A pre-post experimental investigation to determine the clinical responsiveness of motion palpation as a post-manipulation diagnostic tool in patients with chronic ankle instability syndrome.

By

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Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology, in the Department of Chiropractic at the Durban University of Technology.

I, Kym Ashley Belling, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgments indicate to the contrary)

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DEDICATION

To the people I love most in this world- Mom, Dad, Nicole and Dudley.

To my darling Sophie, who watched every page.

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To God, who made my life a better place.

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ABSTRACT

Introduction: Motion palpation is a commonly utilised clinical assessment tool of joint fixations. Most research surrounding motion palpation discusses inter and/or intra-examiner reliability as a pre-treatment tool. However, only two studies have assessed the reliability of motion palpation as a post-treatment diagnostic tool, and both these studies demonstrated that motion palpation has the ability to identify end-feel improvement in a restricted segment which had been manipulated. Therefore the use of motion palpation as a post-manipulation tool within the spine showed a relatively high level of responsiveness/efficacy of motion palpation. However little research has yet to be conducted on the use of motion palpation as a post-manipulation tool on the extremities and therefore this study aims to provide a clearer insight into the use of motion palpation as a post-treatment assessment tool in an extremity in terms of clinical responsiveness/validity of motion palpation. Furthermore the relationship between motion palpation and other clinical measures/short term outcomes, such as pain, functionality, range of motion and proprioception has yet to be seen i.e. when motion palpation indicates a reduction in a fixation due to manipulation does this correlate to a decrease in pain and increase in functionality, range of motion and proprioception. Therefore the primary aim of this study was to determine the clinical responsiveness of motion palpation as a post-manipulation diagnostic tool within the joints of the ankle in symptomatic participants with Chronic Ankle Instability (CAI).

Method: Forty participants with CAI (Grade I and II) were recruited. One Group received manipulation (n=21), the other Group received no treatment (n=19). Motion palpation was performed, and subjective/objective measures were taken in both Groups pre- and post-treatment. Statistical analysis was performed using SPSS 15.0.

Results: The findings of this study demonstrated that when using motion palpation as a post-treatment assessment tool a high level of responsiveness was observed (a highly significant association between being manipulated and End-Feel Improvement (EFI) occurred ($p<0.001$)); it was highly sensitive (0.90); and was highly specific (0.95).

Overall no statistically significant association was observed in either group between, motion palpation results (with respect to EFI or no EFI noted) and any of the short term outcomes (the five subjective/objective clinical measures). Within the manipulation group; Visual Analogue Scale (VAS) ($p=0.944$), Functional Ankle Disability Index (FADI) ($p=0.490$), Pressure Algometer

(p=0.634), Berg Balance Scale (BBS) (p=0.512) and Weight Bearing Dorsiflexion (WBD) (p=0.966). In comparison, the control group; Visual Analogue Scale (VAS) (p=0.063), Functional Ankle Disability Index (FADI) (p=0.491), Pressure Algometer (p=0.828), Berg Balance Scale (BBS) (p=0.695) and Weight Bearing Dorsiflexion (WBD) (p=0.747). The most common fixations noted in this study, were mortise Long Axis Distraction (LAD), subtalar LAD and subtalar eversion.

Conclusion:

Therefore, motion palpation appears to be valid when used as a post-treatment tool in the foot and ankle; and overall, common fixations found in symptomatic participants with CAI in this study are similar to those found in previous studies.

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ABBREVIATIONS

CAI- Chronic Ankle Instability

EFI- End-Feel Improvement

VAS- Visual Analogue Scale

FADI- Foot Ankle Disability Index

BBS- Berg Balance Scale

WBD- Weight Bearing Dorsiflexion

ATFL- Anterior Talofibular Ligament

PTFL- Posterior Talofibular Ligament

CFL- Calcaneofibular Ligament

DEFINITION OF TERMS

Accessory joint movements:

These are involuntary movements that represent the small “give or play” within a joint that is essential for normal function, and it is the joint capsule that is responsible for the smooth give felt, as it allows for sufficient play and articular surface separation to avoid abnormal joint movement (Bergmann *et al.,* 1993). As a consequence, motion palpation is used to assess this accessory joint movement by means of joint play and end-feel. These terms refer to the springy feel which is normally present in a joint when taken further than its active motion limits (Bergmann *et al.,* 1993).

Chronic Ankle Instability (CAI):

This condition is known to present as one of two subtype’s namely mechanical and functional instability (Ajis and Maffulli, 2006). However, for the purpose of this study, CAI is described as a condition where the patient has at least 4 of the following signs and symptoms: joint weakness, pain, edema, adhesions, ligamentous laxity and joint crepitus (Pellow and Brantingham, 2001).

End-feel (EFI):

The consistency which describes the resistance to further stretch, which is encountered at a joint’s passive end range of motion (Bryner, 1987; Bergmann *et al.,* 1993; Leach, 2004; Haldeman, 2005).

End-feel Improvement:

An immediate end-feel restoration of motion segment movement after manipulation (Lakhani *et al.,* 2009).

Fixation:

This is a characteristic of a subluxation, which indicates a lack of a normal range of mobility. It is due to an anomaly in the surrounding tissue which holds the joint in place and limits its motion partially or totally. The fixation is the part of a subluxation which can be corrected by a manipulation (Gillet, 1969). Three types of fixations occur; muscular, ligamentous and articular (Schafer and Faye, 1990).

Joint Play:

This is a discrete, short range movement of a joint independent of the action of voluntary muscles, determined by springing, in different directions, each joint in a neutral position (Bryner, 1987; Bergmann *et al.,* 1993; Leach, 2004 and Haldeman, 2005). An accessory movement which can be defined as that degree of end movement or distension allowed passively that cannot be achieved by voluntary effort (Schafer and Faye, 1990). Joint play is found in neutral position of the joint while end-feel is at the joint's end range of motion (Schafer and Faye, 1990).

Motion Palpation:

Palpation assesses the physiological range of motion possible in all the different axes of motion, generally and specifically with respect to any joint, in the spine or extremity. This evaluation determines if a joint / motion unit has natural movement or it has increased or decreased movement (Ames, 1987; Bergmann *et al.,* 1993; Leach, 2004 and Haldeman, 2005).

Palpation:

The use of the tactile senses to determine variations in tissue consistency to recognize whether these variations are normal or abnormal (Haldeman, 1992).

Responsiveness:

This has been defined as, the percentage response to a manoeuvre itself (Haas *et al*., 1995). It involves the performance outcome measurement over time and is firstly indicates the ability of the outcome measurement instrument to detect clinically important changes (Bolton and Fish, 1997) and secondly indicates the sensitivity of the instrument to real changes (Haas, 1998 and Yeomans, 2000). Responsiveness is also described as sensitivity to change in clinical subjective/objective clinical measures or the ability to detect clinically important change. It is a property of evaluative procedures only (Haas, 1998).

The index used to calculate this is the etiologic fraction/relative response attributable to the manoeuvre (Haas *et al*., 1995). This is the percentage of response caused by spinal manipulation itself as a fraction of the total percentage of end-feel response in the treatment Group. Etiologic fraction is calculated as the percentage of end-feel

improvement (EFI) attributable to spinal manipulation therapy (SMT): (% treatment Group EFI − % control Group EFI) / % treatment Group EFI) (Bergmann *et al.,* 1993).

Static Palpation:

Palpatory diagnosis of somatic structures in a neutral static position (Bergmann *et al.,* 1993).

Subluxation:

A motion segment in which alignment, movement integrity, and physiologic function (example: muscular, vascular, ligamentous and nervous) are altered although contact between the joint surfaces remain intact (Schafer and Faye, 1990 and Gatterman, 2005).

Total joint motion:

Is a voluntary range of motion with / without joint play exhibited at the joint (Schafer and Faye, 1990).

CHAPTER 1
INTRODUCTION

1.1 Introduction

Palpation can be divided into static and motion palpation. Static palpation is palpation of somatic structures in a neutral and stationary position (Bergmann, Petersen and Lawrence, 1993). In contrast, motion palpation is palpation of passive and active segmental joint range of motion (Bergmann, Petersen and Lawrence, 1993). During motion palpation, joint play can be determined in the neutral position with end-feel of the joint being felt by springing the joint at the limit of the passive range of motion (Bergmann, Petersen and Lawrence, 1993). Lack of joint play or end-feel is defined by Schafer and Faye (1990) as a fixation, which is a physical or functional mechanism that leads to a loss of segmental mobility/ joint play / end-feel within the normal physiological range of motion. Motion palpation is commonly utilised by many manipulative therapists as a pre- and post-treatment tool to measure the degree of fixations in various directions within a joint complex (Bergmann, Petersen and Lawrence, 1993; Liebenson and Lewit, 2003; Leach, 2004 and Haldeman, 2005).

According to Ames (1987), there are eight observations that can be made using motion palpation. The first seven observations are related to using motion palpation to determine the motion segment requiring Manipulation and the direction of lost motion. The eighth observation (which is most relevant to this study) discusses the fact that using motion palpation, one should be able to confirm after a Manipulation whether the desired effect has been achieved i.e. whether the Manipulation has affected the outcomes (e.g. improvement in joint alignment, range of motion, and quality of joint movement). This observation was also supported by Bergmann, Petersen and Lawrence (1993). Additionally, the confirmation of Manipulation effect in terms of end-feel improvement is the least researched in terms of the eight observations. If confirmation of this effect is possible, then motion palpation may be used as a post-treatment tool to assess the changes in quality of fixations i.e. end-feel, in a joint during the course of treatments and would allow for consistent monitoring of patients (Ames, 1987 and Haas, Panzer, Peterson and Raphael, 1995).

Until recently, most motion palpation research has focused on inter-examiner and intra-examiner reliability, revealing that the latter fared better overall; and that motion palpation

appeared to be relatively valid in this context (Mootz, Keating, Kontz, Milus, and Jacobs, 1989; Keating, Bergmann, Jacobs, Finer, and Larson, 1989; Haas *et al*., 1995; Strender, Sjoblom, Sundell, Ludwig and Taube, 1997; Hestbaek and Leboeuf-Yde, 2000; Smedmark, Wallin, and Arvidsson, 2000; Marcotte, Normand and Black (2002); Pool *et al*., 2004; Christensen *et al*., 2005; Lakhani, Nook, Haas and Docrat, 2009).

However, the first research performed to confirm the validity of motion palpation as a post-treatment assessment tool (i.e. to analyse if the eighth observation mentioned by Ames (1987) can actually be performed) was in 1995 on the thoracic spine (Haas *et al.,* 1995), and later on the cervical spine (Lakhani *et al.,* 2009). The use of motion palpation as a post-treatment assessment tool in these two studies was shown (studies discussed below) to be valid within the spine (Haas *et al.,* 1995 and Lakhani *et al.,* 2009).

A pre- and post-Manipulation assessment study was performed by Haas *et al.,* (1995) where sixty patients (of which 60% were symptomatic and 40% asymptomatic) were randomly divided into two Groups. The control Group received no Manipulation while the other Group received Manipulation to the thoracic spine. Haas' *et al*., (1995) main focus was to determine the validity of spinal motion palpation and to investigate the sensitivity of motion palpation to clinical change in terms of end-feel. The perceived EFI by examiners was 60% in the Manipulation Group, in contrast with 37% response in the control Group. The study suggested that motion palpation as a post-treatment assessment tool showed a high level of responsiveness within the thoracic spine ($p<0.04$). Segmental end-feel palpation was found to have moderate use as an immediate post-treatment evaluation procedure for end-feel restoration within the thoracic spine. Haas *et al.,* (1995) suggested that further research be done on other patient populations, in other regions of the body, and with different examiners so that the generalisability of the study's results could be determined.

Similarly, Lakhani *et al.,* (2009) undertook a pre- and post-Manipulation assessment study whereby two Groups of fifteen participants were assessed in a blinded, randomized pilot study in which a third of the patients were asymptomatic. In this study, the blinded assessor noted the end-feel changes of the cervical spine post-treatment. For symptomatic participants, a strong relationship appeared to exist between EFI and Manipulation (p =0.006) with the etiologic fraction =78%, sensitivity =90% and specificity =80%. A strong relationship was not found for asymptomatic participants (p=0.444) where EFI was noted, whether participants received Manipulation or detuned ultrasound, the etiologic fraction =40%, sensitivity =100% and specificity =40%. Although the results were better in the symptomatic participants than in the asymptomatic participants, the results for the entire

sample showed that the sensitivity was excellent (93%), the specificity was adequate (67%) and the etiologic fraction was 63% (p<0.002).Therefore, Lakhani *et al.,* (2009) as well as Haas *et al.,* (1995) advocated that motion palpation can be seen as a valid post-treatment tool to detect responsiveness, specificity and sensitivity to change in the end-feel of a joint within the spinal region.

The above two studies were both conducted on the spine (Haas *et al.,* 1995 and Lakhani *et al.*, 2009) and both these studies recommended further research to be conducted on utilising motion palpation as a post-treatment tool to detect responsiveness. Furthermore, it has been shown that the use of motion palpation as a post-treatment assessment tool is valid within the spine and can detect end-feel response attributable to Manipulation (Haas *et al.,* 1995 and Lakhani *et al.*, 2009). However, motion palpation of this sort has yet to be explored throughout the rest of the joints in the body and extremities.

Both Haas *et al.,* (1995) and Lakhani *et al.,* (2009) recommended that further studies of this nature be undertaken to address issues of generalisability of study results to other areas of the body. Furthermore, Lakhani *et al.,* (2009) recommended similar motion palpation studies to be conducted to determine whether post-treatment assessment of an extremity would also lead to a similar level of sensitivity, specificity and etiologic fraction as was found in their study. A further reason to assess the validity of motion palpation in extremities is that in clinical practise, practitioners are not only treating spinal conditions but also extremity conditions to a greater extent (Verhagen, De Keizer, and Van Dijk, 1995; Ajis and Maffulli, 2006; Ajis, Younger and Maffulli, 2006). The validity for motion palpation as a tool to detect change in quality of fixations within the spine has been established (Haas *et al.,* 1995 and Lakhani *et al.*, 2009) but the validity of motion palpation as a tool in extremities has yet to be investigated.

It was also recommended that further studies of this kind be conducted on symptomatic participants only, as these show a greater response to Manipulation (Keating, 1989; Panzer, 1992; Hestbaek and Leboeuf-Yde, 2000; Huijbregts, 2002, Marcotte, Normand and Black, 2002; Vaughan, 2002; van Trijffel, Anderegg, Bossuyt, and Lucas, 2005 and Lakhani *et al.,* 2009). Therefore, all participants included in this study were diagnosed with chronic ankle instability (CAI) to increase homogeneity (Mouton, 1996). CAI was the chosen condition for this study because it is commonly encountered and is frequently seen within the clinical and sporting environments (Verhagen, De Keizer, and Van Dijk, 1995; Ajis and Maffulli, 2006; Ajis, Younger and Maffulli, 2006). Of all ankle sprain varieties, 85% are as a result of an inversion ankle sprain (Ferran and Maffulli, 2006). Although this figure refers to acute ankle

injuries, many people will persist to a state of chronicity if not treated (Ajis, Younger and Maffulli, 2006). According to Ferran and Maffulli, (2006), CAI is commonly encountered in Chiropractic practice. Therefore, this study assessed the validity of motion palpation as a post-treatment assessment tool, in participants with CAI.

Additionally, Ames (1987), Haas *et al.,* (1995), Yeomans (2000), Liebenson and Lewit (2003) and Lakhani *et al.,* (2009) also noted that monitoring of patients clinical progress post-treatment is vital, in order to determine whether patients are improving with treatment. These recommendations concur with Panzer (1992) who stated that motion palpation should be used, not only for clinical decision making in the future, but for monitoring patient progress along with other clinical findings.

Therefore, monitoring the patient for changes in fixations, and the relationship to other clinical indicators is of importance, as combining these elements (viz. subjective data, objective data and changes in fixations in the affected joint complex), can allow for a comprehensive clinical picture in which to monitor patient progress more accurately. However, motion palpation has yet to be incorporated into a study where association with other short term outcomes have been analysed. This study, therefore, attempted to determine the relationship between EFI using motion palpation, and subjective/objective clinical measures.

In summary, research findings show that motion palpation is sensitive and specific (Haldeman, 1992) and combining this post-treatment tool with other clinical measures could potentially yield better clinical effectiveness. Motion palpation as a post-treatment assessment tool appears to be of value within the spine and has the ability to identify end-feel improvement in a restricted segment which had been manipulated. Various studies have recommended (Leboeuf-Yde, Van Dijk, Franz, Hustad, Olsen, Pihl, Robech, Skov Vendrup, Bendix, and Kyvik, 2002; Marcotte, Normand and Black, 2002); Lakhani, 1999 and Haas *et al.,* 1995) further studies to be undertaken to assess and confirm the clinical responsiveness of motion palpation. Spinal motion palpation has been widely explored and studied, and the same is required within the realm of extremities. Since foot and ankle conditions are commonly seen in Chiropractic practice (Ferran and Maffulli, 2006) this was the area chosen in which to conduct this clinical study.

Therefore, this current study was done in the ankle region, on symptomatic participants with CAI. The results of this study may provide a clearer insight into the clinical responsiveness/efficacy of motion palpation as a post-treatment assessment tool in the

ankle region on participants with CAI, and the relationship of motion palpation to other clinical indicators.

1.2 The statement of the problem

The purpose and primary goal of this study was to investigate, via a prospective, blinded, randomized pre-post experiment, the validity of motion palpation as a post-treatment assessment tool to confirm whether the desired effect of the Manipulation had been achieved (i.e. end-feel improvement in the fixated joint has been perceived/achieved in the Manipulation Group as compared to the control Group). This study also considered short term outcomes following a single manipulation as a secondary goal e.g. whether associations between motion palpation results and other clinical measures occurred.

1.3 Aims, objectives and hypotheses

The aim of this study was to determine the clinical responsiveness of motion palpation as a post-treatment diagnostic tool in joints of the ankle. The specific objectives of this study were:

1.3.1 The first objective and hypothesis

1.3.1.1 The first objective

The first objective was to determine the validity of motion palpation as a post-treatment assessment tool in detecting an improvement in end-feel in the ankle region.

1.3.1.2 The first null hypothesis

Motion palpation will neither be beneficial nor unbeneficial as a post-treatment tool in detecting change in end-feel i.e. will not show a high level of responsiveness.

1.3.1.3 The first alternative hypothesis

Motion palpation will be a valid post-treatment tool to assess end-feel improvement i.e. will demonstrate a high level of responsiveness.

1.3.2 The second objective and hypothesis

1.3.2.1 The second objective

The second objective was to establish whether associations existed between motion palpation results and the results of other clinical measures i.e. when EFI was detected the subjective/objective clinical measures improved and when no EFI was detected the subjective/objective clinical measures did not improve. If an association was found to exist between post-treatment motion palpation results and the clinical signs and symptoms of CAI, then motion palpation could be used in conjunction with these clinical outcome measures used in this study in order to monitor the patient's progress.

1.3.2.2 The second null hypothesis

Post-treatment motion palpation results will not be related to the results of other subjective/objective clinical measures used in this study. Therefore EFI will not correlate with improvement in the subjective/objective clinical measures in the Manipulation Group, and a lack of EFI will not correlate with a lack of improvement in the subjective/objective clinical measures in the control Group.

1.3.2.3 The second alternative hypothesis

Post-treatment motion palpation results will be directly proportional to the results of other subjective/objective clinical measures used in this study. Therefore EFI will correlate with improvement in the subjective/objective clinical measures in the Manipulation Group, and a lack of EFI will correlate with a lack of improvement in the subjective/objective clinical measures in the control Group.

1.3.3 The third objective and hypothesis

1.3.3.1 The third objective

The third objective was to identify the most common fixations in symptomatic participants with CAI.

1.3.3.2 The third null hypothesis

The most common fixations within symptomatic participants with CAI in this study will not be established.

1.3.3.3 The third alternative hypothesis

The most common fixations in symptomatic participants with CAI in this study will be established.

1.4 Rationale of the study

1.4.1

Motion palpation is used frequently in the Chiropractic profession for the assessment of fixations pre- and post-Manipulation (Bergmann, Petersen and Lawrence, 1993; Liebenson and Lewit, 2003; Leach, 2004; Haldeman, 2005). In 1995, Haas *et al.,* reported that a tool was required for the assessment of patients in terms of restored or altered motion after Manipulation. Motion palpation has since been researched to assess its validity as a post-treatment tool and has been reported to suggest that it is a valid tool to detect responsiveness/etiologic fraction within the spinal region (Haas *et al.*, 1995; Lakhani *et al.*, 2009). Although motion palpation is commonly used as an assessment tool for both spinal and extremity joint fixations (Gatterman, 1995), no evidence exists at present to confirm or negate its validity as a post-treatment assessment tool in the evaluation of fixations after treatment in any extremity condition (Haas *et al.*, 1995; Lakhani *et al.*, 2009).

1.4.2

Ferran and Maffulli (2006) noted that lateral ankle sprains are the most common injury to the ankle joint. This was supported by Delahunt (2007) and Bozzelle and Kishner (2008) who reported that lateral or inversion ankle sprains were among the common injuries observed within the sporting arena. Up to 40% of these acute inversion ankle sprains will continue to develop into Chronic Ankle Instability (CAI) if left untreated. As a result, CAI is frequently encountered in both a clinical and sporting environment (Verhagen, De Keizer, and Van Dijk, 1995; Ajis and Maffulli, 2006; Ajis, Younger and Maffulli., 2006). Further investigations is, therefore, required to provide much needed information on the ankle joint, its diagnosis and clinical management for chiropractors and clinical physicians.

1.4.3

The inclusion of clinical measures in conjunction with motion palpation has been suggested (Haas *et al.,* 1995) in order to establish whether associations exist between motion palpation results and the results of other clinical measures. If associations do exist then it would strengthen the notion that motion palpation can be used as an adjunct to these clinical measures post-treatment, in order to monitor a patient's clinical progress.

1.5 Delimitations of the study

The limitations of this study are those that could either not be controlled for or were inherent limitations based on the study design and therefore cognizance of these limitations need to be taken.

1.5.1

The results of this study may not necessarily be applicable to all patients suffering from CAI (as there are two subtypes) through the various stages of the disease process, and therefore generalizations to the condition of CAI would be limited. This is due to the fact that this study only used participants with Grade one and two CAI (explained in Chapter Two).

1.5.2

The Hawthorne effect (Mouton, 1996) should be taken into account with respect to the subjective outcomes, which discusses the participants need to produce results that they believe the researcher wishes to see/hear.

1.6 Conclusion of the chapter and way forward in the dissertation

Motion palpation as a post-treatment assessment tool of the spine has been investigated in the realm of research within both the cervical and the thoracic spine (Haas *et al.,* 1995 and Lakhani *et al.,* 2009). Research on validity of motion palpation in these regions, indicated that motion palpation can successfully be used as a post-treatment evaluation tool for the spine. These findings have the potential to be extrapolated to other regions of the body with further studies similar to this study on the foot and ankle. Additionally, the exploration of motion palpation as a post-treatment assessment tool, and more especially, research on

motion palpation in conjunction with subjective/objective clinical measures to observe if EFI changes are associated with changes in these subjective/objective clinical measures has yet to be researched. Furthermore, the evidence presented shows that there is a paucity of literature and research studies involving motion palpation in any extremity region. Furthermore motion palpation appears to be used as a tool to assess the changes of the degree of fixation within a joint complex during the course of treatment to allow constant monitoring of patients (Ames, 1987; Haas *et al.,* 1995). One of the most applicable and important observations described by Ames (1987) is the use of motion palpation as "confirmation of effect after a Manipulation". However motion palpation used in this manner still needs to be validated, particularly on extremities. Therefore in an attempt to provide a clearer insight into the clinical responsiveness/efficacy of motion palpation as a post-treatment assessment tool and the relationship of motion palpation to other clinical indicators, this study was done in the ankle region, on symptomatic participants with CAI.

This chapter has sketched the problem and its setting in order to provide a basis for an overview of the aims, objectives and rationale of this study. Chapter Two highlights the literature surrounding the problem and its setting with particular interest in motion palpation and CAI. Chapter Three describes the materials and methods used in this study, whereas Chapter Four presents the results obtained and Chapter Five provides for a discussion of the results. Chapter Six concludes this study with its conclusions and recommendations based on the outcome of this study.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter gives an overview of the literature related to the validity of motion palpation to determine clinical responsiveness in the ankle joint of a patient with Chronic Ankle Instability (CAI). Therefore, literature on the anatomy of the ankle was discussed, as well as the literature surrounding CAI in terms of: grading, prevalence and incidence, clinical features, mechanism of injury and treatment. In addition to this, motion palpation is discussed, as well as studies related to motion palpation and categorised into: intra- and inter-motion palpation studies within the spine and extremities and then specific studies involving motion palpation as a post-treatment diagnostic tool within the spine. The subjective and objective readings which were utilised in this study have also been reviewed in this chapter and their reliability and reason for being included in the study have been shown with the provided literature.

2.1 Ankle anatomy

2.1.1 Introduction

Motion palpation of the foot and ankle requires a thorough understanding of the anatomy and biomechanics of the foot and ankle. Each joint has a normal range of movement that is determined by the orientation of the joint and surrounding structures. Without an understanding of these features, a clinician will not have accurate motion palpation findings. The following section will explain the movements, function and related structures of each joint that was examined in this study.

2.1.2 The ankle bones and joints

The foot and ankle joints can be divided into two sections by two separate sets of arches, namely the longitudinal and transverse arches (Moore and Dalley, 1999 and Tobias, Arnold and Allan, 1988). Examination of the foot from the medial aspect displays a clear longitudinal arch, which is composed of medial and lateral parts (Tobias, Arnold and Allan, 1988). The medial longitudinal arch is higher and of greater importance with regards to evenly

distributing weight, it is composed of: (Tobias, Arnold and Allan, 1988 and Moore and Dalley, 1999):

1. Calcaneus,
2. Talus,
3. Navicular,
4. Three cuneiforms and
5. Three metatarsals.

The lateral longitudinal arch rests on the ground during standing and is a flatter arch, it is composed of: (Tobias Arnold and Allan, 1988 and Moore and Dalley, 1999):

1. Calcaneus,
2. Cuboid and
3. Lateral two metatarsals.

The transverse arch of the foot runs from side to side and is composed of (Tobias Arnold and Allan, 1988 and Moore and Dalley, 1999):

1. Cuboid
2. Cuneiforms and
3. Base of the metatarsals

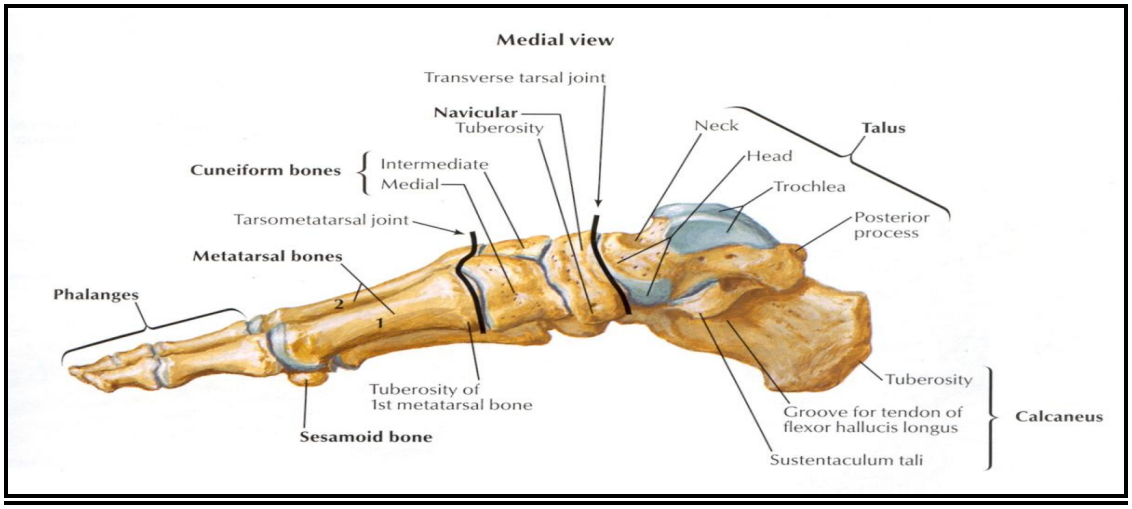


Figure 2.1 Bones in the foot and ankle region (Netter, 1999)

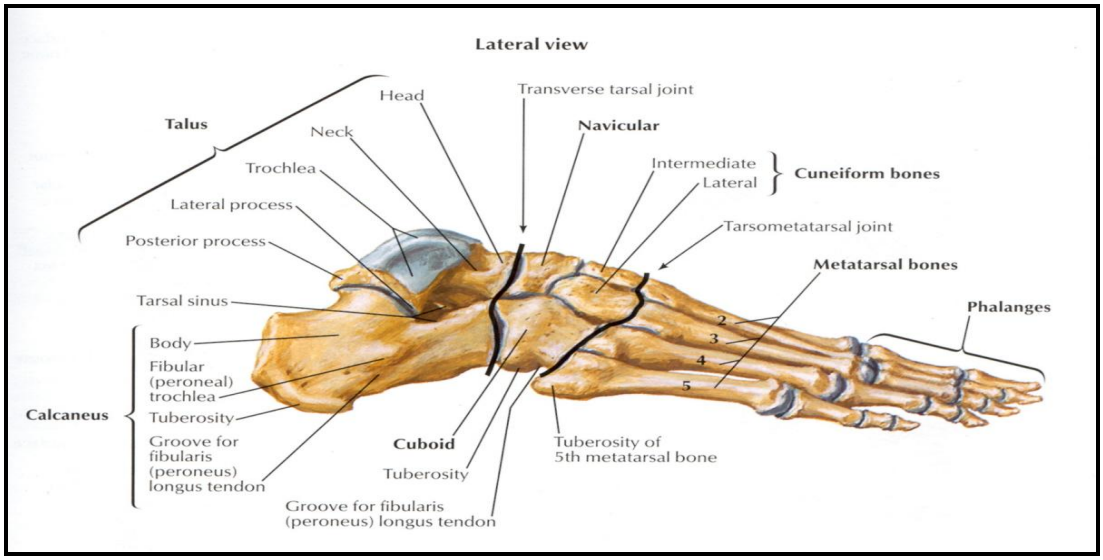


Figure 2.2 Lateral aspect of the bones and joints in the foot and ankle (Netter, 1999)

The ankle joint complex is made up of three articulations: the ankle joint or more specifically the talocrural or mortise joint (Norkin and Levangie, 1992), the subtalar joint and the distal tibiofibular syndesmosis (Hertel, 2002). Each of these joints has ligaments surrounding them which are the structures that are present to reduce the amount of side to side and / or rotatory motions, around the X axis in the joint. They function to connect bone to bone and in doing so, reduce the likelihood of joint separation and incongruency (Moore and Dalley, 1999).

2.1.1.1 The talocrural joint and ligaments

Denegar and Miller (2002) noted that the talocrural joint is a highly congruent joint located between the talus and the mortise and is created by the distal tibiofibular joint. It is a synovial hinge type of joint. The mortise is a deep three sided socket (formed by the two malleoli and the inferior end of the tibia) into which the trochlea of the talus fits (Moore and Dalley, 1999). The trochlea is wider anteriorly than it is posteriorly (Mack, 1982), convex from anterior to posterior and slightly concave from side to side (Moore and Dalley, 1999).

The stability and strength of the talocrural joint depends on joint congruency, supporting ligaments (Hockenbury and Sammarco, 2001) and musculotendinous support (Hertel, 2002). During dorsiflexion of the foot the talus moves from anterior to posterior and becomes “locked” into the mortise (Baker and Todd, 1995) or the “closed packed” position. In this position the ankle joint is considered stable (Baker and Todd, 1995) and very strong (Moore

and Dalley, 1999). When the foot is plantarflexed the talus is “unlocked” (Baker and Todd, 1995) as the trochlea of the talus moves anterior in the mortise (Moore and Dalley, 1999). In full plantarflexion of the foot some side to side movement can be demonstrated and, therefore, in this position the talocrural joint is considered to be fairly unstable (Moore and Dalley, 1999). This is the “open packed” position, where the patient is most prone to injury.

Strong collateral ligaments on either side of the mortise joint support the thin fibrous capsule of the talocrural joint (Gray, 1984). The lateral ligaments, although sturdy, are weaker than the medial deltoid ligaments (Moore and Dalley, 1999). Lateral stability to the talocrural joint is provided for by three ligaments that attach the lateral malleolus to the calcaneus and the talus (Moore and Dalley, 1999). They are the anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL) and the calcaneofibular ligament (CFL) (Hockenbury and Sammarco, 2001). These ligaments provide resistance against inversion and internal rotation (around the Z axis) stress (Hockenbury and Sammarco, 2001).

The ATFL is a weak flat ligament extending from the lateral malleolus to the neck of the talus (Moore and Dalley, 1999) and is a thickening of the lateral capsule (Bassewitz and Shapiro, 1997). Resembling a round cord, the CFL runs postero-inferiorly from the tip of the lateral malleolus to the lateral surface of the calcaneus (Moore and Dalley, 1999). The ATFL and CFL work together to support the lateral ankle (Bassewitz and Shapiro, 1997). In the plantarflexed position the ATFL is aligned vertically and under tension, and in the dorsiflexed position the CFL is vertically aligned and under tension (Bassewitz and Shapiro, 1997).

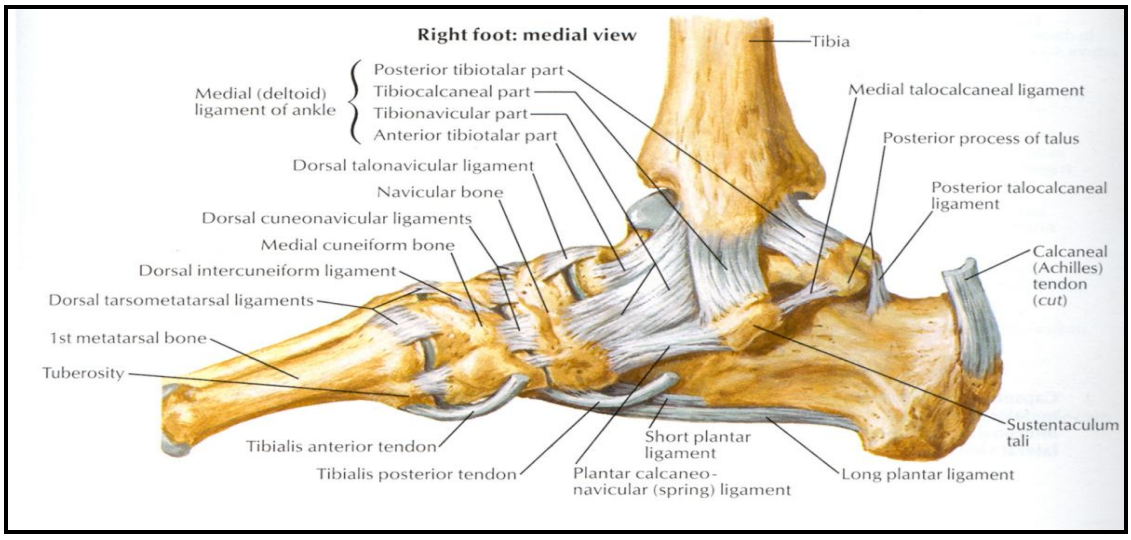


Figure 2.3 Ligaments of the foot and ankle (Netter, 1999)

The PTFL is the strongest of the lateral ligaments and resists forward translation / dislocation of the leg and the foot (Mack, 1982). The PTFL runs horizontally medially and slightly posteriorly from the malleolar fossa to the lateral tubercle of the posterior process of the talus (Moore and Dalley, 1999). Crossing the CFL superficially are the tendons of the fibularis longus and brevis muscles (Moore and Dalley, 1999) which pass distally and inferiorly to the lateral malleolus (Mack, 1982). These tendons further contribute to the ankle stability by being tightly bound down by thickenings of the deep fascia called the retinacula (Moore and Dalley, 1999) and function as pronators and everters of the foot (Mack, 1982). The tendon sheath of these muscles covers the posterior and lateral aspect of the CFL, hence when this ligament is injured; the inner wall of the tendon sheath is also injured. There is an intricate relationship between these tendons and the stabilizing ligaments where the tendons are capable of absorbing stress and protecting the ligaments from injury (Mack, 1982).

2.1.1.2 The subtalar joint

The subtalar joint is a synovial joint (Moore and Dalley, 1999) and is located between the talus and the calcaneus and the anterior part of this joint is known as the talonavicular which is located between the talus and navicular (Moore and Dalley, 1999; Hertel, 2002). The subtalar joint function is to dampen rotational forces imposed by body weight in the weight-bearing position (Norkin and Levangie, 1992). This joint has ample strong ligaments that make it a very stable joint that very rarely dislocates and aids in the weight transfer from the body to the hindfoot and forefoot (Norkin and Levangie, 1992).

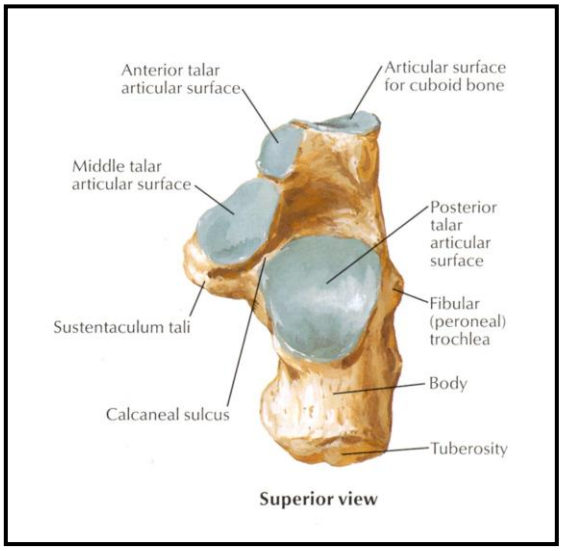


Figure 2.4 Subtalar joint (Netter, 1999)

2.1.1.3 The distal tibiofibular joint

The distal tibiofibular joint is a fibrous syndesmotic joint (Moore and Dalley, 1999) located between the concave facet of the tibia and the convex facet of the fibula (Norkin and Levangie, 1992). The distal tibiofibular joint ligaments are responsible for primarily restricting movement at both the proximal and distal tibiofibular joints and maintain mortise stability (Norkin and Levangie, 1992). According to Norkin and Levangie (1992) the function of the talocrural joint is dependent on the tibiofibular mortise. If the tibia and fibula were allowed to separate or if one side of the mortise was missing the tibia and fibula would be unable to grasp and hold onto the distal joint segment (Norkin and Levangie, 1992).

2.1.2 Summary of the ankle anatomy

According to Reid (1992), the bony configuration of the ankle joint, fibular movement and the fibularis muscles all play an important synergistic role with the ankle ligaments. Reid (1992) concluded that if these biomechanical and anatomic relations are considered then the ATFL is probably one of the most important stabilizing constituents, but is also the weakest link of the lateral ligamentous apparatus. This implies that damage to the ATFL is not a minor injury and can lead to marked chronic ankle instability if the best possible treatment is not received (Reid, 1992).

2.2 Chronic ankle instability

2.2.1 Introduction

Chronic ankle instability (CAI) can additionally be known as recurrent inversion ankle sprains, chronic unstable ankle sprains, chronic ankle instability syndrome, lateral ankle sprains and functional instability (Hertling and Kessler, 1996; Veenema, 2000; Karlsson, Rolf and Orava, 2003; Ajis, Younger and Maffulli, 2006; Ferran and Maffulli, 2006). An inversion ankle sprain can be defined as an injury caused by landing forcefully on an inverted, plantarflexed and internally rotated foot (Hockenbury *and* Sammarco, 2001). This causes the fibres of the adjoining ligaments to become ruptured without disturbing the continuity of the ligament (Hockenbury and Sammarco, 2001). Chronic stable ankle sprains are defined as the recurrent giving way of the ankle and there may be enduring pain and swelling (Hertling and Kessler, 1996) with no mechanical instability (Veeneema, 2000). However, CAI is characterised by the presence of four or more of the following symptoms (which includes

mechanical instability): ankle pain, joint weakness, edema, crepitus, adhesions, restrictions and ligamentous laxity (Caulfield, 2000; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006 and McBride and Ramamurthy, 2006). CAI can be classified into different Grades according to the severity of the injury. For this study the classification system as described by Reid (1992) was used.

Table 2.1 Grading of CAI

Severity:	**Pathology:**	**Signs and Symptoms:**	**Disability:**
Grade 1 stable	- Mild stretch - No instability - Singular ligament involved - Often ATFL	- No haemorrhage - Minimal swelling - Point tenderness - No anterior drawer - No varus laxity	- No or little limp - Minimal functional loss - Difficulty hopping - Recovery 2-10 days
Grade 2 stable	- Large spectrum of injury - Mild to moderate instability - Complete tearing of ATFL or partial tearing of ATFL plus CFL	- Some haemorrhage - Localized swelling - Margins of Achilles less defined - May be anterior drawer - No varus laxity	- Limp with walking - Inability to toe raise - Inability to hop - Unable to run - Recovery 10-30 days
Grade 3 unstable	- Significant instability - Complete tear of anterior capsule and talofibular ligament and associated tear of ATFL and CFL	- Diffuse swelling both sides of Achilles tendon - Early haemorrhage - Medial and lateral tenderness - Positive anterior drawer - Positive varus laxity	- Unable to fully weight bear - Significant pain inhibition - Almost complete loss of range of motion initially - Recovery 30-90 days

2.2.2 Clinical Features of CAI, and their causes

Hertling and Kessler (1996) reported that following the initial injury of the ankle, some patients will suffer “giving way “of the ankle followed by pain and swelling. Symptoms that often continue after this type of injury include pain, instability, crepitus, weakness, joint fixations and stiffness (Kessler and Hertling, 1983; Reid, 1992; Baker and Todd, 1995; Hertling and Kessler, 1996; Bassewitz and Shapiro, 1997; Caulfield, 2000; Richie, 2001; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006; McBride and Ramamurthy, 2006; Delahunt, 2007). Within clinical practice, these ongoing symptoms following an ankle ligamentous injury are frequently seen (Patel and Warren, 1999). The main causes of all the

above symptoms are: functional instability, a tight and sensitive scar, incomplete rehabilitation and stiffness from a loss of fibula and subtalar motion (Reid, 1992).

2.2.2.1 Fixations and hypomobility in the ankle joint

Hypomobility after lateral ankle sprain has been attributed to:

1) Fixations, which occur as a result of altered arthrokinematics, in the ankle-joint complex (Kavanagh, 1999, Lewit, 1999 and Meadows, 2002) as well as
2) Restrictions and adhesion formation in and around the joint (Kessler and Hertling, 1983; Reid, 1992; Caulfield, 2000; Richie, 2001). Meadows (2002), defined a subluxation as ‘‘a biomechanical problem with the joint jamming at one end of the range of movement and blocking movement away from that range.’’

It has been reported that after a lateral ankle sprain, the following joints may be hypomobile and have fixations present:

- Subtalar joint (Greenman, 1996 and Meadows, 2002),
- Talocrural joint (Dannenberg, Shearstone and Guillano, 2000; Denegar, Quesnel and Howard, 2000; Green, Refshauge, Crosbie, and Adams, 2001 and Hertel, 2002),
- Distal tibiofibular joint (Mulligan,1995; Hetherington, 1996; O’Brien and Vicenzino, 1998 and Kavanagh, 1999), and / or
- Proximal tibiofibular joint (Greenman 1996; Dananberg *et al*., 2000. and. Meadows, 2002).

Hypomobility within the ankle joint has been reported in many studies (Greenman, 1996; Lewit, 1999 and Meadows, 2002). Denegar *et al.,* (2002) reported restricted movement in anterior to posterior talar movement (referred to as A-P of mortise joint in this study) in a Group of collegiate athletes who had returned to sport after ankle sprain. Furthermore dorsiflexion has too been found to be limited after a lateral ankle sprain (Garrick and Webb, 1990; Taunton, Smith and Magee, 1996 and Wolfe, Uhl, Mattacola and McCluskey, 2001). It has been suggested that this limitation of movement is due to tightness in the gastrocnemius-soleus complex and capsular adhesions that develop during immobilization (Garrick and Webb, 1990; Taunton, Smith and Magee, 1996; Liu, Siegler and Techner, 2001 and Wolfe *et al*., 2001).

2.2.2.2 “Giving way” and instability of the ankle joint

The sensation of “giving way” and instability within the ankle is as a result of abnormal postural control and proprioceptive alterations as well as generalised laxity noted on orthopaedic tests (such as anterior drawers test) (Reid, 1992; Caulfield, 2000; Richie, 2001; Delahunt, 2007). When the ligament heals with adherence to surrounding tissues it becomes tightened and a forceful stress placed on the ankle, can rupture these adhesions and the person experiences another sprain (Reid, 1992; Caulfield, 2000; Richie, 2001). The muscular weakness and reduced fibularis muscle reaction time from the initial injury also seems to lead to the occurrence of the repeated ankle sprains and sensation of unsteadiness in the ankle. The constant sense of “giving way” in the ankle supports the persistence of the problem and if not corrected may be one of the first clinical features noted on the part of the patient with respect to CAI. The patient may also describe this feeling of “looseness” or “giving way” of the ankle more commonly than pain and they may have a history of recurring inversion injuries to the ankle (Patel and Warren, 1999). Shortening of the invertors’ muscles leads the ankle into further inversion and increases the chance of damage to the ankle.

2.2.2.3 Pain and swelling in the ankle joint

Furthermore, the repetitive trauma can generate pain as a result of tissue inflammation, impaction or local impingement or damage to nerves in the area. These processes can lead to swelling (Patel and Warren, 1999) and according to Esterson (1979) in Tatro-Adams, McGann and Carbone (1995), this typically occurs around the ATFL, CFL and the anterior tibiofibular ligament. Furthermore, this swelling may also compress nerves and cause further pain to be elicited (Reid, 1992).

Based on the clinical features pertaining to CAI (2.2.2.1-2.2.2.3) and for the purpose of this study, CAI is defined by the presence of four or more clinical features (Reid, 1992; Caulfield, 2000). Therefore participants were required to have four or more of these symptoms: lateral ankle pain, weakness, edema, crepitus, adhesions resulting in the formation of restrictions in the joint and ligamentous laxity (Caulfield, 2000; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006; McBride and Ramamurthy, 2006).

2.2.3 Prevalence and Incidence of CAI

The most common injury to the ankle region is a lateral ankle inversion sprain (Mack, 1982) furthermore; this area sustains the highest incidence of sports injuries (Jerosch and Bischof, 1996). Furthermore foot and ankle conditions are commonly encountered in Chiropractic practice (Ferran and Maffulli, 2006). From an epidemiological standpoint, CAI is a frequently encountered condition and is often seen within a clinical as well as a sporting environment (Verhagen, De Keizer, and Van Dijk, 1995; Ajis and Maffulli, 2006; Ajis, Younger and Maffulli, 2006).

According to Wexler (1998), approximately one million ankle injuries occur annually in the United States of America, and most of them are ankle sprains resulting from inversion sprains. Studies have shown that roughly 85% of ankle injuries involve some degree of sprain of the ankle ligaments. Of these, 85% are inversion sprains of the lateral ligaments (Garrick, 1977, Ferran and Maffulli, 2006). Although these figures refers to acute ankle injuries, many people will persist to a state of chronicity if not treated (Ajis, Younger and Maffulli, 2006), resulting in CAI.

Lysens, Steverlyncky, Van den Auweele, Lefevre, Renson, Claessens, and Ostyn (1984) performed a study on the predictability of sports injuries in students and found that students with a previous history of injury were at a higher risk of re-injury. Lysens *et al.,* (1984) also found that out of 162 reported ankle sprains, 72 (44.5%) were re-injured within the 4 year study. In keeping with these findings, Smith and Reischl (1986) reported that the re-injury rate after lateral ankle sprain has been as high as 80% among athletes.

A systemic review on ankle sprain and ankle injury in sports performed by Fong, Hong, Chan, Yung and Chan (2007) showed that ankle sprains were the most common ankle injury in 33 of 43 sports investigated. In sports injuries throughout the countries studied in this systemic review, the ankle was the second most commonly injured site after the knee, with the ankle sprain being the most common type of ankle injury (Fong *et al*., 2007). It was found that ankle sprains were especially found in court sports and team sports, such as rugby, soccer, volleyball, handball and basketball (Fong *et al*., 2007). This supported Karlsson, Rolf and Orava (2003) who had reported that running and jumping sports (e.g. soccer, basketball and volleyball), are high risk activities for ankle ligament injuries.

2.2.4 Mechanism of injury in CAI

As stated by Mack (1982), bony stability in the neutral position is greater medially than laterally, therefore predisposing an individual's ankle towards inversion rather than eversion. Once inversion has begun, the ankle loses its bony stability, and the medial malleolus instead of functioning to stabilize the foot which becomes a fulcrum for further inversion (Mack, 1982; Karlsson, Rolf and Orava, 2003). If the fibularis muscles are not strong enough, the tensile strength of the lateral ligaments may be surpassed (Mack, 1982). These lateral ligaments are responsible for providing strength in this position of reduced bony stability (Anderson, 2002). Furthermore, if the foot is in the plantarflexed position when the injury occurs, then the ATFL is affected (Cailliet, 1997). In this position the ATFL becomes vertically aligned, parallel to the fibula and, therefore, under tension (Bassewitz and Shapiro, 1997). Lateral ankle ligament injury most commonly occurs when the ankle undergoes inversion and internal rotation with the ankle in various degrees of plantarflexion (Bennett, 1994), while the tibia simultaneously rotates externally (Karlsson, Rolf and Orava, 2003). Hence, the ATFL which is under greater tension during plantarflexion is the most commonly injured ligament (Bassewitz and Shapiro, 1997).

In the dorsiflexed or neutral position the calcaneofibular (CFL) experiences injury (Cailliet, 1988) as in this position, the CFL is in line with the fibula and under tension (Bassewitz and Shapiro, 1997). Hence, these ligaments are variably injured depending on ankle position at the time of stress (Bassewitz and Shapiro, 1997). While injury frequently affects the ATFL, the CFL may also be injured, and occasionally the PTFL may also be involved (Brantingham, Snyder, Wong, Brantingham and Haggart, 1993).

According to Reid (1992), a major mechanism of injury is landing from a jump, particularly when landing on another player's foot or on an uneven surface. Other mechanisms of injury include abrupt changing of direction especially if associated with deceleration (Reid, 1992), walking on uneven surfaces or stepping into a hole (Kuwada, 1995).

2.2.5 Complications of CAI

CAI has the potential to become a critical injury if not managed correctly and if untreated, CAI can progress and commonly lead to:

- Fractures of the foot and ankle,
- Damage to the common peroneal nerve sheath,

- Osteochondral fragments,
- Tarsal tunnel syndrome and / or
- Neuritis (Renstrom, Wertz, Incavo, Pope, Ostgaard, Arms and Haugh, 1988; Fallat, Grimm and Saracco, 1998).

2.2.6 Treatment options in CAI

Whilst many surgical interventions are offered for treatment of CAI, surgery is only advocated for severe Grade III CAI, where mechanical instability is marked (Reid, 1992). In addition to this, Ajis and Maffulli (2006) suggested that conservative care should ideally be chosen, as it involves less risk and complication and often demonstrates similar results in the long term for Grade I or II CAI.

Acute management involves the application of the RICE principle (rest, ice, compression and elevation), however, the importance of rehabilitation cannot be overemphasized, as a lack of rehabilitation could lead to persistent pain and swelling, decreased range of motion and chronic joint instability (Wolfe, Uhl, Mattacola and McCluskey ,2003).

Various conservative treatment regimes and modalities can be employed to achieve appropriate care of a patient with CAI. These include:

● Manipulation (Edmond, 1993; Needham, 2001; Pellow and Brantingham, 2001; Green *et al.,* 2001; Collins, Teys and Vicenzino 2002; Gillman 2004; Jennings and Davies, 2005; Brantingham, Pollard, Hicks, Korporaal and Hoskins 2009; Joseph, de Busser and Brantingham, 2010),
● Mobilization (Hockenbury and Sammarco, 2001),
● Cryotherapy (Ogilvie-Harris and Gilbart, 1995; Hockenbury and Sammarco, 2001),
● Ultrasound (Thompson, Skinner and Piercy, 1991; Zammit and Herrington 2005),
● Range of motion and strengthening exercises (Reid, 1992; Anderson, 2002),
● Laser treatment (De Bie, de Vet, Lenssen, van den Wildenberg, Kootstra and Knipschild, 1998) and
● Deep transverse frictions massage (Hertling and Kessler, 1996).

The treatment option utilised in this study i.e. Manipulation is discussed in detail below:

According to Peterson and Bergmann (1993), early intervention for soft tissue injury by means of manual therapy promotes better healing, decreases pain and inflammation, prevents further injury, and promotes flexibility. Manipulative therapy which is a procedure that has been suggested to induce quick distraction and break the intra-articular adhesions (Pellow and Brantingham, 2001) has recently been researched in many studies as a form of treatment for CAI (Pellow and Brantingham, 2001; Green *et al.,* 2001; Collins *et al.,* 2002; Gillman 2004; Jennings and Davies, 2005; Brantingham *et al*., 2009; Joseph, de Busser and Brantingham*,* 2010). In summary, Manipulation has been recommended for the treatment of chronic ligamentous sprains of the lateral collateral ligaments at the ankle to improve range of motion and ankle function and to decrease pain (Pellow and Brantingham, 2001; Green *et al.,* 2001; Collins *et al.,* 2002; Gillman 2004; Jennings and Davies, 2005; Brantingham *et al*., 2009; Joseph, de Busser and Brantingham*,* 2010).

A single blinded controlled pilot study conducted by Pellow and Brantingham (2001) investigated the effects of Manipulation in comparison to detuned ultrasound in 30 patients that were split into two equal treatment Groups suffering with CAI. Group A received a Manipulation (specifically long axis distraction) and Group B received five minutes of detuned ultrasound. The study was conducted over a four week period with all eight treatments conducted in that time frame. The outcome for the study suggested that Manipulation is effective on the treatment of CAI (p=0.001). Inter-Group analysis revealed that a treatment effect for the Manipulation Group was observed at the final treatment. With regards to intra-Group analysis, improvements in the 'only Manipulation Group' were noted specifically with respect to reduced pain on the Numerical Pain Rating Scale (NRS)101 (p=0.001), McGill Pain Questionnaire (p=0.001), Goniometer (p=0.002), Pressure Algometer (p=0.013) and improved general ankle functioning (p=0.001). This is in comparison to the detuned ultrasound Group where NRS101 readings were (p=0.007), McGill Pain Questionnaire (p=0.038), Goniometer (p=0.199) Pressure Algometer (p=0.017) and general ankle function (p=0.004). Thus, it was concluded that Manipulations to the ankle (at the site of fixations in the ankle) would be effective in the treatment of CAI. Improvements were noted specifically in terms of enhanced range of motion, reduced pain intensity and quality and generalised improved ankle function (Pellow and Brantingham, 2001).

In addition, Collins *et al*., (2002), conducted a study on 16 participants with Grade II sub-acute ankle instability to assess the effectiveness that mobilisation with motion has on weight bearing dorsiflexion, pressure and thermal pain. Each of the participants was randomly allocated into one of the three research Groups: Group one was a mobilisation with movement treatment, Group two was a placebo and Group three was a 'no treatment

control Group'. Results of this study showed statistically significance treatment effect in the mobilisation with movement Group, for improved range of motion, specifically for weight bearing dorsiflexion (p=0.013). This was in comparison to the placebo Group (p=0.202) and the no treatment control Group (p=0.208), where no statistically significant values were noted for this outcome. For statistical analysis on pain, there were no inter-Group differences noted but time effects for the mobilisation with movement Group were noted (p=0.010) which was not noted in the placebo or control Groups (p=0.017).

In a single blinded randomised clinical trial that investigated the effects of single versus multiple Manipulations on proprioception and ankle dorsiflexion in CAI patients by Kohne, Korporaal, Price, Brantingham and Globe (2007), thirty participants were placed into two Groups. Both Groups received Manipulation as the form of treatment, however, Group one received six Manipulation treatments over a four week period, whereas the control Group received a single Manipulation to the ankle. The study revealed a statistically significant treatment effect for the six Manipulation treatment Group on two measures of proprioception (p=0.029 and p=0.047) and dorsiflexion range of motion (p=0.028).

In a review article by Brantingham *et al.*, (2009), Manipulation to the lower extremity was advocated as a method of treatment for mechanical conditions, and in addition to this, Manipulation to the foot and ankle appeared to be a treatment intervention of choice in participants with CAI (Pellow and Brantingham, 2001; Gillman, 2004). All literature that was reviewed in the systematic review was deemed as an overall B grade standard of quality i.e. (documented/reported as fair evidence from relevant studies) (Brantingham *et al.*, 2009).

Therefore many studies advocate Manipulation as a form of treatment for CAI, to reduce pain and inflammation, and improve range of motion and general functioning of the ankle (Pellow and Brantingham, 2001; Collins *et al.,* 2002; Eisenhart, Gaeta and Yens 2003; Jennings and Davies, 2005; Vincenzino, Branjerdporn, Teys and Jordan*,* 2006 and Brantingham *et al.,* 2009).

2.2.7 Summary of CAI

Ankle sprains are seen on a daily basis (Reid, 1992; Souza, 1998). More specifically, inversion ankle sprains are the most frequently noted injuries of this particular region, contributing to 85% of all complaints (Caulfield, 2000; Balint, Korda, Hangody, and Balint, 2003; Ferran and Maffulli, 2006; Bozzelle and Kishner, 2008). Epidemiological studies have discussed that in injuries of the lateral ligamentous complex approximately 40% are likely to

progress to a state of CAI (Souza, 1998) within the ankle and the hind foot (Ajis, Younger and Maffulli, 2006; Rimando, 2008). It is evident that CAI is a recurrent problem that is often encountered in the setting of clinical practice (Ajis and Maffulli, 2006; Ferran and Maffulli, 2006). Furthermore, various studies have advocated the use of Manipulation for the treatment of CAI (Pellow and Brantingham, 2001; Green *et al.,* 2001; Collins *et al.,* 2002; Gillman 2004; Jennings and Davies, 2005; Brantingham *et al*., 2009; Joseph, de Busser and Brantingham*,* 2010). Therefore, CAI and Manipulation have been selected as a part of this study.

2.3 Motion palpation

2.3.1 Introduction

Palpation by definition is the use of tactile senses to determine variations in tissue consistency, in order to recognize whether these variations are normal or abnormal (Haldeman, 1992). It can be divided into static and motion palpation (Bergmann, Peterson and Lawrence, 1993), Static palpation is palpation of somatic structures in a neutral and stationary position (Bergmann, Peterson and Lawrence, 1993), where as motion palpation can be defined as a palpatory diagnosis of passive and active segmental joint range of motion (Bergmann, Petersen and Lawrence*,* 1993). Furthermore, Redwood and Cleveland (2003) suggested that when performing motion palpation, moving a joint to its end range of motion or physiological barrier, the examiner can further spring the joint, assessing the end play for a manipulable fixation.

According to Cooperstein and Gleberzon (2004), motion palpation is seen as one of the core practical subjects taught in almost every Chiropractic institute around the world. This is supportive of a survey conducted in Australia, (which was chosen for its high response rate), where it was found that chiropractors regarded motion palpation as one of the most reliable tests to indicate the use of Manipulation. It has also been noted that motion palpation is used frequently for the assessment of fixations both pre- and post-treatment (Bergmann, Petersen and Lawrence, 1993; Liebenson and Lewit, 2003; Leach, 2004; Haldeman, 2005,) and is still the most recognized physical examination technique that supports the presence or absence of manipulable subluxations (Bergmann, Petersen and Lawrence*,* 1993).

Motion palpation is specifically directed at joint movement and addresses several aspects of this joint motion namely:

Accessory Joint Movements: These are involuntary movements that represent the small “give or play” within a joint that is essential for normal function, and it is the joint capsule that is responsible for the smooth feel, as it allows for sufficient play and articular surface separation to avoid abnormal joint movement (Bergmann, Petersen and Lawrence, 1993). As a consequence, motion palpation is used to assess this accessory joint movement by means of joint play and end-feel. These terms refer to the springy feel which is normally present in a joint when taken further than its active motion limits (Bergmann, Petersen and Lawrence, 1993).

Joint Play: This is a discrete, short range movement of a joint independent of the action of voluntary muscles. It can be determined by springing the joint (in a neutral position), in various directions (Bryner, 1987; Bergmann, Petersen and Lawrence, 1993; Leach, 2004 and Haldeman, 2005).

End-Feel: This is encountered at a joint’s passive end range of motion and can describe the resistance of a joint to further stretch (Bryner, 1987; *et al.*, 1993; Leach, 2004; Haldeman, 2005). End-feel evaluation can often be more valuable when measuring the total passive range of motion of a joint rather than in those cases where individual joint movement is restricted. Within end-feel there are three normal end-feels: bone to bone, soft tissue approximation and tissue stretch, and five abnormal end-feels: muscular spasm, capsular, bone to bone, empty and springy block Magee (1992).

End-Feel Improvement (EFI): An immediate end-feel restoration of motion segment movement after Manipulation (Lakhani *et al.,* 2009).

In summary, an accessory movement can be defined as that degree of end movement or distension allowed passively that cannot be achieved by voluntary effort (Schafer and Faye, 1990). Additionally the end-feel is the resistance felt at the end of passive range of motion, while joint play is the resistance felt in the neutral position (Bergmann, Petersen and Lawrence, 1993).

2.3.2 Observation and Principles of motion palpation

Ames (1987) noted several observations that could be made using motion palpation. These observations (discussed below in 2.3.2) are still used today in the diagnosis, treatment and

management of fixations. For example, motion palpation has the capability to detect the range of motion at each individual level of the spine and pelvis in all of the six degrees of freedom (within individual motor units / motion segment). Additionally, Ames (1987) observed that motion palpation could perceive normal and abnormal joint play as well as the end-feel within the motion segments. Furthermore, motion palpation was observed to have the ability to identify pain within the ranges of motion and the capacity to determine the affected muscles length (Ames, 1987). An additional observation stated that, motion palpation can determine the direction of the applied force necessary to correct a fixation (Ames, 1987). A further and final observation was made by Ames (1987) that motion palpation should be used to confirm whether the desired effect has been achieved after a Manipulation has occurred. This final observation underlies the foundation of motion palpation being used as a post-manipulative assessment tool and as it has been used in this study.

In addition to and in support of Ames (1987), Bergmann, Petersen and Lawrence (1993) developed a list of principles for motion palpation. Bergmann, Petersen and Lawrence (1993) stated that movement within a joint can be evaluated by testing how the two bony joint articulations and their soft tissues move in relation to one another. Furthermore, it was noted that when assessing segmental movement, one joint should be tested at a time, in one movement, around one axis and in one plane where possible (Bergmann, Petersen and Lawrence, 1993), and that each motion segment in the sequence should be examined and moved through the complete available range of motion- starting and ending at neutral (Bergmann, Petersen and Lawrence, 1993). Additionally, Bergmann, Petersen and Lawrence (1993) maintained that the motion must be performed slowly and efficiently with the minimal force needed, and that comparisons must also be made to the contra-lateral side and adjoining segments. Bergmann, Petersen and Lawrence (1993) also stated a list of goals that motion palpation should assess:

- Quantity and quality of movement,
- End-feel and joint play of the joint and
- Symptoms (changes in the amount of symptoms or location of symptoms during motion and assessment, i.e. pain and swelling decreased on the lateral portion of the ankle).

These observations, principles and goals were taken into account and followed as closely as possible to ensure effective and valid motion palpation in this study.

2.3.3 History of motion palpation

Gillet (1995) summarized the history of motion palpation in his article: “New light on the history of motion palpation”. Gillet (1995) noted that the introduction of motion palpation was in a book called Modernized Chiropractic, published in 1906 by O.G Smith. Smith’s idea was acknowledged by Gillet (1995), who went on to introduce motion palpation to the world. Smith, his brother, Marcel and Maurice Liekens then proceeded to define a subluxation as ‘A motion segment in which alignment, movement integrity, and physiologic function (example: muscular, vascular, ligamentous and nervous) are altered although contact between the joint surfaces remain intact’. Gillet (1995) along with McAndrews and Faye (1990) were partially credited for emphasizing the role of ‘total and partial’ fixations of spinal segments (Wardwell, 1992).

Furthermore, the first teachings on motion palpation were conducted by Gillet (1995) in New York in 1951. This led to a cascade of seminars and courses throughout the world and it took about fifty years, from the initial concept for motion palpation, to form an essential part of patient examination to gain access to the Chiropractic profession. In 1968, Gillet started teaching motion palpation at the Anglo-European College of Chiropractic in Great Britain. There he met Faye who began teaching the importance of motion palpation. In 1989, Faye created the Motion Palpation Institute in California (Schafer and Faye, 1990) and motion palpation became a component of the syllabus in most colleges as a required topic in the Chiropractic course for subluxation examination.

The article by Gillet (1995) on the history of motion palpation was based on spinal motion palpation. Furthermore, an article by Nelson, Lawrence, Triano, Bronfort, Perle, Metz, Hegetschweiler and LaBrot (2005) suggested that the Chiropractic profession has focussed primarily on spinal conditions, as these were thought to be the model for the future of the profession. This has led to a perception, that the scope of Chiropractic is limited to the management of spinal conditions (Stump and Redwood, 2002). However, according to DD Palmer (Brantingham and Snyder, 1992) and other pioneers (Smith, Langworthy and Paxon, 1906) of the profession, Chiropractic techniques also exist for the management of extremity conditions. At most colleges, chiropractors are trained to diagnose and treat neuromusculoskeletal conditions associated with the appendicular skeleton and not just the axial skeleton (Gillet, 1995). Therefore, the Chiropractic graduate is qualified to manage extremity conditions as well as spinal conditions (Hoskins, McHardy, Pollard, Windsham and

Onley, 2006). Motion palpation is now a recognized assessment tool that plays a vital role in the diagnostic part of the science of Chiropractic.

In order to gain the most precise and valid information from motion palpation and to guarantee the correct diagnosis is made, it is crucial that motion palpation is reliable and consistent (Bezuidenhout, 2002). With motion palpation being one of the common methods utilised within a clinical Chiropractic setting to find fixations within a joint (Schafer and Faye, 1990), it needs to be investigated thoroughly (Mouton, 1996).

2.3.4 Studies pertaining to motion palpation

To date, motion palpation research has been primarily based on reliability studies (Haas *et al.,* 1995). According to Haas *et al.,* (1995), two types of reliability exist: firstly inter-examiner reliability which consists of one assessment of all participants by two or more examiners, blinded to each other's interpretation, and this is used to measure examiner agreement between different examiners. Secondly, intra-examiner reliability is a measure of self-consistency, where each examiner must perform at least two measurements of one particular joint (Gatterman, 2005). Haas *et al.,* (1995) states that the reliability of a procedure can be defined as: "the extent to which a repeated test will produce the same result when evaluating an unchanged characteristic". In this context, motion palpation is required to be reproducible (i.e. inter- and intra-examiner reliability) in the clinical setting (Lakhani, 1999; Bezuidenhout, 2002), in order for practitioners to use the evaluation to obtain valid information on which to base a diagnosis, or to reconsider treatment options while monitoring patient progress (Panzer, 1992).

2.3.4.1 Motion palpation as a pre-treatment evaluation within the spine and extremities

The following table was constructed to display, briefly, some of the palpation (static and motion) studies which have been conducted. Studies have been classified into regions and results. It is to be noted that all motion palpation studies have not been included here, but that an effort was made to include at least one study from each decade (1980-1989, 1990-1999, and 2000-2011), of each region and of both favourable results (finding motion palpation to be valid/reliable) and unfavourable results (wherein motion palpation was not found to be valid/reliable). Results were classified briefly into the two categories of:

- Favourable (with good, good to moderate, moderate, fair and substantial all being in the this column) and,
- Unfavourable (with moderate to poor, fair to poor, poor and inconclusive within this column).

Studies which were found to be of most importance to this study were discussed in further detail below the table.

Table 2.2 Summary of motion palpation studies within each spinal region

Region	**Favourable Results** (good, good to moderate, moderate, fair and substantial)	**Unfavourable Results** (moderate to poor, fair to poor, poor and inconclusive)
Cervical	Jull *et al*., 1988 Viikari-Juntura, 1987 Hubka and Phelan, 1994 Strender *et al*., 1999 Smedmark, Wallin, and Arvidsson, 2000 Pool *et al*., 2004 Marcotte, Normand and Black, 2002 Zito *et al*., 2006 Lakhani *et al*., 2009	Deboer *et al*., 1985 Nansel *et al*., 1989 Fjellner *et al*., 1999 Van Trijffel *et al*., 2005 Hart, 2006
Thoracic	Johnston, 1980 Love and Brodeur, 1987 Jensen *et al*., 1993 Haas *et al*., 1995 Christensen *et al*., 2002	Vincent-Smith and Gibbons, 1999 Brismee *et al*., 2006
Lumbar	Gonnella *et al*., 1982 Keating *et al*., 1989 Mootz *et al*., 1989 Panzer, 1992 Boline *et al*., 1993 Hestbaek and Leboeuf-Yde, 2000 Spring and Tehan, 2001	Matayas and Bach, 1985 Boline *et al*., 1988 Maher and Adams, 1994 Binkley *et al*., 1995 Strender *et al*., 1997 Hicks *et al*., 2003 Huijbregts, 2003
Sacro-iliac	Wiles, 1980 Potter and Rothstein, 1989 Paydar *et al*., 1999 Tong *et al*., 2006	Potter and Rothstein, 1985 Carmichael, 1987 Mior *et al*., 1990 Lewit and Rosina, 1999

A literature review was conducted by Haas *et al.,* (1995), in which 16 data studies and seven review articles were published in the literature with reference to motion palpation which assessed intra-examiner and inter-examiner reliability. It was found that general inter-examiner reliability of active and passive motion palpation procedures was poor, while intra-examiner reliability was reasonable with respect to motion palpation (Haas *et al.,* 1995).

A systematic review was conducted by Van Trijffel, Anderegg, Bossuyt and Lucas (2005), to determine inter-examiner reliability of passive assessment of segmental intervertebral

motion in the cervical and lumbar spine. Nineteen studies were evaluated (nine cervical and ten lumbar) and passive assessment of motion was used to decide on treatments for neck and low-back pain patients. Two studies of the nineteen satisfied criteria for external and internal validity, of which one found fair to moderate validity and one found poor validity. Overall, inter-examiner reliability was poor to fair. However, most studies were found to be of poor methodological quality and the Van Trijffel *et al.,* (2005) proposed recommendations for the conduct and reporting of future research.

Stochkendahl, Christensen, Hartvigsen, Vach, Haas, Hestbaek, Adams and Bronfort, (2006) conducted an additional critical literature review on methodologically sound studies carried out on reproducibility of manual techniques of the spine between 1980 and 2005. Their study assessed a total of 58 tests that were considered for inter-observer reproducibility and 26 tests for intra-observer reproducibility. Motion palpation of the spine was the most frequently investigated procedure. Stochkendahl *et al*., (2006) suggested that even though motion palpation is a widely used procedure to diagnose biomechanical dysfunction, previous literature shows poor levels of inter-examiner agreement. In support of Haas *et al.,* (1995), it was observed that overall, intra-examiner reliability yielded better results and were found to be more reproducible than inter-examiner reliability.

In contrast to the above two literature reviews, an additional literature synthesis was conducted by Haneline, Cooperstein, Young and Birkeland (2008). It was noted there are different means of assessing intersegmental mobility, assessing either excursion of the segments (quantity of movement) or end-feel. The objective of this review was to classify and compare studies based on method of motion palpation used, considering that some studies may have used both methods. The review considered forty-four relevant articles (from 1965 to 2007) fifteen of these studies focused on motion palpation excursion, twenty-four focused on end-feel, and five used both. Eight studies reported high levels of reproducibility (K = ≥0.4), although four were not of acceptable quality, and two were only marginally acceptable. When only high-quality studies were considered (external/internal validity and good methodology), three of twenty-four end-feel studies reported good reliability compared with one of fifteen excursion studies. No statistical difference existed between the two Groups and, therefore, there was no support in the literature for the advantage of one motion palpation method over the other.

In a study conducted by Marcotte, Normand and Black (2002), twenty-four trained students and an experienced chiropractor served as examiners with twelve symptomatic patients between 22 and 42 years of age. All patients had previous episodes of mechanical cervical

spine pain and fixations present. Before the study was performed, examiners had 12 hourly sessions of practical and theoretical motion palpation training, similarly performed in this study. The objectives of Marcotte, Normand and Black (2002) study, were to measure the technical ability of an examiner to reproduce the kinematics of motion palpation for cervical spine rotation and to evaluate the effect of standardization on the reliability of the test. These kinematic tests were conducted by means of a computerized system of analysis of movement. The examiners could conduct the test of motion palpation in cervical rotation with a high degree of accuracy (95%). The successful reproduction of the kinematics of the test raises its reliability to detect the presence of fixations (K rising from 0.337 and 0.352 to 0.682). According to Marcotte, Normand and Black (2002), a greater reliability, arising from a high level of reproducibility, enables to document the advantages of the standardization of motion palpation in Chiropractic. Marcotte *et al.,* (2002) stated that it is imperative to precisely measure the subjective/objective clinical measures of motion palpation to appreciate its limits. Marcotte, Normand and Black (2002), went on to state that motion palpation should be carried out in a normal clinical environment and on participant's representative of the typical Chiropractic patient population. These recommendations were followed, by carrying out the current study at a Chiropractic clinic with the normal symptomatic participants that visit the clinic and with clinical tests to accurately measure the participant's outcomes and by having practice motion palpation sessions which were recommended.

Schneider, Erhard, Brach, Tellin, Imbarlina and Delitto (2008) conducted a study assessing the inter-examiner reliability of motion palpation of the symptomatic lumbar spine on 39 participants. Although results showed poor Kappa results ranging from −0.20 to 0.17, the study utilized blinding, same day assessment and sound methodology comparable to this research study.

Motion palpation of the spine has also been assessed in combination with other examination tests in order to identify a manipulable subluxation. The rationale behind this was that the mechanical joint dysfunction of a manipulable subluxation does not occur in isolation in a patient, but is just one part of the subluxation complex (Redwood and Cleveland, 2003). The reliability of combination testing had mixed results overall. One study conducted by French, Green and Forbes (2000), evaluated commonly used Chiropractic diagnostic methods in combination to detect manipulable subluxations in the lower thoracic, lumbar and sacroiliac joints of chronic mechanical low-back pain participants. These were: visual postural analysis, pain description by the participant, plain static erect x-ray film of the lumbar spine, leg length discrepancy, neurologic tests, motion palpation, static palpation, and orthopaedic tests. They

found that the results showed only fair reliability on their own, and the authors strongly discouraged therapists from relying completely on the findings of these individual examination techniques when assessing patients.

Furthermore, a study by Arab, Abdollahi, Joghataei, Golafshani and Kazemnejad (2009), found that the reliability of motion palpation in combination with pain provocation in the sacroiliac joint showed moderate to excellent results, with the PABAK (prevalence-adjusted and bias-adjusted Kappa) for intra and inter-examiner reliability ranging from 0.44 to 0.92 in combination. Furthermore, the PABAK for intra and inter-examiner reliability of individual tests ranged from 0.36 to 0.84 and 0.52 to 0.84 which is considered fair to substantial for these individual tests on their own. Therefore, it seems that composites of motion palpation and provocation tests together have reliability sufficiently high for use in clinical assessment of manipulable subluxations in the sacroiliac joints.

However, Gemmell and Miller (2005) noted that there are very few studies of adequate quality on multidimensional approaches for identifying manipulable subluxations, and further research is still required in this area. The above articles were taken into account within this study and as a result this study utilized other subjective and objective tests to determine whether associations exist between motion palpation and the other clinical measures.

The following recommendations were made by Van Triffel *et al*., (2005) for future research: instead of healthy individuals, utilize samples with a mix of symptomatic and non-symptomatic participants or only symptomatic participants. Only four (Maher and Adams, 1994; Smedmark, Wallin and Arvidsson, 2000; Hicks, Fritz, Delitto and Mishock, 2003; Pool, Hoving, de Vet, van Mameren and Bouter, 2004) out of 19 reviewed studies used representative patients as participants. According to Streiner and Norman (2003), reliability of a test procedure is closely linked to the population in which it was used. Furthermore, the results of a test are dependent on the sample of participants upon which the test was performed and are therefore only reliable when individuals vary in the characteristic being studied. The above is most commonly seen within symptomatic participants (Streiner and Norman, 2003).

The use of symptomatic joints in reliability studies on motion palpation has been encouraged by numerous authors (Keating, 1989; Panzer, 1992; Hestboek and Leboeuf-Yde, 2000; Huijbregts, 2002, Marcotte, Normand and Black (2002), and van Trijffel *et al*., 2005). Firstly, motion palpation of asymptomatic joints is not representative of clinical practice, and secondly, as symptomatic joints would be expected to have more manipulable subluxations,

with easier identification of these manipulable subluxations, than asymptomatic joints (van Trijffel *et al*., 2005). This is especially true in chronic conditions where there has been a long-standing history of symptoms and functional limitations of joints (Redwood and Cleveland, 2003), possibly leading to more manipulable subluxations. Therefore, the calculation of Kappa could be more accurate in symptomatic joints, leading to higher reliability motion palpation results if symptomatic participants are used (Hestbaek and Leboeuf-Yde, 2000). For this reason, this research study involved symptomatic participants only.

Although the reliability of motion palpation in the spine has been investigated in depth (See table 2.4 above), there is limited literature on the reliability of motion palpation of extremities. Few studies have been conducted and published thus far on motion palpation reliability/validity in the extremities in comparison to studies on the spinal region. The extremity studies include:

- One on the shoulder (Chesworth *et al.,* 1998),
- One on the elbow (Manley, 2010),
- Three involving the knee (Bezuidenhout, 2002; Vaghmaria, 2006 and Farrimond, 2010) and
- Two involving the ankle (Brantingham *et al*., 1997 and Williams, 2010).

In contrast to the outcome of results in the spinal inter-examiner and / or intra-examiner reliability studies mentioned above, recent studies on motion palpation of the extremities (discussed below) appeared to have shown favourable results (Brantingham, Wood, Parkin-Smith, Van der Meulen and Weston, 1997; Chesworth*,* Macdermid, Roth and Patterson, 1998; Bezuidenhout, 2002; Vaghmaria, 2006; Manley, 2010; Farrimond, 2010 and Williams, 2010).

Chesworth *et al.,* (1998) performed a study measuring passive lateral rotation of the shoulder in patients with shoulder pathology for the purpose of assessing end-feel reliability. The study consisted of two physical therapists that performed two assessments of passive lateral rotation of the shoulder in 34 participants. Intra-class association coefficients (ICC/s) were used to analyze the ratio (movement diagram) data and Kappa statistics (K) were used to analyze categorical end-feel data. The results showed that intra-examiner ICC/s varied from 0.58 – 0.89 and the inter-examiner ICCs varied from 0.85 – 0.91. Intra-examiner Kappa values for end-feel were moderate (K=0.48 – 0.59) and inter-examiner Kappa values were moderate (K= 0.62 – 0.76). It was found that end-feel seemed to be more reliable, in terms of inter-examiner agreement, when assessing lateral rotation of the shoulder.

In an unpublished article by Manley (2010) twenty participants (*n*=40 elbows) between the ages of 18 to 65, with one asymptomatic and one symptomatic elbow (chronic lateral epicondylalgia) were examined by three masters Chiropractic students for the presence of manipulable subluxations in end play, using only motion palpation. The examiners were pre-trained, randomised and blinded such as they were within this study. Each examiner individually motion palpated both elbows on each participant, in nine directions of motion palpation, incorporating the humeroulnar and proximal radioulnar joints. They were also required to identify which elbow was symptomatic. Fleiss' Kappa and percentage agreement (perfect percentage agreement and mean percentage agreement) were used to measure reliability. There was an insignificant difference in Kappa values between the two Groups (*p*=0.260), although there was a trend towards the symptomatic Kappa values being higher than the asymptomatic values. The difference between symptomatic and asymptomatic elbows was significant in proximal radioulnar posterior to anterior glide in pronation (*p*=0.013), as well as proximal radioulnar rotation of the radial head on the ulna (*p*=0.008). Overall, more manipulable subluxations were found in the symptomatic elbows than in the asymptomatic elbows. The examiners correctly identified the symptomatic elbow in 65% to 90% of participants (*p*=1.000).

Bezuidenhout (2002) investigated the intra and inter-examiner reliability of motion palpation of the patella for asymptomatic patients. The unpublished study consisted of 50 Chiropractic students and four examiners who were masters Chiropractic students trained in assessing motion palpation of the patella. The inter-examiner results of this study revealed that the Kappa values for intra-examiner reliability (K ranged from 0.005 – 0.035) were relatively fair. And there was an association between the examiners and their motion palpation findings, as demonstrated by Pearson's Chi-Square test (*p*=0.05). This meant that all examiners had co-ordinated motion palpation findings, demonstrating motion palpations validity and consistency within different examiners. Intra-examiner reliability results (K ranged from 0.000 – 0.48) were relatively low, allowing only for fair agreement overall and demonstrated that the consistency of the motion palpation findings of the examiners between their first and second examination as demonstrated by McNemar's Test (*p*<0.05) was significant. Nevertheless, even though Pearson's Chi-Square and McNemar tests showed association and consistency of results,

In the above study, the examiners felt they were not given enough time to practice their motion palpation skills, and recommended further studies to include practice sessions before commencing the research study (Bezuidenhout, 2002). This recommendation was taken into

account in this current study, where the examiner had three months in which to practice and this could have had an impact on the findings. Bezuidenhout (2002) recommended further research to include symptomatic participants, because motion palpation is a diagnostic procedure that looks for pathomechanics of a joint, which may not have been present in asymptomatic participants. In this current research study only symptomatic participants were used.

Vaghmaria (2006) conducted an unpublished study with sixty symptomatic participants suffering from osteoarthritis of the knee and patellofemoral pain syndrome. Overall, four directions of patella movement were motion palpated and the examiners were able to reliably detect patella restrictions in the symptomatic population as opposed to asymptomatic patella (of the opposite healthy patella on each of the sixty symptomatic participants) motion in both Groups. Agreement between examiners for the superior to inferior direction was fair (K=0.222) and the medial to lateral direction was also fair (K=0.201). The rest of the agreement between directions of movement showing poor agreement with both inferior to superior (K=0.167) as well as the lateral to medial direction (K=0.176). This indicates that, even though motion palpation is lacking concluding research to define it as an assessment tool, these findings propose that motion palpation has a level of validity that is able to differentiate between the direction and Grade of fixations.

An additional unpublished article by Farrimond (2010) studied inter-examiner reliability on 30 patients, each with one knee with patellofemoral pain syndrome and one asymptomatic knee. Each patient had both of their knees motion palpated by three independent examiners blinded to which was the symptomatic knee. Fleiss Kappa statistic was used to give a Kappa score for each direction of motion palpation and these scores evaluated the inter-examiner reliability of motion palpation in the symptomatic and the asymptomatic knee. A comparison of the inter-examiner reliability of motion palpation between the two Groups was performed using a paired Wilcoxin signed ranks test. The Kappa scores for motion palpation ranged from -0.2081 to 0.1802 for the symptomatic knee joint and -0.2836 to 0.0339 for the asymptomatic knee. This shows poor agreement in both cases. Furthermore, no significant difference in Kappa values was noted (p= 0.609) for the two Groups for the Wilcoxin signed ranks test and the number of positive and negative ranks were similar. This indicates that the reliability of motion palpation in both Groups was similar.

Brantingham *et al.,* (1997) conducted a study on the inter-examiner reliability of the circumduction test for general foot mobility and joint dysfunction. The study consisted of two Chiropractic practitioners who evaluated each of the seventeen patients diagnosed with

moderate to severe painful lower leg, ankle or foot disorder. Two Chiropractic practitioners, one with 14 years experience and the other with two years experience, independently evaluated each patient. Inter-examiner agreement was assessed using Kappa coefficient and it was found that the agreement into whether there was decreased mobility in affected feet was 0.64 ('moderate agreement'). Similarly agreement as to whether there was decreased mobility in unaffected feet was 0.598 ('moderate agreement'), but agreement of the exact grade of decreased movement in affected feet was 0.1785 ('low agreement'), however agreement into the exact grade of decreased in unaffected feet was 0.453 ('moderate agreement'). A discrepancy noted in the study, by the authors, was that the examiners were not blinded to the injured feet (Brantingham *et al.,* 1997). This could unintentionally have influenced the outcome of this study, by the examiners having preconceived ideas as to the type of joint fixation / dysfunction with which the participants presented (Mouton, 1996). In this research study the motion palpator was completely blinded throughout to prevent this from occurring.

Furthermore, Brantingham's *et al.,* (1997) study appeared to show that detecting forefoot dysfunction was relatively reliable with regards to inter-examiner reliability, however, having had a larger sample size may have helped identify satisfactory agreement (Brantingham *et al.,* 1997) and would support Haas's (1991) recommendation to increase population size for increased reliability. Therefore, Haas's recommendation was taken into account and 40 participants were included in this study.

A further motion palpation study was conducted on the ankle and foot by Williams (2010). Williams (2010) carried out an unpublished study involving inter-examiner motion palpation by three examiners of the distal tibiofibular, mortise, subtalar, navicular, cuboid and metatarsal joints of both the symptomatic foot as well as the asymptomatic foot of 20 patients with CAI. The inter-examiner reliability ranged from poor to almost perfect with Kappa values ranging from -0,279 to a perfect Kappa value of 1 when looking at all three-examiner combinations (i.e. Examiner 1 vs. 2, 1 vs. 3 and 2 vs. 3). The mean Kappa was 0.267 indicating fair agreement. The inter-examiner reliability ranged from –0.154 to 0.459 between the three examiner combinations and the average Kappa value was 0.419 indicating moderate agreement between the examiners. There has been a lack of inter-examiner reliability studies performed to investigate whether motion palpation is a reliable assessment tool to detect instability. It was found that instability in long axis distraction (p=0.001), anterior to posterior glide of the tibiotalar joint (p=0.003), posterior to anterior glide of the subtalar joint (p=0.001), and lateral to medial tilt of the subtalar joint (p=0.006) was significantly more common in symptomatic feet. A statistical comparison showed that

asymptomatic feet showed to have more agreement when restrictions were present; however, no other difference reached statistical significance between symptomatic and asymptomatic feet. This supports previous research that suggests the presence of joint dysfunction prior to Manipulation in patients with CAI (Pellow and Brantingham, 2001). The percentage agreement between the three examiners was high; and included agreement that there was no restriction or instability present. This is a positive finding for the use of motion palpation because the examiners showed a high (above 80%) percentage of agreement. It was noted that the joints that show to have the highest percentage agreement are those joints that the examiners did not find to be restricted or unstable in any of the patients, therefore, it was assumed that joint dysfunction was not present.

The examiners within Williams (2010) study underwent seven sessions of training and practice of motion palpation of the foot and ankle joints. Mootz, Keating, Kontz, Milus and Jacobs (1989) and Currier, Froehlich, Carow, McAndrew, Cliborne, Boyles Mansfield and Wainner (2007) recommended that preparatory lessons are important so as to ensure consistency of the technique. Therefore, this study included three months of clinical practise to ensure uniformity and reliability of the technique.

Thus, with respect to motion palpation, only a few reliability studies involving the extremities have been conducted (Brantingham *et al.*, 1997; Chesworth *et al.*, 1998; Bezuidenhout, 2002; Vaghmaria, 2006, Manley 2010, Farrimond, 2010 and Williams, 2010). The outcomes of these studies have shown motion palpation in extremities to be consistent and valid/reliable. Therefore, motion palpation has been deemed to be valid, but with so few published studies conducted, further research is needed to fully investigate the validity of motion palpation, particularly within extremities.

However, all of the above studies have been pre-treatment motion palpation studies. As discussed earlier, Ames (1987) stated within his observations on motion palpation that motion palpation should be able to confirm whether the desired effect has been achieved after a Manipulation has occurred. Two studies have therefore been performed to assess the validity of motion palpation as a post-treatment assessment tool with encouraging results. However, both studies were conducted on the spine (Haas *et al.,* 1995 and Lakhani *et al.,* 2009) and the extremities have yet to be investigated to determine if similar results can be seen within other joints.

2.3.4.2 Motion palpation as a post-treatment evaluation within the spine

One of the two reliability studies was a pre- and post-treatment assessment study performed by Haas *et al.,* (1995) where sixty patients, of which 60% were symptomatic and 40% asymptomatic, were randomly divided into two Groups. Motion palpation was conducted by two examiners using a blind, randomized, repeated-measure. Participants who were found to have end-play restrictions were randomly assigned into the two Groups, a treatment Group and a control Group. The treatment Group received spinal Manipulation (from a third chiropractor) to a target motion segment that was determined by the pre-selected examiner. The control Group received no treatment. The two examiners were blinded from the treatment received. The follow-up examiner was then required to re-examine the target motion segment and indicate whether normal end-play had been restored. The response (change from a positive result to a negative result) of motion restriction to spinal Manipulation was 60% compared with the 37% response in the control Group that received no Manipulation ($p<0.04$). The results of this study present some evidence that chiropractors may be able to manually palpate segmental end-play restriction and changes that occur to this motion restriction, in participants using motion palpation. The main focus of the study was to determine the validity of motion palpation and its ability to identify end-feel improvement in the fixated segments in response to Manipulation. Haas *et al.,* (1995) suggested that motion palpation when used as a post-treatment assessment tool, showed high levels of specificity and ability to detect change to the fixated segment in the thoracic spine.

In the other reliability study, Lakhani, Nook, Haas and Docrat (2009) undertook a pre- and post-treatment assessment study whereby two Groups of fifteen participants were assessed in a blinded, randomized pilot study in which a third of the patients were asymptomatic. In this study, the blinded assessor noted whether the end-feel improvement of fixated segments in the cervical spine post-treatment could be identified in the Group that was manipulated, compared to the Group that received placebo treatment. There was a high statistical indication ($p=0.006$), that with the use of motion palpation, the blinded assessor, was able to identify end-feel improvement and, therefore, responsiveness in the participants that were manipulated, compared to the participants who were not. Therefore, this study, as well as Haas *et al.*, (1995) advocated that motion palpation can be used as a valid post-treatment tool to detect responsiveness (i.e. its accuracy to detect change in the end-feel of a joint following Manipulation within the spinal region).

Both of the above studies indicated that motion palpation as a post-Manipulation assessment tool is valid and effective in the spine. However, both Haas *et al.*, (1995) and Lakhani *et al.*, (2009) recommended that further motion palpation studies investigating the

validity of motion palpation as a post-treatment assessment tool be undertaken to address issues of generalisability of study results to other areas of the body. Lakhani *et al.*, (2009) recommended further studies to be conducted to determine if post-treatment assessment of an extremity would also lead to the level of responsiveness that was found in their study. Lakhani *et al.*, (2009) further recommended that a post-treatment assessment study should be done on a Group of only symptomatic participants as it was seen in their study that motion palpation had an increased responsiveness in the symptomatic participants. In response to this recommendation, this study was carried out on participants who were symptomatic and had CAI. For that reason this study was conducted on the foot and ankle and, moreover, was performed as a post-treatment assessment study.

2.3.5 Summary of motion palpation

Ames (1987) described eight uses of motion palpation which may be used in diagnosis and treatment of fixations. Furthermore, motion palpation is commonly utilised by many manipulative therapists as a tool to measure the degree of fixations within a joint complex (Bergmann, Petersen and Lawrence, 1993; Liebenson and Lewit, 2003; Leach, 2004; Haldeman, 2005). Motion palpation is, therefore, seen as a common diagnostic tool utilised by chiropractors in order to assess disorders of the ankle (Schafer and Faye 1989; Brantingham *et al*., 1997). However, Lewit and Liebenson (1993) suggested that motion palpation is subjective, and that further studies are needed to establish the reliability of this commonly used tool.

Furthermore, motion palpation appears to be used as a tool to assess the changes of the degree of fixation within a joint complex during the course of treatment to allow constant monitoring of patients (Ames, 1987; Haas *et al.,* 1995). One of the most applicable and important observations described by Ames (1987) is the use of motion palpation as “confirmation of effect after a Manipulation”. However, motion palpation used in this manner still needs to be validated, particularly on extremities.

In summary, many research findings show that motion palpation is sensitive and specific (Haldeman, 1992) and that combining this post-treatment tool with other clinical measures when monitoring the patients clinical progress, could potentially yield better clinical effectiveness (Haas *et al.,*1995 and Lakhani *et al.*, 2009). Thus far, studies (Haas *et al.,* 1995; Lakhani *et al.*, 2009) demonstrating responsiveness have indicated that, spinal motion palpation as a post-treatment assessment tool appears to have the ability to identify end-feel improvement in a restricted segment which had been manipulated. However, this point has

yet to be researched in non-spinal or extremity participants and motion palpations validity in the realm of extremities has yet to be fully investigated. Therefore, various studies have recommended (Haas *et al,* 1995; Lakhani *et al.*, 1999; Marcotte, Normand and Black (2002); Leboeuf-Yde, van Dijk, Franz, Hustad, Olsen, Pihl, Robech, Skov Vendrup, Bendix and Kyvik, 2002) further studies to be undertaken to reiterate the clinical responsiveness and specificity of motion palpation in different contexts that they have found within their studies.

Therefore, in an attempt to provide a clearer insight into the clinical responsiveness/efficacy of motion palpation as a post-treatment assessment tool and the relationship of motion palpation to other clinical indicators, this study is to be conducted in the ankle region, on symptomatic participants with CAI.

2.4 Reliability of subjective/objective clinical measures used in this study

2.4.1 Introduction

The inclusion of clinical measures in conjunction with motion palpation has been suggested (Haas *et al.,* 1995) in order to establish whether associations exist between motion palpation results and other clinical measures. If associations do exist, then it would strengthen the notion that motion palpation can be used as an adjunct to these clinical measures post-treatment in order to monitor a patient's clinical progress (Lakhani *et al.,* 2009).

In addition, Ames (1987), Haas *et al.,* (1995), Yeomans (2000), Lewit and Liebenson (2003) and Lakhani *et al.*, (2009) also indicated that monitoring of patients clinical progress post-treatment is vital, in order to determine whether patients are improving with treatment or not. Similar recommendations were also made by Panzer (1992) who stated that motion palpation should be used, not only for clinical decision making in the future, but for monitoring patient's progress along with other clinical findings. Therefore, monitoring the patient for changes in fixations and the relationship to other clinical indicators is of importance (Lewit and Liebenson 2003); as combining these elements (viz. subjective data, objective data and changes in fixations in the affected joint), can allow for a comprehensive clinical picture in which to monitor patient progress more accurately (Lakhani, 1999). However, motion palpation has yet to be incorporated into a study where it has been associated with other clinical measures. This study, therefore, attempted to determine the

relationship between end-feel improvement, subjective clinical improvement and subjective clinical improvement.

2.4.2 Discussion of reliability of tests used in this study

2.4.2.1 Visual Analogue Scale (Appendix G)

Most patients who have experienced an ankle sprain are treated conservatively and the outcome is usually satisfactory. However, some participants may continue to experience pain after what appears to be a routine sprain (Bassewitz and Shapiro, 1997). In clinical practice, ongoing symptoms following an ankle ligamentous injury are frequently seen (Patel and Warren, 1999). Most of these continuing symptoms include pain, instability, crepitus, weakness and stiffness (Pellow and Brantingham, 2001). The visual analogue scale (VAS) is a subjective pain scale, and is known as the gold standard with respect to its validity and reliability of detecting pain (Liggins, 1982; Jensen and Karoly, 1993; Yeomans, 2000 and Salaffi, Stancati, Silvestri, Ciapetti and Grassi, 2003).

2.4.2.2 Functional Ankle Disability Index (Appendix H)

Twenty to forty percent of patients that have been treated conservatively for CAI continue to complain of residual pain and instability (Calliet, 1997), as well as stiffness, weakness and loss of proprioception (Bassewitz and Shapiro, 1997). In a study conducted by Hale and Hertel (2005), 50 athletes with sub-acute and acute ankle sprains completed the Functional Ankle Disability Index (FADI) three consecutive times over a period of seven weeks. The results demonstrated moderate to good reliability and, in addition, FADI was found to be responsive to improvements in function after treatment. FADI, therefore, was utilised to appraise the general ankle function in the participants and was used as an inclusion criteria as well as a pre- and post-measurement tool (Hale and Hertel, 2005).

2.4.2.3 Weight-bearing Dorsiflexion Test (Appendix I)

A frequent consequence of ankle sprains is the loss of ankle dorsiflexion, as a result of which the talus cannot lock fully into the mortise joint which leads to a loss of bony stability during locomotion (Baker and Todd, 1995). Normal locomotion requires the ankle to be able to actively dorsiflex 10 degrees and plantarflex between 20 and 25 degrees. A decreased ankle dorsiflexion range grants an increased risk of lower limb injuries, especially ankle sprains (Magee, 1992). The weight-bearing dorsiflexion test is frequently used to measure talocrural dorsiflexion range of motion and has been found to be of a satisfactory level of reliability (Vicenzino, Prangley and Martin, 2001; Collins, Teys and Vicenzino, 2003; Jones,

Carter, Moore and Willis, 2005; Vicenzino, Branjerdporn, Teys and Jordan, 2006). This test was, therefore employed to measure changes that may occur in the range of motion within the ankle joint post-treatment.

2.4.2.4 Pressure Algometer (Appendix J)

According to Hertling and Kessler (1996), after the initial injury of the ankle some patients will suffer recurrent “giving way “of the ankle followed by pain and swelling. This pain has been reported to be on the lateral complex of the ankle joint (Hertling and Kessler, 1996). In a study by Vaughan, Mclaughlin and Gosling (2007), a total of 300 measurements were collected from a pressure algometer as it was applied to a force plate at five different pressures. The pressure algometer was found to be acceptable and consistent. For that reason, pressure algometer readings were taken by applying the device to the lateral joint complex to assess the participant’s pain threshold at the joint (Vaughan *et al*., 2007). The Pressure Algometer that was utilised was the Wagner FDK20 Force Dial (Wagner Instruments, P.O.Box 1217, Greenwich, CT, 06836, USA).

2.4.2.5 Berg Balance Scale (Appendix K)

Functional instability is referred to as a subjective feeling of ankle instability due to proprioceptive and neuromuscular deficits (Hertel, 2000). Neuromuscular deficits may become evident as impaired balance, reduced proprioception, slower firing of the fibularis muscles to inversion perturbation of the ankle, slowed nerve conduction velocity, impaired cutaneous sensation, strength deficits and decreased dorsiflexion range of motion (Hertel, 2000). In a study carried out by Forkin, Koczer, Battle and Newton (1996), it was revealed that of 11 amateur gymnasts (who were monitored to determine if chronic ankle sprains decreased ankle proprioception), 63% of the gymnasts displayed a balance deficit. The capability of the researcher to detect passive plantarflexion of the injured ankle in comparison to the uninjured side was also investigated. A diminished ability to sense passive ankle motion on the injured side as opposed to the uninjured side was also established.

The Norwegian version of the Berg Balance Scale was shown to have acceptable interrater reliability as well as high internal consistency (Halsaa, Brovold, Graver and Sandvik, 2007). The Berg Balance Scale was consequently utilised to appraise the proprioceptive function of

the ankle and the subsequent stability that is present generally in the ankle joint (Kornetti, Fritz, Chiu, Light and Velozo, 2004; Halsaa *et al.*, 2007).

2.5 Summary of Literature Review

The majority of the research conducted on motion palpation to date has been primarily based on intra- and inter-examiner reliability (Haas *et al.,* 1995). This study however aims to determine whether motion palpation is a valid post-treatment diagnostic tool, as this has only been investigated twice before (Haas *et al.,* 1995 and Lakhani *et al.,* 2009) in the thoracic spine and cervical spine respectively, with encouraging results. Assessing whether motion palpation is a valid post-treatment diagnostic tool in an extremity has yet to be performed although some extremity studies do exist (Brantingham *et al.*, 1997; Chesworth *et al.*, 1998; Bezuidenhout, 2002; Vaghmaria, 2006; Manley 2010; Farrimond, 2010; Williams, 2010), two of which are motion palpation studies conducted on the foot and ankle (Brantingham *et al.*, 1997 and Williams, 2010), both of which utilize motion palpation as a pre-treatment tool.

The use of symptomatic joints in reliability studies on motion palpation has been encouraged by numerous authors (Keating, 1989; Panzer, 1992; Hestboek and Leboeuf-Yde, 2000; Huijbregts, 2002; Vaughan, 2002 and van Trijffel *et al*., 2005) and the reasons for this have been discussed previously (In section 2.3.4.1). Therefore, within this study, only participants with CAI were included.

In addition, it has also been indicated that monitoring of patients clinical progress post-treatment is crucial, in order to determine whether patients are improving with treatment or not (Ames 1987; Haas *et al.,* 1995; Yeomans 2000; Lewit and Liebenson 2003 and Lakhani *et al.*, 2009). Furthermore, the combination of motion palpation as post-treatment assessment tool with other clinical measures could potentially yield greater clinical effectiveness in terms of monitoring the patient's clinical progress (Haas *et al.,* 1995 and Lakhani, 2009). Therefore, this study aimed to determine whether associations exist between motion palpation and the other clinical measures. If an association was found to exist between motion palpation and the clinical signs and symptoms of CAI, this could be used to monitor the patient's progress and aid in patient management.

Therefore, in an effort to provide a clearer insight into the clinical responsiveness/efficacy of motion palpation as a post-treatment assessment tool and the relationship of motion palpation to other clinical indicators, this study was done in the ankle region, on symptomatic participants with CAI.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this study was to determine the clinical responsiveness of motion palpation as a post-treatment assessment tool in joints of the ankle (i.e. to determine if motion palpation could validly detect improvement in end-feel of the joints of patients that were manipulated compared to those that were not manipulated) and whether associations can be made between post-treatment motion palpation results and other clinical readings in patients with Chronic Ankle Instability (CAI). This research methodology was approved by the DUT Ethics committee (Appendix O).

3.2 Design

This research study was designed in the form of a quantitative, blinded, randomized pre-post experimental investigation (Mouton, 1996).

3.3 Participants

3.3.1 Advertising for participant recruitment

Numerous methods of recruiting participants were employed. Advertisements and posters were placed on the notice boards of the Chiropractic Day Clinic (CDC) (Appendix A), around the Durban University of Technology (DUT) Berea and City campuses, local universities, gyms, libraries, the local shopping complexes, the local newspaper (for which permission was received) and direct contact with participants. The researcher conducted a telephonic interview to assess the eligibility of the participant for the study in question.

The telephonic interview was conducted and the following questions that were posed to the participants:

1. What is your age (must have been between 18-45 years)? (Pellow and Brantingham, 2001; Parker, 2005).

2. When did you last sprain your ankle (participants must have had their last sprain at least six weeks prior)? (Reid, 1992; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006; McBride and Ramamurthy, 2006).
3. Does any pain, swelling, clicking and/or weakness reside in your ankle? (participants must have had at least four of the symptoms) (Reid, 1992; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006; McBride and Ramamurthy, 2006).
4. Are you currently taking any pain medication and if so when was the last medication taken? (Poul *et al.*, 1993; Seth, 1999).

If the participant had answered yes to question four (i.e. if pain medication was used), a three day wash out period was necessary for the participant to be included into the study (Poul *et al.*, 1993; Seth, 1999).

Based on the criteria listed below, certain participants who may have been eligible were then provided with more information about the study by the researcher. Thereafter, those who wished to participate in the study were invited for a consultation at the CDC to confirm eligibility.

3.3.2 Sampling

Forty participants with CAI participated in the study. Each participant fell into a randomization table which placed participants in either one of the two treatment Groups to ensure homogeneity in the study (Mouton, 1996). (The randomization sampling method (Esterhuizen, 2010) was conducted throughout the sampling process).

3.3.3 Inclusion and Exclusion criteria

These criteria were chosen to maintain homogeneity (Mouton, 1996) within the study population (i.e. similar age, similar injury/Grade of instability, similar symptoms and similar test readings).

Inclusion criteria:

- Participants that had Grade one or two CAI (Reid, 1992; Pellow and Brantingham, 2001; Rimando, 2008).
- Participants that were between 18–45 years of age (Pellow and Brantingham, 2001; Parker, 2005).
- Participants that had signed the informed consent form (Mouton, 1996).

- Participants that clinically presented with symptoms of CAI. Participants had to have had four or more of the following clinical features including: lateral ankle pain, joint weakness, oedema, joint crepitus, adhesions resulting in the formation of fixations in the joint and ligamentous laxity (Reid, 1992; Tatro, 1995; Pellow and Brantingham, 2001; Ajis and Maffulli, 2006; McBride and Ramamurthy, 2006).
- Participants had to have a VAS score of between 20 and 70 to maintain homogeneity within the sample (Mouton, 1996).
- Participants had to have a Functional Ankle Disability Index score (Hale and Hertel, 2005) of between 50 and 90 to maintain homogeneity within the sample (Mouton, 1996).
- Participants had to have had fixations in at least one of the three joint segments (subtalar, mortise and tarsal joints) to participate in the study for Manipulation of a restricted joint to occur.

Exclusion criteria:

- Patients that had a connective tissue disorders that could have created excessive ligamentous laxity (Mouton, 1996)
- Participants that had Grade III ankle sprains and /or excessive mechanical instability of the lateral ankle (Reid, 1992; Pellow and Brantingham, 2001; Rimando, 2008).
- Patients that were contraindicated to Manipulations were excluded. This included but was not limited to (Kirkaldy – Willis and Burton, 1992):
    - Absolute contraindications:
        - Destructive lesions of the spine, ribs and pelvis; a healing fracture or dislocation; gross instability; cauda equina syndrome; abdominal aneurysm; visceral referred pain.
    - Relative Contraindications:
        - Osteopenia; spondyloarthroapthies; patients on anticoagulant therapy; bleeding disorders; psychological conditions.

3.4 Practise sessions

Before commencement of the study, the researcher practiced motion palpation of the mortise, subtalar and tarsal joints daily for four months to ensure correct, precise and skilled use of motion palpation as an assessment tool. To ensure that the study ran adequately, a small pilot study was conducted one week prior to initiation of the study, where all three of

the research team met and practiced the routine on ten volunteers, who were not used later in the study.

3.5 Clinical assessment procedure

This study was conducted in two phases:

3.5.1 Phase one: the introductory stage

After their telephonic interview with the researcher at the CDC a verbal explanation of the study was given to the participant by the researcher at the consultation and any queries regarding the study were addressed by the researcher

↓

Participants who were willing to participate in the study at this point signed the Letter of Information and Informed Consent Form (Appendix B). Those not willing to sign were excluded from the study.

↓

A full case history, a senior physical examination and a foot and ankle regional examination (Appendix C, D and E) were performed.

↓

Participants not eligible for participation in the study were then excluded based on the inclusion / exclusion criteria listed above (Section 3.3.3)

↓

The eligible participants were then randomly allocated into one of the two treatment Groups by a computer generated randomisation table (Appendix N). This randomisation table used in this study was prepared by a statistician (Esterhuizen, 2010). These participants were either placed in a Manipulation Group (Group A) or in the control/no treatment Group (Group B).

3.5.2 Phase two: The treatment and [pre- and post- test readings]

The role of the researcher and assistants:

The researcher performed both the pre- and post-motion palpation.

↓

Assistant One performed the pre- and post- subjective and objective readings.

↓

Assistant Two performed the Manipulation.

↓

The following precautions were taken to ensure blinding throughout:

1. The participants were advised not to talk unnecessarily to either the motion palpator (the researcher) or Assistant One to ensure they remain blinded throughout the study. However, they were able to speak freely to Assistant Two.
2. The participants were also advised not to move during the above process and not to bear weight on either foot before post-treatment readings were taken, as this could alter the results.
3. No two assessors were in the same room at the same time or communicated about the research in any way.
4. The researcher was blinded to the Groupings of participants (who received Manipulation and who did not receive Manipulation) and the subjective and objective readings.
5. Assistant One was blinded to the Groupings of participants, and the motion palpation results.
6. Assistant Two was blinded to the post-treatment motion palpation results and the subjective and objective readings.
7. To ensure points four to six occurred, all paperwork was only collected and seen by the researcher at the end of the entire study.

3.5.3 The procedure

Participants in both Group A and B were then taken to a specified clinic room by the researcher.

↓

Assistant One performed the pre-treatment readings which consisted of Pressure Algometer (Appendix J), WBD test (Appendix I), and BBS (Appendix K) and asked the participant to fill

in the VAS (Appendix G) and FADI (Appendix H) (details of each test are explained in section 2.4).

↓

The researcher now performed motion palpation on the involved ankle and foot. The researcher then noted the three worst fixations within the mortise, subtalar and tarsal joints as these have been found to be commonly affected in participants with CAI (Pellow and Brantingham, 2001) and wrote these down on a piece of paper (Appendix L) which was left in the clinic room on the desk for Assistant Two.

↓

Assistant Two entered the clinic room and remained with each participant for three minutes irrespective of which Group they were in (whether Manipulation occurs or not).

↓

Assistant Two viewed the list of fixations written on Appendix L and wrote these three fixations on Appendix M. Assistant Two then proceeded to manipulate a minimum of one and a maximum of three fixations found for Group A participants (and made a note of which fixations were manipulated on Appendix M and took Appendix M with her so as to ensure blinding). If no cavitations had occurred, Assistant Two made a note of this on Appendix M. The Manipulation Group (Group A) received a low amplitude high velocity thrust to the fixations found within the ankle joint (Bergmann, Petersen and Lawrence, 1993). Group B received no Manipulation and both Groups were asked to remain in the same position and not walk around throughout the consultation.

↓

The researcher then re-motion palpated the three worst fixations originally listed on Appendix L. The researcher noted beside each fixation on Appendix L, whether the end-feel at that restricted joint had improved or remained the same.

↓

Assistant One then performed all the post-treatment readings again. The FADI was not done at this stage but was done two days later via telephonic or personal interview.

↓

The participant was then free to leave as all data had been collected and was to be analysed.

3.6 Measurement and observations

The study incorporated both subjective and objective data mentioned below:

3.6.1 Subjective data

1. Visual Analogue Scale (Appendix G) was used to assess the amount of pain that the patient was experiencing and to note if there was a decline in the pain post-treatment assessment. This subjective pain scale is known as the gold standard with respect to its validity and reliability (Liggins, 1982).

2. A Functional Ankle Disability Index (FADI) (Appendix H) was utilised to appraise the general ankle function in the participants and was used as an inclusion criteria as well as a pre- and post-treatment assessment tool (Hale and Hertel, 2005). The post-treatment analysis of FADI was not done with the other tests but rather was completed two days later via telephonic or personal interview to allow time for the index to alter.

3.6.2 Objective data

1. Motion palpation was used as a post-treatment assessment tool to determine if there was an improvement in end-feel within the ankle joints of participants that were manipulated, compared to those that were not. Motion palpation (Appendix L and M) was utilised: as a commonly used assessment tool for both spinal and extremity joint fixations (Gatterman, 1995), as no evidence exists at present to confirm its validity as a post-treatment tool in the evaluation of fixations after treatment in any extremity condition (Haas *et al.*, 1995; Lakhani *et al.*, 2009). Therefore, motion palpation was employed to determine joint fixations that may have been present within the ankle joints (Maitland,

2001) and if a change was detected within these joints. The motion palpation was performed according to Schafer and Faye (1990).

Table 3.1 Motion palpating the ankle joint

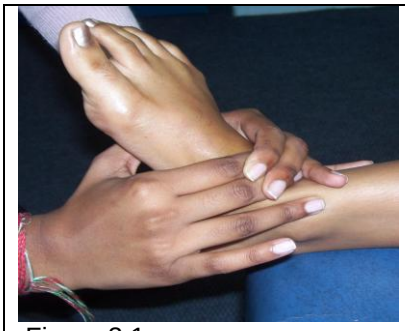
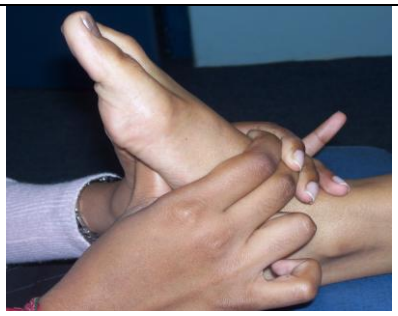
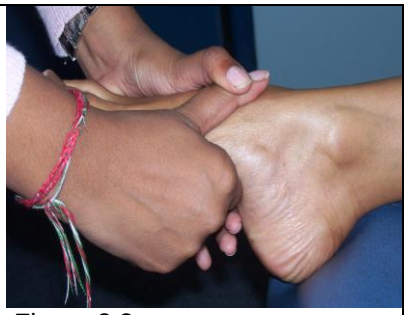
		

Figure 3.1 Mortise long axis distraction	Figure 3.2 Mortise dorsiflexion	Figure 3.3 Mortise plantarflexion

Table 3.2 Motion palpating the subtalar joint

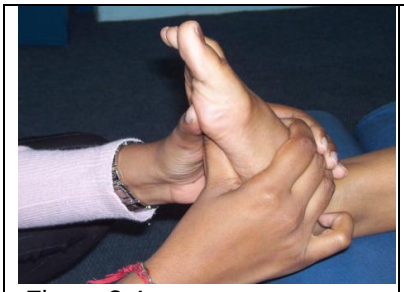
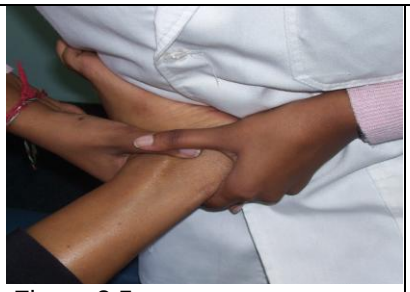
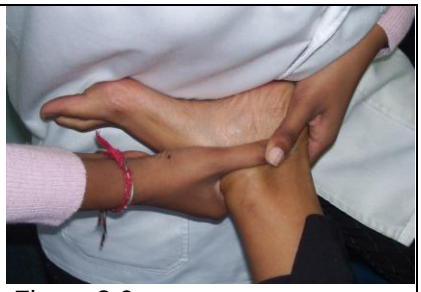
		

Figure 3.4 Subtalar long axis distraction	Figure 3.5 Subtalar eversion	Figure 3.6 Subtalar inversion

Table 3.3 Motion palpating the tarsals

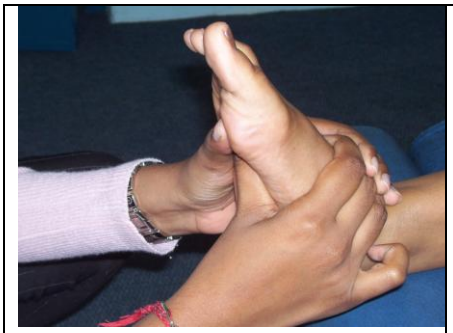
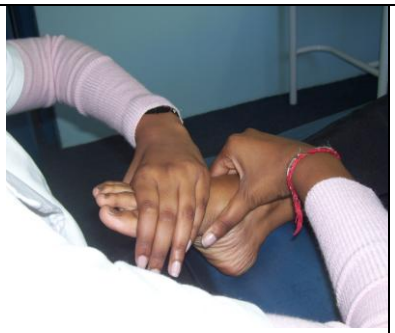
	

Figure 3.7 Tarsal shearing	Figure 3.8 Tarsal adduction	Figure 3.9 Tarsal abduction

2. Pressure Algometer readings (Appendix J) were taken by applying the device to the lateral joint complex to assess the participant's pain threshold at the joint (Vaughan, 2007).
3. The Berg Balance Scale (Appendix K) was utilised to appraise the proprioceptive function of the ankle and the subsequent stability that was present generally within the ankle joint (Kornetti *et al.*, 2004; Halsaa *et al.*, 2007).
4. Weight Bearing Dorsiflexion test (Appendix I) was utilised to measure changes that

occurred in the range of motion within the ankle joint post-treatment assessment (Vicenzino, 2006). This test was frequently used to measure talocrural dorsiflexion range of motion (Vicenzino, 2006). The procedure for this test was as follows: the participant performed a weight bearing lunge on the foot being tested in which the knee was in contact with the wall and the participants toes were just touching the wall the knee was perpendicular to the participant's heel. The participant was then instructed to slide their foot backwards maintaining contact between their heel and the ground throughout the test. In this position, maximum dorsiflexion of the talocrural joint was achieved. Using a tape measure, the distance between the wall and big toe was measured and compared pre- and post-treatment.

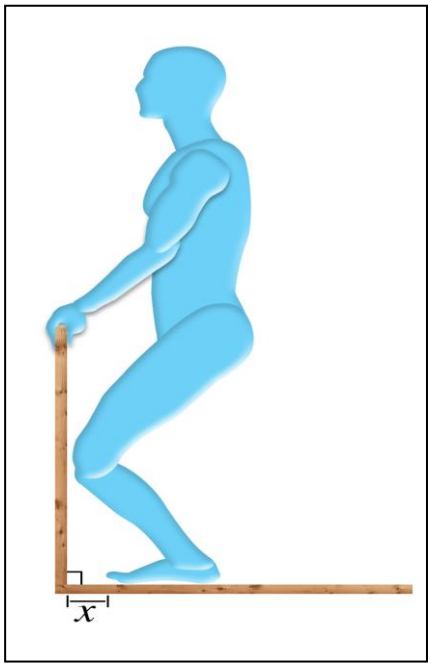


Figure 3.10 Weight Bearing Dorsiflexion test

3.7 Data analysis

3.7.1 Statistical Analysis

SPSS version 15.0 was used to analyse the data. A p value <0.05 was considered as statistically significant (Esterhuizen, 2010).

The etiologic fraction was defined as EF= N_e-N_n/N_e where N_e is the Number of exposed individuals in a population that develop a disease, or in the context of this research, the

number of manipulated individuals which improved, and N_n is the number of unexposed individuals in the same population which develop the disease, or in this context the number of non manipulated individuals which improve (Greenland and Robins, 1988).

Sensitivity was calculated as number of improved individuals in the manipulated Group/number of improved individuals in the control Group. Specificity was calculated as number of non-improved individuals in the control Group/number of non-improved individuals in the manipulated Group. A 95% confidence interval was calculated for these estimates using the public domain internet program, Epi Calc 2000 version 1.02 (Joe Gilman and Mark Myatt, 1998 Brixton Books).

The association data was statistically analysed using Fisher's exact tests to determine whether EFI is correlated to improvement in subjective/objective outcomes taken before treatment, and whether no EFI is correlated to subjective/objective outcomes getting worse or remaining the same. Therefore this analysis was conducted on the manipulated and control Groups to investigate the above theory. Pearson's chi square tests were used to determine presence of associations between categorical variables. Independent samples t-tests were used to compare means between two Groups. Repeated measures ANOVA testing was used to compare changes in quantitative variables over time between Groups. A significant time Group interaction effect signified the presence of a differential time effect between the Groups. Profile plots were generated in order to assess the direction of the effect and the trends (Esterhuizen, 2010).

3.7.2 Clinical significance

The phrase "clinical significance" is that used to describe the change that is assessed as a result of the effect of the clinical implication of a treatment both within and between Groups (Ogles *et al.,* 2001 and Atkins *et al*., 2005). Clinical significance can be positive, negative or insignificant and it allows the results that are interpreted from the study, to be taken and utilised within a population outside the Group that had been studied, which cannot be completed with statistical significance (Fetheney, 2010). The reason that clinical significance is employed is to convey the possible uses and practical implications of the treatment and application in clinical practice (Ogles *et al.,* 2001 and Fetheny, 2010). Two terms that are linked with clinical significance are MDC (Minimal Detectable Change) which is the minimum amount of change that can be detected on an outcome measure and MCID (Minimally Clinically Important Difference) which reflects the changes in results due to the treatment are in fact meaningful to the patient (Cook, nd). Therefore, it was noted that clinically significant

results play a major role in determining the value of the treatment and the impact it has on patients in terms of their recuperation (Cook, nd).

Tabulated below are the clinically significant values for the outcomes in this study:

Table 3.4 Clinically significant values for each test utilised in the study

Test	**Clinically significant value**
Visual Analogue Scale	A 30 % improvement must be noted on the 100mm scale (i.e. a 30mm improvement) for MCID to be met for this parameter and for clinical significance to be reached (Farrar *et al.,* 2001).
Foot and Ankle Disability Index	The acceptable MCD level for this parameter is an eight point improvement on the 104 point scale (Eeschaute *et al.,* 2007).
Pressure Algometer	The MCID is an improvement of 1.77kg.cm^2 for this parameter in order for clinical significance to be met (Chesterton *et al.,* 2007).
Berg Balance Scale	For this outcome the accepted MDC is 3.3 points for participants that fall into the 45-56 category and 4.9 point change in the 35-44 point category, the MCID has yet to be established for this outcome (Donohugue and Stokes, 2009).
Weight Bearing Dorsiflexion	For this test an improvement of 0.4-0.5cm is significant however a 1cm change must be made in order for MCID to be met and for the clinical significance to be reached (Green *et al.,* 2001 and Vicenzino *et al.,* 2006).

CHAPTER 4

RESULTS

4.1 Introduction

This chapter involves the presentation of the demographic data (age, gender, Ethnicity, occupation and mechanism of injury) and the results after statistical analysis of the data obtained from the subjective (Visual Analogue Scale and Functional Ankle Disability Index) and objective (Pressure Algometer, Weight Bearing Dorsiflexion test and Berg Balance Scale and motion palpation) results.

Primary Data: Data was collected only from those patients who met the research criteria and who participated for the full duration of the research programme. Only subjective and, objective readings taken by the researcher and the researcher assistants were utilized.

Secondary Data: Data was obtained from journal articles, books and any related literature, to obtain information on the procedure, reliability and signs to look for on motion palpation to diagnosis fixations.

Abbreviations:

EF = Etiologic fraction also referred to as responsiveness (which is the calculation of RRAM= Relative responsiveness attributable to the manoeuvre).

EFI = End-feel improvement.

4.2 Aims and objectives

The aim of this study was to determine the clinical responsiveness of motion palpation as a post-treatment diagnostic tool in joints of the ankle. The specific objectives of this study were:

- To determine the validity of motion palpation as a tool to detect an improvement in end-feel in the ankle region.
- To establish whether associations exist between motion palpation and the other clinical measures. If an association was found to exist between motion palpation and the clinical signs and symptoms of CAI, this could be used to monitor the patient's progress.
- To identify the most common fixations in symptomatic participants with CAI in this study.

The following results and statistical analyses are presented in this chapter:

1. Demographic data that was collected in the statistical analysis.
2. Motion palpation results with Etiologic fraction, sensitivity and specificity.
3. EFI association to the subjective/objective clinical measures (VAS, FADI, Algometer, BBS and WBD), as well as inter-Group analysis and clinical significance.
4. Common fixations found during the motion palpation readings.

4.3 Demographic data

The sample in this study consisted of forty participants with CAI with either Grade one or two ankle instability. Participants were placed into one of the two treatment Groups according to a randomization table produced by Esterhuizen (2010). Statistically significant differences were not noted with respect to any of the demographic variables between the treatments Groups in terms of any of the demographic variables.

Table 4.1 Comparison of demographic data between treatment Groups

		Group				*p* value
		Manipulation		Control		
		Count	Percentile	Count	Percentile	
Gender	Female	12	57.1%	7	36.8%	0.199
	Male	9	42.9%	12	63.2%	
Ethnicity	Black	3	14.3%	2	10.5%	0.095
	Coloured	2	9.5%	1	5.3%	
	Indian	5	23.8%	0	.0%	
	White	11	52.4%	16	84.2%	
Occupation	Accountant	0	.0%	3	15.8%	0.267
	Chiropractor	3	14.3%	1	5.3%	
	Graphic Designer	1	4.8%	0	.0%	
	Housewife	1	4.8%	1	5.3%	
	Insurance broker	0	.0%	1	5.3%	
	Lab technician	1	4.8%	0	.0%	
	Marketing manager	2	9.5%	0	.0%	
	Student	13	61.9%	12	63.2%	
	Unemployed	0	.0%	1	5.3%	
Mechanism of injury	Non-sport	5	23.8%	9	47.4%	0.119
	Sport	16	76.2%	10	52.6%	

Table 4.2 Comparison of demographic data between treatment Groups

	Group				*p* value
	Manipulation		Control		
	Mean	Standard Deviation	Mean	Standard Deviation	
Age	24.00	4.5	24.89	4.8	0.548
Chronicity (months)	41.00	42.4	46.63	41.9	0.676
BMI	23.29	3.6	24.68	5.1	0.316

Table 4.3 Table measuring all baseline readings of subjective and objective data

		Sum of Squares	df	Mean Square	F	Sig.
VAS pre-treatment	Between Groups	38.400	2	19.200	.056	.945
	Within Groups	12603.200	37	340.627		
	Total	12641.600	39			
Pressure Algometer pre-treatment	Between Groups	1.052	2	.526	.358	.701
	Within Groups	54.296	37	1.467		
	Total	55.348	39			
FADI pre-treatment	Between Groups	334.897	2	167.449	1.189	.316
	Within Groups	5212.078	37	140.867		
	Total	5546.975	39			
BBS pre-treatment	Between Groups	36.506	2	18.253	1.040	.364
	Within Groups	649.494	37	17.554		
	Total	686.000	39			
WBD pre-treatment	Between Groups	20.541	2	10.270	.967	.390
	Within Groups	392.883	37	10.618		
	Total	413.424	39			

There were no significant differences noted between the two Groups in terms of age, gender, ethnicity, and mechanism of injury, BMI, baseline measurements or any other demographic or baseline data. ANOVA testing was used to compare mean values of subjective and objective measurements pre-treatment between the three fixations that were first identified at the outset. It is evident from Table 4.3, that all baseline readings at the outset of the study were similar between the Groups for each of the subjective/objective clinical measures (all $p>0.05$). These parameter readings were not significantly different between the two treatment Groups due to the randomization process and the inclusion and

exclusion criteria that were set prior to the commencement of the study (Mouton, 1996). This indicated that adequate homogeneity was reached and both Groups were similar and no inference can be made with regard to baseline readings.

4.4 Data pertaining to motion palpation and subjective/objective clinical measures used in this study

- Motion palpation (Appendix L and M) (Schafer and Faye, 1990; Haas *et al.*, 1995 and Lakhani *et al.*, 2009).

Subjective data

- Visual Analogue Scale (Appendix G) (Liggins, 1982; Jensen and Karoly, 1993; Yeomans, 2000 and Salaffi *et al.*, 2003).
- Functional Ankle Disability Index (Appendix H) (Hale and Hertel, 2005).

Objective data

- Weight Bearing Dorsiflexion test (Appendix I) (Collins *et al.*, 2002 and Vicenzino, 2006).
- Pressure Algometer readings (Appendix J) (Vaughan *et al.*, 2007).
- The Berg Balance Scale (Appendix K) (Kornetti *et al.*, 2004 and Halsaa *et al.,* 2007).

4.4.1 Motion palpation

The data below was analysed to determine the validity of motion palpation as a tool (i.e. its ability to detect that end-feel had improved in the treatment/Manipulation Group and that end-feel stayed the same in the control Group). Forty participants were randomly divided into two Groups; a control (no Manipulation Group) and a Manipulation Group. Twenty-one participants were manipulated (treatment Group) whereas 19 were not manipulated (control Group). In both Groups the three most notable fixations were recorded and in the Manipulation Group at least two of the three fixations found on examination were manipulated by the research assistant.

4.4.1.1 Equations used to calculate: etiologic fraction, sensitivity and specificity

The etiologic fraction/responsiveness is defined as: the percentage of response caused by Manipulation itself as a fraction of the total percentage of end-feel response in the treatment

Group. Therefore, the etiologic fraction/responsiveness of motion palpation was calculated by the following equation: EF= N_e-N_n/N_e where N_e is the number of manipulated individuals which improved, and N_n is the number of non manipulated individuals which improved (Greenland and Robins, 1988) An etiologic fraction equal to 0 (or equivalently likelihood ratio = 1) indicated test performance that was equivalent to chance. Etiologic fraction equal to 1 indicated a perfect test performance (sensitivity = specificity = 1) (Greenland and Robins, 1988; Bergmann, Petersen and Lawrence, 1993 and Haas *et al.,* 1995).

Sensitivity was determined by the following equation: Sensitivity = (number of improved individuals in the Manipulation Group) / (number of improved individuals in the manipulated Group + number of non-improved individuals in the manipulated Group).

Specificity was established by the following equation: Specificity = (number of non-improved individuals in the control Group)/ (number of non-improved individuals in the control Group + number of improved individuals in the control Group). Sensitivity and specificity were calculated for both these estimates using the public domain internet program, Epi Calc 2000 version 1.02 (Joe Gilman and Mark Myatt, 1998 Brixton Books).

4.4.1.2 Motion palpation data on the first fixations

The methodology of this study stipulated that wherever possible, three of the worst fixations be identified on motion palpation. This section analyses and discusses the first fixation noted by the blinded motion palpator on each participant.

Table 4.4 Cross tabulation of Manipulation versus EFI in the first fixation

			End-feel improvement		Total
			Yes	No	
Manipulated (yes/no)	No	Count	1	18	19
		Row %	5.3%	94.7%	100.0%
	Yes	Count	20	1	21
		Row %	95.2%	4.8%	100.0%
Total		Count	21	19	40
		Row %	52.5%	47.5%	100.0%

$p<0.001$

In this first fixation (i.e. the first fixation detected on motion palpation) the etiologic fraction is: EF= N_e-N_n/N_e (20-1)/ 20 =0.95 or 95% of the improvement was due to the Manipulation.

Sensitivity = (number of improved individuals in the Manipulation Group) / (number of improved individuals in the manipulated Group + number of non-improved individuals in the manipulated Group). Therefore, in this first fixation the sensitivity is: 20/ (20+1) =0.95 [95% CI 0.74, 1.00].

Specificity = (number of non-improved individuals in the control Group)/ (number of non-improved individuals in the control Group + number of improved individuals in the control Group). Therefore, in this first fixation the specificity is: 18/ (18+1) =0.95 [95% CI 0.72, 1.00].

The statistics show that three fixations per participant were identified. For the first fixation nineteen were not manipulated and twenty-one were manipulated. There was a highly significant association between being manipulated and EFI of the fixations felt on motion palpation (p<0.001). The EF was 0.95, meaning that 95% of the improvement was due to the Manipulation. The sensitivity was also 95%, meaning that 95% of those who improved were manipulated. The specificity was also 95% meaning that 95% of those who did not improve were not manipulated.

4.4.1.3 Motion palpation data on the second fixations

The methodology of this study stipulated that wherever possible, three of the worst fixations be identified on motion palpation. This section analyses and discusses the second fixation noted by the blinded motion palpator on each participant.

Table 4.5 Cross tabulation of Manipulation versus EFI in the second fixation

			End-feel improvement		Total
			Yes	No	
Manipulated (yes/no)	No	Count	1	19	20
		Row %	5.0%	95.0%	100.0%
	Yes	Count	17	3	20
		Row %	85.0%	15.0%	100.0%
Total		Count	21	18	40
		Row %	52.5%	45.0%	100.0%

p<0.001

For the second fixation (i.e. the second fixation detected on motion palpation) twenty participants were not manipulated and twenty were manipulated. There was a highly significant association between being manipulated and EFI (p<0.001) in the noted fixations.

Furthermore the etiologic fraction for the second fixation was: EF= N_e-N_n/N_e therefore (17-1)/ 17 =0.94 or 94% of the improvement was due to the Manipulation.

Sensitivity = (number improved individuals Manipulation Group) / (number of improved individuals in the manipulated Group + number of non-improved individuals in the manipulated Group). Therefore, in the second fixation the sensitivity was: 17/ (17+3) =0.85 [95% CI 0.71, 1.00].

Specificity = (number of non-improved individuals in the control Group)/ (number of non-improved individuals in the control Group + number of improved individuals in the control Group). Therefore, in this second fixation the specificity was: 19/ (19+1) =0.95 [95% CI 0.64, 0.96].

For the second fixation twenty participants were not manipulated and twenty were manipulated. There was a highly significant association between being manipulated and end-feel improvement of the fixations felt on motion palpation (p<0.001). The EF was 0.94, meaning that 94% of the improvement was due to the Manipulation. The sensitivity was 0.85, meaning that 85% of those who improved were manipulated. The specificity was 0.95 meaning that 95% of those who did not improve were not manipulated.

4.4.1.4 Motion palpation data on the third fixations

The methodology of this study stipulated that wherever possible, three of the worst fixations be identified on motion palpation. This section analyses and discusses the third fixation noted by the blinded motion palpator on each participant.

Table 4.6: Cross tabulation of Manipulation versus EFI in the third fixation

			End-feel improvement		Total
			Yes	No	
Manipulated (yes/no)	No	Count	3	20	23
		Row %	13.0%	87.0%	100.0%
	Yes	Count	13	4	17
		Row %	76.5%	23.5%	100.0%
Total		Count	16	24	40
		Row %	40.0%	60.0%	100%

p<0.001

For the third fixation (i.e. the third fixation detected on motion palpation) twenty-three were not manipulated and seventeen were. There was a highly significant association between

being manipulated and EFI (p<0.001). Furthermore the etiologic fraction for the third fixation was: EF= N_e-N_n/N_e therefore (13-3)/ 13 =0.77 or 77% of the improvement was due to the Manipulation.

Sensitivity = (number improved individuals Manipulation Group) / (number of improved individuals in the manipulated Group + number of non-improved individuals in the manipulated Group). Therefore, in the third fixation the sensitivity was: 13/ (13+4) =0.76 [95% CI 0.54, 0.95].

Specificity = (number of non-improved individuals in the control Group)/ (number of non-improved individuals in the control Group + number of improved individuals in the control Group). Therefore, in this third fixation the specificity was: 20/ (20+3) =0.87 [95% CI 0.62, 0.95].

For the third fixation twenty-three participants were not manipulated and seventeen were manipulated. There was a highly significant association between being manipulated and end-feel improvement of the fixations felt on motion palpation (p<0.001). The EF was 0.77, meaning that 77% of the improvement was due to the Manipulation. The sensitivity was 0.76, meaning that 76% of those who improved were manipulated. The specificity was 0.87 meaning that 87% of those who did not improve were not manipulated.

4.4.1.5 Motion palpation data on the overall EFI (where at least two of the three fixations improved between the initial and final readings)

The methodology of this study stipulated that wherever possible, three of the worst fixations be identified on motion palpation. This section analyses and discusses the overall EFI which for the purpose of this study was defined as having at least two of the three fixations as having improved.

Table 4.7: Overall EFI statistics regarding Manipulation versus EFI in the two treatment Groups

			Overall EFI (greater than or equal to 2 out of the 3)		Total
			Yes	No	
Group	Manipulation	Count	19	2	21
		% within Group	90.5%	9.5%	100.0%
	Control	Count	1	18	19
		% within Group	5.3%	94.7%	100.0%
Total		Count	20	20	40
		% within Group	50.0%	50.0%	100.0%

$p<0.001$

Overall EFI in motion palpation was defined as having at least two of the three fixations improve between the initial and final readings. In Table 4.7 above, it is shown that in total, twenty participants showed overall EFI, of which nineteen were from the manipulated Group and in the control Group, overall EFI was noted in one out of nineteen who also improved. There was no EFI noted in twenty of the participants and of these, two of these were from the manipulated Group.

Overall there was a highly significant association between being manipulated and overall EFI ($p<0.001$). Furthermore, the etiologic fraction for the overall EFI was: $EF= N_e-N_n/N_e$, therefore, (19-1)/ 19 =0.95 or 95% of the overall EFI was due to the Manipulation.

Sensitivity = (number improved individuals Manipulation Group) / (number of improved individuals in the manipulated Group + number of non-improved individuals in the manipulated Group).

Therefore, for the overall EFI the sensitivity was: 19/ (19+2) =0.90 [95% CI 0.73, 1.00]. Therefore this means 90% of those who improved were manipulated.

Specificity = (number of non-improved individuals in the control Group)/ (number of non-improved individuals in the control Group + number of improved individuals in the control Group)

Therefore, for the overall EFI the specificity is: 18/ (18+1) =0.95 [95% CI 0.67, 0.9]. Therefore, 95% of those who did not improve were not manipulated.

4.4.1.6 Association between motion palpation results and other subjective/objective measures

The data below was statistically analysed using Fisher's exact tests to determine whether EFI is correlated to improvement in subjective/objective outcomes taken before treatment, and whether no EFI is correlated to subjective/objective outcomes getting worse or remaining the same. Therefore this analysis was conducted on the manipulated and control Groups to investigate the above theory.

Within the tables below, there were no significant associations. In fact, most were highly non significant with *p* value =1. All the tables suggest therefore that within each Group (Manipulation and control); there was no statistically significant difference in terms of the subjective/objective clinical measures between the proportion who had EFI and those who did not. In fact, with respect to the control Group, the tables suggest that most did not have EFI and yet some had clinical improvement.

4.4.1.6.1 Association between overall EFI and VAS

Table 4.8: Association between overall EFI and VAS improvement in the manipulated Group (n=21)

End-Feel Improvement	VAS Improvement	
	Yes	No
Yes	14	6
No	1	0

Table 4.9: Association between overall EFI and VAS improvement in the control Group (n=19)

End-Feel Improvement	VAS Improvement	
	Yes	No

Yes	1	0
No	10	8

In the Manipulation Group, 70% (fourteen out of twenty-one) participants experienced an association between EFI and perceived VAS improvement despite no statistical association. Within the control Group, 47% (nine out of nineteen) experienced an association between EFI and perceived VAS improvement despite no statistical association. The Fisher Exact Test (two tailed) =1.000000 for the manipulated and the control Group, therefore, no statistical association between EFI and subjective/objective clinical measures occurred.

Table 4.10 VAS readings in the manipulated Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.908	0.182
Time*Group	Wilk's lambda =1.00	0.944
Group	F =0.097	0.759

Table 4.11 VAS readings in the control Group

Effect	Statistic	*p* value
Time	Wilk's lambda =0.749	0.029
Time*Group	Wilk's lambda = 0.811	0.063
Group	F =0.462	0.506

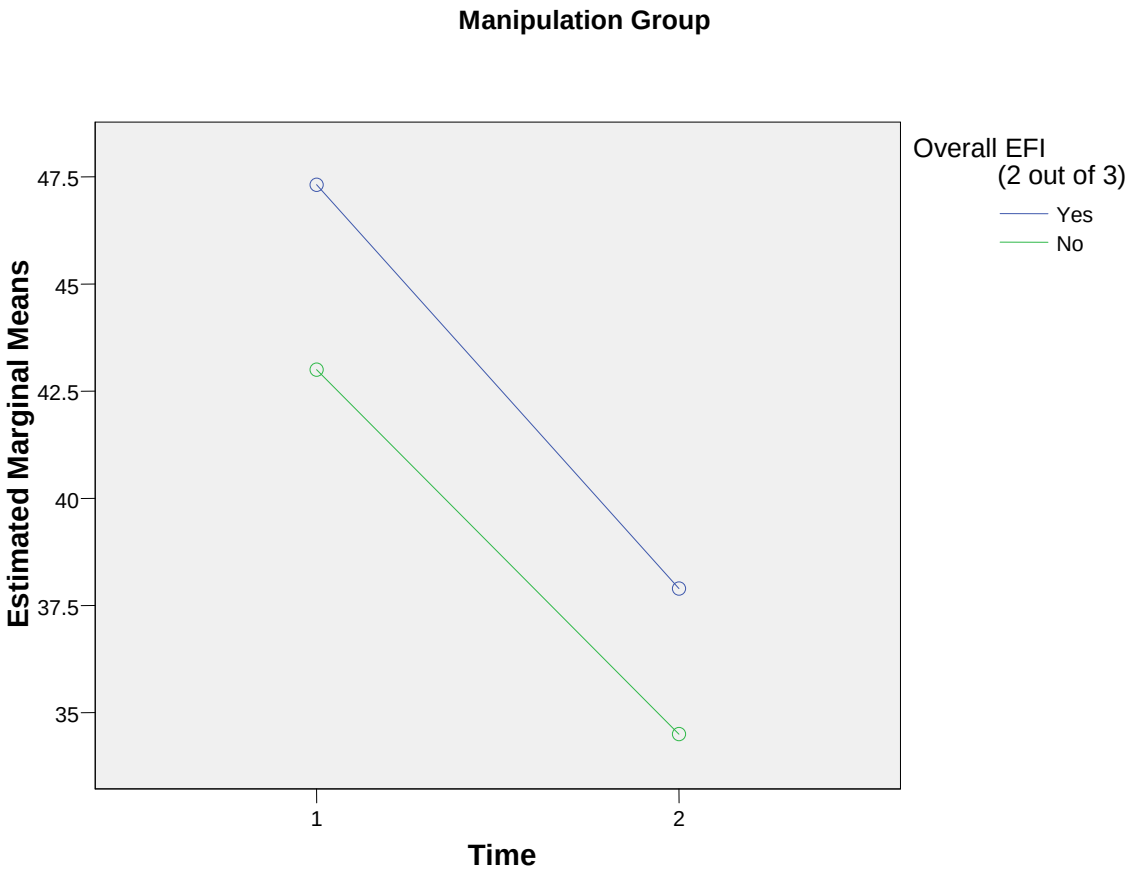


Figure 4.1 Profile plot of VAS over time by overall EFI in the manipulated Group

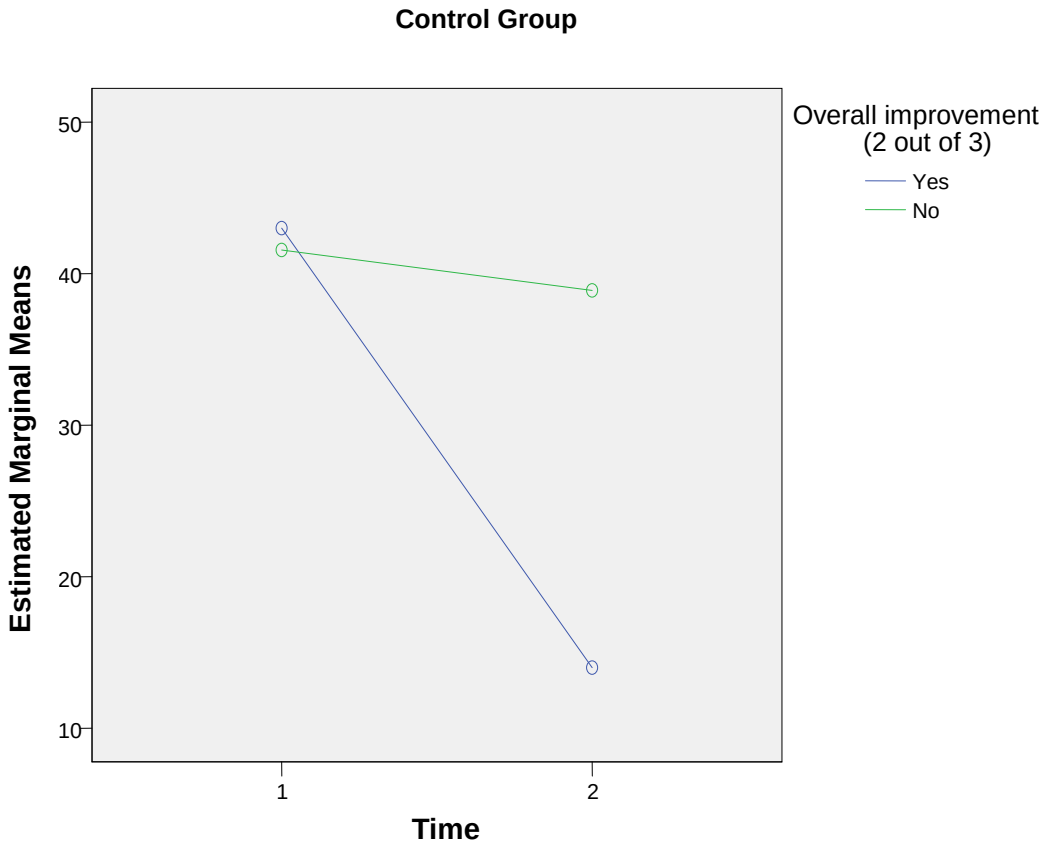


Figure 4.2 Profile plot of VAS over time by overall EFI in the control Group

In the Manipulation Group there was no noted statistical association between the overall EFI in motion palpation results and readings from the VAS over time (p=0.944). The profile plot (Figure 4.1) shows that in the Manipulation Group, those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of reduction of VAS over time and, therefore, no link between the two can be made. In comparison, overall EFI in the control Group predicted outcome of VAS to some extent but not quite statistically significantly (p=0.063). The profile plot (Figure 4.2) shows that those who showed overall EFI showed a larger reduction of VAS over time compared to those who showed no EFI.

4.4.1.6.2 Association between overall EFI and FADI

Table 4.12 Association between overall EFI and Improvement in FADI scores in the manipulated Group (n=21)

End-Feel Improvement	FADI Improvement	
	Yes	No
Yes	14	6
No	1	0

Table 4.13 Association between overall EFI and Improvement in FADI scores in the control Group (n=19)

End-Feel Improvement	FADI Improvement	
	Yes	No
Yes	1	0
No	13	5

In the Manipulation Group, 70% (fourteen out of twenty-one) participants experienced an association between EFI and perceived FADI improvement despite no statistical association. Within the control Group, 32% (six out of nineteen) experienced a association between EFI and perceived FADI improvement despite no statistical association. The Fisher Exact Test (two tailed) =1.000000 for the manipulated and the control Group, therefore no statistical association between EFI and subjective/objective clinical measures occurred.

Table 4.14 FADI readings in the manipulated Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.950	0.330
Time*Group	Wilk's lambda = 0.975	0.490
Group	F =0.006	0.941

Table 4.15 FADI readings in the control Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.874	0.136
Time*Group	Wilk's lambda = 0.972	0.491
Group	F= 0.089	0.770

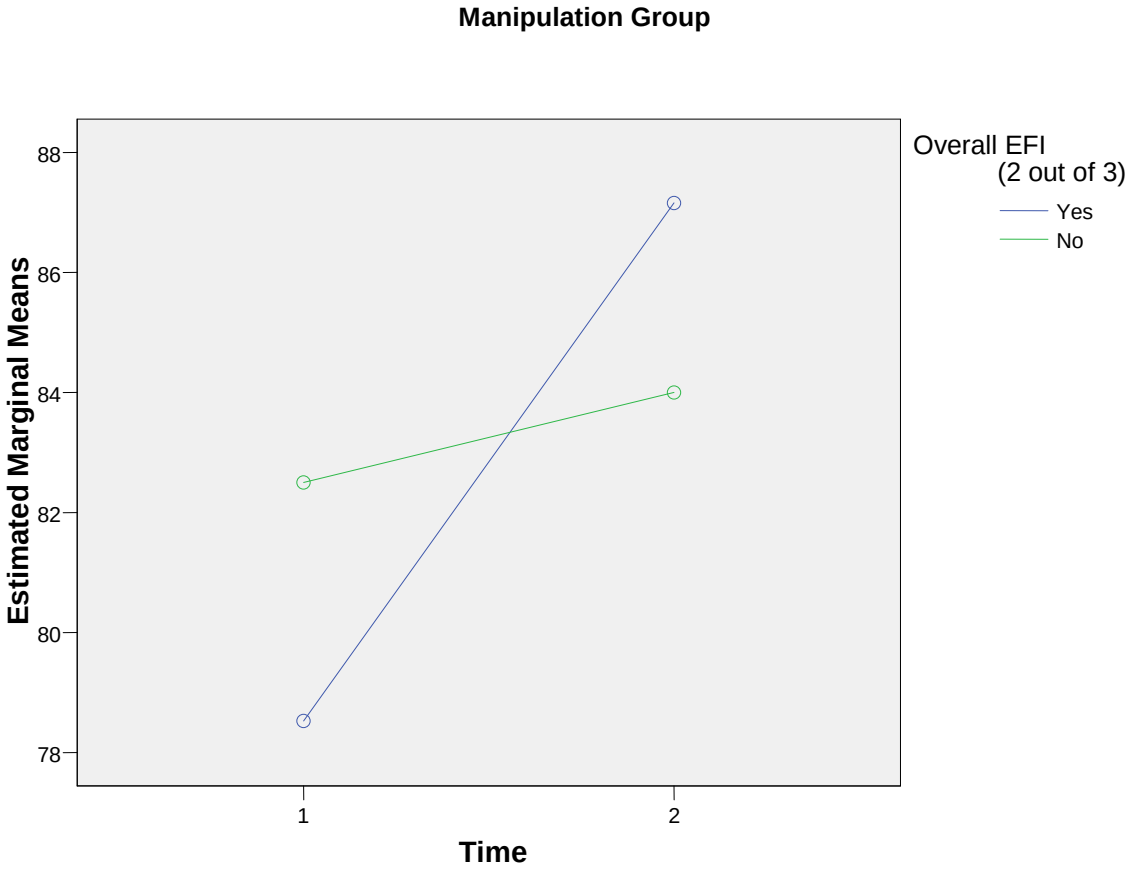


Figure 4.3 Profile plot of FADI score over time by overall EFI in the manipulated Group

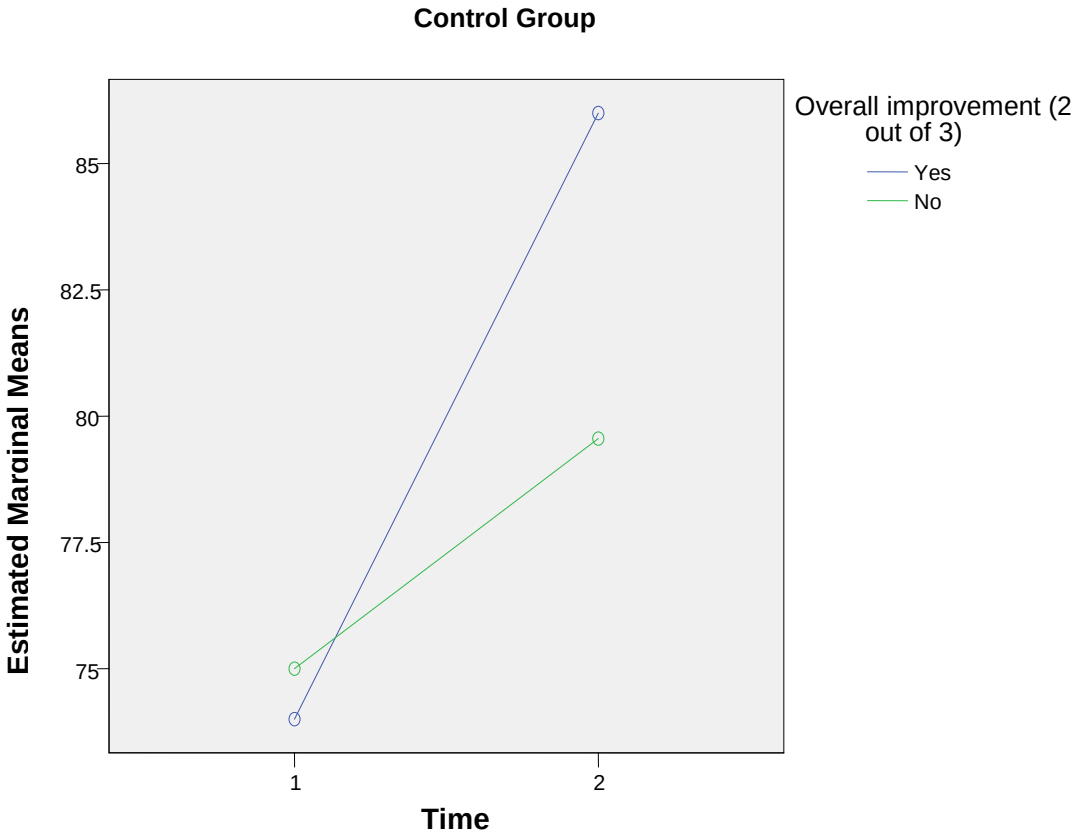


Figure 4.4 Profile plot of FADI score over time by overall EFI in the control Group

In the Manipulation Group there was no statistical association between the overall EFI in motion palpation results and scores from FADI over time (p=0.490). However, the profile plot shows a strong trend that those who showed overall EFI in motion palpation readings (i.e. those who showed a decrease in fixations), also showed an increase in FADI score to a greater extent over time, compared to those who did not show EFI in the Group who were manipulated. However, the statistical power was too low to detect this trend as statistically significant. In the control Group, there was no effect of the overall EFI in motion palpation readings on FADI (p=0.491). However, the profile plot shows a slight trend towards the greatest increase in FADI being in the Group which showed EFI in motion palpation.

4.4.1.6.3 Association between overall EFI and Pressure Algometer

Table 4.16 Association between overall EFI and improvement in Pressure Algometer scores in the manipulated Group (n=21)

End-Feel Improvement	Pressure Algometer Improvement	
	Yes	No
Yes	10	10
No	1	0

Table 4.17 Association between overall EFI and improvement in Pressure Algometer scores in the control Group (n=19)

End-Feel Improvement	Pressure Algometer Improvement	
	Yes	No
Yes	1	0
No	10	8

In the Manipulation Group, 48% (ten out of twenty-one) experienced an association between EFI and perceived Pressure Algometer score improvement despite no statistical association. Within the control Group, 47% (nine out of nineteen) experienced an association between EFI and perceived Pressure Algometer score improvement despite no statistical association. The Fisher Exact Test (two tailed) =1.000000 for the manipulated and the control Group, therefore, no statistical association between EFI and subjective/objective clinical measures occurred.

Table 4.18 Pressure Algometer readings in the manipulated Group

Effect	Statistic	*p* value
Time	Wilk's lambda =0.973	0.479
Time*Group	Wilk's lambda = 0.988	0.634
Group	F=0.522	0.479

Table 4.19 Pressure Algometer readings in the control Group

Effect	Statistic	*p* value
Time	Wilk's lambda =0.933	0.268
Time*Group	Wilk's lambda = 0.977	0.828
Group	F =0.020	0.889

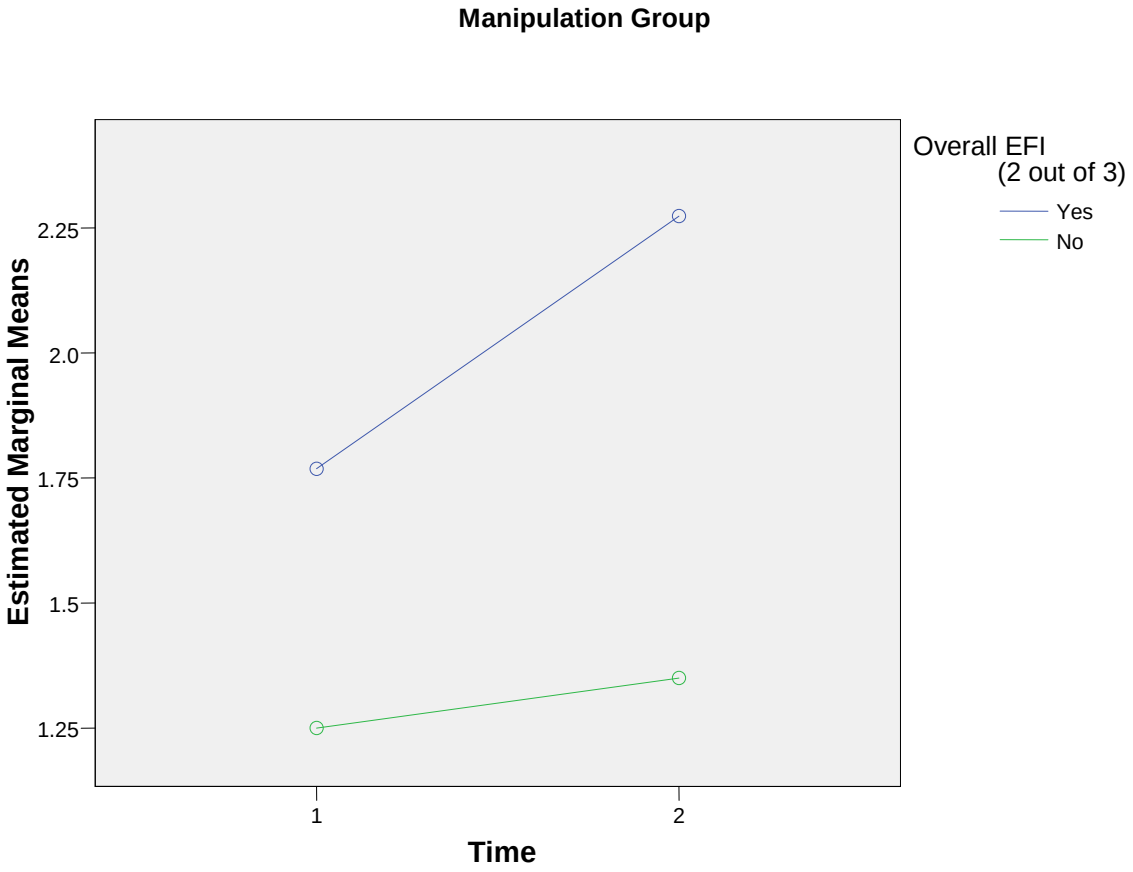


Figure 4.5 Profile plot of Pressure Algometer over time by the overall EFI in the manipulated Group

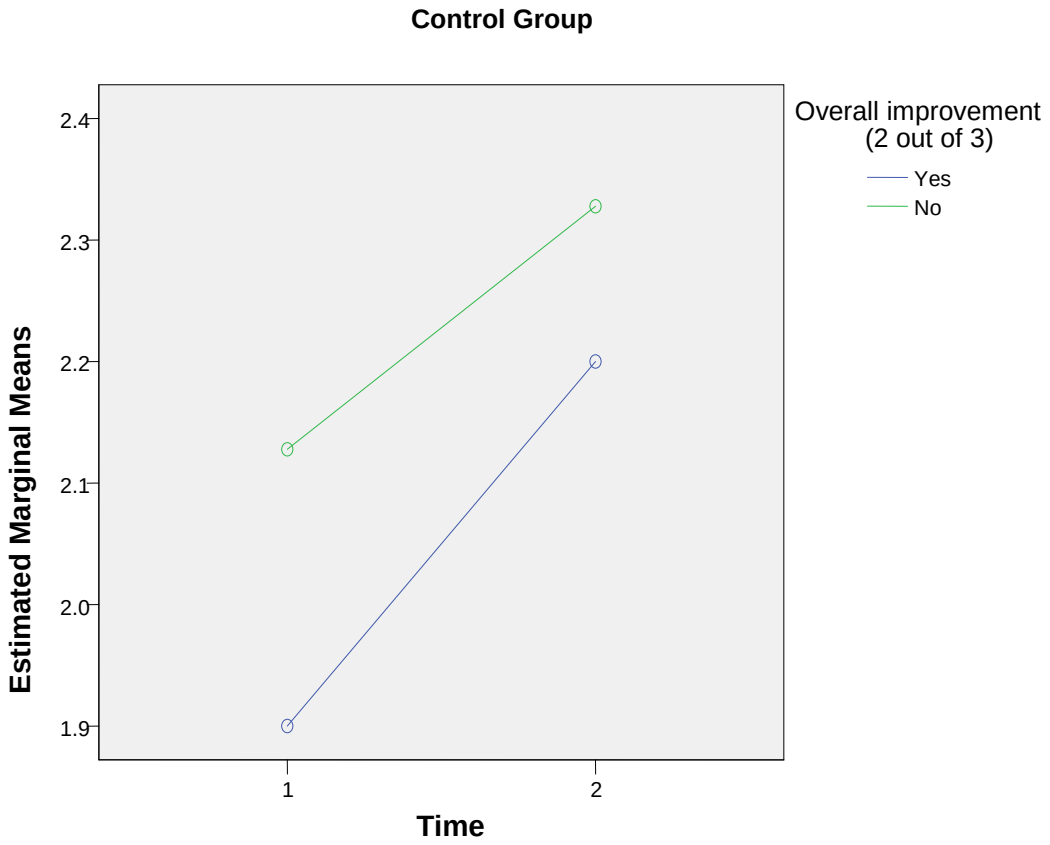


Figure 4.6 Profile plot of Pressure Algometer over time by overall EFI in the control Group

In the manipulated Group, there was no noted relationship between the overall EFI in motion palpation results and readings from the Pressure Algometer over time (p=0.634). The profile plot shows that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of increase of Pressure Algometer readings of over time in the Manipulation Group (p=0.828). In the control Group, there was no effect of the overall EFI in motion palpation readings on Pressure Algometer over time. The profile plot shows that both those who showed overall EFI and those who did not, fared equally well in terms of increase of Pressure Algometer readings over time in the control Group.

4.4.1.6.4 Association between overall EFI and BBS

Table 4.20 Association between overall EFI and Improvement in BBS scores in the manipulated Group (n=21)

End-Feel Improvement	BBS Improvement	
	Yes	No
Yes	19	1
No	1	0

Table 4.21 Association between overall EFI and Improvement in BBS scores in the control Group (n=19)

End-Feel Improvement	BBS Improvement	
	Yes	No
Yes	0	1
No	12	6

In the Manipulation Group, 90% (nineteen out of twenty-one) experienced an association between EFI and perceived BBS improvement despite no statistical association. Within the control Group, 32% (six out of nineteen) experienced an association between EFI and perceived BBS improvement despite no statistical association. The Fisher Exact Test (two tailed) = 1.000000 for the Manipulation Group and the Fisher exact test (two tailed) = 0.368421 for the control Group, therefore an association between EFI and subjective/objective clinical measures was detected but it was not statistically significant.

Table 4.22 Berg Balance Scale readings in the manipulated Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.622	0.003
Time*Group	Wilk's lambda = 0.977	0.512
Group	F =0.013	0.912

Table 4.23 Berg Balance Scale readings in the control Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.994	0.761
Time*Group	Wilk's lambda = 0.991	0.695
Group	F =3.762	0.069

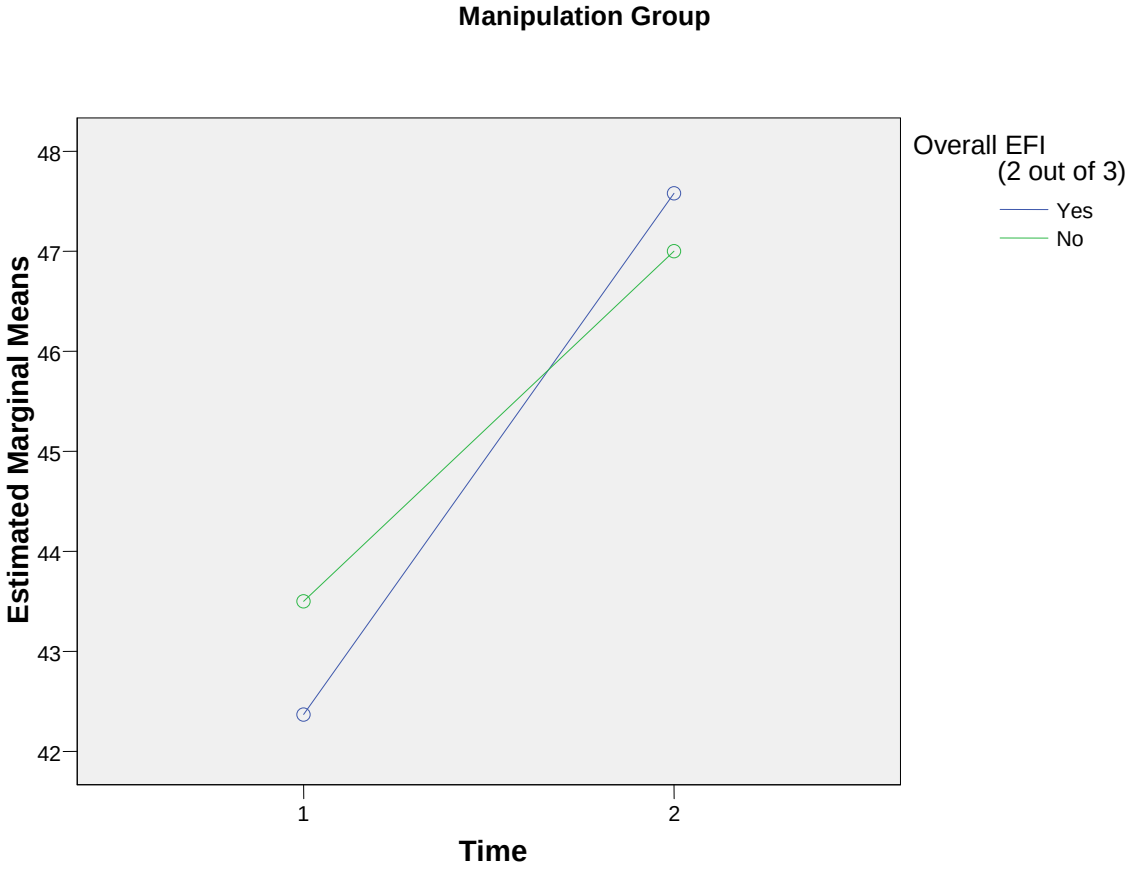


Figure 4.7 Profile plot of Berg Balance Scale over time by overall EFI in the manipulated Group

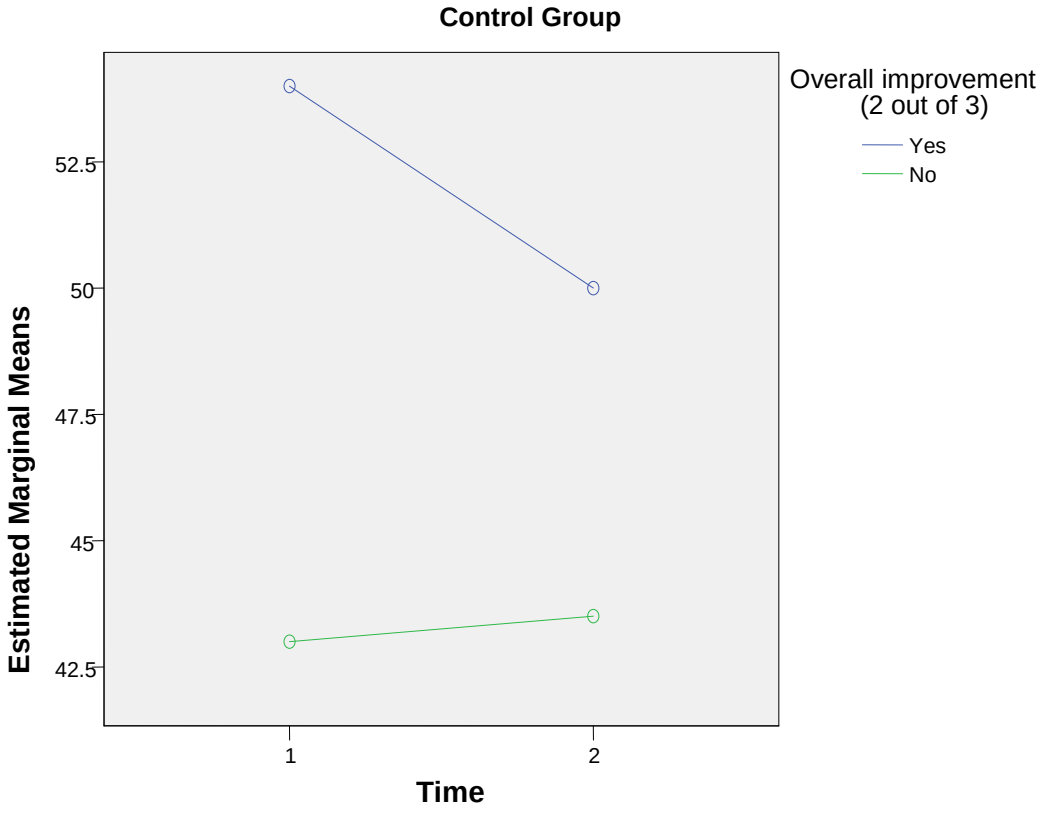


Figure 4.8 Profile plot of Berg Balance Scale over time by overall EFI in the control Group

In the Manipulation Group, there was no statistical association between the overall EFI in motion palpation readings and the Berg Balance Scale score over time (p=0.512). However, the profile plot shows a slight trend that those who showed overall EFI in motion palpation readings also improved in BBS to a greater extent over time, compared to those who did not show overall EFI in the Manipulation Group. However, the statistical power was too low to detect this trend as statistically significant. In the control Group, there was no effect of the overall EFI in motion palpation readings on BBS over time (p=0.695). Therefore no trend was noted between BBS and EFI in the control Group

4.4.1.6.5 Association between overall EFI and WBD

Table 4.24 Association between overall EFI and Improvement in WBD scores in the Manipulation Group (n=21)

End-Feel Improvement	WBD Improvement	
	Yes	No
Yes	12	8
No	1	0

Table 4.25 Association between overall EFI and Improvement in WBD scores in the control Group (n=19)

End-Feel Improvement	WBD Improvement	
	Yes	No
Yes	0	1
No	11	7

In the Manipulation Group 57% (twelve out of twenty-one) experienced a association between EFI and perceived WBD improvement despite no statistical association. Within the control Group 37% (seven out of nineteen) experienced an association between EFI and perceived WBD improvement despite no statistical association. The Fisher exact test (two tailed) = 1.000000 for the Manipulation Group and the Fisher exact test (two tailed) =0.421053 for the control Group, therefore slight association between EFI and subjective/objective clinical measures, but it was not statistically significant.

Table 4.26 Weight Bearing Dorsiflexion readings in the manipulated Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.989	0.656
Time*Group	Wilk's lambda = 1.00	0.966
Group	F =2.041	0.169

Table 4.27 Weight Bearing Dorsiflexion readings in the control Group

Effect	Statistic	*p* value
Time	Wilk's lambda = 0.996	0.801
Time*Group	Wilk's lambda = 0.994	0.747
Group	F= 0.218	0.647

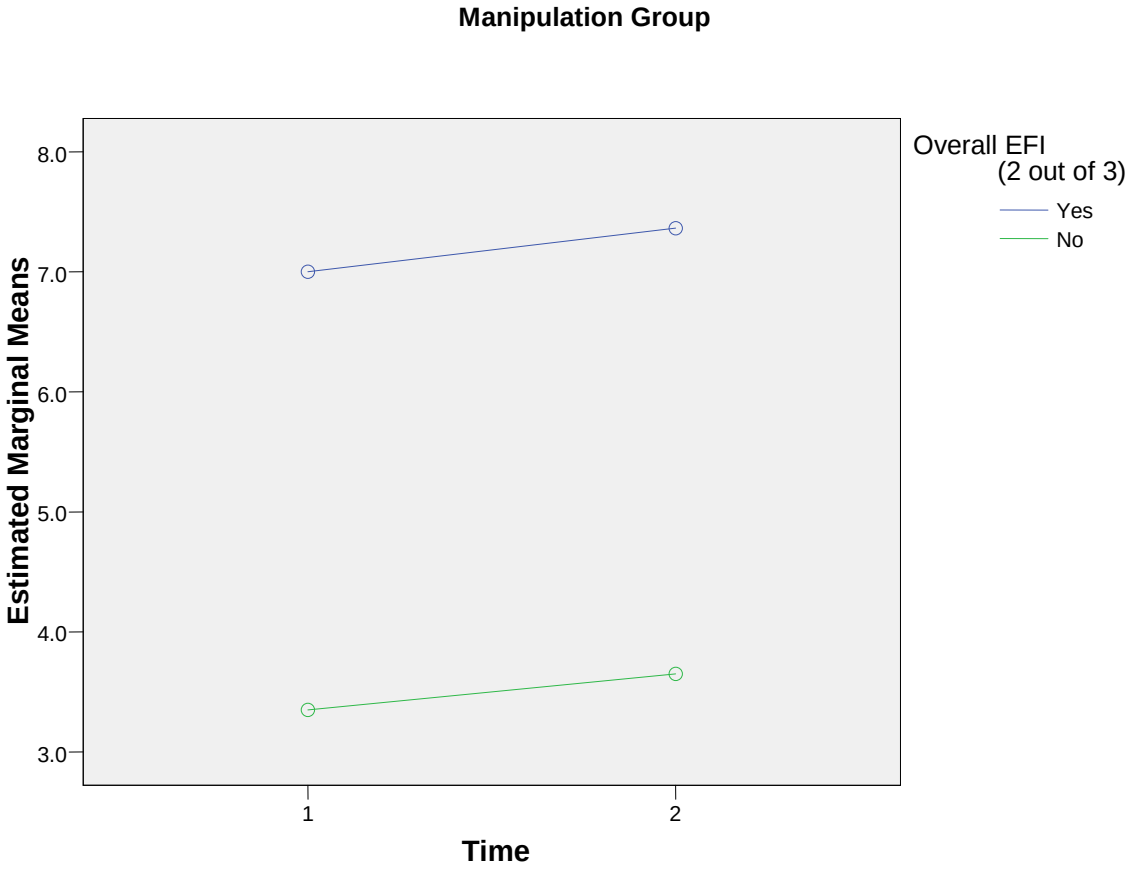


Figure 4.9 Profile plot of Weight Bearing Dorsiflexion over time by overall EFI in the manipulated Group

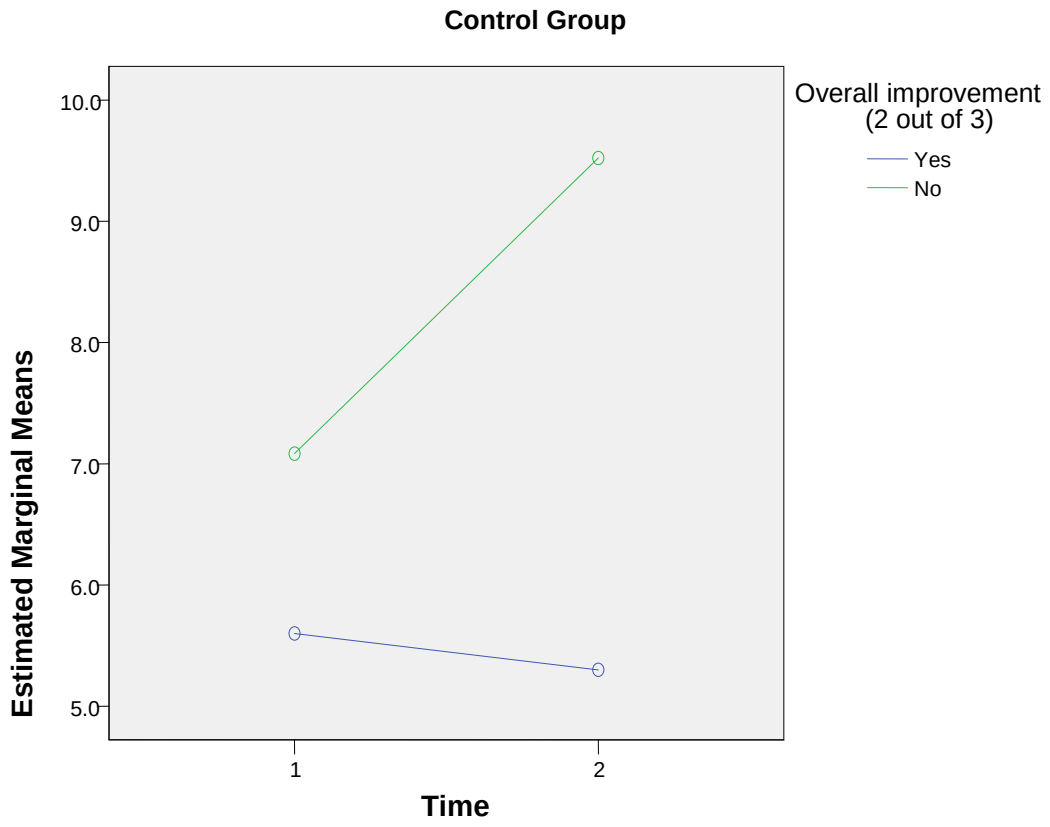


Figure 4.10 Profile plot of Weight bearing dorsiflexion over time by overall EFI in the control Group

In the manipulated Group there was no association between the overall EFI in motion palpation readings and WBD over time (p=0.966). The profile plot shows that those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of an improvement in weight bearing dorsiflexion readings of over time within the Manipulation Group. Therefore, no link was found to correlate WBD improvement in participants who showed overall EFI. In the control Group, there was no effect of the overall EFI in motion palpation readings on WBD over time (p=0.747). Therefore no association could be noted between EFI and WBD in the control Group.

4.4.1.6.6 Summary of overall EFI associations

- No statistically significant association occurred within this study between EFI and clinical parameter improvement, and no EFI and a lack of clinical parameter improvement.

1. In the manipulation group it can be seen that:

a) FADI and BBS showed a slight trend that those participants who showed overall EFI in motion palpation readings also increased in FADI and BBS scores to a greater extent over time, compared to those who did not show an end-feel improvement in motion palpation in the Group who were manipulated. However the statistical power was too low to detect this trend as statistically significant.

b) Within the other subjective/objective clinical measures: VAS, Pressure Algometer and WBD the profile plot showed that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of improvement of VAS, Pressure Algometer and WBD readings of over time.

2. In the control Group:

a) VAS and FADI showed a slight association between EFI and their readings, but not to a statistically significant degree.

b) In the rest of the subjective/objective clinical measures, Pressure Algometer, BBS and WBD, the profile plot showed that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of improvement over time in the control Group.

- Therefore, all of the subjective/objective clinical measures indicated that there was no noted statistical association between the overall EFI (EF=95%) in motion palpation results and readings from the subjective/objective clinical measures over time in the Group that was manipulated and therefore, no statistical link between the two can be made.

4.4.1.7 Further data for subjective/objective outcomes (Intra- and Inter-Group analysis and clinical significance)

Given that there was no statistical association between EFI and any of the subjective/objective clinical measures improvement in the manipulated Group, and between no EFI and a lack of parameter improvement in the control Group, the data needed to be further analysed, in terms of inter-Group analysis and clinical significance. This was conducted to determine if statistical significant difference in subjective/objective outcomes, or even in terms of clinical significance, in fact occurred between the Group who received Manipulation, as compared to the Group that didn't in this study, in an attempt to understand why no association was noted.

4.4.1.7.1 Visual Analogue Scale: (Subjective)

Inter-Group analysis for VAS

Table 4.28 Repeated measures ANOVA for VAS in both Groups

Effect	Statistic	*p* value
Time	Wilk's lambda= 0.838	0.010
Time*Group	Wilk's lambda= 0.971	0.291
Group	F=0.257	0.615

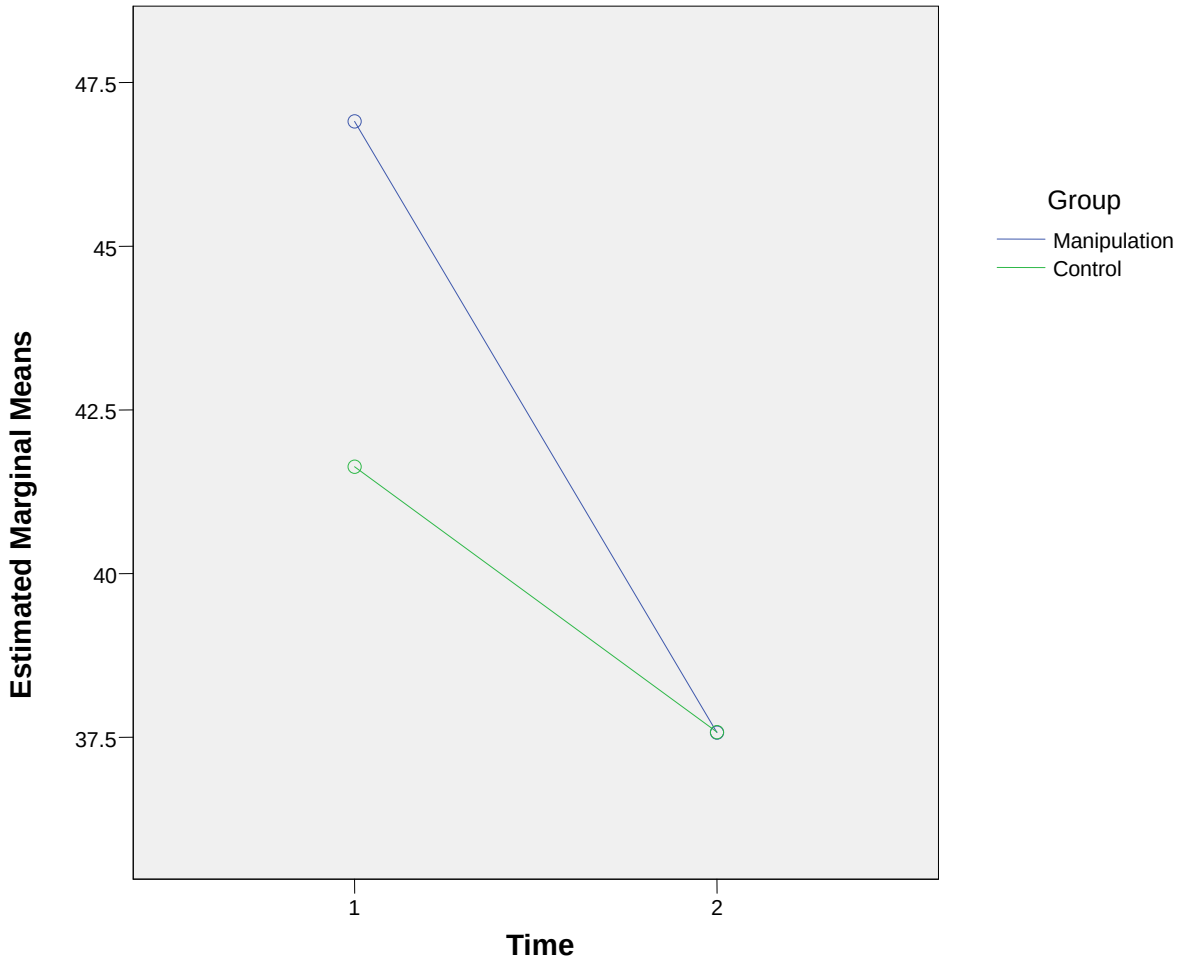


Figure 4.11 Profile plot of VAS over time in both Groups

Inter-Group analysis of VAS, revealed that no significant Manipulation effect compared with the control over time (p=0.291) but the profile plot reveals a trend which suggests that the rate of improvement in the Manipulation Group was greater than that in the control Group (the slope of the line in the Manipulation Group was steeper than in the control Group).

Clinical significance for VAS: Control Group

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistically significant difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis

assessing clinical significance was performed to determine whether substantial differences occurred between the Groups with respect to any subjective/objective clinical measures.

Table 4.29 Table of raw data (pre and post) for VAS in control Group (no Manipulation) (n=19)

Participant	Pre (in mm)	Post (in mm)	Difference (in mm)	Percent change
1	43	50	+7	16%increase in pain
2	20	18	2	10% decrease in pain
3	68	39	29	43% decrease in pain
4	43	14	29	67%decrease in pain
5	33	30	3	9%decrease in pain
6	70	62	8	11%decrease in pain
7	23	30	+7	30%increase in pain
8	28	25	3	11%decrease in pain
9	33	24	9	27%decrease in pain
10	22	43	+21	95%increase in pain
11	67	70	+3	4%increase in pain
12	25	29	+4	16%increase in pain
13	55	56	+1	2%increase in pain
14	41	52	+11	27%increase in pain
15	27	21	6	22%decrease in pain
16	18	21	+3	17%increase in pain
17	70	36	34	49%decrease in pain
18	69	63	6	9%decrease in pain
19	36	31	5	14%decrease in pain
Mean	41.63	37.58		
Highest	70	70		
Lowest	18	14		

Table 4.30 Breakdown of clinically significant improvements made by participants in the control Group (no Manipulation) (n=19)

% Improvement	Number of participants
0-9	2
10-19	4
20-29	2
*30-39	-
*40-49	2
*50-59	-
*60 and above	1
Worsening (an increase in score)	8

**indicates clinically significant improvement was made*

Within the control Group there was an average change in score between pre- and post-visit findings in this Group of 4mm. The greatest improvement in score was 34mm (49% improvement) and the lowest improvement was an increase in score of 21mm (95% increase of pain) between the pre- and post-treatment findings. For clinical significance to be achieved for this parameter a score improvement of 30% must be made on the 100 point scale (Farrar *et al.,* 2001). Participants within this Group have improved up to 10% as an average. In terms of average Group improvement this change in value from the pre-evaluation to the post-evaluation is not above the MCID for VAS. Clinically significant improvement was not detected for 84% (sixteen out nineteen participants) of these participants, but was detected in the remaining 16% (three out nineteen participants) post-treatment.

Clinical significance for VAS: Manipulation Group

Table 4.31 Table of raw data (pre and post) for VAS in Manipulation Group (n=21)

Participant	Pre (in mm)	Post (in mm)	Difference (in mm)	Percent change
1	20	39	+19	95%increase in pain
2	26	21	5	19%decrease in pain
3	46	14	32	70% decrease in pain
4	47	40	7	15% decrease in pain
5	50	34	16	32% decrease in pain
6	71	10	61	86% decrease in pain
7	65	55	10	15% decrease in pain
8	55	30	25	45% decrease in pain
9	36	28	8	22% decrease in pain
10	20	5	15	75% decrease in pain
11	30	22	8	27% decrease in pain
12	40	56	+16	40%increase in pain
13	25	25	0	0% decrease in pain
14	29	12	17	59% decrease in pain
15	66	56	10	15% decrease in pain
16	55	64	+9	16%increase in pain
17	60	48	12	20% decrease in pain
18	45	45	0	0% decrease in pain
19	64	60	4	6% decrease in pain
20	68	55	13	19% decrease in pain
21	67	70	+3	4%increase in pain
Mean	46.90	37.57		
Highest	71	70		
Lowest	20	5		

Table 4.32 Breakdown of clinically significant improvements made by participants in the Manipulation Group (n=21)

% Improvement	Number of participants
0-9	3
10-19	5
20-29	3
*30-39	1
*40-49	1
*50-59	1
*60 and above	3
Worsening (an increase in score)	4

**indicates clinically significant improvement was made*

The average change in score between pre- and post-visit findings in the Manipulation Group in this Group was 9mm.The highest change in score was 61mm (86% improvement) and the lowest was an increase in score of 19mm (a 95% increase in pain) between the pre- and post-treatment findings. For clinical significance to be achieved for this parameter a score improvement of 30% had to be made on the 100 point scale (Farrar *et al.,* 2001). Participants within this Group have improved up to 20% as an average. This change in value from the pre-evaluation to the post-evaluation is not above the MCID for VAS. Clinically significant improvement was not detected in for 71% (fifteen out twenty one participants) of these participants, but was detected in the remaining 28% (six out twenty one participants).

Summary for VAS

1. EFI Association was analysed above (section 4.4.1.6) and is summarised as follows for the parameter of VAS:

a.) Percentage association: In the Manipulation Group 70% (fourteen out of twenty-one) of the participants experienced an association between EFI and perceived VAS improvement despite no statistical association. Within the control Group 47% (nine out of nineteen) of the participants experienced an association between EFI and perceived VAS improvement despite no statistical association.

b.) Statistical significance: In the Manipulation Group, those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of reduction of VAS (p=0.944) over time and therefore no link between the two can be made. In comparison, overall EFI in the control Group predicted outcome of VAS to some extent but not quite statistically significantly (p=0.063) and the profile plot revealed that those who showed overall EFI showed a larger reduction of VAS over time compared to those who showed no overall EFI within the control Group.

2. Inter-Group analysis

There was no significant Manipulation effect compared with the control over time (p=0.291) but the profile plot reveals a trend which suggests that the rate of change of improvement in the Manipulation Group was greater than that in the control (the slope of the line in the Manipulation Group was steeper than in the control).

3. Clinical significance

Within the Manipulation Group, 28% (six out of twenty-one participants) reached clinical significance and 16% (three out of nineteen participants) reached clinical significance.

4.4.1.7.2 FADI Score: (Subjective)

Inter-Group analysis of FADI

Table 4.33 Repeated measures ANOVA for FADI in both Groups

Effect	Statistic	*p* value
Time	Wilk's lambda=0.767	0.002
Time*Group	Wilk's lambda= 0.984	0.434
Group	F=4.769	0.035

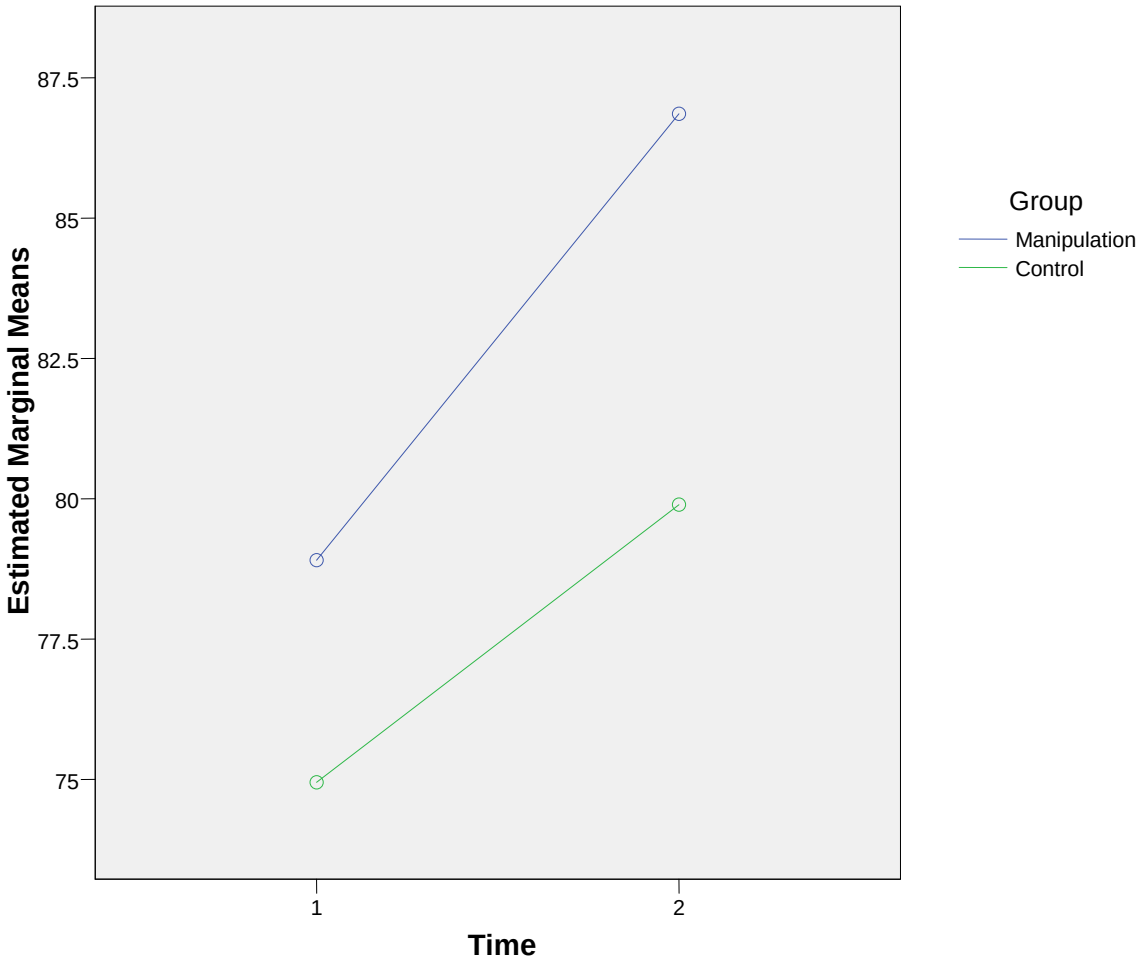


Figure 4.12 Profile plot of FADI score over time in both Groups

There was no noted significant Manipulation effect compared with the control over time (p=0.434). The profile plot shows relatively parallel lines over time in the two Groups.

Clinical significance for FADI: Control Group

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistically significant difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis assessing clinical significance was performed to determine whether substantial differences occurred between the Groups with respect to any subjective/objective clinical measures.

Table 4.34 Table of raw data (pre and post) for FADI in control Group (no Manipulation) (n=19)

Participant	Pre	Post	Difference (in points)	Percent change
1	73	90	17	23%increase in score
2	86	90	4	5% increase in score
3	73	84	11	15% increase in score
4	74	86	12	16% increase in score
5	57	87	30	53% increase in score
6	81	80	-1	1%decrease in score
7	90	83	-7	8%decrease in score
8	87	73	-14	16%decrease in score
9	87	91	4	5% increase in score
10	88	85	-3	3%decrease in score
11	57	60	3	5% increase in score
12	64	77	13	20% increase in score
13	86	77	-9	10%decrease in score
14	80	85	5	6% increase in score
15	74	79	5	7% increase in score
16	81	82	1	1% increase in score
17	59	74	15	25% increase in score
18	66	68	2	3% increase in score
19	61	67	6	10% increase in score
Mean	74.9	79.9		
Highest	90	91		
Lowest	57	67		

Table 4.35 Breakdown of clinically significant improvements made by participants in control Group (no Manipulation) (n=19)

Points improvement	Number of participants
0-7	7
*8-29	6
*30 and above	1
Worsening (a decrease in score)	5

**indicates clinically significant improvement was made*

For this Group it was noted on average, a change of 4.9 points between participants pre- and post-readings. The greatest improvement made in the Group was 30 points (53% improvement) and the lowest improvement was a decrease in 14 points (16% decrease in score) between the pre- and post-readings which is a worsening of the symptoms. According to Eechaute *et al.,* (2007) the MCID of the FADI is an eight point change on the scale. The average of 4.9 points improvement was noted in this Group and therefore the average increase in FADI was not deemed clinically significant. From this Group there were 37% (seven out of nineteen participants) that made a clinically significant change individually, 37% (seven out of nineteen participants) who improved but not statistically significant and 26% (five out of nineteen) who decreased in points and therefore worsened. Eechaute *et al.,* (2007) proceeded to describe the MDC that a participant is able to perceive in the FADI is approximately 4.48 points which is below the Group average and therefore majority of the Group would have detected a change.

Clinical significance for FADI: Manipulation Group

Table 4.36 Table of raw data (pre and post) for FADI in the Manipulation Group (n=21)

Participant	Pre	Post	Difference (in points)	Percent
1	90	93	3	3%increase in score
2	90	90	0	0%increase in score
3	88	89	1	1%increase in score
4	90	97	7	8%increase in score
5	64	86	22	34%increase in score
6	86	79	-7	8%decrease in score
7	90	77	-13	14%decrease in score

8	69	90	21	30%increase in score
9	90	88	-2	2%decrease in score
10	90	89	-1	1%decrease in score
11	55	95	40	73%increase in score
12	80	89	9	11%increase in score
13	89	92	3	3% increase in score
14	90	94	4	4% increase in score
15	74	86	12	16% increase in score
16	64	86	22	34% increase in score
17	75	78	3	4% increase in score
18	79	74	-5	6%decrease in score
19	83	84	1	1% increase in score
20	68	80	12	18% increase in score
21	53	88	35	66% increase in score
Mean	78.9	86.8		
Highest	90	97		
Lowest	53	74		

Table 4.37 Breakdown of clinically significant improvements made by participants in the Manipulation Group (n=21)

Points improvement	Number of participants
0-7	8
*8-29	6
*30 and above	2
Worsening (a decrease in score)	5

**indicates clinically significant improvement was made*

The average change in score for the FADI in this Group was 7.9 points. The greatest change in the Group was 40 points (73% improvement) and the least improvement was a decrease (therefore worsening of the symptoms) of 13 points (14% decrease). It must be noted that for FADI to be deemed clinically significant in this Group, an improvement of eight points must be made (Eechaute *et al.,* 2007). The average change of 7.9 points is therefore not deemed

as clinically significant for this Group as a unit but is very close to it (i.e. has missed the clinical significance benchmark of 8 points by 0.1 points). From this Group, 38% (eight out of twenty one participants) made a clinically significant improvement individually.

Summary for FADI

1. EFI Association was analysed above (section 4.4.1.6) and is summarised as follows for the parameter of FADI:

a.) Percentage association: In the Manipulation Group 70% (fourteen out of twenty-one) of the participants experienced an association between EFI and perceived FADI improvement despite no statistical association. Within the control Group 32% (six out of nineteen) of the participants experienced an association between EFI and perceived FADI improvement despite no statistical association.

b.) Statistical significance: the profile plot shows a slight trend towards the greatest increase in FADI being in the Group which showed an overall EFI in motion palpation.

2. Inter-Group analysis

There was no significant Manipulation effect compared with the control over time (p=0.434). The profile plot shows relatively parallel lines over time in the two Groups.

3. Clinical significance

Within the Manipulation Group, 38% (eight out of twenty-one participants) reached clinical significance and 37% (seven out of nineteen participants) reached clinical significance in the control Group.

4.4.1.7.3 Pressure Algometer: (Objective)

Inter-Group analysis of Pressure Algometer

Table 4.38 Repeated measures ANOVA for Pressure Algometer readings in both Groups

Effect	Statistic	*p* value
Time	Wilk's lambda=0.860	0.018
Time*Group	Wilk's lambda= 0.976	0.340
Group	F=0.444	0.509

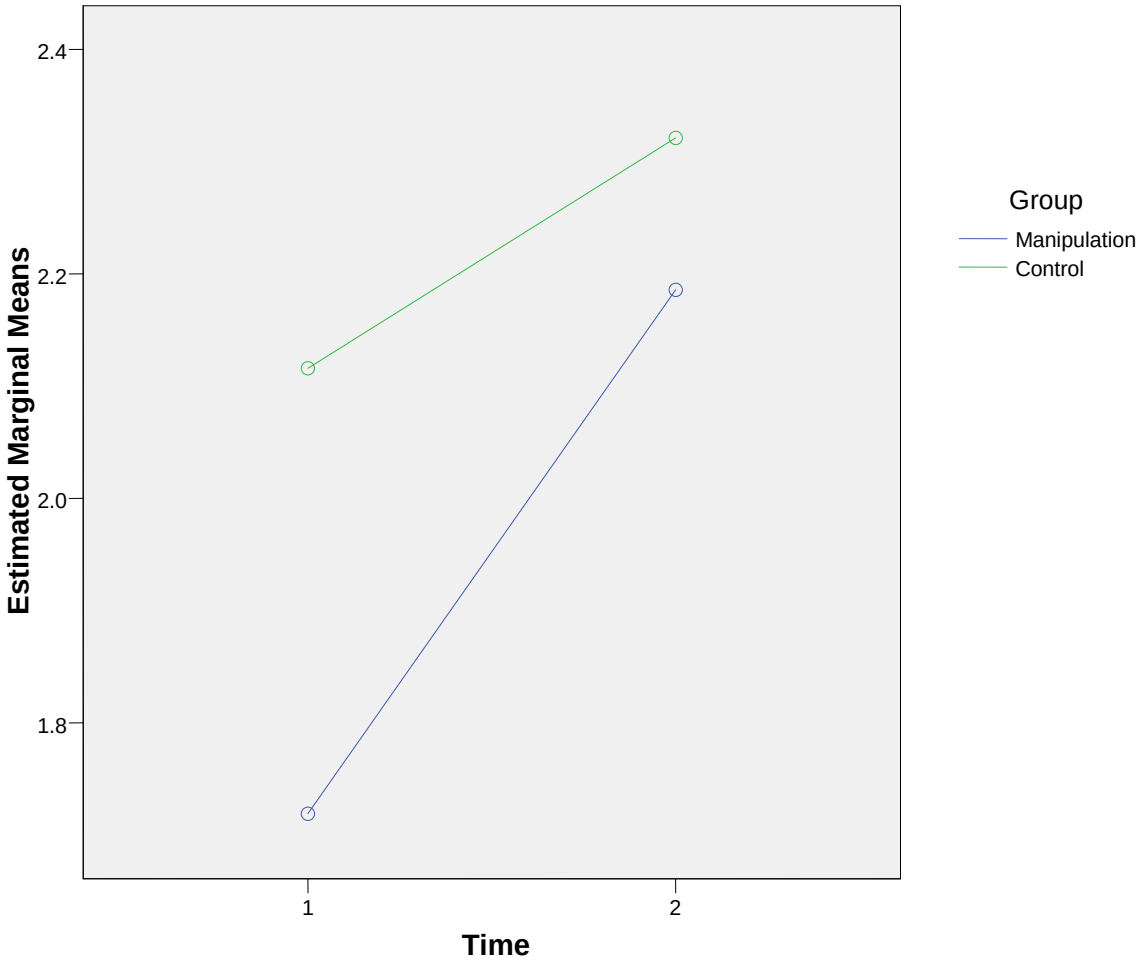


Figure 4.13 Profile plot of Pressure Algometer over time in both Groups

There was no significant Manipulation effect compared with the control over time (p=0.340). The profile plot shows relatively parallel lines over time in the two Groups.

Clinical significance for Pressure Algometer: Control Group

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistical significance difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis assessing clinical significance was performed to determine whether substantial differences occurred between the Groups with respect to any subjective/objective clinical measures.

Table 4.39 Table of raw data (pre and post) for Pressure Algometer in the control Group (no Manipulation) (n=19)

Participant	Pre	Post	Difference (in $kg.cm^{2)}$	Percent change
1	2.2	2.1	-0.1	5%decrease in pain tolerance
2	3.0	2.6	-0.4	13%decrease in pain tolerance
3	2.0	1.9	-0.1	5%decrease in pain tolerance
4	1.9	2.2	0.3	16%increase in pain tolerance
5	1.4	2.7	1.3	93% increase in pain tolerance
6	1.0	1.3	0.3	30% increase in pain tolerance
7	1.3	1.1	-0.2	15%decrease in pain tolerance
8	1.8	2.0	0.2	11% increase in pain tolerance
9	2.0	2.2	0.2	10% increase in pain tolerance
10	2.0	1.8	-0.2	10%decrease in pain tolerance
11	1.1	1.1	0	0% increase in pain tolerance
12	3.3	3.6	0.3	9% increase in pain tolerance
13	0.4	0.4	0	0% increase in pain tolerance
14	0.8	1.0	0.2	25% increase in pain tolerance
15	4.8	4.8	0	0% increase in pain tolerance
16	2.3	2.4	0.1	4% increase in pain tolerance
17	3.9	4.4	0.5	13% increase in pain tolerance
18	1.0	2.2	1.2	120%increase in pain tolerance
19	4.0	4.3	0.3	8%increase in pain tolerance
Mean	2.07	2.32		
Highest	4.8	4.8		
Lowest	0.4	0.4		

Table 4.40 Breakdown of clinically significant improvements made by participants in the control Group (no Manipulation) (n=19)

Improvement in kg.cm^2	Number participants
0.0-0.9	12
1.0-1.6	2
*1.7 and above	-
Worsening (a decrease in score)	5

**indicates clinically significant improvement was made*

The average change in Pressure Algometer score was noted as 0.2kg.cm^2. The greatest improvement change between pre- and post-readings was an increased value of 1.3kg.cm^2 (93% improvement). The lowest improvement that was made was a value of 0.4kg.cm^2 (13% decrease in pain tolerance) lower than the initial reading on visits one, and thus describes a worsening of symptoms in that time. A MCID of 1.77kg.cm^2 is deemed as clinically significant (Chesterton *et al.,* 2007). The Group average was far below the MCID. Therefore, a clinically significant improvement was not noted in this Group. No participants (zero out of nineteen participants) in this study made an improvement of more than 1.77kg.cm^2, indicating that none of the participants made a clinically significant improvement.

Clinical significance for Pressure Algometer: Manipulation Group

Table 4.41 Table of raw data (pre and post) for Pressure Algometer in the Manipulation Group (n=21)

Participant	Pre	Post	Difference (in kg.cm$^{2)}$	Percent change
1	1.0	1.0	0	0%increase in pain tolerance
2	1.0	0.9	-0.1	10%decrease in pain tolerance
3	5.0	6.0	1	20% increase in pain tolerance
4	1.8	1.8	0	0% increase in pain tolerance
5	1.2	2.1	0.9	75% increase in pain tolerance
6	0.1	2.2	2.1	2100% increase in pain tolerance
7	3.5	3.7	0.2	6% increase in pain tolerance
8	0.8	0.9	0.1	13% increase in pain tolerance
9	1.8	2.9	1.1	61% increase in pain tolerance

10	1.6	5.6	4.0	250% increase in pain tolerance
11	1.0	0.1	-0.9	90%decrease in pain tolerance
12	2.3	2.0	-0.3	13%decrease in pain tolerance
13	0.6	0.1	-0.5	83%decrease in pain tolerance
14	1.0	1.0	0	0% increase in pain tolerance
15	1.2	1.1	-0.1	83%decrease in pain tolerance
16	1.5	3.2	1.7	113% increase in pain tolerance
17	1.5	1.8	0.3	20% increase in pain tolerance
18	1.3	1.3	0	0% increase in pain tolerance
19	1.3	1.6	0.3	23% increase in pain tolerance
20	4.0	4.8	0.8	20% increase in pain tolerance
21	2.6	1.8	-0.8	31%decrease in pain tolerance
Mean	1.72	2.18		
Highest	5.0	6.0		
Lowest	0.1	0.1		

Table 4.42 Breakdown of clinically significant improvements made by participants in the Manipulation Group (n=21)

Improvement in $kg.cm^2$	Number of participants
0.0-0.9	10
1.0-1.6	2
*1.7 and above	3
Worsening (a decrease in score)	6

**indicates clinically significant improvement was made*

The average improvement made by the Manipulation Group was $0.46kg.cm^{2.}$ The greatest improvement noted in this Group between pre- and post-readings was $4.0kg.cm^2$ (250% improvement) and the lowest improvement that was made was a value of $0.9kg.cm^2$ (90% decrease) lower than the initial reading on visit one and thus describes a worsening of symptoms in that time. According to Chesterton *et al.*, (2007) a MCID of $1.77kg.cm^2$ is deemed as clinically significant. The Group average was far below the MCID and therefore,

a clinically significant improvement was not noted in this Group either. However, clinically significant improvement was noted in 14.3% (three out of twenty one of the participants) who made a greater than 1.77kg.cm^2 improvement.

Summary of Pressure Algometer

1. EFI Association was analysed above (section 4.4.1.6) and is summarised as follows for the parameter of Pressure Algometer:

a.) Percentage association: In the Manipulation Group 48% (ten out of twenty-one) of the participants experienced an association between EFI and perceived Pressure Algometer score improvement despite no statistical association. Within the control Group 47% (nine out of nineteen) of the participants experienced an association between EFI and perceived Pressure Algometer score improvement despite no statistical association.

b.) Statistical significance: There was no noted relationship between the overall EFI in motion palpation results and readings from the Pressure Algometer over time in the manipulated Group.

2. Inter-Group analysis

There was no significant Manipulation effect compared with the control over time (p=0.340). The profile plot shows relatively parallel lines over time in the two Groups which indicates no change between the Groups was evident.

3. Clinical significance

Within the Manipulation Group, 14.3% (three out of twenty-one participants) reached clinical significance and 0% (zero out of nineteen participants) reached clinical significance.

4.4.1.7.4 Berg Balance Scale: (Subjective)

Inter-Group analysis of BBS

Table 4.43 Repeated measures ANOVA for Berg Balance Scale in both Groups

Effect	Statistic	*p* value
Time	Wilk's lambda= 0.891	0.038
Time*Group	Wilk's lambda= 0.910	0.060
Group	F=1.031	0.316

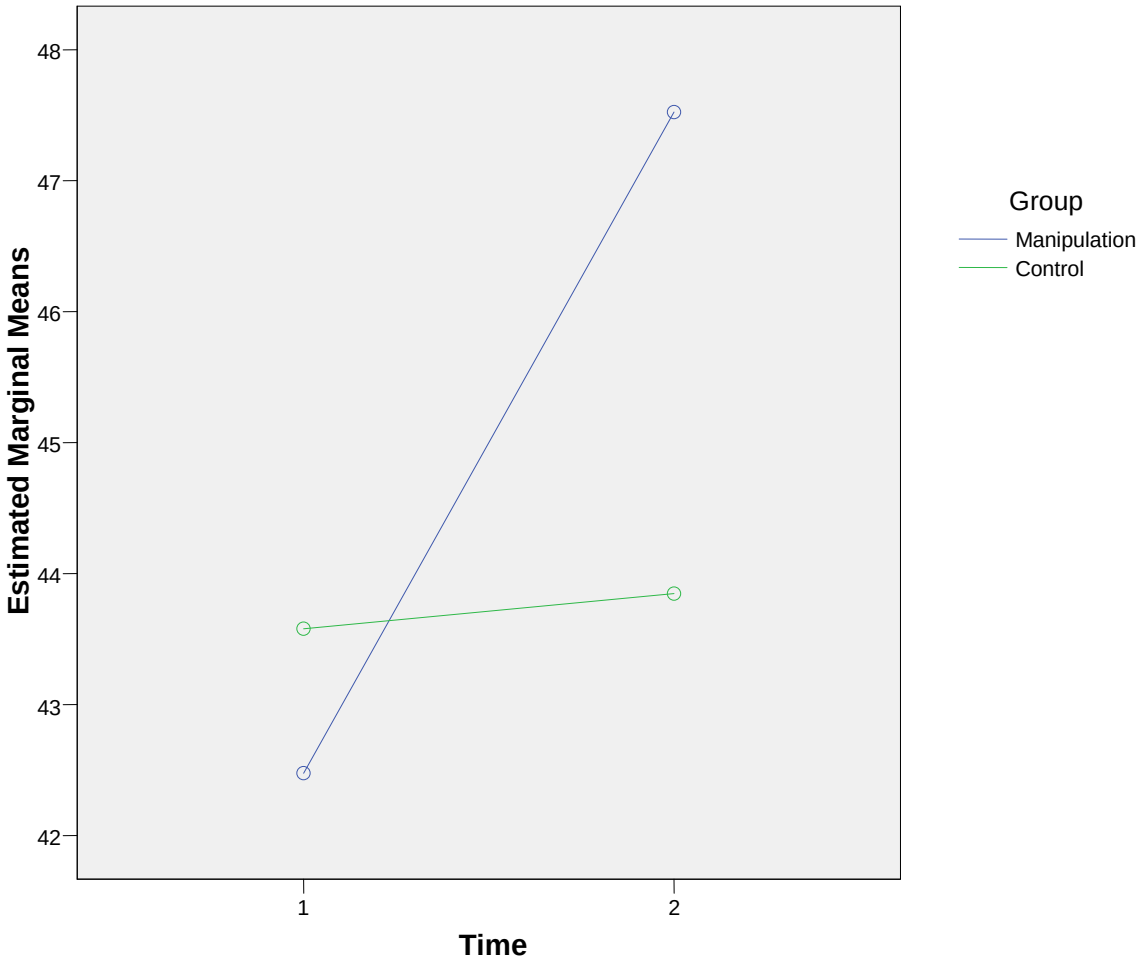


Figure 4.14 Profile plot of Berg Balance Scale over time in both Groups

There was a marginally non significant Manipulation effect (p=0.060) and the profile plot shows that the Manipulation had a clinically significant effect on this outcome as the two profiles intersect. In the control Group the increase was very small while the manipulated Group showed a vast improvement. Perhaps the power of the study was slightly too low to show this effect as statistically significant.

Clinical significance for BBS: Control Group

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistically significant difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis

assessing clinical significance was performed to determine whether substantial differences occurred between the Groups with respect to any subjective/objective clinical measures.

Table 4.44 Table of raw data (pre and post) for the Berg Balance Scale in the control Group (no Manipulation) (n=19)

Participant	Pre	Post	Difference (in points)	Percent change
1	43	49	6	14%increase in score
2	43	43	0	0% increase in score
3	45	50	5	11% increase in score
4	54	50	-4	7%decrease in score
5	45	45	0	0% increase in score
6	43	43	0	0% increase in score
7	54	12	-42	78%decrease in score
8	45	49	4	9% increase in score
9	45	44	-1	2%decrease in score
10	45	46	1	2% increase in score
11	40	41	1	3% increase in score
12	39	48	9	23% increase in score
13	44	50	6	14% increase in score
14	45	52	7	16% increase in score
15	38	37	-1	3%decrease in score
16	40	44	4	10% increase in score
17	36	38	2	6% increase in score
18	48	50	2	4% increase in score
19	36	42	6	17% increase in score
Mean	43.5	43.8		
Highest	54	52		
Lowest	36	12		

Table 4.45 Breakdown of clinically significant improvements made by participants in the control Group (no Manipulation) (n=19)

Point Improvement	Number of participants
Participants in 35-44 category below 4.9	5
*Participants in 35-44 category above 4.9	4
Participants in 45-56 category below 3.3	3
*Participants in 45-56 category above 3.3	3
Participants in both categories who decreased in score (worsened)	4

**indicates clinically significant improvement was made*

Participants had an average improvement of 0.6 points between the pre- and post-readings in this Group. The greatest improvement that was noted was a change by 9 points (23% improvement) and the lowest improvement was a decrease, and therefore a worsening of symptoms, of 42 points (78% decrease). The accepted MDC for this scale is 3.3 points for participants that fall into the 45-56 category and 4.9 points in the 35-44 point categories (Donoghue and Stokes, 2009). The MCID is yet to be established at this point for this outcome measure (Donoghue and Stokes, 2009). It is important to note that if the amount of improvement in points of individual participants are analysed in this Group, it can be observed that 44.4% (four out of nine participants) participants started at a value between 35 and 44 and reached clinical significance of a change by 4.9 points at the post-treatment evaluation. In participants who scored between 45 and 56 points at the pre-treatment evaluation 50% (three out of six) met the clinically significant change of 3.3 points. A decrease in some participants was noted, which indicates a worsening of the symptoms, occurred in 21% of the participants (four out of nineteen participants).

Clinical significance for BBS: Manipulation Group

Table 4.46 Table of raw data (pre and post) for the Berg Balance Scale in the Manipulation Group (n=21)

Participant	Pre	Post	Difference (in points)	Percent change
1	45	46	1	2%increase in score
2	44	47	3	7% increase in score
3	44	48	4	9% increase in score
4	45	46	1	2% increase in score

5	37	39	2	5% increase in score
6	44	49	5	11% increase in score
7	43	47	4	9% increase in score
8	35	49	14	40% increase in score
9	45	52	7	16% increase in score
10	43	48	5	12% increase in score
11	40	47	7	18% increase in score
12	44	50	6	14% increase in score
13	44	51	7	16% increase in score
14	44	50	6	14% increase in score
15	43	52	9	21% increase in score
16	38	39	1	3% increase in score
17	43	47	4	95 increase in score
18	44	43	-1	25%decrease in score
19	47	54	7	15% increase in score
37	35	44	9	26% increase in score
40	45	50	5	11% increase in score
Mean	42.5	47.5		
Highest	47	54		
Lowest	37	39		

Table 4.47 Breakdown of clinically significant improvements made by participants in the Manipulation Group (n=21)

Point Improvement	Number of participants
Participants in 35-44 category below 4.9	6
*Participants in 35-44 category above 4.9	9
Participants in 45-56 category below 3.3	2
*Participants in 45-56 category above 3.3	3
Participants in both categories who decreased in score (worsened)	1

**indicates clinically significant improvement was made*

Participants had an average improvement of 5.3 points between the pre- and post-readings in this Group. The highest amount of change that was noted was an improvement by 14

points (40% improvement) and the lowest was a decrease, and therefore a worsening of symptoms, of 1 point (25% decrease). The accepted MDC for this scale is 3.3 points for participants that fall into the 45-56 category and 4.9 points in the 35-44 point categories (Donoghue and Stokes, 2009). The MCID is yet to be established at this point for this outcome measure (Donoghue and Stokes, 2009). It is important to note that if the amount of improvement in points of individual participants are analysed in this Group, it can be observed that 60% (nine out of fifteen participants) participants started at a value between 35 and 44 and reached clinical significance of a change by 4.9 points at the post-treatment evaluation. In participants who scored between 45 and 56 points at the pre-treatment evaluation 60% (three out of five) met the clinically significant change of 3.3 points. A decrease in one participant was noted, which indicates a worsening of the symptoms, this occurred in 4.8% of the participants (one out of twenty one participants).

Summary for BBS

1. EFI Association was analysed above (section 4.4.1.6) and is summarised as follows for the parameter of BBS:

a.) Percentage association: In the Manipulation Group 90% (nineteen out of twenty-one) of the participants experienced an association between EFI and perceived BBS improvement despite no statistical association. Within the control Group 32% (six out of nineteen) of the participants experienced an association between EFI and perceived BBS improvement despite no statistical association.

b.) Statistical significance: There was no statistical association between the overall EFI in motion palpation readings and the Berg Balance Scale score over time in the Group who were manipulated. However, the profile plot shows a slight trend that those who showed overall EFI in motion palpation readings also increased in Berg Balance score to a greater extent over time than those who did not show an improvement in motion palpation in the Group who were manipulated. The statistical power was too low to detect this trend as statistically significant.

2. Inter-Group analysis

There was a marginally non significant Manipulation effect (p=0.060) and the profile plot shows that the Manipulation had a clinically significant effect on this outcome as the two profiles intersect. In the control Group the increase was very small while the manipulated

Group showed a vast improvement. Perhaps the power of the study was slightly too low to show this effect as statistically significant.

3. Clinical significance

Within the Manipulation Group, 60% (nine of out fifteen participants) of those participants in the 35 to 44 point category reached clinical significance and 60% (three out of five participants) of participants in the 45 to 56 point category reached clinical significance. In the control Group, 44.4%(four out of nine participants) of those participants in the 35 to 44 point category reached clinical significance and 50% (three out of six participants) of participants in the 45 to 56 point category reached clinical significance.

4.4.1.7.5 Weight bearing dorsiflexion: (Objective)

Inter-Group analysis of WBD

Table 4.48 Repeated measures ANOVA for Weight Bearing Dorsiflexion in both Groups

Effect	Statistic	*p* value
Time	Wilk's lambda=0.945	0.145
Time*Group	Wilk's lambda= 0.970	0.284
Group	F=0.768	0.386

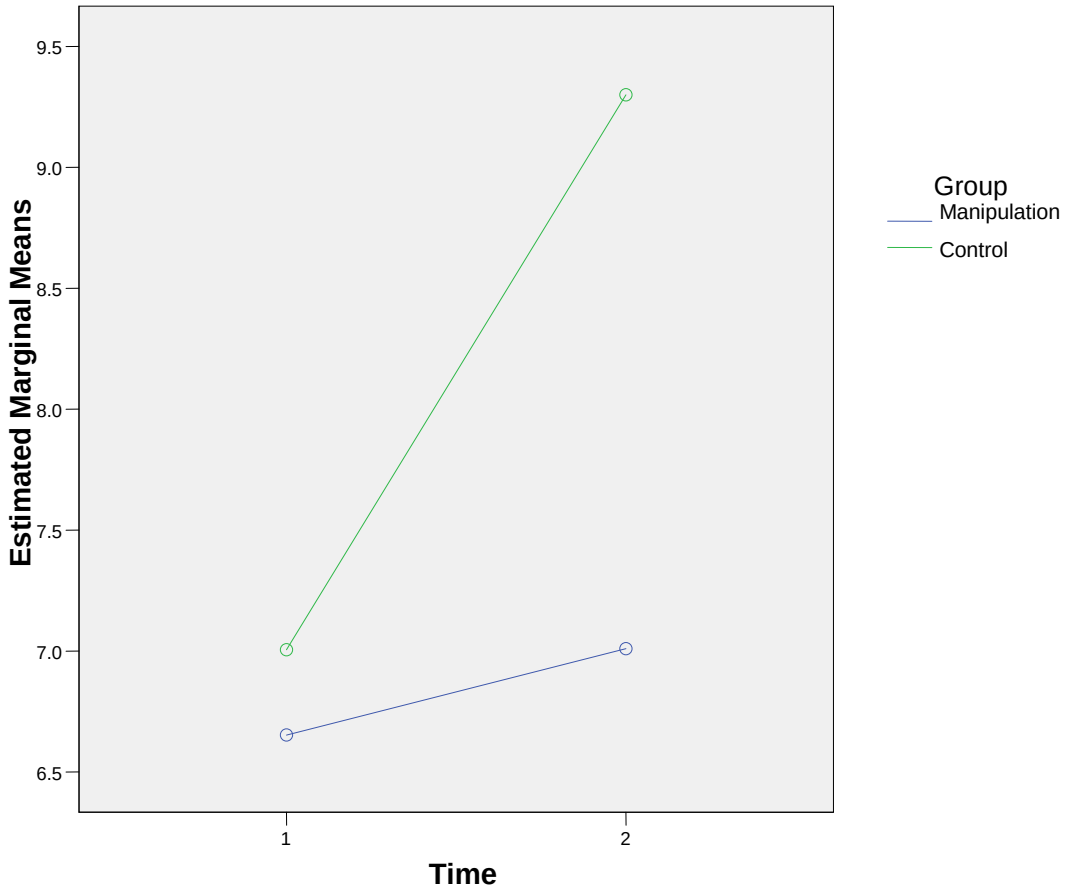


Figure 4.15 Profile plot of Weight Bearing Dorsiflexion over time in both Groups

There was no significant Manipulation effect compared with the control over time (p=0.284) but the profile plot reveals a trend which suggests that the rate of improvement in the control Group was greater than that in the Manipulation Group (the slope of the line in the control Group was steeper than the Manipulation Group).

Clinical significance for WBD: Control Group

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistically significant difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis assessing clinical significance was performed to determine whether substantial differences occurred between the Groups with respect to any subjective/objective clinical measures.

Table 4.49 Table of raw data (pre and post) for the Weight Bearing Dorsiflexion test in the control Group (no Manipulation) (n=19)

Participant	Pre	Post	Difference (in cm)	Percent change
1	9.6	10.3	0.7	7%increase in dorsiflexion
2	7.6	7.7	0.1	1% increase in dorsiflexion
3	3.5	9	5.5	157% increase in dorsiflexion
4	5.6	5.3	-0.3	5%decrease in dorsiflexion
5	5.9	5.3	-0.6	10%decrease in dorsiflexion
6	11.3	12	0.7	6% increase in dorsiflexion
7	12.4	47	34.6	279% increase in dorsiflexion
8	6.4	6.6	0.2	3% increase in dorsiflexion
9	6.2	7.1	0.9	4%increase in dorsiflexion
10	8.4	8.1	-0.3	19%decrease in dorsiflexion
11	1.6	1.3	-0.3	19% decrease in dorsiflexion
12	4.8	4.9	0.1	2% increase in dorsiflexion
13	4.8	4.8	0	0% increase in dorsiflexion
14	7.8	8.8	1.0	13% increase in dorsiflexion
15	2.7	2.8	0.1	1%increase in dorsiflexion
16	7.8	7.6	-0.2	2% decrease in dorsiflexion
17	9.8	10.1	0.3	3% increase in dorsiflexion
18	9.9	11.1	0.2	1%increase in dorsiflexion
19	7.0	6.9	-0.1	1% increase in dorsiflexion
Mean	7.0	10.7		
Highest	12.4	47		
Lowest	1.6	1.3		

Table 4.50 Breakdown of clinically significant improvements made by participants in control Group (no Manipulation) (n=19)

Centimetre improvement	Number of participants
0-0.9	10
*1.0-1.9	1
*2.0-2.9	-
*3.0 and above	2
Worsening (a decrease in score)	6

**indicates clinically significant improvement was made*

It must be noted that this Group made an average of 2.2cm improvement between the pre- and post-treatment readings. The largest improvement that was made was 34.6cm (279% improvement) and the smallest improvement was a decrease in 0.6cm (10% decrease in functionality) which indicates worsening of the symptoms. An increase of about 0.4-0.5cm ankle dorsiflexion appears significant, while a 1cm increase is generally considered clinically important (Green *et al.,* 2001 and Vicenzino *et al.,* 2006). Within this Group, 16% (three out of nineteen participants) made clinically significant improvements on the post-treatment evaluation, 52.6% (ten out of nineteen participants) improved but not to a clinically significant level and 31.5% (six out of nineteen participants) showed a decrease in centimetres and therefore got worse.

Clinical significance for WBD: Manipulation Group

Table 4.51 Table of raw data (pre and post) for the Weight Bearing Dorsiflexion test in the Manipulation Group (n=21)

Participant	Pre	Post	Difference (in cm)	Percent change
1	3.6	2.7	-0.9	25%decrease in dorsiflexion
2	5.4	5.8	0.4	7%increase in dorsiflexion
3	5.0	5.6	0.6	12% increase in dorsiflexion
4	6.5	8.6	2.1	32% increase in dorsiflexion
5	4.6	10.8	6.2	135% increase in dorsiflexion
6	5.8	5.7	-0.1	2%decrease in dorsiflexion
7	8.5	8.9	0.4	55% increase in dorsiflexion

8	2.2	3.5	1.3	59% increase in dorsiflexion
9	5.1	6.4	1.3	25% increase in dorsiflexion
10	5.5	1.4	-4.1	75%decrease in dorsiflexion
11	5.4	5.5	0.1	2% increase in dorsiflexion
12	15.5	15.5	0	0% increase in dorsiflexion
13	2.7	2.0	-0.7	26%decrease in dorsiflexion
14	11.1	10.7	-0.4	4%decrease in dorsiflexion
15	5.0	7.5	2.5	50% increase in dorsiflexion
16	5.1	5.6	0.5	10% increase in dorsiflexion
17	1.3	1.5	0.2	15% increase in dorsiflexion
18	8.9	8.9	0	0% increase in dorsiflexion
19	12.4	12.6	0.2	2% increase in dorsiflexion
20	8.0	8.1	0.1	1% increase in dorsiflexion
21	12.1	9.9	-2.2	18%decrease in dorsiflexion
Mean	6.6	7.0		
Highest	15.5	15.4		
Lowest	1.3	1.4		

Table 4.52 Breakdown of clinically significant improvements made by participants in the Manipulation Group (n=21)

Centimetre improvement	Number of participants
0-0.9	10
*1.0-1.9	2
*2.0-2.9	2
*3.0 and above	1
Worsening/ below 0.0	6

**indicates clinically significant improvement was made*

It must be noted that this Group made an average of 0.35cm improvement between the pre- and post-treatment readings. The largest improvement that was made was 6.2cm (135% improvement) and the smallest improvement was a decrease in 4.1cm (75% decrease) which indicates worsening of the symptoms. An increase of about 0.4-0.5cm ankle

dorsiflexion appears significant, while a 1cm increase is generally considered clinically important (Green *et al.,* 2001 and Vicenzino *et al.,* 2006). Clinically significant improvement was therefore not noted in this Group (improvement of 0.035cm as an average as mentioned above). Within this Group, 24% (five out of twenty one participants) made clinically significant improvements on the post-treatment evaluation and 28.6% (six out of twenty one participants) showed a decrease in centimetres and therefore got worse.

Summary for WBD

1. EFI Association was analysed above (section 4.4.1.6) and is summarised as follws for the parameter of WBD:

a.) Percentage association: In the Manipulation Group 57% (twelve out of twenty-one participants) of the participants experienced an association between EFI and perceived WBD improvement despite no statistical association. Within the control Group 37% (seven out of nineteen) of the participants experienced an association between EFI and perceived WBD improvement despite no statistical association.

b.) Statistical significance: In the manipulated Group there was no association between the overall EFI in motion palpation readings and WBD over time (p=0.966). In the control Group, there was no effect of the overall EFI in motion palpation readings on WBD over time (p=0.747). Therefore no link was found to correlate WBD improvement in participants who showed overall EFI.

2. Inter-Group analysis

No significant Manipulation effect was found when compared with the control over time (p=0.284) but the profile plot reveals a trend which suggests that the rate of improvement in the control Group was greater than that in the Manipulation Group (the slope of the line in the control Group was steeper than the Manipulation Group).

3. Clinical significance

Within the Manipulation Group, 24% (five out of twenty-one participants) reached clinical significance and 16% (three out of nineteen participants) reached clinical significance.

4.5 Summary

A general overview of all the subjective/objective clinical measures revealed that although some differences were found in terms of clinical significance between the two Groups (marginal with respect to FADI and greater with respect to VAS, Pressure Algometer, BBS and WBD), no statistically significant differences were observed when inter-Group analysis was performed. This is in keeping with the results observed when motion palpation association was analysed, where some degree of association was observed when percentages were calculated, however, no statistical significant association was observed when Fishers exact tables were calculated i.e. no association between EFI and improvement in the subjective/objective clinical measures in the Manipulation Group and between no EFI and a lack of improvement in subjective/objective clinical measures in the control Group. Therefore, this lack of association is actually in keeping and supportive of the previous results where no Manipulation effect was noted in this study. Hence, motion palpation was indirectly effective as all the outcomes were in keeping with one another and the results matched.

Table 4.53 Summary of motion palpation results

	Etiologic fraction	Sensitivity	Specificity	Association of EFI and Manipulation
First fixation	0.95	95%	95%	*p<0.001*
Second fixation	0.94	85%	95%	*p<0.001*
Third fixation	0.77	76%	87%	*p<0.001*
Overall EFI	0.95	90%	95%	*p<0.001*

Table 4.54 Summary of all subjective/objective clinical measures

	Association of EFI and Manipulation	Profile plot suggesting trend in favour of Manipulation (Manipulation Group)	Association of EFI and control	Profile plot suggesting trend in favour of Manipulation (Control Group)	Inter-analysis for both Groups	Trend (improvement in the manipulated participants)	Clinical significance in the Manipulation Group		Clinical significance in the control Group	
VAS	No	No	No	Yes	No	Yes	28%		16%	
FADI	No	Yes	No	Yes	No	No	38%		37%	
Pressure Algometer	No	No	No	No	No	No	14.3%		0%	
BBS	No	Yes	No	No	No	Yes	60%	60 %	44.4 %	50%
WBD	No	N	No	Yes	No	No	24%		16%	

4.6 Common fixations

Table 4.55 Table of most common fixations within each joint region

Joint (total number of fixations)	Frequency	Percent
Tarsal's	47	39.17
Subtalar	42	35.00
Mortise	31	25.83
Total	120	100.00

Table 4.56 Table of most common fixations within each movement

Movement	Joint	Frequency	Percent
LAD	49		40.83%
	-Mortise LAD	25	20.8%
	-Subtalar LAD	24	20.0%
Eversion	17		14.17%
	-Subtalar eversion	17	14.2%
Abduction	17		14.17%
	-Navicular abduction	8	6.7%
	-Cuboid abduction	7	5.8%
	-2nd cuneiform abduction	1	0.8%
	-3rd cuneiform abduction	1	0.8%
P-D	17		14.17%
	-Cuboid P-D	6	5.0%
	-Navicular P-D	5	4.2%
	-1st cuneiform P-D	3	2.5%
	-2nd cuneiform P-D	2	1.7%
	-3rd cuneiform P-D	1	0.8%
D-P	6		5.0%
	-Cuboid D-P	3	2.5%
	-Navicular D-P	2	1.7%
	-1st cuneiform D-P	1	0.8%
Shear	6		5.0%
	-Cuboid/3rd cuneiform shear	2	1.7%
	-Navicular/1st cuneiform shear	2	1.7%
	-Navicualr/1st cuneiform shear	1	0.8%
	-Navicular/3rd cuneiform shear	1	0.8%
DF	6		5.0%
	-Mortise D-F	6	5.0%
Adduction	1		0.83%
	-Cuboid adduction	1	0.8%

Inversion	1		0.83%
	-Subtalar Inversion	1	0.8%
Total		120	100.0%

The data was evaluated to assist in identifying the most common fixations in symptomatic participants with CAI. The 120 fixations are shown in the table above (Table 4.55 and 4.560 ranked in order of frequency. The most common fixations were Mortise Long Axis distraction (LAD) and Subtalar LAD.

For the first fixation identified, only three types were found: mortise LAD, subtalar LAD and subtalar eversion. The pre-treatment parameter measurements were compared between the three types of fixations and no differences were found between them in terms of these pre-treatment measurements. Therefore, this indicates that not one specific joint was identified as the most common joint fixation found in participants with CAI, but rather three were found to be common; mortise LAD, subtalar LAD and subtalar eversion.

4.7 Conclusion

As it can be seen by the results displayed in Chapter Four, subjective and objective changes were demonstrated in both the control and the Manipulation Groups. Baseline readings and demographics of both Groups were shown to provide a clearer outlook of the sample population and their characteristics. All subjective and objective measures were represented (in both Groups) and motion palpation was analyzed in terms of responsiveness. Statistically and clinically significant subjective/objective clinical measures were presented and will be discussed in further detail in Chapter Five.

CHAPTER 5

DISSCUSSION

5.1 Introduction

This Chapter will explain and discuss the results in greater detail and comparisons will be made with current literature. The discussion is based on:

1. Demographic data collected at the outset of the study.

2. Motion palpation data:

- Etiologic fraction/responsiveness,
- Sensitivity and
- Specificity.

3. Association between motion palpation results and subjective/objective clinical measures, inter-Group analysis and clinical significance data:

3.1 Subjective clinical measures

- Visual Analogue Scale and
- Foot Ankle Disability Index.

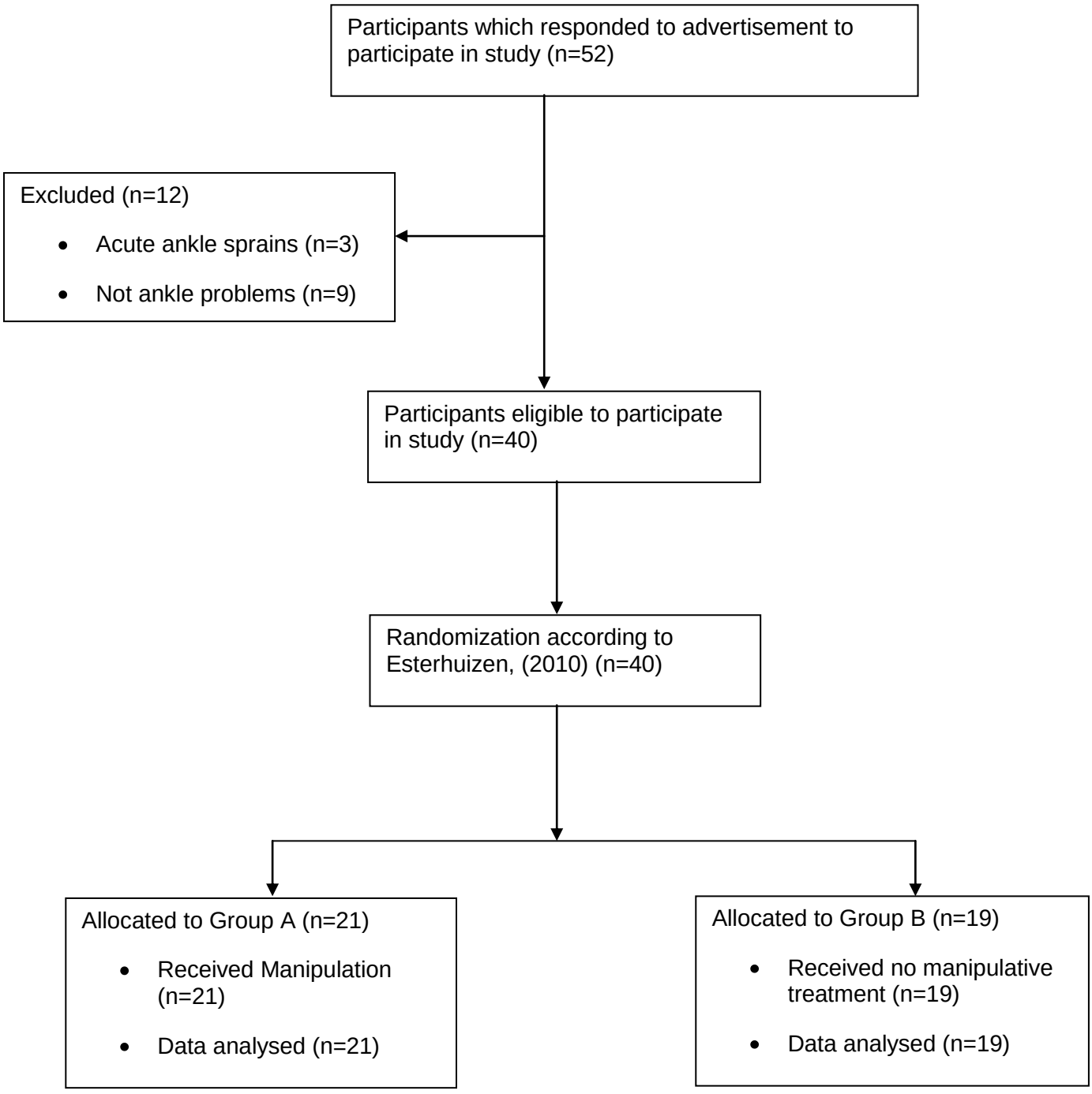
3.2 Objective clinical measures

- Pressure Algometer readings,
- Berg Balance Scale and
- Weight Bearing Dorsiflexion test.

4. Common fixations found within the treatment and control Groups.

All pre and post data was collected at the first visit (i.e. before and after the consultation), with the exception of the post FADI reading. These FADI readings were completed two days after the initial consultation and were conducted via a telephonic interview with the patient.

5.2 Flow diagram (Adapted from Schulz *et al.,* (2010))



From the above-mentioned diagram it is evident that nine of the participants were not included into the study due to their condition not being related to the ankle and three were patients that presented with acute ankle sprains which had to be ruled out from the outset.

There were no dropouts in the study after the initial intake as this was a once off assessment study and all forty participants that began in the study completed the study.

5.3 Demographic data discussion

There were no statistical differences noted between Groups with respect to demographic data. In terms of age as a demographic variable, the mean age of the Manipulation Group was 24 years and 24.89 years in the control Group. The range of ages was 20-38 years for the entire study population with the range of ages between 20 and 38 for the Manipulation Group and 20 and 36 for the control Group. This is in keeping with Pellow and Brantingham, (2001) and Brantingham *et al.,* (2009) who reported similar age ranges within their studies.

In the total population Group there were nineteen females (n=19) which equates to 47.5% and twenty-one males (n=21) which accounts for 52.5%. Garrick (1977) reported that there was no gender predisposition for experiencing an ankle sprain. Beynnon *et al*., (2002) also found that gender does not appear to be a risk factor for suffering an ankle sprain. This, therefore, has no statistical significance and is consistent with previous studies conducted by Pellow and Brantingham (2001) and Lindsay-Renton (2010).

No statistical differences were noted in the ethnicity distribution between the Groups, with 67% of the study being White (n=27), 12.5% being Indian (n=5) another 12.5% were Black (n=5) and 7.5% of the population were Coloured (n=3). Although no statistically significant findings were noted with regard to ethnic distribution it is evident that the white ethnicity represented a larger percentage of the study population. This could be as a result of the recruitment method used and the fact that the DUT is in the Musgrave area which is predominantly White area.

With respect to the mechanism of injury, the most common cause of CAI was because of sport related incidents which comprised 65% (twenty-six out of the forty participants) however, 35% (fourteen out of the forty participants) were non sport related (i.e. as a result of trauma due to a fall). According to Karlsson, Rolf and Orava, (2003) the different profiles of sporting activities within a population, leads to a varying incidence of ankle ligament injuries. Running and jumping sports e.g.: soccer, basketball and volleyball, are high risk activities for ankle ligament injuries (Karlsson, Rolf and Orava, 2003).

With respect to the sport associated injuries within this study: twelve related to soccer (30% of the entire population), six related to rugby (15% of the total population), four as a result of ballet induced injuries (10% of the total population), and two due to netball (5% of the total population) and two related to hockey (5% of the total population). Statistical data on the above mentioned sports causing ankle injury is in keeping with various other studies on sports injuries (Mack, 1982; Thaker *et al.,* 1999; Kohne *et al.,* 2007; Oztekin, 2008 and Walls *et al.,* 2010), where CAI is most commonly noted in and among sports people and as a result, the greater number of patients cause of CAI would be related to sport incidents.

Chronicity also plays in role in CAI and in this study, 72.5% of participants have had ankle sprains for longer than one year with the greatest being a fifteen year history of ankle sprains. The average duration of ankle sprains within the control Group was 46.6 months and 41 months in the Manipulation Group. However, there were no statistical differences noted between the two Groups in terms of chronicity.

Furthermore, there were no statistical differences between the two Groups, in terms of demographic data at the outset of the study. This indicates that both Groups were similar at the outset and no biases and statistical adjustments could be proposed. This indicates that all the criteria were met in ensuring that homogeneity was evident in both Groups.

5.4 Results discussed with respect to the three objectives in the study

5.4.1 Motion palpation (etiologic fraction, sensitivity and specificity)

The first objective was to determine the validity of motion palpation as a post-treatment assessment tool i.e. its ability to detect change in end-feel in the ankle region.

The results revealed the following: Overall EFI was defined as having at least two of the three fixations improve between the pre and post readings. Table 4.7 demonstrated that twenty participants in total, showed overall EFI, of which nineteen were from the manipulated Group. There was no overall EFI noted in twenty of the participants (EFI did not occur in two or more fixations in these twenty participants), and eighteen of these were from the control Group.

Therefore, the etiologic fraction/responsiveness was calculated as 0.95 (Table 4.7). This signifies that in 95% of the participants that were manipulated in this study, a highly detectable EFI was noted with respect to the end-feel quality of the fixations i.e. in 95% of the participants, the EFI was attributable to the Manipulation. The study results, therefore, revealed that there was a highly significant association between being manipulated and EFI (p<0.001). The sensitivity was 90%, meaning that when using motion palpation as a post-treatment assessment tool, 90% of those who were documented to have EFI were manipulated. The specificity was also 95% meaning that when using motion palpation as a post-treatment assessment tool, 95% of those who were documented not to show EFI were not manipulated.

Therefore, this demonstrated that when using motion palpation as a post-treatment assessment tool, a high level of responsiveness was found within the study. This showed it was highly sensitive.

The theory that has been proposed to account for this change in the end-feel of fixations in the Manipulation Group is as reported by Gatterman (1990) and Bergmann, Petersen and Lawrence (1993): These theories state that if a fixation is present in the body, and in this case the foot, that joint alignment and biomechanics is not optimal. When the Manipulation is applied, the joint is taken to its end-feel (Redwood and Cleveland, 2003) and the cavitation is heard. This aids to improve the motion and end-feel in that joint that has been manipulated (Lakhani *et al.,* 2009) and restore normal motion (Haldeman, 1992). Removal of the fixation through this process of Manipulation will allow that joint alignment to be restored and an improvement in the quality of end-feel to be noted. When a Manipulation is performed on the foot or ankle, adhesions and the neural scar is removed and the neuromuscular firing of the nerves is restored. Wyke receptors are also stimulated to cause a reflex change in muscle spasm and in doing so correct alignment, increase joint play and improve end-feel (Sandoz, 1978 and Wyke, 1981).

It was suggested, as previously discussed in chapter two, that it should be possible to detect these changes within the joint via motion palpation of the joint (Ames, 1987; Haldeman, 1992). Within this study, 95% of those participants who were manipulated were identified by the blinded motion palpator. This indicates that motion palpation not only recognise fixations but can detect EFI within the quality of the fixation and distinguish between a joint that has been manipulated from one that has not in 95% of the cases. Therefore, the findings of this study are in keeping with studies by Haas *et al.,* (1995) and Lakhani *et al.,* (2009) in the thoracic and cervical spine respectively, where motion palpation

was also found to be a valid post-treatment assessment tool with the ability to detect responsiveness within a joint.

With respect to objective one, the results of this study reveal that motion palpation appears to be a valid post-treatment assessment tool to detect change in end-feel in the ankle region.

5.4.2 Motion palpation association with respect to subjective/objective clinical measures

The second objective in this study was to establish whether associations exist between motion palpation and the other clinical measures. If an association was found to exist between motion palpation and the clinical signs and symptoms of CAI, this could be used in conjunction with subjective/objective clinical measures to monitor the patient's progress in the clinical sphere.

In this section, three factors were assessed i.e. association data, inter-Group analysis data and clinical significance data. The study results will be discussed below as a summary first and, thereafter, more specifically one parameter at a time.

Association in this section refers to: EFI noted on motion palpation, with improvement in the parameter being analysed e.g. VAS, FADI, Pressure Algometer, BBS and WBD and no EFI noted on motion palpation, with a lack of improvement in the parameter being analysed.

5.4.2.1 Summary of all subjective/objective clinical measures

1. EFI Association

a.) Percentage association:

VAS: In the Manipulation Group 70% (fourteen out of twenty-one) of the participants experienced a association between EFI and VAS improvement, and in the control Group 47% (nine out of nineteen) of the participants experienced a association between no EFI and no VAS improvement.

FADI: In the Manipulation Group 70% (fourteen out of twenty-one) of the participants experienced a association between EFI and FADI improvement, and in the control Group 32% (six out of nineteen) of the participants experienced a association between no EFI and no FADI improvement.

Pressure Algometer: In the Manipulation Group 48% (ten out of twenty-one) of the participants experienced a association between EFI and Pressure Algometer score improvement, and in the control Group 47% (nine out of nineteen) of the participants experienced a association between no EFI and no Pressure Algometer score improvement.

BBS: In the Manipulation Group 90% (nineteen out of twenty-one) of the participants experienced a association between EFI and BBS improvement, and in the control Group 32% (six out of nineteen) of the participants experienced a association between no EFI and no BBS improvement despite no statistical association.

WBD: In the Manipulation Group 57% (twelve out of twenty-one) of the participants experienced a association between EFI and WBD improvement, and in the control Group 37% (seven out of nineteen) of the participants experienced a association between no EFI and no WBD improvement despite no statistical association.

In summary it was noted that in all the EFI percentage associations the Manipulation Group had a far greater percentage of association than the control Group (except in Pressure Algometer readings were the Manipulation Group was higher but only marginally so). Additionally it was further noted that the Manipulation Group had a higher percentage of association between EFI and improvement in the subjective/objective clinical measures, but in the control Group many participants had improvement in clinical measures despite the fact that no treatment was given, and no EFI was noted.

b.) Statistical significant association:

1. Within the manipulation group:

a) Overall no statistically significant association was observed between motion palpation results, EFI, and any of the five subjective/objective clinical measures utilised.

b) EFI predicted outcome of FADI (p=0.490) and BBS (p=0.512) to some extent but not quite statistically significantly. The profile plot also shows that those who showed overall EFI showed a larger reduction of FADI and BBS over time compared to those who showed no overall EFI.

c) In comparison there was no noted relationship between the overall EFI in motion palpation results and readings from VAS (p=0.944), Pressure Algometer (p=0.634) and WBD (p=0.966) over time in the manipulated Group. The profile plot shows that both Groups (those who showed overall EFI in motion palpation readings and those

who did not) fared equally well in terms of increase of VAS, Pressure Algometer and WBD readings of over time in the Group who were manipulated.

2. Within the control Group:

a) VAS (p=0.063) and FADI (p=0.491) showed a slight association to EFI and their readings, but not to a statistically significant degree.

b) In the rest of the subjective/objective clinical measures, Pressure Algometer (p=0.828), BBS (p=0.695) and WBD (p=0.747), the profile plot showed that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of improvement over time in the control Group.

Reason for the expected association between EFI and an improvement in subjective/objective clinical measures, and no EFI and a lack of improvement in the subjective/objective clinical measures at the outset of the study are presented below, based on 1) previous research and 2) theories

1. Previous research

Manipulation has been advocated, as an effective form of treatment for CAI in many studies that have been conducted (Pellow and Brantingham, 2001; Green *et al.,* 2001; Collins *et al.,* 2002; Gillman 2004; Jennings and Davies, 2005; Brantingham *et al*., 2009; Jospeh *et al.,* 2010).

The results of the study, by Pellow and Brantingham (2001), suggested that Manipulation is effective for the treatment of CAI (p=0.001), where the inter-Group analysis revealed that a treatment effect for the Manipulation Group was observed at the final treatment. With regards to intra-Group analysis, improvements in the only Manipulation Group were noted specifically with respect to reduced pain on the NRS101 (p=0.001), McGill Pain Questionnaire (p=0.001), Goniometer (p=0.002), Pressure Algometer (p=0.013) and improved general ankle functioning (p=0.001). This is in comparison to the detuned ultrasound Group where NRS101 readings were (p=0.007), McGill Pain Questionnaire (p=0.038), Goniometer (p=0.199) Pressure Algometer (p=0.017) and general function (p=0.004). Thus it was concluded that Manipulations to the ankle (at the site of fixations in the ankle) would be effective in the treatment of CAI. Improvements were noted specifically in terms of enhanced range of motion, reduced pain intensity and quality and generalised improved ankle function (Pellow and Brantingham, 2001).

The study by Kohne *et al.,* (2007), revealed a statistically significant treatment effect for the six treatment Manipulation Group on two measures of proprioception (p=0.029 and p=0.047) and dorsiflexion range of motion p=0.028.

Therefore as seen (from the examples) above, other studies have reported that Manipulation has the ability to decrease pain, increase range of motion, proprioception and functionality in a joint (Pellow and Brantingham, 2001; Kohne *et al.,* 2007.)

2. Theories

The possible theory in the literature that explains the results above:

Manipulation has been known to restore the neuromuscular firing (Leach, 2004) of the joint, as well as to ensure better alignment and the correction of the biomechanics to restore the ankle to its near normal state (Gatterman, 1990; Bergmann, Petersen and Lawrence, 1993; Redwood and Cleveland, 2003; Leach, 2004 and Haldeman, 1992). Many theories have been proposed to explain this phenomenon, with Gatterman (1990) and Bergmann, Petersen and Lawrence (1993) stating/reporting that manipulating an articular lesion improves joint alignment and any dysfunction of motion that the joint previously had. When the Manipulation is applied the joint is taken to its end-feel (Redwood and Cleveland, 2003) and the cavitation is heard. It thus serves to improve the motion/end-feel in that joint that has been manipulated (Schafer and Faye, 1990; Lakhani *et al.,* 2009) and maximise normal motion (Haldeman, 1992).

The theory which correlates to reduced pain e.g. VAS and Pressure Algometer improvement in participants is that the Manipulation initially causes the fixated area, which is generally restricted in motion due to a subluxation complex, joint dysfunction and reflex muscle spasm and pain (Bergmann, Petersen and Lawrence*,* 1993; Vicenzino *et al*., 2006) to stimulate superficial and deep somatic mechanoreceptors, proprioceptors and nociceptors. This restores motion and relieves spasm. The Manipulation may also alter motor and sensory function (Gatterman, 1993; Lopez-Rodriguez *et al.,* 2007) which leads to afferent stimulation of the sensory neurons of the spinal cord. This reflexly reduces pain and allows the joint to be restored to normality. A further theory to explain the ability Manipulation has to reduce a participants pain threshold is possibly due to the effect that Manipulation has on the Type IV Wyke receptors (Wyke, 1981). These types of receptors are stimulated whenever there is mechanical stimulation at the level of the joint. In the Manipulation Group, the joint is taken into the paraphysiologial space to generate the cavitations; which stimulate the Type IV receptors. When the joint is taken to its end-feel in order to administer the thrust, stretching of ligaments and tendons will inadvertently take place. As a result of this, the Type IV

receptors are stimulated even further. This stimulation of these receptors causes a response in the central nervous system to dampen the effects of the pain and increase the pain threshold (Wyke, 1981). Manipulation also has an inherent neurological effect on the fixated segment and alters motor and sensory function and as a result affects pain threshold accordingly (Gatterman, 1990). Therefore participants may experience a reduction of pain, an improvement in VAS and Pressure Algometer, and re-instated function as a result (Bergmann, Petersen and Lawrence, 1993 and Joseph, de Busser and Brantingham, 2010).

The theory that supports the notion that Manipulation improves the general functioning of the joint, used in subjective/objective clinical measures such as FADI and WBD it acts on is described by Bergmann, Petersen and Lawrence, (1993). When a fixated segment is manipulated it affects the autonomic nervous system which leads a reflex vasoconstriction of the vessels at the site of the Manipulation. This vasoconstriction increases the pump action of the muscle leading to enhanced circulation at the joint and re-establishes normal joint function, therefore improving the general function of the joint with the elimination of abnormal joint function and alignment and therefore improved FADI and WBD scores (Bergmann, Petersen and Lawrence, 1993).

The proposed theory as to how Manipulation affects range of motion, WBD, is explained by using the four types of mechanoreceptors that are present in the joints, namely Type I to IV (Wyke, 1981). Type I receptors detect amplitude of joint motion and Type III receptors are affected by external range of motion when considerable stress is placed on the joint. A Manipulation to a joint or fixated segment stimulates the Type I and II mechanoreceptors when placed at end-feel and into accelerated joint motion and changes in articular pressure and the Type III will be stimulated when stretched at the elastic barrier. As a result, the Manipulation should have an effect on WBD especially at the end of range of motion.

With respect to BBS and proprioception, the basis of the proposed effect of a subluxation is that aberrant joint mechanics in the ankle will subsequently lead to aberrant firing of Wyke receptors. In turn, abnormal neural firing will lead to abnormal proprioception and balance at the ankle. Manipulation can correct this aberrant pattern by stimulating an afferent input and in doing so corrects the proprioception problem (Bergmann, Petersen and Lawrence, 1993). Furthermore, Manipulation causes change in all afferent output and restores normality to the Golgi tendon and proprioceptive organ and in the same time functions to remove the neural scar (Bergmann, Petersen and Lawrence, 1993).

Therefore, this study expected the Manipulation to have an effect on the joint and subsequently alter the subjective/objective clinical measures to an extent that they would improve statistically. However, this association was not observed in this study. For this reason, inter-Group analysis was conducted to check whether a Manipulation effect did in fact occur in this study or not i.e. whether there was a statistically significant difference noted with respect to decreased pain and tenderness, increased range of motion and functionality or proprioception in the manipulated Group as compared to the control Group in this study.

2. Inter-Group analysis

- With respect to inter-Group analysis overall, no statistically significant Manipulation effect was observed when compared with the control over time in any of the five subjective/objective clinical measures.

- With regards to VAS, FADI and Pressure Algometer there was no significant Manipulation effect compared with the control over time (p=0.291), (p=0.434) and (p=0.340) for VAS, FADI and Pressure Algometer respectively; but the profile plot did reveal a trend which suggests that the rate of change of improvement in the Manipulation Group was greater than that in the control (the slope of the line in the Manipulation Group was steeper than in the control).

- With respect to the BBS there was a marginally non significant Manipulation effect (p=0.060) and the profile plot shows that the Manipulation had a clinically significant effect on this outcome as the two profiles intersect. In the control Group the increase was very small while the manipulated Group showed a vast improvement. However, the power of this study was slightly too low to show this effect as statistically significant.

- In comparison, the WBD results revealed that no significant Manipulation effect was found when compared with the control over time (p=0.284) but the profile plot in fact revealed a trend which suggested that the rate of improvement in the control Group was greater than that in the Manipulation Group (the slope of the line in the control Group was steeper than the Manipulation Group).

Upon reflection of the results, some possible reasons and suggestions for the lack of statistical association between EFI and the five subjective/objective clinical measures and reason for lack of a Manipulation effect in the inter-Group analysis based on 1) previous research and 2) theories have been described below:

a) Only one treatment

A single blinded randomised clinical trial was conducted that investigated the effects of single versus multiple Manipulations on proprioception and ankle dorsiflexion in CAI patients by Kohne, Korporaal, Price, Brantingham and Globe (2007). Thirty participants were placed into two Groups and both Groups received Manipulation as the form of intervention however, Group one received six Manipulation treatments over a four week period whereas the control Group received a single Manipulation to the ankle. The study revealed a statistically significant treatment effect for the six Manipulation treatment Group on two measures of proprioception (p=0.029 and p=0.047) and dorsiflexion range of motion (p=0.028) and therefore the multiple treatments were found to be of greater value as they increased proprioception and well as range of motion (Kohne *et al*., 2007). Therefore one of the possible reasons why participants did not have correlating improvements in subjective/objective clinical measures along with EFI; or between no EFI and a lack of clinical improvement, is because only one treatment was performed on each participant in this study.

This concurs with Vernon and Mrozek (2005) who state that Manipulation of a joint with clinically reduced range of motion takes place within a clinical physiological range and not at the end range of normal motion. The Manipulation causes breaking down of adhesions, increasing the 'clinical physiological' range of motion. However, it is possible that adhesions will remain post-treatment and not all fibres will be broken after a single Manipulation. Thus, multiple Manipulations would have the beneficial effect of progressively breaking down intra-articular and capsular adhesions and improving the range of motion of the joint until there is no further restriction of the joint due to adhesions (Leach, 2004 and Haldeman, 2005).

Furthermore Pellow and Brantingham (2001), Clark and Burden (2005), Hale and Hertel (2005) and Hughes and Rochester (2008) all used six treatments over a minimum of three weeks and a maximum of five weeks, suggesting that this is perhaps the ideal treatment course in order to alter symptoms. Studies conducted using multiple Manipulations with results showing significant decrease in pain and increase in functionality are Green, (2001); Pellow and Brantingham, (2001); Eisenhart *et al.,* (2003); Kohne *et al.,* (2007) and Joseph, de Busser and Brantingham*,* (2010).

Therefore although one treatment did restore normal end-feel i.e. alter the quality of the end-feel in the joints enough to be picked up using motion palpation immediately after the Manipulation, perhaps one treatment was not sufficient to alter symptoms i.e. reduce pain/tenderness, improve range of motion, function and proprioception. Therefore future

studies of a similar nature should be conducted with a series of treatments (Pellow and Brantingham, 2001; Clark and Burden, 2005; Hale and Hertel, 2005; Hughes and Rochester, 2008) to allow for these changes to occur and alter the results accordingly.

b) Time between Manipulation and post-treatment readings

In this study the time frame from the Manipulation to the post-treatment readings was three minutes; as this was sufficient time for the person performing the Manipulation to complete treatment i.e. a maximum of one minute per fixation was set at the outset. This was done to ensure blinding i.e. to ensure that the motion palpator would not know if a Manipulation had occurred or not in that participant if the time was standardised throughout. However, according to Haldeman (1992), when a participant's foot/ankle is manipulated mechanical changes can cause neural scar tearing which inadvertently causes increased blood flow to the affected area. This increased blood flow causes inflammatory mediators to be brought to the area which could lead to a transient increase in pain perception at the affected site (Haldeman, 1992) and since the post-treatment reading was taken within such a short time the participants may have been experiencing pain as a result of the Manipulation, therefore affecting the VAS and Pressure Algometer readings as well as FADI, BBS and WBD as the pain would hinder range of motion and functionality. Perhaps in future studies, more time should be given between the Manipulation and post-treatment readings to allow for the post-treatment pain/tenderness to subside, should there be any.

c) Chronicity of CAI in participants

According to Schafer and Faye, (1990) the long term effects of a persistent and chronic fixations will show signs of hypoactivity with the inclusion of symptoms of weakness, reduced function and general musculoskeletal degeneration. These changes may be related either to neural facilitation (spasm and hypertonicity) or with inhibition (weakness and trophic changes). Therefore if the participant has had the injury for a long period of time this weakness, muscle spasm and poor functionality could not be corrected immediately, compared to participants who have only had CAI for 3-6months. Therefore another possible reason for the EFI and subjective/objective clinical measures to not correlate could be because in this study the chronicity of participants was too widespread (minimum was three months and maximum was 180 months in this study). Participants with long term injuries logically would take a longer time to improve and change the subjective/objective outcomes, than a participant with a more recent injury.

In this study 72.5% of participants have had ankle sprains for longer than one year with the greatest being a fifteen year history of ankle sprains. Although there were no statistical differences noted between the two Groups in terms of chronicity, this could be an explanation to why the Manipulation Group did not fare as well as other Manipulation Groups in other studies, because in a participant with a one year, and more especially a fifteen year history of CAI, one treatment was unable to affect that joint enough to lead to a change in clinical measures. In future studies chronicity should perhaps be capped or narrowed down to a specific time frame to not only increase homogeneity but to monitor how Manipulation affects varying stages of chronicity.

d) Grading of CAI

As stated previously, there are three Grades of CAI. In this study, participants with Grade I and II CAI were allowed to participate. A Grade I injury results in a mild stretch of a single ligament (Forcum, 1997) and these patients can bear weight on the ankle immediately after the injury (Garrick and Schelkun, 1997). Some tearing of the ligaments occurs in a Grade II injury, with more swelling and the patient can generally bear some weight (Garrick and Schelkun, 1997). Forcum (1997) noted that a complete tear of the ATFL or a partial tear to both the ATFL and the CFL can occur in a Grade II injury. Therefore according to Forcum (1997) the pain associated with a tear of the AFFL and CFL, in a Grade II CAI, will be greater than a mild stretch of a single ligament, Grade I CAI. Therefore there could be a difference clinically between a Grade I and a Grade II CAI participant in terms of symptoms and its intensity, and therefore the length of treatment that each will require to improve may differ. In this study, this could have been a potential reason why no EFI association or Manipulation effect occurred; one treatment was perhaps unable to affect the joint enough to lead to a change in clinical measures.

This theory only applies to WBD:

According to a study by Vincenzo *et al.,* (2009) it was noted that there were no statistically significant differences between the control Group and treatment Group with respect to the WBD test, as in this study. The control Group was smaller than the treatment Group (as is the case with this study). The proposed reasoning for the control Group to have made such a statistically significant change is because of the repetition of the test which may have helped to increase range of motion. However in the Manipulation Group, the mechanical

effects produced as the joint is stressed at end range of motion may have caused inflammation and therefore pain as an immediate temporary result of the Manipulation (Haldeman, 1992). Therefore, in the Manipulation Group placing weight on the foot and doing a range of motion test may have displayed unfavourable results temporarily until the swelling and pain lessened. This could be a possible reason for why the control Group fared better statistically, although not to a significant degree, in this study.

Due to the fact that inter-Group analysis revealed that there was no Manipulation effect i.e. no statistical significant difference between the Group that was manipulated and the Group that wasn't with respect to all five subjective/objective clinical measures, further analysis assessing clinical significance was performed to determine whether differences occurred between the Groups with respect to some subjective/objective clinical measures that were too slight to be picked up statistically.

3. Clinical significance

VAS: Clinically significant improvement was achieved in 28% (six out of twenty-one) of the participants in the Manipulation Group, compared to 16% (three out of nineteen) in the control Group.

FADI: Clinically significant improvement was achieved in 38% (eight out of twenty-one p) of the participants in the Manipulation Group, compared to 36% (seven out of nineteen) in the control Group.

Pressure Algometer: Clinically significant improvement was achieved in 14% (three out of twenty-one) of the participants in the Manipulation Group, compared to 0% (zero out of nineteen) in the control Group.

BBS: Clinically significant improvement was achieved in 60% (nine out of fifteen) of the participants in the Manipulation Group, compared to 44.4% (four out of nine p) in the control Group in the 35 to 44 point category, and clinically significant improvement was achieved in 60% (three out of five) of the participants in the Manipulation Group, compared to 50% (three out of six) in the control Group in the 45 to 56 point category.

WBD: Clinically significant improvement was achieved in 24% (five out of twenty-one) of the participants in the Manipulation Group, compared to 16% (four out of nineteen) in the control Group.

Although the difference in numbers of participants experiencing clinically significant improvement was marginal in some subjective/objective clinical measures (FADI and WBD), other subjective/objective clinical measures (VAS, Pressure Algometer and BBS) showed that clinically significant improvement occurred in many participants in the Manipulation Group compared to the control Group.

Therefore in summary, the second objective in this study had aimed at assessing whether an association had occurred between the two i.e. EFI noted in participants who display an improvement in subjective/objective clinical measures and no EFI noted in those participants who showed no improvement in the subjective/objective clinical measures. However this association could not be made i.e. EFI association was not observed in subjective/objective clinical measures. This means that those who exhibited EFI did not necessarily exhibit improvement in the subjective/objective clinical measures, and those who displayed no EFI did not necessarily display a lack of improvement in the subjective/objective clinical measures. Therefore to try and understand these results, further inter-Group analyses and clinical significance analyses were performed to check whether a Manipulation effect did in fact occur in this study or not. Results revealed that even though a higher proportion of participants who met clinical significance were in the Manipulation Group, in comparison to the control Group; there was no Manipulation effect over the control in any of the five subjective/objective clinical measures when inter-Group analysis was conducted, (i.e. VAS, FADI, Pressure Algometer, BBS and WBD did not improve to a statistically significant degree in the participants who were manipulated as compared to those that were not manipulated). Similarly, when data pertaining to association of motion palpation to the five subjective/objective clinical measures was calculated, although there were marginal to substantial differences noted in percentages of association between the two Groups, statistical association did not occur.

It stands to reason then, that the EFI noted as a result of the Manipulation also did not correlate with improvement in VAS, FADI, Pressure Algometer, BBS and WBD to a statistically significant degree, because this improvement in fact did not occur to a statistically significant degree in this study. In light of this, the lack of association of motion palpation results (end-feel) to the subjective/objective clinical measures (calculated using Fischers Exact Test), actually co-ordinates well with the lack of a Manipulation effect observed in all subjective/objective clinical measures as a result of the Manipulation, (calculated using ANOVA (Analysis of variance).

Motion palpation has therefore, although perhaps indirectly in the case of this objective in this study, appeared to be an efficacious assessment tool, that could be used in conjunction with other subjective/objective clinical measures. However the author stresses that one must be cautious not to assume that the improvement noted on motion palpation i.e. EFI has definitely led to an improvement in pain, range of motion, functionality etc., and therefore must assess for these symptoms as well when monitoring a patients progress in practise.

5.4.2.2 Results of this study as it pertains to other studies

Subjective Data

5.4.2.2.1 VAS

Studies which have investigated the Manipulation effect on VAS readings and have seen favourable results i.e. VAS improvement are: Green, (2001); Pellow and Brantingham, (2001); Eisenhart *et al.,* (2003); Kohne *et al.,* (2007) and Joseph, de Busser and Brantingham (2010). Contrary to the results noted in this current study, all of these studies noted a statistically significant improvement in pain intensity and quality as well as a significant Manipulation effect in the Manipulation Groups.

5.4.2.2.2 FADI

Contrary to the lack of improvement in foot function scores following manipulation in this study, improvement with respect to foot function scores following Manipulation can be seen in the following studies by Pellow and Brantingham, (2001); Clarke and Burden, (2005) and Joseph, de Busser and Brantingham (2010), which found contrary results to this study.

Objective clinical measures

5.4.2.2.3 Pressure Algometer

Contrary to the lack of improvement in Algometry readings following manipulation in this study, improvement Manipulation studies that have been conducted by Pellow and Brantingham, (2001) and Kohne *et al.,* (2007) have noted increased Pressure Algometer scores and therefore an increase in pain threshold via the theory's noted above, which in contrary to this studies Pressure Algometer findings.

However, the lack of statistically significant association between EFI and parameters and lack of a statistically significant manipulation effect in the inter-Group analysis found in this study in terms of algometry readings are in keeping with another clinical trial for inversion ankle sprains where statistically significant difference was not achieved for algometry readings (Van der Wees *et al.*, 2006).

5.4.2.2.4 BBS

Contrary to the lack of improvement in proprioception following manipulation in this study, studies conducted by Kohne et al., (2007) Joseph, de Busser and Brantingham (2010) noted an increased proprioception in the participants in the Manipulation group as well as improved joint position sense as compared to the control group, contrary to this study.

5.4.2.2.5 WBD

Contrary to the lack of improvement in range of motion following manipulation in this study, improvement in WBD was found in studies conducted by Dannenberg (2000), Collins *et al.,* (2002); Vincenzo *et al*., (2006); Kohne *et al.,* (2007); and Joseph, de Busser and Brantingham, (2010*),* noted that Manipulation Groups noted a statistically significant increase in WBD, contrary to the WBD results in this study.

5.4.3 Common fixations identified within this study

The third objective in this study was to identify the most common fixations in symptomatic participants with CAI in this study.

The data was evaluated to identify the most common fixations in the participants of this study. Between the 40 participants in the study, 120 fixations were found collectively. The three most common joints in which fixations were found are: 1.Subtalar 35% (42 fixations out of 120), 2.Mortise 25.83% (31 fixations out of 120) and 3.Joints relating to the Cuboid 15.8% (19 fixations out of 120) and Navicular 15.8% (19 fixations out of 120). Collectively, the tarsal joint region accounted for the most fixations found; 39.17% (47 fixations out of 120). However, when the joints in the tarsal region was assessed for individual fixations, it was noted that the joints surrounding the Cuboid and Navicular each made up 15.8% % (19 fixations out of 120) of the total and those surrounding the Cuneiforms constituted 7.5% (9 fixations out of 120).

The most common of direction of restrictions of the fixations was Long Axis Distraction (LAD) with 40.83% (49 fixations out of 120) of the total fixations. Eversion, Abduction and Plantar-Dorsal (P-D) were found to be next with each accounting for 14.17% (17 fixations out of 120) fixations. Dorsal-flexion (DF), Shear and Dorsal-Plantar (D-P) followed with each movement accounting for 5% (6 fixations out of 120) of the total fixations and lastly Adduction and Inversion which each accounting for 0.83% (1 fixation out of 120) of the total fixation. These were all recorded at the beginning of the study prior to the treatment.

These fixations above have been established as the most common within this study but have been mentioned previously in many other studies which are described below:

It has been reported that after an inversion ankle sprain, the following joints may commonly be hypomobile (in no particular order):

- Subtalar (Greenman 1996 and Meadows, 2002),
- Talocrural/Ankle joint, (Dananberg, Shearstone and Guillano, 2000; Denegar, Quesnel and Howard, 2000; Green *et al*., 2001; Hertel and Fonseca, 2002),
- Distal tibiofibular joint, (Mulligan, 1995; Hetherington, 1996; O'Brien and Vicenzino, 1998; Kavanagh, 1999).

With respect to the Subtalar joint this study found similar results to Greenman (1996) and Meadows (2002), as 35% of the total fixations were found within the subtalar region. However this study found contrasting results within the distal tibiofibular joint when compared to Mulligan (1995), Hetherington (1996), O'Brien and Vicenzino (1998) and Kavanagh (1999), in this study as it was only detected in 2.5% (3 out of 120) in the total fixations.

In this study the Mortise joint LAD was the most common specific fixation (joint and direction) noted with 20.8% (25 fixations out of 120) of the total fixations. This is in agreement with literature showing the common involvement of the mortise joint in CAI (Green *et al*., 2001. and Denegar *et al.,* 2002). The second most commonly noted fixation (joint and direction) in this study was the Subtalar joint LAD which accounted for 20% (24 fixations out of 120) of the total fixations; this too is in agreement with literature on subtalar fixations in participants with CAI (Meadows, 2002. and Greenman 1996). The third fixation which was frequently noted was subtalar eversion (joint and direction) which was noted 14.2% (17 fixations out of 120) times this too is in agreement with literature on subtalar fixations in participants with

CAI (Meadows, 2002. and Greenman 1996). In totality these three fixations account for 55% of the overall fixations (66 fixations out of 120).

However, with regards to dorsiflexion restriction in the mortise joint, and contrary to the results of this study, many studies have noted this fixation as the most common in participants with CAI (Dananberg *et al*., 2000; Green *et al.,* 2001; Denegar *et al.,* 2002; Vincenzino *et al.,* 2006).

In this study the tarsal joints collectively accounted for 39.17% (47 fixations out of 120), 15.8% of which were noted in the cuboid joint. This is inconsistent with a study by Jennings and Davies (2005), which looked at patients who had endured an ankle sprain between one to eight weeks prior, the presence of cuboid fixations as a result of this injury and how Manipulations to this fixated cuboid would reduce clinical symptomatology. In the Jennings and Davies (2005) study (n=7) two treatments were conducted on patients. All seven of the participants in the study had cuboid fixations recorded following their inversion sprain. Therefore in this study 15.8% of fixations were found to be of the cuboid region, out of the total 100% of fixations whereas the Jennings and Davies (2005) study found 100% of cuboid fixations within the total 100% of total fixations. However in the above study the sample size was far smaller, n=7 as opposed to the larger sample size, n=40 in this study, this could perhaps be part of the reason for the differing results.

5.5 Extra observations made during the course of the study

Although not part of the objectives of this study, the following extra observations were made throughout the study process:

5.5.1 Mobilisation versus Manipulation

In the Manipulation Group, certain participants were manipulated but no cavitations occurred. It was noted immediately by the manipulator, Assistant two, that these participants were mobilized and not manipulated. This occurred in four participants from the twenty-one within the Manipulation Group. When analysed statistically, there was a statistically significant difference between the mobilized and manipulated participants in terms of overall improvement (p=0.029). Of the mobilization Group, 50% (two out of four participants) showed overall EFI in the number of fixations whereas 100% (seventeen out of seventeen participants) of the manipulated Group showed an overall EFI in the quality of the fixations.

Table 5.1 Comparison of mobilized and manipulated participants in the treatment Group

			Overall improvement (2 out of 3)		Total
			Yes	No	
Mobilized	Mobilized	Count	2	2	4
		%	50.0%	50.0%	100.0%
	Manipulated	Count	17	0	17
		%	100.0%	.0%	100.0%
Total		Count	19	2	21
		%	90.5%	9.5%	100.0%

p=0.029

5.5.2 Distal tibiofibular joint observations

The distal tibia-fibular joint was motion palpated on each participant as a part of the motion palpation sequence. Fixations in this joint were detected once in the control Group (one out of nineteen participants) and twice (two out of twenty-one participants). In the Manipulation Group, each time this fixation was felt it was in the same direction, which was anterior to posterior. When analysed, this observation lacked any statistical significance within this study, previous studies noted above found contrasting results in participants with CAI, as they found distal tibiofibular fixations common (Mulligan, 1995; Hetherington, 1996; O'Brien and Vicenzino, 1998; Kavanagh, 1999).

5.6 Revision of aims, objectives and hypothesis of this study

The aim of this study was to determine the clinical responsiveness of motion palpation as a post-treatment diagnostic tool in joints of the ankle. The specific objectives of this study were:

- **The first objective**

  To determine the validity of motion palpation as a tool to detect an improvement in end-feel in the ankle region.
- **The first null hypothesis**

  Motion palpation will not demonstrate validity as a post-treatment tool in detecting change in end-feel i.e. will not show a high level of responsiveness. This null

hypothesis was rejected as motion palpation was found to have an etiologic fraction of 0.95 and therefore was able to detect change within the joint, and did show a high level of responsiveness.

- **The first alternative hypothesis**

  Motion palpation will be a valid post-treatment tool to assess end-feel improvement i.e. will demonstrate a high level of responsiveness. This alternative hypothesis was accepted as motion palpation was found to be a valid tool to detect EFI, and did show a high level of responsiveness.

- **The second objective**

  To establish whether associations exist between motion palpation and the other clinical measures. If an association was found to exist between motion palpation and the clinical signs and symptoms of CAI, this could be used to monitor the patient's progress.

- **The second null hypothesis**

  Post-treatment motion palpation results will not be related to the results of other subjective/objective clinical measures used in this study. Therefore EFI will not correlate with improvement in the subjective/objective clinical measures in the Manipulation Group, and a lack of EFI will not correlate with a lack of improvement in the subjective/objective clinical measures in the control Group. This null hypothesis was accepted as participants in whom EFI was noted did not necessarily have improvement in the subjective/objective clinical measures and those with no EFI did not necessarily have no improvement in the subjective/objective clinical measures. Therefore no association between EFI and the subjective/objective parameter results could be made.

- **The second alternative hypothesis**

  Post-treatment motion palpation results will be directly proportional to the results of subjective/objective clinical measures used in this study. Therefore EFI will correlate with improvement in the subjective/objective clinical measures in the Manipulation Group, and a lack of EFI will correlate with a lack of improvement in the subjective/objective clinical measures in the control Group. This alternate hypothesis was rejected as participants in whom EFI was noted did not necessarily have improvement in the subjective/objective clinical measures and those with no EFI did not necessarily have no improvement in the subjective/objective clinical measures, therefore no association could be made.

- **The third objective**

  To identify the most common fixations in symptomatic participants with CAI.

- **The third null hypothesis**

  The most common fixations within symptomatic participants with CAI will not be established. This null hypothesis was rejected as the most common fixations within this studies population were established.

- **The third alternative hypothesis**

  The most common fixations in symptomatic participants with CAI will be established. This alternative hypothesis was accepted as the most common fixations within this studies population were established.

5.7 Limitations of the study

5.7.1 Objective

Even though a blinded independent research assistant performed all the objective and subjective parameter testing (excluding motion palpation) it is possible that some of the objective data may have been subject to human error and observer bias (Mouton, 1996).

5.7.2 Subjective

The Hawthorne effect (Mouton, 1996) should be taken into account with respect to the subjective outcomes, this deals with the participants need to produce results that they believe the researcher wishes to see. Additionally, human error (Mouton, 1996) should too be taken into consideration despite efforts to reduce this completely.

5.8 Conclusion

This chapter focused on the results of this study and the theories based on the motion palpation results as well as the objective and subjective parameter findings. All results were explained in detail and were discussed. The following chapter will assess the conclusions, limitations and recommendations for future studies.

CHAPTER 6

CONCLUSION AND RECCOMENDATIONS

6.1 Introduction

This chapter discusses the outcomes of this study and makes suggestions for future studies on motion palpation as well as CAI.

6.2 Conclusion

6.2.1 The aim of the study

The aim/primary goal of this study was to determine the clinical responsiveness of motion palpation as a post-treatment diagnostic tool within the joints of the ankle in symptomatic participants with CAI. Therefore the purpose of this study was to investigate, via a prospective, blinded, randomized pre-post experiment, the validity of motion palpation as a post-treatment assessment tool to confirm whether the desired effect of the Manipulation had been achieved with short term outcomes (i.e. end-feel improvement in the fixated joint has been perceived/achieved in the Manipulation Group as compared to the control Group; the secondary goals were to determine whether associations between motion palpation results and other clinical measures occurred and what the common fixations were).

6.2.2 Results of the study

Demographic data

It was noted within this study that there were no statistical differences between the two Groups, in terms of demographic data at the outset of the study. This indicates that both Groups were similar at the outset and no biases and statistical adjustments could be proposed.

Motion palpation data (etiologic fraction, sensitivity and specificity)

Table 6.1 Summary of motion palpation results

	Etiologic fraction	Sensitivity	Specificity	Association of EFI and Manipulation
First fixation	0.95	95%	95%	*p<0.001*
Second fixation	0.94	85%	95%	*p<0.001*
Third fixation	0.77	76%	87%	*p<0.001*
Overall EFI	0.95	90%	95%	*p<0.001*

- The first objective of this study was to determine the validity of motion palpation as a tool to detect an improvement in end-feel in the ankle region.
- The etiologic fraction was 0.95 therefore demonstrating 95% of the EFI noted by the blinded examiner was due to the Manipulation and was apparent when performing post-treatment motion palpation.
- Within this study the sensitivity was 0.90; therefore 90% of those participants who were manipulated were identified to be in the Manipulation Group by the blinded motion palpator.
- Furthermore, the specificity of this study was 0.95; this can be interpreted as 95% of participants who were not manipulated were identified to be in the control Group by the blinded motion palpator. Therefore, these results suggest that motion palpation can not only recognize fixations but can detect a change within the quality of the fixation and distinguish between a joint that has been manipulated from one that hasn't been manipulated.

- Therefore, the statistics show that there was a highly significant association between being manipulated and end-feel improvement ($p<0.001$).

- These study findings are in keeping with studies by Haas *et al.,* (1995) and Lakhani *et al.,* (2009) where motion palpation was also found to be a valid post-treatment assessment tool with the ability to detect responsiveness within a joint. By implication these results indicate that motion palpation is a useful clinical entity with respect to the clinical evaluation of the patient, as this research has shown validity within the clinical setting. This means that motion palpation appears to be a useful tool in determining the presence of motion restrictions as well as any change in the

quality of end-feel in these fixations following treatment, within the context of clinical assessment.

- Motion palpation of EFI appeared to be a valid and effective post-treatment assessment tool for deciphering whether perceived motion restriction found before Manipulation improved after Manipulation in this study. This observation may be limited to symptomatic participants, as no asymptomatic participants were utilised within this study.

EFI association to subjective/objective clinical measures

Table 6.2 Summary of all subjective/objective clinical measures

	Association of EFI and Manipulation	Profile plot suggesting trend in favour of Manipulation (Manipulation Group)	Association of EFI and control	Profile plot suggesting trend in favour of Manipulation (Control Group)	Inter-analysis for both Groups	Trend (improvement in the manipulated participants)	Clinical significance in the Manipulation Group		Clinical significance in the control Group	
VAS	No	No	No	Yes	No	Yes	28%		16%	
FADI	No	Yes	No	Yes	No	No	38%		37%	
Pressure Algometer	No	No	No	No	No	No	14.3%		0%	
BBS	No	Yes	No	No	No	Yes	60 %	60 %	44.4%	50 %
WBD	No	No	No	Yes	No	No	24%		16%	

- The second objective of this study was to establish whether associations exist between motion palpation and the other clinical measures. If an association was found to exist between motion palpation and the clinical signs and symptoms of CAI, this could be used to monitor the patient's progress.
- The inclusion of clinical measures in conjunction with motion palpation had been suggested (Haas *et al.,* 1995) in order to establish whether associations exist between motion palpation results and other clinical measures i.e. when EFI was

detected the subjective/objective clinical measures improved and when no EFI was detected the subjective/objective clinical measures did not improve.

- Overall no statistically significant association was observed between motion palpation results with respect to EFI and no EFI noted, and any of the five subjective/objective clinical measures utilised.

- With regards to the subjective/objective clinical measures;

  1. Within the manipulation group:

  a) EFI predicted outcome of FADI (p=0.490) and BBS (p=0.512) to some extent but not quite statistically significantly. The profile plot shows that those who showed overall EFI showed a larger reduction of VAS, FADI and BBS over time compared to those who showed no overall EFI.

  b) In comparison there was no noted relationship between the overall EFI in motion palpation results and readings from VAS (p=0.944), Pressure Algometer (p=0.634) and WBD (p=0.966) over time in the manipulated Group. The profile plot shows that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of increase of VAS, Pressure Algometer and WBD readings over time.

  2. In the control Group:

  a) VAS (p=0.063) and FADI (p=0.491) showed a slight association to EFI and their readings, but not to a statistically significant degree.

  b) In the rest of the subjective/objective clinical measures, Pressure Algometer (p=0.828), BBS (p=0.695) and WBD (p=0.747), the profile plot showed that both those who showed overall EFI in motion palpation readings and those who did not, fared equally well in terms of improvement over time.

Inter-Group analysis data

- With respect to inter-Group analysis overall, no statistically significant Manipulation effect was observed when compared with the control over time in any of the five subjective/objective clinical measures.

- With regards to VAS, FADI and Pressure Algometer there was no significant Manipulation effect compared with the control over time (p=0.291), (p=0.434) and (p=0.340) for VAS, FADI and Pressure Algometer respectively; but the profile plot did

reveal a trend which suggests that the rate of change of improvement in the Manipulation Group was greater than that in the control (the slope of the line in the Manipulation Group was steeper than in the control).

- With respect to the BBS there was a marginally non significant Manipulation effect (p=0.060) and the profile plot shows that the Manipulation had a clinically significant effect on this outcome as the two profiles intersect. In the control Group the increase was very small while the manipulated Group showed a vast improvement.

- In comparison, with respect to WBD no significant Manipulation effect was found when compared with the control over time (p=0.284) but the profile plot in fact revealed a trend which suggested that the rate of improvement in the control Group was greater than that in the Manipulation Group (the slope of the line in the control Group was steeper than the Manipulation Group).

Clinical significant data

- In this study, a higher proportion of the participants that met clinical significance within each subjective/objective clinical measures were from the Manipulation Group compared to the control Group.

- In VAS 28% of the Manipulation Group met clinical significance in comparison to only 16% of the control Group who met the MCID for this parameter.

- With regards to FADI 38% of the Manipulation Group met clinical significance, in comparison to 37% of the control Group who met the MCID for this parameter.

- In terms of Pressure Algometer, 14% of the Manipulation Group met clinical significance, in comparison to 0% of the control Group for this parameter.

- With respect to BBS, clinically significant improvement was achieved in 60% of the participants in the Manipulation Group, compared to 44.4% in the control Group in the 35 to 44 point category, and clinically significant improvement was achieved in 60% of the participants in the Manipulation Group, compared to 50% in the control Group in the 45 to 56 point category.

- Lastly, for WBD 24% of the Manipulation Group met clinical significance in comparison to 16% of the control Group who met the MCID for this parameter.

- Therefore the Manipulation Group fared slightly better within each parameter than the control participants in terms of clinical significance.

Common fixations data

- The third objective in this study was to determine the most common fixations in symptomatic participants with CAI.
- This was established and the most common fixations noted were mortise LAD, subtalar LAD and subtalar eversion.
- In this study the Mortise joint LAD was the most common specific fixation (joint and direction) noted with 20.8% (25 fixations out of 120) of the total fixations. This is in agreement with literature showing the common involvement of the mortise joint in CAI (Green *et al*., 2001. and Denegar *et al.,* 2002).
- The second most commonly noted fixation (joint and direction) in this study was the Subtalar joint LAD which accounted for 20% (24 fixations out of 120) of the total fixations; this too is in agreement with literature on subtalar fixations in participants with CAI (Meadows, 2002. and Greenman 1996). Furthermore, with respect to the Subtalar joint this study found similar results to Greenman (1996) and Meadows (2002), as 35% of the total fixations were found within the subtalar region.
- The third fixation which was frequently noted was subtalar eversion (joint and direction) which was noted 14.2% (17 fixations out of 120) times this too is in agreement with literature on subtalar fixations in participants with CAI (Meadows, 2002. and Greenman 1996).
- In totality these three fixations account for 55% of the overall fixations (66 fixations out of 120).

6.2.3 Summary

In conclusion, it can be seen that in this study, motion palpation validity (i.e. EFI/responsiveness, sensitivity and specificity) and its association to other subjective/objective clinical measures was tested; and the common fixations in symptomatic participants with CAI were established.

When analysing the validity of motion palpation as a post-treatment assessment tool to detect end-feel improvement, a high level of responsiveness was found; it was highly sensitive and was highly specific; and the study results therefore revealed that there was a highly significant association between being manipulated and EFI ($p<0.001$).

When assessing for associations between EFI and clinical measures it was noted that, no statistically significant association between EFI and improvement in clinical measures was detected, or between no EFI and a lack of improvement in clinical measures was detected

for all five subjective/objective clinical measures. For this association to occur a manipulation effect in favour of the manipulation group over the control group; would have had to occur in this study. However, although a higher proportion of the participants that met clinical significance within each subjective/objective clinical measure were from the manipulation group compared to the control group, there was also no statistically significant difference noted between the two Groups on inter-Group analysis for all five of the subjective/objective clinical measures.

It stands to reason then, that the EFI that was immediately noted by the blinded motion palpator as a result of the Manipulation, did not correlate with improvement in VAS, FADI, Pressure Algometer, BBS and WBD to a statistically significant degree. This may have occurred, due to the fact that improvement in these subjective/objective clinical measures (when conducting inter-Group analysis) did not occur to a statistically significant degree in this study. Therefore, this lack of association of motion palpation results (end-feel) to the subjective/objective clinical measures, actually co-ordinates well with the lack of a Manipulation effect observed in all subjective/objective clinical measures.

Motion palpation therefore, appears, although perhaps indirectly, in terms of objective two in this study, to be an efficacious assessment tool, that could be used in conjunction with other subjective/objective clinical measures. However, one must be cautious not to assume that the improvement noted on motion palpation i.e. EFI has definitely led to an improvement in pain, range of motion, functionality etc., and therefore must assess for these symptoms as well when monitoring the participants progress.

The third objective in this study was to determine the most common fixations in symptomatic participants with CAI. The most common fixations noted were mortise LAD, subtalar LAD and subtalar eversion. Therefore, it was observed that the common fixations found in symptomatic participants with CAI in this study, are similar overall, to those found in most other studies.

Knowledge has been gained in terms of motion palpations' validity as a post-treatment assessment tool, within an area that had yet to be investigated. In this study, motion palpation appears to be valid when used as a post-treatment tool in the foot and ankle. However, motion palpation must be used in conjunction with other subjective/objective clinical measures during the patient monitoring process in a clinical setting; and more motion palpation research is necessary in other joints of the body, based on the recommendations made in 6.3.

6.3 Recommendations

1. Due to the fact that no statistical significant association was found in this study i.e. EFI noted in those participants that improved in subjective/objective clinical measures and no EFI in those participants that did not improve in clinical outcome measures. The following further recommendations have been made that may improve the study methodology, and EFI association in future studies:

    a. Participants with varying chronicity were allowed to enter the study. Therefore, as discussed in chapter five participants with long term injuries logically would take a longer time to improve and for fixations to change the subjective/objective outcomes than a participant with a more recent injury. To further ensure homogeneity and to perhaps improve association results of future studies, the chronicity should be limited to a certain time frame of chronicity, or a stratification process could be incorporated in order to separate the varying stages of chronicity and therefore the chronicity should be capped to maintain homogeneity.

    b. Both Grade one and two ankle sprains were allowed into the study. As discussed in chapter five, different Grades leads to different intensity of symptoms and more time/treatment is required to change a Grade II injury than a Grade I. To ensure homogeneity and perhaps attempt to improve association results in future studies, the Grade should be limited to only one Grade of ankle sprain. (I.e. only allow participants with Grade two inversion sprains into the study).

    c. In this study only one treatment was performed. Although this was enough treatment to alter end-feel of the fixations it may not have been enough to alter symptoms, especially in participants who have had CAI for a long period of time. Therefore a series of treatments is recommended, as a greater change in symptomatology might be detected over a series of Manipulations.

    d. It is recommended that the post-treatment parameter readings take place over a larger time span. In this study the time span was three minutes between Manipulation and the post-treatment measurements and this may not have been enough time to allow inflammation and pain to subside after the Manipulation. Therefore it is recommended to allow more time for the

inflammation and pain to subside before post-treatment measurements are taken.

2. It is recommended that further research be carried out on motion palpation as a post-treatment assessment tool, on both spinal as well as extremity regions that have not been analysed thus far, in order to assess the generalisability of the study results to all joints/areas of the body.

3. When analysed, there were no statistically significant differences between the two Groups in terms of ethnicity, age, gender, occupation etc. in this study. However the population that participated was a small representation of the South African population and a sample with varying stratified ethnicity Groups, ages, genders and occupations etc. may construct a greater clinical picture. In order to ensure homogeneity (in future studies) and ensure that no statistically significant difference occurs (in future studies), stratification of ethnicity Groups as well as other variables e.g. age, gender, and occupation is recommended where possible.

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Appendix A

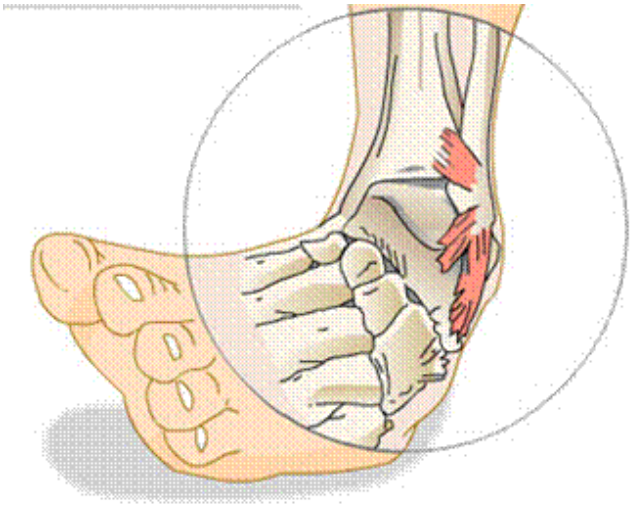
Do you suffer with Chronic ankle sprains /

sprain your

ankle repeatedly

DO YOU SUFFER WITH

1. Pain in and around your ankle?
2. A feeling of “giving way”?
3. Swelling in and around your ankle?
4. Recurrent ankle sprains?
5. Joint clicking in your ankle?



Then you may have unstable ankles!!!

If you are between the ages of 18 – 45 then come receive free treatment at the DUT Chiropractic Clinic

Contact: 031-3732205 (Clinic)

Appendix B

Letter of Information and Consent

Title of the Research Study: The clinical responsiveness of motion palpation as a post-treatment diagnostic tool in patients with chronic ankle instability syndrome.

Principle Investigator/s: Kym Graham

Co-Investigator/s: Dr E Lakhani and Dr C Korporaal

Brief Introduction and Purpose of the Study: This study is to determine whether motion palpation of the ankle joint can be seen as an objective test. This will be done by motion palpating the ankle joint before and after the treatment session. The subject will be allocated to one of two Groups, Group one receiving Manipulation of the ankle and the Group two will receive no treatment. Both Groups will have the option of joining another related study in which all subjects will receive treatment. This study will also be involving other clinical test is will be done to see if a association can be drawn between motion palpation and the clinical test.

Outline of the Procedures: Participants will be required to attained the consultations at the Chiropractic day clinic

To be part of this study you must

1 Be between the ages of 18-45 years.
2 Give informed consent to participate in the research.
3 Have the presence of at least 4 of these clinical features lateral ankle pain, joint weakness, oedema, joint crepitus, adhesions resulting in the formation of restrictions in the joint and ligamentous laxity.

You will not be eligible to take part in this study if you

1 Have any contraindications to adjustments.
2 Have been taking any pain medication.

Risks or Discomforts to the Participant: Transient muscle pain due to the Manipulation may be possible.

Benefits: the Group that receives Manipulation will benefit in terms of pain and mobility and both Groups have the choice to join a related study where all participants will receive treatment.

Reason/s why the Participant May Be Withdrawn from the Study: Patients with connective tissue disorders that create excessive ligamentous laxity will be excluded from the study.

- Participants with Grade three ankle sprains and /or excessive mechanical instability of the lateral ankle complex will be excluded from the study.
- Patients that are contraindicated to Manipulations will be excluded. This may include but may not be limited to .
    - Absolute contraindications:
        - Destructive lesions of the spine, ribs and pelvis; a healing fracture or dislocation; gross instability; cauda equina syndrome; large abdominal aneurysm; visceral referred pain.
    - Relative Contraindications
        - Osteopenia; spondyloarthroapthies; patients on anticoagulants; bleeding disorders; psychological overlay.

Remuneration: None

Costs of the Study: None

Confidentiality: The participant's information will be held in their file at the CDC and will be shredded after five years.

Research-related Injury:

Persons to Contact in the Event of Any Problems or Queries: Dr E Lakhani (031-3732533) and Dr C Korporaal (031-3732611)

Statement of Agreement to Participate in the Research Study:

I,……participant's full name, ID number……., have read this document in its entirety and understand its contents. Where I have had any questions or queries, these have been explained to me by ……to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Participant's name (print) ……

Participant's signature:…….. Date:……

Researcher's name (print) signature: ……...

Researcher's signature:……..Date:.....

Witness name (print) signature: ……...

Witness signature: …….....Date:……

Appendix C

DURBAN UNIVERSITY OF TECHNOLOGY

CHIROPRACTIC DAY CLINIC

CASE HISTORY

Patient:_____ Date:_____

File # : _____ Age: _____

Intern: _____ Signature _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature:

Case History:

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL: Reason for Conditional:
Signature: Date:

Conditions met in Visit No:	Signed into PTT:	Date:
Case Summary signed off:		Date:

Intern's Case History:

1. Source of History:

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

3. Present Illness:

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

4. Other Complaints:

5. Past Medical History:

- General Health Status
- Childhood Illnesses
- Adult Illnesses
- Psychiatric Illnesses
- Accidents/Injuries
- Surgery
- Hospitalization

6. Current health status and life-style:

- Allergies
- Immunizations
- Screening Tests incl. x-rays
- Environmental Hazards (Home, School, Work)
- Exercise and Leisure
- Sleep Patterns
- Diet
- Current Medication

  Analgesics/week:
- Tobacco
- Alcohol
- Social Drugs

7. Immediate Family Medical History:

- Age
- Health
- Cause of Death
- DM
- Heart Disease
- TB
- Stroke
- Kidney Disease

- CA
- Arthritis
- Anaemia
- Headaches
- Thyroid Disease
- Epilepsy
- Mental Illness
- Alcoholism
- Drug Addiction
- Other

8. Psychosocial history:

- Home Situation and daily life
- Important experiences
- Religious Beliefs

9. Review of Systems:

- General
- Skin
- Head
- Eyes
- Ears
- Nose/Sinuses

- Mouth/Throat
- Neck
- Breasts
- Respiratory
- Cardiac
- Gastro-intestinal
- Urinary
- Genital
- Vascular
- Musculoskeletal
- Neurologic
- Haematologic
- Endocrine
- Psychiatric

Appendix D

Durban University of Technology
PHYSICAL EXAMINATION: SENIOR

Patient Name : _____ **File no :** **Date :**

Student : **Signature :**

VITALS:

Pulse rate:			Respiratory rate:	
Blood pressure:	R	L	Medication if hypertensive:	
Temperature:			Height:	
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period

GENERAL EXAMINATION:

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

SYSTEM SPECIFIC EXAMINATION:

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

Appendix E

Foot and ankle regional examination

Patient:_____ File no:_____

Date:__

Intern / Resident _____ Signature:_____

Clinician:_____ Signature:_____

Observation

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

Swelling

Heloma dura / molle

Skin

Nails

Shoes

Contours (achilles tendon, bony prominences)

Active movements

Weight bearing: **R** **L** ***Non weight bearing:*** **R**

L

Plantar flexion			50°		
Dorsiflexion			20°		
Supination					
Pronation					
Toe dorsiflexion			40°(mtp)		
Toe plantar flexion			40° (mtp)		
		Big toe dorsiflexion (mtp) (65-70°)			
		Big toe plantar flexion (mtp) 45°			
		Toe abduction + adduction			
		5° first ray dorsiflexion			
		5° first ray plantar flexion			

Passive movement motion palpation (Passive ROM quality, ROM overpressure, joint play)

R L R

L

Ankle joint: *Plantarflexion*			Subtalar joint: *Varus*		
Dorsiflexion			*Valgus*		
Talocrural: *Long axis distraction*			Midtarsal:*A-P glide*		
First ray: *Dorsiflexion*			*P-A glide*		
Plantarflexion			*rotation*		
Circumduction of forefoot on fixed rearfoot			Intermetatarsal glide		
			Tarso metatarsal joints: *A-P*		
Interphalangeal joints: *L□A dist*			Metatarsophalangeal dorsiflexion (with associated plantar flexion of each toe		
A-P glide					
lat and med glide					
rotation					

Resisted Isometric movements

R L R

L

Knee flexion			Pronation (eversion)		
Plantar flexion			Toe extension (dorsiflexion)		
Dorsiflexion			Toe flexion (plantar flexion)		
Supination (inversion)					

Neurological

R

L

Dermatomes		
Myotomes		
Reflexes		
Balance/proprioception		

Special tests

R **L**

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

Alignment

R **L**

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

Palpation

Anteriorly

R **L**

Medial maleoli		
Med tarsal bones, tibial (post) artery		
Lat.malleolous, calcaneus, sinus tarsi, and cuboid bones		
Inferior tib/fib joint, tibia, mm of leg		

Anterior tibia, neck of talus, dorsalis pedis artery		

Posteriorly

Calcaneus, Achilles tendon, Musculotendinous junction		

Plantarily

Plantar muscles and fascia		
Sesamoids		

21/10/2002

Appendix F

DURBAN UNIVERSITY OF TECHNOLOGY

Patient Name:	***File #:*** ***Page:***
Date: ***Visit:*** ***Intern:***	
Attending Clinician:	***Signature:***
S: ***Numerical Pain Rating Scale (Patient)***	***Intern Rating*** ***A:***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst	
0:	***P:***
	E:
Special attention to:	***Next appointment:***
Date: ***Visit:*** ***Intern:***	
Attending Clinician:	***Signature:***
S: ***Numerical Pain Rating Scale (Patient)***	***Intern Rating*** ***A:***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst	
O:	***P:***
	E:
Special attention to:	***Next appointment:***

Date: ***Visit:*** ***Intern:***

Attending Clinician: ***Signature***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating*** ***A:***

Least 0 1 2 3 4 5 6 7 8 9 10 Worst ☐

O: ***P:***

E:

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

Appendix G

Visual Analogue Scale

0 100

_____

Patient Name:

Patient File Number:

Date:

Appendix H

Foot/ankle disability index

Foot and Ankle Disability Index Item

• Standing	4 3 2 1 0 n/a
• Walking on even ground	4 3 2 1 0 n/a
• Walking on even ground without shoes	4 3 2 1 0 n/a
• Walking up hills	4 3 2 1 0 n/a
• Walking down hills	4 3 2 1 0 n/a
• Going up stairs	4 3 2 1 0 n/a
• Going down stairs	4 3 2 1 0 n/a
• Walking on uneven ground	4 3 2 1 0 n/a
• Stepping up and down curves	4 3 2 1 0 n/a
• Squatting	4 3 2 1 0 n/a
• Sleeping	4 3 2 1 0 n/a
• Coming up on your toes	4 3 2 1 0 n/a
• Walking initially	4 3 2 1 0 n/a
• Waling 5 minutes or less	4 3 2 1 0 n/a
• Walking approximately 10 minutes	4 3 2 1 0 n/a
• Walking 15 minutes or greater	4 3 2 1 0 n/a
• Home responsibilities	4 3 2 1 0 n/a
• Activities of daily living	4 3 2 1 0 n/a
• Personal Care	4 3 2 1 0 n/a

• Light to moderate work (standing, walking)	4	3	2	1	0	n/a
• Heavy work (push/pulling, climbing, carrying)	4	3	2	1	0	n/a
• Recreational activities	4	3	2	1	0	n/a
• General level of pain	4	3	2	1	0	n/a
• Pain at rest	4	3	2	1	0	n/a
• Pain during your normal activity	4	3	2	1	0	n/a
• Pain first thing in the morning	4	3	2	1	0	n/a

Patients select the statement, which most closely describes their condition within the past week (i) no difficulty at all (4 points), (ii) Slight difficulty (3 points) (iii) Moderate difficulty (2 points), (iv) Extreme difficulty (1 point), (v) unable to do (0 points), (vi) N/A (not applicable).

Appendix I

<u>Weight Bearing Dorsiflexion test readings</u>.

Patient Name:

Patient File Number:

	FIRST			**SECOND**					
DATE									
READING									

Appendix J

Pressure Algometer readings.

Patient Name:

Patient File Number:

	FIRST			**SECOND**					
DATE									
READING									

Appendix K		**Berg balance scale**
1. SITTING TO STANDING		**8. REACHING FORWARD WITH OUTSTRETCHED ARM**
Able to stand without using hand and stabilise independently	4	Can reach forward confidently > 25 cm
Able to stand independently using hands	3	Can reach forward >12 cm safely
Able to stand using hands after several tries	2	Can reach forward >5cm safely
Needs minimal aid to stand or stabilise	1	Reaches forward but needs supervision
Needs moderate or maximal assist to stand	0	Loses balance while trying; requires external support
2. STANDING UNSUPPORTED		**9. PICK UP OBJECT FROM FLOOR**
Able to stand safely for two mins	4	Able to pick up slipper safely and easily
Able to stand two minutes with supervision	3	Able to pick up slipper but needs supervision
Able to stand 30 seconds unsupported	2	Unable to pick up but reaches to 2-5cm from slipper and keeps balance independently
Needs several tries to stand 30 seconds unsupported	1	Unable to pick up and needs supervision while trying
Unable to stand 30 seconds unassisted	0	Unable to try /needs assist to keep from losing balance or falling
3. SIITING UNSUPPORRTED		**10.TURN TO LOOK BEHIND**
Able to sit safely and securely 2 minutes	4	Looks behind from both sides and weight shifted well
Able to sit two minutes under supervision	3	Looks behind one side only other side shows left weight shift
Able to sit 30 seconds	2	Turns sideways only but maintains balance
Able to sit 10 seconds	1	Needs supervision when turning
Unable to sit without support 10 seconds	0	Needs assist to keep from losing balance or falling
4.STANDING TO SITTING		**11. TURN 360 ^{o}**
Sits safely with minimal use of hands	4	Able to turn 360 degrees safely in 4 seconds or less
Controls descent by using hands	3	Able to turn 360degrees safely one side only in 4 seconds or less
Uses back of legs against chair to control descent	2	Able to turn 360 degrees safely but slowly
Sits independently but has uncontrolled descent	1	Needs close supervision or verbal cueing
Needs assistance to sit	0	Needs assistance while turning
5.TRANSFERS		**12. PLACE ALTERNATRE FOOT ON STEP OF STOOL**

Able to transfer safely with minor use of hands	4	Abel to stand independently and safely and complete 8 steps in 20 seconds
Able to transfer safely minor use of hands	3	Able to stand independently and compete 8 steps > 20 seconds
Able to transfer with verbal cueing and/or supervision	2	Able to complete 4 steps without aid with supervision
Needs one person to assist	1	Able to complete > 2 steps needs minimal assist
Needs two people to assist	0	Needs assistance to keep from falling / unable to try
6. STANDING UNSUPPORTE DWITH EYES CLOSED		**13.TANDEM STANCE**
Able to stand 10 seconds safely	4	Able to place foot tandem independently and hold 30 seconds
Able to stand 10 seconds with supervision	3	Able to place foot ahead of other independently and hold 30 seconds
Able to stand 3 seconds	2	Able to take small step independently and hold 30 seconds
Unable to keep eyes closed 3 seconds but stays steady	1	Needs help to step but can hold 15 seconds
Needs help to keep from falling	0	Loses balancer whilst stepping or standing
7.STANDING UNSUPPORTED WITH FEET TOGHETRE		**14. STANDING ON ONE LEG**
Able to place feet together independently and stand one minute safely	4	Able to lift le independently and hold > 10 seconds
Able to pace feet together independently and stand one minute with supervision	3	Able to lift leg independently and hold 5-10 seconds
Able to place feet together independently but unable to hold for 30 seconds	2	Able to lift leg independently and hold = or > 3 seconds
Needs help to attain position but unable to stand 15 seconds feet together	1	Tries to lift leg unable to hold 3 seconds but remains standing independently
Needs help to attain position and unable to hold for 15 seconds	0	Unable to try or needs assist to prevent fall

Appendix L

Motion Palpation Record Sheet 1

Date:

Patient name:

Patient file number:

Fixations found pre- treatment:

1.

2.

3.

Fixations found post- treatment:

1.

2.

3.

Was participant in motion palpator's opinion manipulated?

If yes to above question, what joint, what fixation and what side?

Motion palpator name:

Signature:

Clinicians on duty:

Clinicians on duty signature:

Appendix M

Motion Palpation Record Sheet 2

Independent manipulator name:

Patient name:

Patient file number:

Fixations found pre- treatment by motion palpator:

1._____

2._____

3._____

Fixations manipulated (note which side and joint):

1._____

2._____

3._____

Appendix N

Randomisation table

0001: A	0005: A
0002: B	0006: B
0003: B	0007: A
0004: B	0008: A

==========

0009: B	0012: A
0010: A	0013: A
0011: B	0014: B

==========

0015: A	0017: A
0016: B	0018: B

==========

0019: B	0022: B
0020: A	0023: B
0021: A	0024: A

==========

0025: B	0028: B
0026: B	0029: A
0027: A	0030: A

==========

0031: A	0033: A
0032: B	0034: B

==========

0035: A 0037: A

0036: B 0038: B

==========

0039: A 0040: A

ETHICS CLEARANCE CERTIFICATE

Student Name	CYM Graham	**Student No**	20503467
Ethics Reference	207/10	**Date of FRC Approval**	19.4.2010
Qualification	M.tech Chiropractic		
Research Title:	The clinical responsiveness of motion palpation as a post-manipulation diagnostic tool in patients with chronic ankle instability syndrome.		

In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations:

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. ***The following section must be completed if the research involves human participants:***

	YES	NO	N/A
❖ Provision has been made to obtain informed consent of the participants	✓		
❖ Potential psychological and physical risks have been considered and minimized	✓		
❖ Provision has been made to avoid undue intrusion with regard to participants and community	✓		
❖ Rights of participants will be safe-guarded in relation to: - Measures for the protection of anonymity and the maintenance of Confidentiality.	✓		
- Access to research information and findings.	✓		
- Termination of involvement without compromise	✓		
- Misleading promises regarding benefits of the research	✓		

[redacted]

15/03/2010
DATE

15/03/2010
DATE

15/3/2010
DATE

24/4/2010
DATE