled phase.

6.4.10 RIGHT FOOT, FIRST METATARSAL, COMPARING FOOT SCAN #2 AND SCAN #3

This section will compare the foot scan #2 against foot scan #3 for the metatarsal 1 (m1) on the right foot.

When comparing the (m1) scores on the right foot with foot scan #2 – 20.6 mean impulse %, and (10.3) (SD) with foot scan #3 – 18.7 mean impulse % and (9.0) (SD) a moderate effect of OM procedures treatment can be seen. These findings were too small to be statistically significant.

A reason for not reaching statistical significance may be the fact that the right medial longitudinal arch was slightly higher, which according to the clinical findings
indicates that the lateral supportive structures, including ligaments and muscles held the medial longitudinal arch higher on the left side.

6.4.11 RIGHT FOOT, SECOND METATARSAL, COMPARING FOOT SCAN #1 AND SCAN #2

This section below represents a comparison of the findings between foot scan #1 and foot scan #2 for the second metatarsal (m2) on the right foot.

Findings through the statistical analysis showed a small decrease in impulse % and change in (SD) between foot scan #1 and foot scan #2 of the (m2). The value of the mean impulse % and (SD) decreased during foot scan #2 – mean impulse % 25.2 and (SD) – 4.3 when compared with foot scan #1 – mean impulse % 25.2 and (SD) at (4.4).

6.4.12 RIGHT FOOT, SECOND METATARSAL, COMPARING FOOT SCAN #2 AND SCAN #3

This section below compares the statistical analysis between foot scan #2 and foot scan #3 for the metatarsal 2 (m2) on the right foot.

Findings of the (m2) scores of the right foot are compared between foot scan #2 mean impulse % 25.2 and (SD) 4.4 against foot scan #3 – mean impulse % 24.5 and (SD) 4.3. Findings show a small affect of the OM procedures treatment on the mean and (SD). The impulse % and (SD) changed in a positive way to benefit the patient.
6.4.13 RIGHT FOOT, MEDIAL HEEL, COMPARING FOOT SCAN #1 AND SCAN #2

This section below represents a comparison of the findings between foot scan #1 and foot scan #2 for the lateral heel (lh) of the right foot.

Findings through the statistical analysis showed a small effect between foot scan #1 and foot scan #2 on the left heel. The value of the mean impulse % increased during foot scan #2 – mean impulse % 47.2 and (SD) 3.3 when compared with foot scan #1 – mean impulse % 46.5 and (SD) 2.9.

6.4.14 RIGHT FOOT, MEDIAL HEEL, COMPARING FOOT SCAN #2 AND SCAN #3

This section below represents a comparison of the findings between foot scan #2 and foot scan #3 for the lateral heel of the right foot.

In comparing the medial heel scores on the right foot between foot scan #2 – 52.8 mean impulse % and (3.3) (SD) with foot scan #3 – mean impulse % 52.5 and (3.2) (SD) a small effect of the OM procedures treatment can be seen, however because the variation in the impulse % and (SD) are so small and unable to reach the P value, it is not statistically significant.
6.4.15 RIGHT FOOT, LATERAL HEEL, COMPARING FOOT SCAN #1 AND SCAN #2

This section below represents a comparison of the findings between foot scan #1 and foot scan #2 for the lateral heel (lh) on the right foot.

Findings through the statistical analyses showed a small effect between foot scan #1 and foot scan #2 on the (lh). The value of the mean impulse % increased during foot scan #2 which finished the controlled phase of the research with mean impulse % 47.2 and (SD) 3.3; when compared with foot scan #1 – mean impulse % 46.5 and (SD) 2.9.

6.5.16 RIGHT FOOT, LATERAL HEEL, COMPARING FOOT SCAN #2 AND SCAN #3

This section will compare the results between foot scan #2 and foot scan #3 (the final foot scan) for the lateral heel (lh) on the right foot.

If the findings of the (lh) scores on the right foot are compared between foot scan # 2 – 47.2 - mean impulse % and (3.3) (SD) with foot scan #3 - mean impulse % 47.5 and (3.2) (SD), then a small increase in impulse percentage value be seen, which points that no improvement in pressure distribution was reached through the OM procedure treatment.
6.4.17 SUMMARY OF THE DATA DISCUSSION

In summary, the statistical analysis showed a significance of the OM procedures treatments on the first metatarsal (ml) scores on the left foot (p=0.0013) during the experimental phase of this research as proved through data collection during scan #2 and scan #3.

Other findings include a very small change in the impulse % on the lateral heel during the experimental phase as measured during foot scan #2 and scan #3. These were the only positive changes which occurred between foot scan #2 and scan #3 on the left foot.

Areas that improved on the right foot and decreased the impulse % plantar pressure were the medial heel, first metatarsal, and second metatarsal, however they did not reach statistical significance. When comparing the means of the GAIT measurement between the second and third foot scan of the above tested landmarks on the right foot, it can be seen that the mean score did decrease between these two visits. This also occurred on the left foot. A change in results between foot scans #2 and #3 showed that there were tendencies for the score values to change, therefore benefitting subjects in the study due to pressure reduction under the aforementioned landmarks.

The possible reasons for only M1 on the left foot showing a statistical significance and not any other landmarks are as follows:

- The order in which the treatments were given may not have been correct
- The number of OM procedures were insufficient
• The osteopathic student was not an expert in administering the techniques

• Before the experimental phase the subjects continued to wear the shoes that they had before the study. The subjects should have changed to new shoes, therefore not enabling an established wear pattern to influence the results.

Kapandji (1987) reveals that the collapse of the medial longitudinal arch is the result of weakness and insufficiency of peroneus longus and tibialis posterior. Both muscles are responsible for the support of the medial longitudinal arch and receive their innervations from the tibial nerve a branch of the sciatic nerve (peroneus longus muscle is innervated by peroneal nerve L5, S1) and (tibialis posterior is innervated by tibial nerve L4,5).

It is therefore important to clear any sacral, pelvic and lumbar lesions in these areas to influence proper nerve impulse passage and establish a longer holding pattern in altered changes at the foot level. It is quite predictable that disturbances at the lumbar or pelvic level would produce distorted sensorial input from the musculoskeletal system locally and caudally which would also affect the motor function of the plantar aspect of the foot resulting in muscular weakness of both muscles. These muscles also wind around the subtalar joint (which is the most important joint of the foot) and affect the function of the subtalar joint by bringing it closer to pronation.

A lack of OMT to the pelvis, sacrum and lumbar region would keep the impulse % value unchanged for M1 and M2 due to the fact that improper nerve impulse
facilitation would cause both muscles that support the arch to stay disengaged therefore producing increased pressure on those landmarks.

An interesting approach to treat pronated feet was used by Dr. Pratt (1951) who in his investigation suggested that to correct any condition it is first necessary to know the mechanism by which it was produced. He points at several areas which need to be addressed in the global OMT to create changes in the postural characteristics of those with flat feet:

- Lumbar spine – due to increased anterior curve
- Sacrum – tilted downward and forward
- Coccyx – tilted downward and forward
- Iliopsoas muscle – relaxes causing femur, tibia and foot to medially rotate.
- Knee – medial undergoes torsion and moves the knee into valgus position.
- Tibia and fibula rotates medially against the foot that is fixed when standing.

Poor supportive function of the peroneus longus and tibialis posterior muscles causes increased impulse % values of planter pressure under the (m1) and (m2) landmarks, thereby overloading the medial longitudinal arch and add to its flattening. These stresses change the axis of motion for the subtalar joint from within normal to beyond normal thereby making it more difficult to move and less sufficient to neutralize
GRF. The same scenario would apply to the midtarsal joint axes and the muscles that wrap around them and produce movement.

The findings in this study were in agreement with the mainstream research of Gefen et al. (2000) and Michaud (1997), who frequently found the following lesions: the talonavicular joint positioned low, calcaneo-cuboid joint positioned inferior, navicular bone positioned in external rotation and a low cuboid.

In looking at a local OM treatment approach versus a global OM treatment approach one may ask if the global approach might bring about a greater statistical significance. Osteopathy does not focus on one part of the body but on the entire patient, therefore a global approach to assessment and treatment of flexible flat foot would be a recommended and reasonable approach to treatment with a better outcome for the patient. One should address the uniqueness of every patient and that every patient influences the nature, site and clinical impact of their own somatic dysfunction. Korr (1986)
CHAPTER SEVEN: SELF CRITIQUE
7.1 SELF CRITIQUE

According to Patterson (2001) there is a “gold standard” for conducting a perfect clinical research study; it involves randomization of subjects, double blinding with a placebo-control element.

This research was a quantitative two-phase (controlled and experimental) within-subject design study. It was not possible to apply the same study design as that listed above, but it was possible for the researching osteopath to be blinded to the plantar pressure results, since the secretary knew how to take the measurements.

This section summarizes what went wrong during this experimental study.

PITFALLS

• The researching osteopath had very little experience with conducting proper research, the limitation in that area caused for a very difficult start-up. Proper investigation into literature and other means where information could have been retrieved was not very well known.

• There was difficulty with finding a statistician and thesis advisor which also caused some stressful moments.

• There were only 2 participants who dropped out, but since they were the “extra” subjects this study still had the suggested number of volunteers as recommended by the statistician.
- Writing and computer skills were not up to par with the CCO expected level and therefore, it was hard to carry on with the research steps.

- What now became clear is that a good literature review is necessary, not only to be able to find good articles but also to interpret the results, and to recognize the work of other researchers and to take their work into advisement. There were many variables that occurred during the course of this research study. The most important aspect that kept pulling me back was the inability to understand the concept of the research, not only the different types or designs but the general feeling in regards to it. In part, that came from a lack of extensive knowledge about the elements of the research and the subject chosen. The difference in being able to understand this research process came about after I received input from a variety of friends and business acquaintances who directed me along the path through helpful comments, support and interaction.

- This research study turned out to be a very long one that took lots of time and was relatively expensive.

Given the opportunity to do this research again the following elements could be changed, assuming this study would receive a study grant.

1. As general criteria for enrolment a comparison x-ray should be performed as mandatory, in a standing weight bearing position and in a sitting, non-weight bearing position. This test would give clear
evidence of flat foot/somatic dysfunction. This presented research did not follow that recommendation due to financial limitations.

2. A Metrecom should be used to measure the navicular drop instead of a student ruler. The Metrecom is able to give a more realistic measurement, and it has greater reliability than a student ruler. Also due to financial limitations this study could not use that testing tool.

3. An in-foot F-scan would give more reliable data since more than one step could be done for data collection. TOG pressure platform has its benefits which in shoe F-scan doesn’t have but for this study multiple foot scans would give more reliable information. This study used the Orthotic Group pressure platform as a dependent variable to measure the outcome. TOG equipment is also expensive but not as expensive as the proposed in foot F-scan.

4. Methodology could improve by adding other OM procedures techniques, for example: corrections for pelvic lesions and sacral torsions.

5. Statistical analysis should include time/percentage column, which gives information about the landmark start time/end time and total time and peak pressure. Having that extra data would give a more rounded picture of what is going on with the foot when it takes a step.
The section below discusses the benefits that the researcher gained during this research study.

During this study I, possibly like many others, experienced many challenges and frustrations. The recruitment phase was lengthy and time consuming, but after the subjects enrolled and all the preliminary testing performed things started to look much more promising. The researcher experienced no problems with the participants’ commitment to attending their scheduled appointments.

**BENEFITS**

- Although this research study was a lengthy one, during this time a substantial growth on many levels was noticed.

- Patience and proper motivation were the virtues that advanced this work to another level. Since all 34 participants of this study were healthy individuals and they were young, no soreness or injuries were reported during the study period.

- During this process the researching osteopath learned how to stay focused and connected to his peers, including the thesis advisor, the statistician and learned to receive guidance and constructive criticism, which is an element that allows for personal growth.

- A study like this brings wholeness, widens the horizon and makes us smarter in the area of research. This knowledge will benefit future patients during my
clinical work. The participants brought their support, patience and interest, as well as the human element of love.

- In spite of rather large group of participants (34), and their attendance of multiple required visits, these scheduled visits went well and were completed in a timely manner.

The effort and time dedicated to do this within-subject experimental research study will stay with me for a long time during my practice as an Osteopath. The research brought about an epiphany that the relationship between practitioner and patient is a partnership between both groups and everyone must be actively engaged in it to optimize the patient’s health. There is also a sense of perseverance and commitment which all adds to the osteopathic values. In summary, hard work and determination can lead to the completion of a research study, and hopefully in the end this study adds to the growing body of evidence seeking to prove that OMT has its place in patient care.
CHAPTER EIGHT: CONCLUSION

8  CHAPTER EIGHT: CONCLUSION
CONCLUSION

8.1 INTRODUCTION

The purpose of this research was to determine whether specific OAT to the lower limbs and feet could significantly improve flexible flat feet.

8.2 HYPOTHESIS

Standard osteopathic manipulation treatment improves the distributing plantar pressure in individuals assessed with flexible flat foot pronation by bringing significance to the dynamic values of The Orthotic Group gait scan.

This research produced a number of important findings, which contributed to understanding the osteopathic value of a local approach to treatment of flexible flat foot – somatic dysfunction. The data collected during this study suggests that there was a significant statistical difference in pressure distribution under the first metatarsal of the left foot. Tendencies under other landmarks in the left and right foot also improved the pressure distribution.

Statistical analysis was able to show evidence of the efficiency of OM procedures on flexible flat feet during the experimental phase of the study. This study demonstrated that local OM procedure treatments supported the hypothesis presented in this research study. There was significant statistical change in the P value = 0.0011, means change (SD) = 4.1 (6.1) that was recorded for the 1st metatarsal between the second and final visit for the left foot. The other seven measurements did not score high enough to be
statistically significant. The other outcomes did benefit the patient through the change in the impulse %. This study was not based on the premise of a “null hypothesis” but the study was able to show results favoring the original hypothesis through a significant statistical P value.

8.3 RELEVANCE OF THE RESEARCH

Plantar pressure related problems found either in diabetics or flatfooted individual is an important health concern that affects millions of patients and costs billions of dollars every year. Related studies as mentioned earlier, along with this study were able to reveal increased plantar pressure distribution under the foot during dynamic activities. This study does show a link to the relationship between the OM procedures and flexible flat feet.

Although further research is necessary, the results of this investigation have some important clinical findings and broader application. One needs to mention that even though this researcher treated the foot locally the score proves some level of effectiveness since the statistical significance has been achieved in 1 out of 8 tested landmarks. The remaining 5 out of 7 landmarks had values that showed improvement which can be attributed to the OM procedure treatment.
As previously mentioned in the discussion chapter it would be beneficial for another study to approach this topic from a global perspective. This approach may have a greater effect in results due to the fact that it is a global treatment and would address the mechanisms of the tested dysfunction and its important elements. This would include the cranial structures, fascia, lines of gravity, muscles, bones and joints as well as organs. The body functions as one unit where the elements of the musculoskeletal system are interconnected via the fascia, the nervous system and vascular system for the purpose to produce appropriate outcomes to a given stimuli. Osteopaths therefore must work to support that balance and through its applications restore harmony.

8.4 OSTEOPATHIC CONSIDERATIONS

There is a growing need for further expansions into flat foot pathology research and the effectiveness of OMT on pressure distribution. Statistics show that the numbers of plantar pressure related problems are on the rise. The improvement of recognized impediments in the healing process for the flexible flat foot through the application of OM procedures and its principles can serve the profession as a recognizable resource in foot care. This study did demonstrate how subjects with flexible flat foot can benefit from a local osteopathic approach to treatment. It also showed that a more global approach to treatment may be necessary in order to achieve more significant results. This could be another much needed study in the endeavors to treat and restore normal function to functional flat feet.

Patients need an Osteopath who recognizes their needs. OMT is one way in which as an Osteopath one can optimize the patients’ natural healing capacity. Andrew
Taylor Still, told his students “look for health: anyone can find disease” (Korr, 2002, pg. 65).
BIBLIOGRAPHY
BIBLIOGRAPHY


Michaud, T. C. (1997). *Foot Orthoses and Other Forms of Conservative Foot Care Medical Book*.


APPENDICES
APPENDIX A: Written Consent Form for Participants Involved in Control and Experimental Research Study

Name of research participant: Mr. / Mrs. __________________________________________

I __________________________________________ hereby agree to be an active participant in the study titled: The effects of osteopathic manipulative treatment on the plantar pressure distribution within a population with flexible flat foot.

I am aware that participation in this two-phase with-in subject study design research (control phase 6 weeks and experimental phase 6 weeks) is voluntary and does not involve any health risks and that I can withdraw from it at any time.

This study is a requirement for Mr. Paul Lorenc to graduate from the Canadian College of Osteopathy in Toronto.

I agree to be examined prior to the study and comply with the treatment outlined.

The information provided by me for the medical questionnaire is honest and thought to be true to the best of my knowledge.

I agree to notify the research practitioner about any health change throughout the study period.

I agree to complete osteopathic treatment as outlined by the research practitioner.

All personal and medical information will be kept confidential.

I am aware that there are not any health risks for participants of control or experimental study groups.

I agree that I will not look for any form of reimbursement for the participation in this study.

Patient name ___________________________ Signature ___________________________

Witness name ___________________________ Signature ___________________________

Dated ___________________________ 2009.

Signed by: (Research Practitioner) ____________________________________________

Paul Lorenc
APPENDIX B: OSTEOPATHY, MASSAGE THERAPY AND ORTHOTIC CLINIC

CONFIDENTIAL CASE HISTORY FORM

Personal Information:

Name _______________________________________________________

Date ______________________

Address _____________________________________________________

Postal Code_________________

Phone # (Res.)____________________________

Phone # (Bus.) __________________________

Date of Birth__________________________     Age_____   Weight____________

Height____________

Occupation_____________________________________________   Full Time_____   Part Time_____

Massage Experience: Yes _____ No _____   Osteopathy: Yes _____ No _____

Pedorthic Experience: Yes _____ No _____

Health Information:

Main reason for coming:

Date of last M.D. exam __________________________

Results_________________________________

M.D. Name _______________________________

M.D. Phone # ( )_______________________

M.D. Address ____________________________________________

Current Medication/Conditions treated________________________

Are you under stress at home and/or work? __________________________

Health History:   Please check any conditions that you experience:

Head/Neck:   Headaches-Type_________ Vision Problems _____ Contacts/Glasses______

Women:   PMS_____   Are you pregnant? _____   If yes due date:_______________   # of children_____  

Gynecological conditions ______   what? ____________________________

Overall, how is your general health? ________________________________
Respiratory:

Chronic Cough ____ Shortness of breath ____ Asthma____

Bronchitis ____ Emphysema ____ Congestion ____ Smoking ____ → Heavy ___ Light ___

Is there a family history of any of the above? Yes........ No.........

Muscle/Joints:

Pain _____ Stiffness ____ Swelling ____ Easy to Fatigue ____

Limitations of Movement ____ Arthritis - Type ____________________________

Do you have: tingling _____ numbness _____ others: _________________________

Cardiovascular:

High blood pressure ____ Low Blood Pressure ____

Chronic congestive heart failure ____

Heart attack ____

Phlebitis / varicose veins ____

Stroke / CVA ____

Dizziness ____

Pacemaker or similar device ____

Is there a family history of any of the above? Yes ____ No ____

Digestive:

Poor Appetite ____ Excessive Appetite ____ Diarrhea ____

Constipation ____ Liver Problem ____ Gas ____

Abdomen Pain ____ Difficult Digestion ____ Nausea ____

Alcohol Consumption ____ Heavy ____ Light ____
Uro/Genital:

Frequent Urination _____ Kidney/Bladder _____ Diabetes _____

Surgery/Injury:

Type: __________________________________________

Date: _______________________________________

Current Symptoms: ____________________________

Other Illnesses:

Anemia _____ Epilepsy _____ Thyroid Disease _____ Gout _____

Bursitis/location _____ Osteoporosis _____ Hernia _____

Ulcer _____ Cancer _____ HIV/AIDS _____ TB _____ Hemophilia _____

Loss of sensation, where? _______________________

Allergies / hypersensitivity to what? _______________

Type of reaction: __________________________________

Is there a family history of arthritis? Yes _____ No _____

I acknowledge that the Osteopathic Student discussed with me all the procedures of the treatment and I agree to be treated.

Date: ___________________ Patient Signature ___________________

Do you have extended insurance plan? Yes _____ No _____

How did you hear about our clinic? ____________________________

CANCELLATION POLICY:

24 HR notice is requested for the cancellation of Massage therapy appointment.

If 24 HR notice is not provided patient will be billed the full fee for missed appointment.
APPENDIX C: Assessment Protocol

A. Right and Left lower extremity

<table>
<thead>
<tr>
<th>RIGHT OR LEFT</th>
<th>NORMAL / PHYSIOLOGICAL / NON-PHYS. / NON-PHYS. / COMPACATION</th>
</tr>
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<tbody>
<tr>
<td>LOWER EXTREMITY</td>
<td>/ WITH RESPECT / WITHOUT RESPECT /</td>
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Tibia ............................................................................................................................................................
Fibular ...........................................................................................................................................................
Talus ..............................................................................................................................................................
Calcaneus ......................................................................................................................................................
Navicuular .....................................................................................................................................................
Cuboid ...........................................................................................................................................................
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4th Toe ........................................................................................................................................................
5th Toe ........................................................................................................................................................

B. List of Osteo-Articular Lesions Present

Left Foot ......................................................................................................................................................
Right Foot ....................................................................................................................................................
PRM of Cuboid .........................................................................................................................................
PRM of Navicular ......................................................................................................................................
APPENDIX D: TOG GAIT SCAN

The Dynamic Scan

After a brief look at the Static scan to see the pressure distribution while the foot is not in motion, use the Dynamic scan to illustrate the flow of pressure over the full length of the step from point of contacting the GaitScan™ hardware until the foot has left the plate. The GaitScan™ software records pressure on the GaitScan™ hardware at a rate of 300 frames per second for USB2 plates and 125 frames per second for USB1 plates. The average walking stride is seven-tenths of a second (0.7/second). Your patient's Dynamic scan is documented in the Gait Analysis report. Only the Dynamic scan can be used for placing an order.

If you have saved more than one scan we suggest you use the scan that best represents your patient's gait.

Taking the Dynamic scan:

The Dynamic scan is recorded individually for each foot. Ensure the patient is facing the plate in line with the standed Dynamic arrows and that there is sufficient room to take a few steps before and after stepping on the plate. The more important issues are to have the patient walk with a loose natural stride and to step as close to the center of the plate as possible. Patients might like to take a few practice attempts before recording a scan.

1. Do one of the following:
   a. From the Static scan window, click F4-Dynamic Scan to bring you directly to the Dynamic scan window. Ensure that the dyn radio button is checked in the toolbar. Your current patient's record is still active.
   b. If you have just logged-in and would like to take a Dynamic scan only, from the Main screen, ensure that you have the correct patient selected, and click F10-Dynamic Scan to open the Dynamic scan window. Ensure that the dyn radio button is checked in the toolbar.

2. To activate the GaitScan™ hardware, click F2-Activate GaitScan™ hardware. The notification “Measurement in Progress” appears in red type on the screen.

3. Ask your patient to face the Dynamic arrows and walk onto and past plate, with one foot stepping as close to the center of the GaitScan™ hardware as possible as the other foot swings past. As the scan is recorded it plays as a continual loop in the far left-hand view of the window.

4. After the scan is captured it is auto-assigned as left or right foot accordingly. If the scan is not acceptable click F2—Active GaitScan™ and have the patient step across again. If the left/right foot assignment is not correct due to abnormalities click the manual radio button and repeat from step 2. After each scan the foot will need to be manually assigned by click F3-L for left or F4-R for right.

5. To capture a scan of the other foot, click F2-Activate GaitScan™ hardware and repeat the actions.

6. To save the scans, click F9-Save. You can now continue to optionally go to the squat scan or click F2—Activate GaitScan™ hardware to take another set of Dynamic scans.
APPENDIX E: RECRUITMENT NOTICE

Participants wanted to enroll in 12 weeks long Osteopathic research study lead by Mr. Paul Lorenc.

The title of the study

The effects of osteopathic manipulative treatment on the plantar pressure distribution within a population with flexible flat foot.

Participants must have low arched feet and be committed to be seen 5 times for osteopathic treatments/visits. If you would like to participate please call Paul at (905) 891-6061 or talk to Paul’s secretary to schedule you time for evaluation.

This study is a requirement for Mr. Paul Lorenc to graduate from the Canadian College of Osteopathy in Toronto.

All personal and medical information will be kept confidential.

There are not any health risks for participants of control or experimental study.
APPENDIX F: THESIS PROTOCOL APPROVAL

[Forwarded: Paul Lorenc Thesis Protocol approval]

Seena Patel, Registrar
From: ccoregistrar@rogers.com
Sent: June 2, 2009 4:46:20 PM
To: pmlorenc@msn.com
1 attachment

Paul Lorenc...mht (5.4 KB)

Hi Paul,

There was a delay in getting this email to you as we have an incorrect or outdated email on our system. This is the email in follow up to our conversation earlier today. Please confirm you have received this email.

Seena
Registrar
CCO, Toronto Campus

--Forwarded Message Attachment--
From: principalcco@gmail.com
To: pmlorenc@3web.com; janestark@on.aibn.com; ccoregistrar@rogers.com
Subject: Paul Lorenc Thesis Protocol approval
Date: Wed, 27 May 2009 22:03:32 -0400

I have read and am pleased that all the changes required by Paul Lorenc Jury have been made on time by Paul Lorenc.

I give my permission for him to begin data collection as of May 29th 2009.

Brad McCutcheon D.O. (MP)
Principal
Canadian College of Osteopathy
Toronto Campus
www.osteopathy-canada.com
1. Myofascial Interosseous membrane release of the lower leg

(Posterior Release)

Indications/Objectives: To release interosseous membrane between tibia and fibular.

Osteopath Position: Seated at patient’s side

Client Position: Supine with towel under slightly flexed knee

Hand Placement:

Lower Hand: fingers curled to bring 2nd, 3rd, 4th digits into equal length

Upper Hand: sensing over the lower hand’s fingers on anterior leg surface (hands communicate)

Technique Description: With curled fingers positioned under the extended leg, Osteopath lets weight of leg sit on the tips. Upper hand follows the myofascial pulls and creates a slight drag on them. Await release of tissues. Osteopath asks patient to breathe in and while this takes place the Osteopath lifts the patient’s leg, by holding on the plantar
surface of the foot, and then places curled fingers further down the interosseous membrane to repeat the procedure. Osteopath repeats this all the way down the membrane to the distal joint.

Additional Information/Advice:

Note: the interosseous membrane is subject to tensions from Tibialis Posterior, Tibialis Anterior, Peroneus Longus and other muscles which insert to it.

2. **Proximal Tibio-fibular joint correction (Anterior or Posterior)**

   **Anterior Proximal Tibio-fibular joint correction**

   (Osteo-articular Technique)

   Indications/Objectives: Rigidity in joint. Absence of PRM.

   Osteopath Position: Side of patient

   Client Position: Supine with pillow under knee
Hand Placement:

Upper Hand: heel of hand on fibular head

Lower Hand: stabilizing talocrural joint overall, the same position as GOT-style technique).

Technique Description:

Osteopath visualizes glide surfaces. Osteopath finds the rigidity and the ease within it, then delivers the impulse directly down (into the table).

Additional Information/Advice:

Osteopath may need to rotate the leg internally or externally to set up for the impulse.

**Posterior Proximal Tibio-fibular head correction**

(Osteo-articular Technique)

Indications/Objectives: Rigidity in the joint. Absence of PRM.

Osteopath Position: At patient’s feet
Client Position: Supine with leg bent

Hand Placement:

Upper Hand: behind the knee of the bent leg (palm of hand grasping the fibular head)

Lower Hand: on ankle

Technique Description:

Osteopath fully flexes the knee to determine if it is pain free before proceeding with the correction.

Osteopath places his/her hand behind the knee and flexes with external rotation to place the fibular head in palm of the hand.

Osteopath places the bent knee against his/her own sternum and senses the rigidity and the ease with the lower hand, then delivers the impulse via that hand while stabilizing with the upper hand.

Additional Information/Advice:
This technique is contraindicated if patient experiences pain when flexing the leg or when a meniscal tear is suspected.

3. **Distal Tibio-fibula joint correction (Anterior or Posterior)**

   (Osteo-articular Technique)

   **Anterior distal Tibio-fibular joint correction**

   Indications/Objectives: Rigidity in the joint. Absence of PRM.

   Osteopath Position: At patient’s feet with shoulder, elbow and hand aligned over joint

   Client Position: Supine with pillow under the ankle

   Hand Placement:

   Upper Hand: heel of hand on fibula

   Lower Hand: on tibia

   Technique Description:
Osteopath visualizes glide surfaces.

Osteopath finds the rigidity and the ease within it, then delivers the impulse directly down (into the table).

Additional Information/Advice:

Osteopath may need to rotate the leg internally or externally to set up for the impulse.
Glide surface should be perpendicular to the table.

**Posterior Distal Tibio-fibular joint correction**

(Osteo-articular Technique)

Indications/Objectives: Rigidity in joint. Absence of PRM.

Osteopath Position: At patient’s feet

Client Position: Prone with towel under ankle that overhangs the end of the table (other leg crossed over back of lesioned leg – to internally rotate it, if required), head turned to opposite side.
Hand Placement: Both thumbs on the lateral maleolus with hands across the back of the ankle (or use heel of hand on the maleolus)

Technique Description:

Osteopath visualizes glide surfaces.

Osteopath finds the rigidity and the ease within it, then delivers the impulse directly down (into the table).

4. **Compaction/Decompaction of the mortise**

*Compaction of the mortise* (Normalization Technique)

Indications/Objectives: To test and correct any compactions in the distal tibio-fibular joint.

Osteopath Position: Side of patient

Client Position: Supine with pillow under knee

Hand Placement:
Upper Hand: Distal fibular head

Lower Hand: Distal fibular head

Technique Description:

Osteopath assesses the joint for compaction in that region.

If only one of the joints is compacted, Osteopath will compact that joint. Awaits balance point, still point, and release.

If both joints are compacted, Osteopath will lean foreward into both joints to compact it and then will allow the joints to open up and release. Awaits balance point, still point and releases.

Upon release Osteopath asks patient to dorsiflex their feet to aid the decompaction.

Integration: Use breath and feet parameters to integrate for 3-5 cycles.

**Decompression of mortise** (Normalization Technique)

Indications/Objectives: To decompact the distal tibio-fibular joint.

Osteopath Position: At patient’s feet
Client Position: Supine with towel under knee (if required)

Hand Placement:

One hand on lateral maleolar tip, other hand on medial maleolar tip.

Technique Description:

Osteopath listens to PRM to assess.

Osteopath initiates a compaction by approximating the maleoli, awaits balance point, still point (adds dorsiflexion and inhalation), and release.

Integrate with breath, hand, and feet parameters.

Osteopath listens to PRM to assess.

Integration: Walking.

Additional Information:

Additional Integration Parameter – Hands:
During Inhalation: (with elbows straight) wrists flex

During Exhalation: (with elbows straight) wrists extend

5. **Compaction/Decompaction of Talocrural Joint**

(Normalization Technique)

Indications/Objectives: To normalize the 2 joints. To free up globally.

Osteopath Position: Seated at patient’s feet

Client Position: Supine with pillow under hip to neutralize external rotation of leg

Hand Placement:

Classical Hold

Technique Description:

Osteopath assesses then compacts or decompacts the tibia and talus joint by approximating calcaneus and talus towards tibia. Hands can accommodate some rotation felt in joint as required. Awaits balance point and still point.
Upon still point Osteopath then compacts the entire structure superiorly toward the tibia by leaning forward. Await balance point, still point and release.

Upon release patient dorsiflexes both feet.

For decompaction Osteopath leans back holding calcaneus and talus in his hands,

Wait for release.

Integrate with breathing and feet parameters.

Osteopath assesses again the joint for correction.

Integration: Walking.

6. Talocrural joint osteo-articular adjustment (Ant or Post).

Differential Diagnosis of Tibia and Talus

Indications/Objectives: To determine which of the tibia or talus is to be treated.

Osteopath Position: At patient’s side

Client Position: Supine (with towel under ankle while testing talus; without while testing tibia)
Hand Placement:

Upper Hand: on tibia with 2-5th fingers on medial side of ankle

Lower Hand: on talus with 2-5th fingers on medial side of ankle

Technique Description:

With feet extended off the end of the table:

Osteopath has patient bilaterally dorsiflex and plantarflex and observes which foot can move further into dorsiflexion and plantarflexion.

Results Interpretation: If one foot can dorsiflex better than the other it may indicate a posterior talus in the joint that moves easier into dorsiflexion. Or it may indicate an anterior talus in the other foot.

Same reasoning can apply with plantarflexion.

To establish the specific restriction: With foot off the end of the table and a towel under the ankle, Osteopath grasps ankle as above (while stabilizing the leg with his/her own thigh), stabilizes tibia and then leans forward (inducing an inspiration movement into
talus) and then leans backward (inducing an expiration movement into talus). Osteopath senses the motion (ease or lack of) as well as the “spring” of rebound. Osteopath controls the plantarflexion or dorsiflexion by placing his/her thumbs under the Achilles tendon.

With foot on the table and no towel under it, Osteopath stabilizes the talus and presses down into the table (to induce an expiration motion) and then pulls up toward ceiling (to induce an inspiration motion). Osteopath senses the motion (ease or lack of) as well as the “spring” of rebound. Osteopath should be careful not to allow greater than 10 degrees of plantarflexion when positioning for testing.

Additional Information:

In Normality:

The anterior motion of the talus is 2x the range of its posterior motion.

During Inspiration:

Tibia in relation to Talus moves: Anterior/External

Talus in relation to Tibia moves: Posterior/Internal

During Expiration:
Reverse the parameters as above.

**Correction of an Anterior Tibia** (Osteo-articular Technique)

Indications/Objectives: Rigidity in the tibiotalar joint. Absence of PRM.

Osteopath Position: At patient’s side

Client Position: Supine with pillow under extended knee

Hand Placement:

Upper Hand: on tibia at tibio-talar joint

Lower Hand: stabilizing talus on calcaneus

Technique Description:

Osteopath senses the rigidity, the ease and sends impulse down into the tibia

Alternate Method:
Osteopath has patient bend the leg and places a rolled towel under the foot to keep a bit of dorsiflexion. He/she accumulates the tensions and delivers impulse from his/her shoulder in direct line with the joint glide surface.

Integration: Mennelle technique.

Additional Information/Advice:

Osteopath bends the knee to keep the joint surface perpendicular to the table.

Correction of a Posterior Tibia (Osteo-articular Technique)

Indications/Objectives: Rigidity in the tibio-talar joint. Absence of PRM.

Osteopath Position: At patient’s feet supporting the overhanging foot with thigh

Client Position: Prone with feet extended off the end of the table supported with a towel under the talus only

Hand Placement:

Upper Hand: distal tibia
Lower Hand: calcaneus

Technique Description:

Osteopath stabilizes the talocrural joint and senses the tension, ease and delivers impulse down into tibia (toward the table).

Integration: Mennelle technique.

**Correction of an Anterior Talus - “The Wave”**

(Osteo-articular Technique)

Indications/Objectives: Rigidity in the tibiotalur joint. Absence of PRM.

Osteopath Position: At patient’s feet

Client Position: Supine with legs extended and off the end of the table

Hand Placement:

Hands grasp the ankle along the talus bilaterally with thumbs in the low tarsal plantar fascia, fingers interlocked over the dorsum with little fingers on anterior talus region.
Technique Description:

Osteopath may set up a G.O.T.-like motion in the lower leg then when ready simultaneously bends his/her knees and flicks his/her wrists (throw it down) to deliver the impulse forward and down into the table (like shaking out a sheet).

Integration: Mennelle technique.

Additional Information:

If patient’s knee may be at risk, Osteopath may bring the leg down closer to the table to deliver the impulse thereby using the table to block the knee from extending too much.

It is important for the Osteopath to avoid tractioning the foot while executing this technique.

**Correction of a Posterior Talus - “The Wave”**

(Osteo-articular Technique)

Indications/Objectives: R rigidity in the tibiotalur joint. Absence of PRM
Osteopath Position: At patient’s feet

Client Position: Prone with legs extended off the end of the table

Hand Placement:

Hands grasp the ankle along the talus bilaterally with thumbs on either side of calcaneus and fingers interlocked over the dorsum, with indexes on anterior talus.

Technique Description:

Similar to previous technique, using the same wave-like motion to deliver the impulse forward and down in the direction of the table.

Integration: Mennelle technique.

It is important for Osteopath to avoid tractioning the foot while executing this technique.

7. Compaction/ Decompaction of the Subtalar joint (Normalization Technique)

Compaction of subtalar joint
Indications/Objectives: To normalize these two bones. To free up the joint globally.

Osteopath Position: Seated at patient’s feet

Client Position: Supine with pillow under knee to neutralize external rotation of leg

Hand Placement:

Classical Hold

Technique Description:

Osteopath assesses then compacts the subtalar joint by approximating calcaneus and talus. Hands can accommodate some rotation felt in joint as required. Awaits balance point and still point.

Await balance point, still point and release. Upon release patient dorsiflexes both feet.

Integration with breath and feet parameters. Osteopath assesses again.

Integration: Walking.
Decompaction of Subtalar Joint

Indications/Objectives: To test the interosseous ligament between talus and calcaneus. To test the ability to decoapt the joint.

Osteopath Position: At patient’s side

Client Position: Supine with sole of foot on Osteopath’s stomach

Hand Placement:

One Hand on calcaneus with thumb along the axis, medial side of foot

One Hand on talus with thumb along the axis, medial side of foot (thumbs form straight line with tip to tip)

Technique Description:

Osteopath stabilizes talus by bringing the appropriate elbow into his/her body, then applies a tractioning force on calcaneus by turning his/her body appropriately, then assesses the joint for decompaction and rebound.
Osteopath stabilizes calcaneus by bringing the appropriate elbow into his/her body, then applies a tractioning force on talus by turning his/her body appropriately, then assesses the joint for decoaptation and rebound.

Additional Information:

It is important that the Osteopath does not “break wrists” while working this technique. Elbows are to follow the axis.

This technique can also be used as a Functional or Normalizing Technique by applying the appropriate method.

8. Talonavicular osteo-articular adjustment (superior or inferior glide)

(Osteo-articular)

Indications/Objectives: Rigidity in the joint. Absence of PRM. Navicular stuck in superior or inferior position. No response to decoaptation.

Osteopath Position: At patient’s feet

Client Position: Supine
Hand Placement:

Left hand holds the heel by making firm contact proximal to the midtarsal articulation, while the right hand creates strong either superior or inferior gliding motion on the fixed foot. The left hand must be carefully positioned in front to the tibia and on talus to ensure that the shearing motion occurs at talonavicular joint.

Integration: Walking, GOT

9. **Calcaneo-cuboid osteo-articular adjustment (superior or inferior glide).**

Correction of a superior cuboid in Relation to Calcaneus and inferior cuboid in Relation to Calcaneus

Indications/Objectives: Rigidity in the joint. Absence of PRM. No response to decoaptation.

Osteopath Position: At patient’s feet

Client Position: Supine

Hand Placement:
Hands in the Classical Hold (may be reversed depending on Osteopath’s comfort at wrists – see below)

Technique Description: Treatment for right foot

While the thumb of right hand holds the distal calcaneus, the thenar eminence of left hand manipulates through the dorsolateral forefoot for superior lesion working into supination. For inferior glide correction the left hand that holds the dorsolateral border is working into OA into pronation.

It is important that the Osteopath does not traction while executing this technique.

10. **Navicular osteo-articular adjustment (externally or internally rotated)**

Navicular externally rotated = low

Navicular internally rotated = high

Indications/Objectives: To free a lesioned navicular.

Osteopath Position: patient’s side

Client Position: Sideline
Hand Placement:

In scissor position: one hand on navicular tubercle with appropriate directing to suit the desired correction; other hand stabilizing talus.

Technique Description:

**A Low Navicular** is low along its cubo/navicular joint, therefore it is high on the navicular tubercle. Impulse is directed such that it will bring the navicular tubercle down.

Mnemonic: “Fingers Face Feet”

**A High Navicular** is high along its cubo/navicular joint; therefore it is low on the navicular tubercle. By reversing the scissored position of the hands the impulse can be translated into the appropriate direction to bring the navicular tubercle up.

Additional Information:

The essence of this technique is to roll the navicular around its central axis to correct.
If the navicular is high on both sides, this means there is no axis respected and the whole bone is sitting high.

This technique can be easily converted into a Functional Technique by applying that technique when hands are in position.

11. Cuboid osteo-articular (low or high)

Correction for a Low Cuboid

(The “Snap”)

Indications/Objectives:

To release a low cuboid as observed in evaluation of cubo/navicular joint. “To open the door of the cuboid.”

Osteopath Position: Kneeling with one knee on the ground

Client Position: Prone on table with leg off the table and bent (towel under ASIS at edge of table)
Hand Placement:

Grasping the metatarsals with thumbs stacked on top of the cuboid

Technique Description:

Osteopath rocks the leg forward and back to create inertia in order to introduce the snap.

When adequate rocking is gained Osteopath pushes forward and out to meet the backward motion during the rock. This creates the “snap” effect and translates the force into the cuboid, via the thumbs, to raise it.

Additional Information:

It is important that Osteopath avoids plantarflexing the foot while executing this technique.

Correction of a High Cuboid

(Osteo-articular)
Indications/Objectives: To bring a high cuboid back down into position. Absence of PRM.

Osteopath Position: At patient’s side

Client Position: Prone with leg bent

Hand Placement: Pinches cuboid between thumb and index finger.

Other arm traps the forefoot in axilla of osteo, passes anterior to their tibia and grasps his/her own wrist or locks this arm along the chest of Osteopath.

Technique Description:

Osteopath accumulates the tensions in the pinching fingers by lowering the elbows.

Osteopath delivers the impulse through the thumbs by bending his knees.

Additional Information:

It is important to keep the foot parallel to the table, to avoid rotation, and avoid dorsiflexion.
12. PRM for naviculo-cuboid joint.

(Sensorial technique)

Listening Technique for PRM of Navicular and Cuboid

Indications/Objectives: To evaluate the motions of the navicular and cuboid.

Osteopath Position: Seated at patient’s feet

Client Position: Supine

Hand Placement:

Lateral Hand: index finger on cuboid (between 5th metatarsal base, arching over the cuboid to space between 3rd and 4th metatarsals).

Medial Hand: index finger arching over navicular to meet the tip of the cuboid finger.

Technique Description:

Osteopath listens to both bones for PRM motion.
Osteopath induces both bones by increasing the arch between the 2 bones, and then induces by decreasing the arch between the 2 bones. Tests the direction of restriction and which bone is it.

To flatten the arch, Osteopath lifts the elbows.

To increase the arch, Osteopath drops the elbows.

Compaction of the navicular and cuboid is easily performed by simply pressing them together with hands in this configuration (can also perform a functional technique in this position).

Additional Information:

It is always important to clarify your reference for the axis of the foot. Either a central axis in the foot or with the reference to the midline of the body. Internationally the convention is to use the midline of the body.

If using the midline of the body as the axis then motion of navicular on inspiration is considered medial rotation, and motion of the cuboid is considered lateral rotation. On expiration the motion of the navicular is lateral rotation and the cuboid is medial rotation.
Motion of Navicular and Cuboid in Normality:

Inspiration: both bones move “high”

Expiration: both bones move “low”

13. **Cuniforms osteo-articular adjustment (superior or inferior glide)**

   **“The Flute”**

Indications/Objectives: To release metatarsals at their joints with the cuneiforms and cuboid.

Osteopath Position: At patient’s feet

Client Position: Supine

Hand Placement: Grasps feet with thumbs on plantar surface with fingers of both hands in line on the appropriate metatarsal – “like a flute.”

Technique Description:

Osteopath places thumbs on the metatarsal base he/she wishes to release and then delivers the snap via the thumbs.
Osteopath can do all 5 metatarsals then the 3 cuneiforms with this technique.

Additional Information: An indication of lesions of cuboid or cuneiforms is soreness on the plantar surface of the foot under these bones. Osteopath can curl surface together (relaxes the fascia), then tests for sore spots by pressing directly onto the bones. Often metatarsals will be lesioned in rotation – very painful. This condition responds well to functional technique.

14. **Lemniscate maneuvers** (Functional technique)

Indications/Objectives: To test for restrictions between the structural and sensorial parts of the foot. To integrate any release work done on the foot.

Osteopath Position: Standing at the front, facing patient feet

Client Position: Supine with feet extended off the end of the table

Hand Placement: Lateral Hand: index finger on calcaneus, thenar eminence on cuboid, and fingers curled under to grasp 4th and 5th metatarsals (structural foot)

Medial Hand: thumb on talus and navicular, rest of hand grasps the medial longitudinal arch (sensorial foot)
Technique Description:

With lateral hand stabilizing, use the medial hand to move the sensorial foot in a lemniscat motion – first in one direction, then in the other.

With the medial hand stabilizing, use the lateral hand to move the structural foot in a lemniscat motion – first in one direction, then in the other.

Additional Information/Advice: Osteopath uses his/her body to move the lemniscat.

Osteopath searches for zones of tension during this process so that attention can be brought to these areas specifically. Then very localized lemniscat motion can be brought to the specific spot.

By running lemniscats at the Talus/Calcaneus pair, then the Cuboid/Navicular pair, then across the rays separating between Metatarsals 1, 2, 3 and Metatarsals 4, 5, it is possible to free up the entire structural/sensorial border of the foot (Druelle, 1992; Foot lecture notes, 2000).
APPENDIX: H

BRODY’S NAVICULAR DROP TEST

In standing position

Each subject was instructed first to stand in a relaxed position with their feet a comfortable distance apart on a marked Plexiglas sheet located on a hardwood floor for consistency in foot placement. The measurements of the navicular drop involved placing the subtalar joint (ankle) in a full weight-bearing position. Then the navicular tuberosity was palpated and marked with a horizontal line by a pen, 2 repeated measurements for each foot in a standing position were taken using a student ruler in millimeters.

In sitting position

Then the subject was asked to sit on a chair with the feet shoulder width apart. The researcher positioned each subjects’ subtalar joint in neutral position. “Subtalar neutral position is the position in which the foot is neither pronated or supinated.” Cited in Elveru et al., 1988, p. 678 and Original Root, Orien, Weed, et al., 1971.

Navicular tuberosity was palpated and remarked for each navicular height measurement to avoid skin marking error. A student ruler was used to measure the distance from navicular tuberosity to the Plexiglas. The investigating osteopath performed two navicular drop measurements for each foot in a sitting position to obtain a more reliable value as recommended in the literature. The two measurements were then averaged and the mean value was used as criteria of foot pronation (Mueller et al., 1993, p. 199).
APPENDIX I: APPROVED THESIS PROPOSAL
APPENDIX J: COMMENTS FROM THESIS ADVISOR AFTER A PRE-READING

Re: Thesis title; The effects of osteopathic manipulative treatment on the plantar pressure distribution within a population with flexible flat foot.

Report

Hypothesis

Does not have significance I the hypothesis

Abstract

3 pages should be 2 pages as required by the cco.

Introduction

Page 4 is about Druelle from the foot course. No sure if it is word for word or not.

Why is he doing this, what is so important about flat feet for osteopathy? Etc.

Literature review

Only 12 pages of literature review. I would be concerned if he had to face the jury with this.

I feel he may have missed out some good articles related to the subject, and with the current papers he has cited there is not enough background on other bibliography articles that these papers have cited.

P Druelle is cited from the foot course book. Unless it is in communication, it would be difficult to allow this in a lit review (not sure what CCO recommends).
The flow is poor. Introduction needs to be stronger, also how he got his literature, where, and when.

I only found 5 osteo papers, 4 if you minus the p Druelle in the foot course.

5 biomedical, 1 foot, 2 foot and ankle, 1 geriatric, 1 pod, 1 phys rehab.

4 unknown, 11 missing.

Many major bibliography errors (throughout).

Justification

31 articles, 6 osteopathy, and 14 miscellaneous (pt, podiatry, cli bio etc).

6 books

3 internet

2 not cited.

My concern is

Pages 21, 23, 24, 25, 27 p Druelle foot course, very closely written from the book.

P22, 29 kirby podiatrist very closely written from the paper.

P 41, 51, 52... are they the writers own words?

I felt this wasn’t fully justified and perhaps should be stronger in the osteopathy field.

There is section on gait analysis and perhaps he could strengthen this by looking at some of the systematic reviews that have been written?
Diagrams need to be explained fully and clearer.

Bibliography errors.

Methodology

24 pages of techniques (should be in appendix)

12 pages of methodology

I always look to see if I can reproduce the study from his writing and found it very difficult to so do.

Forms need to be in appendix, not in protocol appendix.

Clearer explanation required for the two measurements. Navicular foot drop... how is it done why are you doing it etc (justification)

What is sub talar jt neutral

Methods for study should be precise

More info on TOG, talk about studies that tog has been used and verified.

I do have a question about the crossover design

Cross over design as I understood is a crossover of treatments between two groups.

This study the control is gait plate measurements, and then the experimental group is gait plate measurements and navicular drop measurements and treatments.

This is almost a one way repeated measure design. (I spoke to Darryl for help on this one)
Page 74 is confusing independent variables.

Statistics

Was only 3 pages

No input from statistician

Two tables, no graphs. The text was not clear about the two tables.

Needs to be clear how data was analyzed.

Gait plate

Nav drop measurements.

I have briefly read discussion self critique and conclusion, This will have to change once the corrections have been made.