INVESTIGATION OF THE DIFFERENCES IN FOOT AND ANKLE CHARACTERISTICS OF PATIENTS WITH LOWER LIMB OSTEOARTHRITIS - IMPLICATIONS FOR CLINICAL PRACTICE

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Sketch by Leonardo da Vinci

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Leonardo da Vinci (1452 – 1515) an outstanding genius of the Renaissance had an understanding of most sciences well beyond his time. He referred to the foot as *"un'opera d'arte, un capolavoro di ingegneria"* which translates as *a masterpiece of engineering and a work of art.*

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Acknowledgement of Illustrations

Unless otherwise stated all illustrations were supplied by the Medical Photography Department of the Nuffield Orthopaedic NHS Trust or were downloaded from the internet. Photographs were taken by the author.

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Glossary of Terms

Biomechanical podiatrist : a specialist in analysis of the biomechanics of gait

Biomechanics: the science which studies the movement or structure of living organisms using the knowledge and methods of mechanics

Closed chain exercise: carried out with feet on ground or fixed (can also be applied to upper limb) – open chain exercise: carried out without foot on ground or otherwise fixed

Close packed : in dorsiflexion the trochlear surface of the talus slides backwards into the mortice formed by the malleoli and the joint becomes close-packed, particularly as the part of the talus going into the mortice is increasingly wider

Degrees of freedom: the number of directions in which a body can move

First ray: a term in podiatry for the structures of the first metatarsal and its joints proximal to the first metatarso-cuneiform joint

Force: a physical quantity that can accelerate and/or deform a body

Forefoot: all of the foot distal to the midtarsal joint

Gait cycle: the time interval between two successive occurrences of one of the repetitive events of walking

Ground Reaction Force (GRF): the force generated on impact with the ground.

Hallux: the great toe

Hindfoot: all of the foot proximal to the midtarsal joint

Relaxed calcaneal stance : normal position of the foot in stance phase

Shear : loading mode in which a load is applied parallel to the surface of the structure causing internal angular deformation

Torque: quantity of force necessary to angularly accelerate a body, usually expressed in Newton meters

Translation: parallel motion of one surface across another

Planes of movement:

Sagittal plane divides a body into right and left portions

Coronal plane divides a body into front and back portions (also called frontal plane)

Transverse plane divides a body into upper and lower portions (also called horizontal plane)

Movements:

Adduction: an action which brings body part closer to the main body, inward movement in the coronal plane

Abduction: an action which brings body part further from main body, outward movement in the coronal plane

Flexion: an action which brings body part closer to the main body, inward movement in the sagittal plane

Extension: an action takes body part further from main body, outward movement in the sagittal plane

In the ankle flexion is called dorsiflexion and extension is called plantarflexion

Rotation: an action in which a body part turns on its axis, can be internal or inwards also called medial rotation or external or outwards also called lateral rotation

Pronation: Inward rotation about the long axis of the foot which occurs in the subtalar joint in closed chain movement
Feet can be pronated, *flat* or described as pes planus

Supination: Outward rotation about the long axis of the foot an action which occurs in the subtalar joint in closed chain movement
Feet can be supinated, *high arched* or described as pes cavus

CONTENTS

ABSTRACT

To date, the foot posture of patients with lower limb osteoarthritis (OA) has not been explored from an orthopaedic perspective. In other medical fields such as neurology and sports medicine, a relationship between foot posture, gait and pathology has been acknowledged. In view of the current high incidence of lower limb OA, investigation of any differences in foot posture in patients with lower limb OA that may lead to improved assessment and conservative management is worthy of consideration.

The first component of the thesis investigated a clinically observed difference in the foot posture of 60 patients with hip OA, 60 patients with medial compartment osteoarthritis of the knee (MCOA) and 60 healthy volunteers using an observational study. A significant difference in foot characteristics was demonstrated. Patients with hip OA demonstrated a lack of dorsiflexion and a greater degree of calcaneal inversion, presenting with a supinated foot. Patients with MCOA demonstrated ample dorsiflexion and a greater degree of calcaneal eversion, presenting with a pronated foot. In general, the healthy volunteers demonstrated average dorsiflexion and average calcaneal eversion and this gave the appearance of a normal foot. This did not, however, provide evidence of any causal relationship.

A pre and post operative observational study of 55 patients with MCOA who underwent the Oxford unicompartmental knee arthroplasty was then undertaken. As a result of this surgery there is a major correction of varus to valgus knee orientation which is significant clinically and statistically. Although there is a major change in knee orientation, this study showed that the foot posture was not altered. This study also does not provide evidence that foot posture is causal in the development of MCOA. It does, however, give an indication of the robustness of the foot postures of these patients.

The second component of the thesis was concerned with clinical outcome measures for the assessment of foot posture in patients with lower limb OA. Currently there is no standard practice for physiotherapists. Routine examination of the foot is rare. Two systems of measurement: (a) The Foot Posture Index and (b) the F-Scan in-shoe pressure measurement system were examined in detail with a cohort of patients with lower limb osteoarthritis. The two measurement systems were found to be useful in a clinical setting and sensitive enough to support the findings in Component 1 of the thesis. In addition, the use of the Foot Posture Index score allowed investigation of the relationship between foot posture and talocrural dorsiflexion. A high degree of talocrural dorsiflexion corresponds with a positive FPI score indicating a pronated foot. A low degree of dorsiflexion corresponds with a negative FPI score indicating a supinated foot. This is the first time that talocrural dorsiflexion has been shown to be associated with foot posture, although previously it has been accepted anecdotally in clinical podiatry.

The third component was a systematic review which explored the current clinical practice of using lateral wedges in the conservative management of MCOA by orthopaedic surgeons. This contrasts with the use of *medial* wedges in the world of sports medicine, physiotherapy and podiatry to correct over-pronation problems. As the foot posture of patients with MCOA had been shown to be pronated, it was felt necessary to examine the evidence for the use of lateral wedges. The systematic review found no strong evidence to support the use of lateral wedges in the conservative management of MCOA.

Finally, the main findings of the thesis are discussed, the findings summarised and suggestions made for clinical practice and further research.

CHAPTER 1. INTRODUCTION AND AIMS OF RESEARCH

1.1 OVERALL AIM OF THESIS

The overall purpose of this thesis was to explore a clinically observed difference in the foot posture of patients with lower limb osteoarthritis and to consider the implications of this for physiotherapy practice. This has not previously been examined, although in other medical fields such as neurology and sports medicine, a relationship between foot posture, gait and pathology has been acknowledged. In view of the current high incidence of lower limb osteoarthritis and the subsequent increase in demand for joint replacements, any new information is worthy of consideration as it might lead to improved assessment and add to the treatment options in the conservative management of lower limb osteoarthritis.

1.2 RESEARCH OBJECTIVES

The thesis was divided into three component parts with distinct objectives:

1.2.i. Component 1

The purpose of component 1 was to investigate the clinically observed difference in the foot posture of patients with hip osteoarthritis (OA) and those with medial compartment osteoarthritis of the knee (MCOA).

A further investigation sought to assess the impact of unicompartmental knee replacement surgery on foot position and lower limb alignment.

1.2.ii Component 2

The second component was concerned with clinical outcome measures for the assessment of foot posture in patients with lower limb OA. Two measurement systems were examined, the Foot Posture Index (Redmond et al, 2006) and the F-Scan in-shoe pressure measurement system. Neither has previously been used in a clinical physiotherapy setting. The study sought to investigate the effectiveness of these tools in the clinical evaluation of patients with lower limb osteoarthritis.

1.2.iii. Component 3

Current orthopaedic literature recommends the use of lateral wedge orthoses in the conservative management of MCOA. Currently, this is the only conservative biomechanical intervention concerned with the foot which is recommended. If, as postulated, patients with MCOA have a pronated foot position then this practice is questionable. It was thought appropriate, therefore, to carry out a systematic review of the literature on lateral wedges to ascertain what benefits, if any, this practice offered to the patient.

HYPOTHESES

H_1 Patients with osteoarthritis of the hip and patients with medial compartment osteoarthritis of the knee have different foot postures.

NULL HYPOTHESES

H_{O1} There is no difference in the foot posture of patients with medial compartment osteoarthritis of the knee and patients with hip osteoarthritis.

1.3 STRUCTURE OF THESIS

Chapter 1 - introduction and aims of research

Chapter 2 - provides the background and literature related to the anatomy and biomechanics of the foot

Chapter 3 - provides background and literature related to osteoarthritis, especially MCOA and hip OA.

Chapter 4 - presents reliability of measurement of foot posture and joint range of movement

Chapter 5 - presents the method, results and discussion of the observational component 1 study

Chapter 6 - presents the method, results and discussion of the pre and post operative observational study of component 1

Chapter 7 - introduces component 2 with an overview of clinical outcome measures for the foot. Two measures are subjected to more in-depth clinical study. It presents the methods, results and discussions of both the Foot Posture Index and the F-Scan system studies.

Chapter 8 - presents the methods, results and discussion of the systematic review of component 3

Chapter 9 discusses the main findings of the thesis, states the conclusion and makes suggestions for further research.

CHAPTER 2. BACKGROUND

2.1 GENERAL

The ideal foot posture is one which demonstrates no evidence of either over-supination or over-pronation (Figures 1 - 2). The effect of variation of talocrural dorsiflexion and calcaneal angle resulting in a supinated/high arched or pronated/flat foot has only recently begun to be examined (Manoli, 2005). However, it is anecdotally accepted in podiatry circles that flat or pronated feet are characterised by large ranges of talocrural dorsiflexion and high arched or supinated feet are characterised by small ranges of talocrural dorsiflexion (Figures 3 - 6).

Figure 1 – Posterior aspect view of a normal foot

Figure 2 – Medial aspect view of a normal foot

Figure 3 - Posterior aspect view of a supinated or high arched foot of a patient with hip OA showing more of medial toes than lateral toes and inverted calcaneus

Figure 4 – Medial aspect view of a supinated foot of a patient with hip OA showing high arch

Figure 5 – Posterior aspect view of a pronated or flat foot of patient with medial compartment OA knee showing more of lateral toes than medial and also everted calcaneus

Figure 6 – Medial aspect view of a pronated foot of patient with medial compartment OA knee showing medial arch almost totally in contact with ground

The effects of foot postures on lower limb musculoskeletal injuries have been widely reported (Fu and Feldman, 1990; Tiberio, 1987; Evans, 1990). Much of this work focuses on the effects on younger people, particularly athletes, or on older active runners. A study of U.S. marine recruits found that supinated feet were more susceptible to stress fractures than pronated feet as they were less able to absorb shock (Kaufman et al, 1999). In the same study, pronated feet were found to be associated with shin splints or knee pain. Other studies have demonstrated the relationship between foot postures and athletic problems such as patellar pain and lower extremity overuse injuries (Powers et al, 2002). It has been suggested that supinated feet are inflexible (Giladi et al, 1985), while pronated feet are more mobile than normal (Mann and Hagy 1981). In one study, athletes with either pronated and supinated feet have been shown to have significantly more knee pain than a group with neutral foot characteristics (Dahle et al, 1991). Nigg et al (1993) suggest that a functional relationship between arch height and knee injury may exist. Sports medicine has, therefore, had a long tradition of considering the foot in its management of lower limb soft tissue problems.

In neurology, a more comprehensive approach has been adopted in the consideration of the pathology of gait in patients with neurological problems.

The mobility of the foot and ankle is seen as essential for effecting transfer of body weight from one leg to another (Edwards, 2002). It is acknowledged that restriction of dorsiflexion of the talocrural joint will necessitate complimentary adjustments such as hip hitching (Duffy and Cosgrove, 2002). In the young patient with neurological problems such as cerebral palsy, correction of foot posture is often attempted with casting, botulinum injection or orthotics while the foot is still flexible (Duffy and Cosgrove, 2002).

The effects of different foot posture and ranges of motion in the healthy, adult, non-athletic population has been the subject of a study by Hogan and Stahell (2001). The population studied was workers in a grocery chain store who were aged 18 to 65. This paper did not report that either pronated or supinated feet were associated with problems of ambulation. It was suggested by the authors that an explanation for their findings was that those individuals who did have disabilities derived from foot posture, might not have remained in this kind of employment. An interesting finding was that in this normal population the incidence of both pronated and supinated feet was relatively low and most individuals were in the mid range group. Unfortunately, the ages of the subjects with feet which demonstrated the extremes of dorsiflexion were not given. This would have been relevant as it has been shown the dorsiflexion decreases with age (Boone et al, 1981) and it is suggested that pronated feet can also develop in the adult (Henceroth and Deyerie, 1982) and need not have been present in early years. Attempts made to discover the ages of these subjects through communication with the Hogan and Stahell (2001) have not met with success. The subjects were of working age and since OA is a disease which affects mainly the elderly, this study did not attempt to link foot posture and the incidence of any osteoarthritic symptoms.

Considering the fact that OA of the lower limb is one of the most important causes of pain and disability in the ageing population (Felson, 1998; Lawrence et al, 1998) it is surprising that there has been so little research looking at the influence of foot postures on lower limb OA. The only other work to date is by Gross et al (2007) in which a relationship between forefoot varus and ipsilateral hip pain and hip OA was noted. It was suggested that this is a risk factor and is potentially modifiable with foot orthoses.

MCOA has been proposed as a distinct clinical pathologic entity from standard knee OA. The specific localisation of the lesions to the anteromedial quadrant of the knee suggests it is mechanically driven (White et al, 1991). It was the marked confinement of OA to this area, and the fact that this is the contact area of the femur and tibia when the leg is extended during midstance phase of gait, that led to the investigation of the subtalar joint, which re-supinates at this phase of the gait cycle. In the same way hip OA is localised to the superolateral aspect of the acetabulum which may be indicative of the involvement of a mechanical factor (Murray and O'Connor, 1998). This area is loaded immediately after heel strike up to the early mid stance phase of gait when normal pronation of the subtalar joint occurs. These localised OA lesions on the lower limb joints are strongly suggestive of a biomechanical aetiology which may be connected with the biomechanics of the foot.

By examining talocrural range of movement, calcaneal angle and foot posture in patients with lower limb OA in this study, a unified approach, combining elements of orthopaedics, physiotherapy and podiatry is presented.

2.2 ANATOMY

An overview of lower limb anatomy is given to describe the principle structures involved in the biomechanics of gait. The main anatomical bony landmarks of the joints and the most important muscles producing movement at the joints are described to familiarise the reader and to contextualise the work presented later in the thesis concerning lower limb OA and alteration of biomechanical loading.

2.2.i The ankle joint complex

The foot and ankle joint complex consists of the talocrural joint and the subtalar joint (Figure 7).

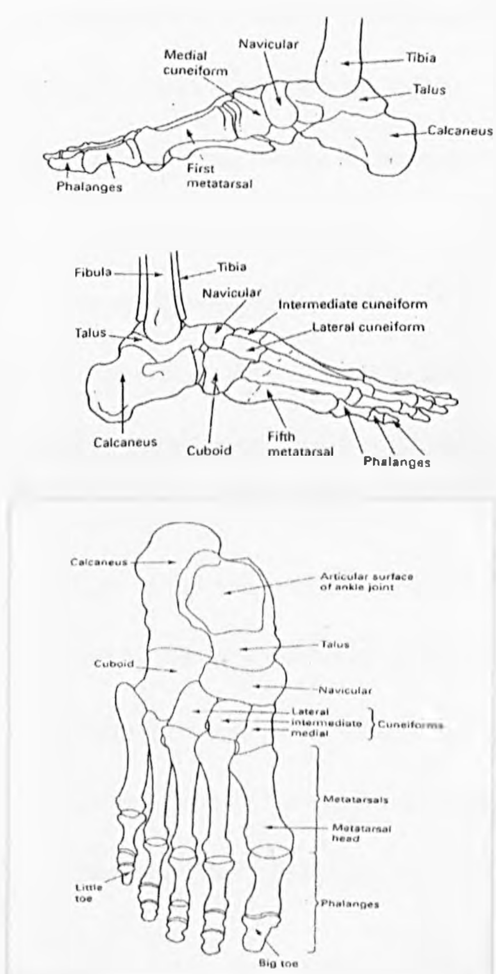

Figure 7 - Medial, lateral and superior view of the bones of the foot and ankle joint complex

2.2.ii The talocrural joint

The talocrural joint is the articulation between the talus and distal tibia and fibula (Figure 8). The proximal joint surface is the concave surface of the distal tibia and tibial and fibular malleoli. The distal joint surface is the convex dome of the talus. The joint capsule is weak anteriorly and posteriorly but is reinforced medially by the deltoid ligament and laterally by the anterior and posterior talofibular ligaments and the calcaneal-fibular ligament (Norkin and White, 1985). The body of the talus is wedge-shaped from front to back, being wider anteriorly (Palastanga et al, 1994). Full dorsiflexion is the position of least laxity, reflecting its geometry. The anterior and posterior ligaments of the joint are localised thickenings of the joint capsule; neither appears to play any major role in ankle stability. In contrast the anterior talofibular ligament (Figure 9) appears to be an extremely important structure and can probably be considered as the primary stabiliser of the ankle as it maintains the close packed position of the talocrural joint in dorsiflexion (Palastanga et al, 1994). The interosseus membrane between the tibia and fibula proximal to the talocrural joint acts as a fibrous joint and works with the anterior talofiblular ligament in its stabilising function (Palastanga et al, 1994) (Figure 9).

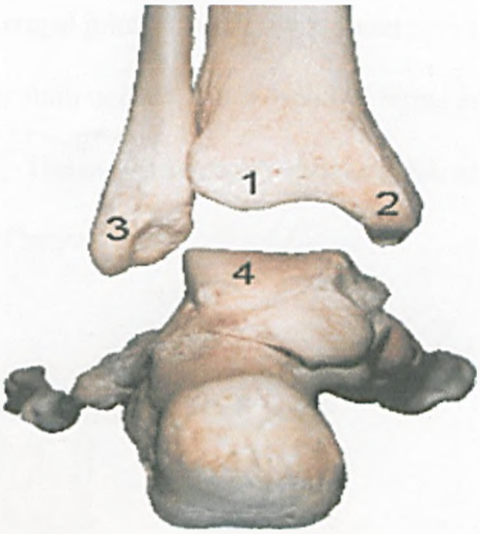

Figure 8 - The ankle joint complex showing the lower end (1) and medial malleolus (2) of the tibia and the lateral malleolus (3) of the fibula and the trochlear surface of the talus (4)

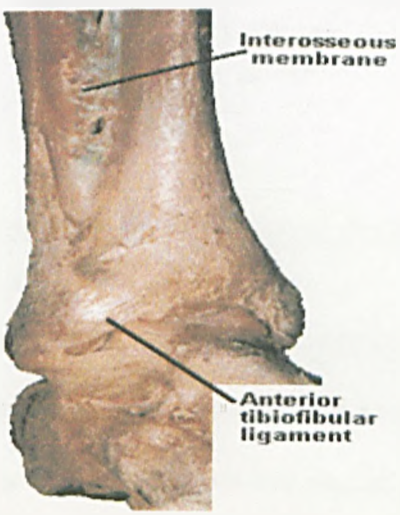

Figure 9 - The anterior tibiofibular ligament and interosseus membrane

The talocrural joint is the fulcrum about which sagittal plane movements of the lower limb occurs. It is a synovial hinge joint with one degree of freedom. The movements which take place are dorsiflexion and plantar flexion (Figure 10).

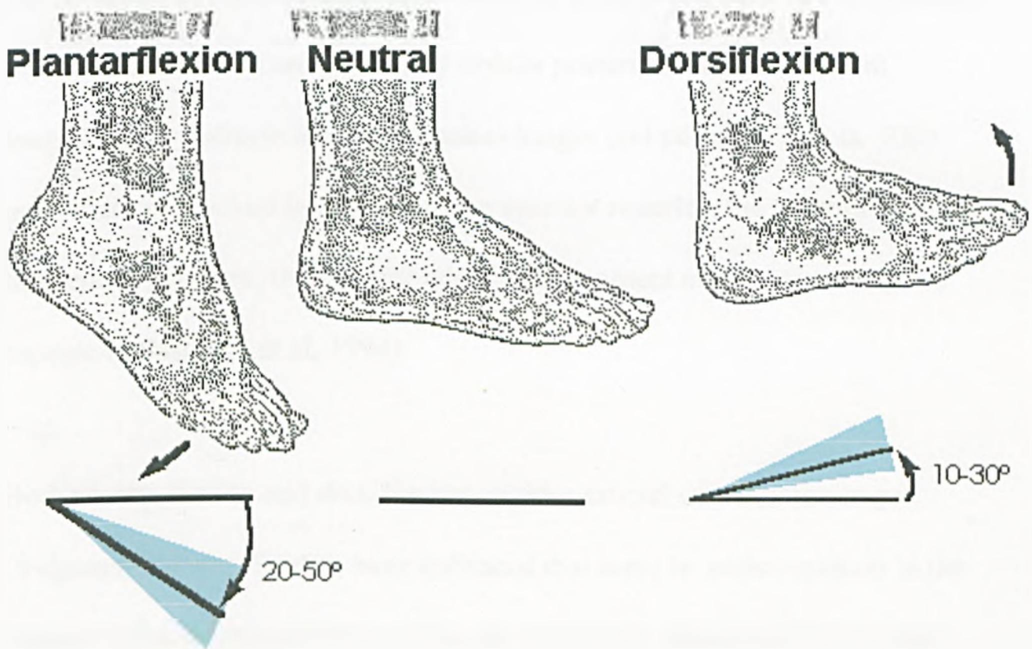

Figure 10 - Showing plantar flexion, the neutral position and dorsiflexion

These occur around an oblique axis which is mainly, but not purely, in the sagittal plane. Dorsiflexion is an upwards and lateral movement, plantar flexion is downwards and medially (Norkin and White, 1985). Dorsiflexion is produced by the tibialis anterior, extensor hallucis longis, extensor digitorum and peroneus tertius muscles crossing the joint anteriorly. It is limited by tension in the gastrocnemius and soleus, the posterior part of the deltoid ligament, the calcaneofibular ligament and the posterior joint capsule and the wedging of the talus between the malleoli.

Plantar flexion is brought about mainly by soleus and gastrocnemius. However, all of the muscles which enter the foot behind the malleoli produce plantar flexion at the ankle, namely tibialis posterior, flexor digitorum longus, flexor hallucis longus, peroneus longus and peroneus brevis. This movement is checked by tension in the anterior muscles, the anterior part of the deltoid ligament, the anterior talofibular ligament and the anterior joint capsule (Palastanga et al, 1994).

Both plantar flexion and dorsiflexion, make a crucial contribution to gait (Valmassy, 1996). Studies have indicated that there is wide variation in the range of talocrural dorsiflexion (Waugh et al, 1983; Roaas and Andersson, 1982; Saxema and Kim, 2003. Work with young dancers has indicated that ankle joint dorsiflexion is already fixed by age of eight indicating that dorsiflexion is probably blocked by bony apposition rather than soft tissue (Bennell et al, 2001; Khan et al, 2000). Although the range for the individual appears to remain fairly constant in early life, Boone et al (1981) demonstrated that dorsiflexion decreases over the age of sixty by approximately 50%.

2.2.iii The subtalar joint

The subtalar joint articulates posteriorly between the concave facet on the inferior surface of the talus and a convex facet on the calcaneus. Anterior and middle articulations are formed by the two convex facets on the talus and the two concave facets on the calcaneus. Laterally it is reinforced by the anterior-lateral and medial talocalcaneal ligaments and the interosseus talocalcaneal ligament (Norkin and White, 1985). Interestingly, the talus has no muscular attachments, depending on ligaments and its alignment to other joints for its movement.

The subtalar joint is a plane synovial joint with one degree of freedom. Movement at the sub-talar joint takes place in the horizontal plane. The motion which takes place is inversion and eversion which occur around an oblique axis. In inversion the calcaneus slides laterally on a fixed talus, in eversion the calcaneus slides medially on the talus (Kisner and Colby, 1992). Whilst the foot is weight bearing, in a closed chain position, the same movements are conventionally described using the terms pronation and supination.

Subtalar joint motion is very complex and the reported range of movement is very variable. Norkin and White (1985) suggest using a conventional goniometer, and taking the measurement with the patient non-weightbearing in a prone lying position. The range they suggest is 0° - 5° of inversion and 0° - 5° of eversion. However, since it is in a weightbearing position during gait that the subtalar joint is interacting with the hip and knee, range of motion of the subtalar joint derived from navicular height measurements might be more pertinent (Williams and Clay, 2000).

2.2.iv The medial longitudinal arch

During relaxed standing, little intrinsic or extrinsic muscle activity occurs in the foot and the medial longitudinal arch (MLA) is maintained primarily by static supporting elements (Basmajian and Stecko, 1963). In addition, the passive structures of the foot have energy storage capabilities and much of the energy required for locomotion is stored by means of these elastic structures (Ker et al, 1987). The structures contributing to overall stability of the MLA in order of importance are the plantar fascia, the long and short plantar ligaments and the calcaneonavicular or spring ligament. The plantar fascia or aponeurosis is the thickest fascia in the body being up to 80 mm thick. It is triangular in shape with the apex at the heel spreading out anteriorly into five slips which pass forwards and become continuous with the fibrous flexor sheaths of the toes (Palastanga et al, 1994). It spans the transverse tarsal, tarsometatarsal and metatarsophalangeal joints. Dorsiflexion of the metatarsophalangeal joints places traction on the plantar fascia and causes elevation of the arch through a mechanism known as the "windlass effect" (Hicks, 1953). Figures 11 and 12 illustrate this mechanism which can be demonstrated by flexing the hallux. In a normal or supinated foot this activates the "windlass effect" and the arch springs up. In a pronated foot it is not possible to flex the hallux as it is weightbearing and the spring effect is lost (Hicks, 1953). The spring ligament forms a sling for the talar head, which prevents medial and plantar migration and therefore provides static arch support (Davis et al, 1996).

Figures 11 and 12 - Demonstrating the windlass effect

The beam model can be used to describe the medial longitudinal arch of the foot (Sarrafian, 1987). This states that the arch is a curved beam made up of interconnecting joints whose structure is dependent on joint and ligamentous interconnections for stability. Tensile forces are produced on the inferior surface of the beam mainly through the plantar fascia and compressive forces are concentrated on the superior surface of the beam through the close packed position of the bones of the foot. Neuropathic joint changes, trauma or excess loading may disrupt the bone and joint support of the arch, leading to arch collapse and a resultant rocker bottom foot deformity. This foot type does not demonstrate a medial arch but curves in the opposite direction, essentially like a rocker. The sequelae of joint destruction lends credence to the beam model of arch stability (Nordin and Frankel, 1989).

2.2.v Overview of the ankle joint complex

Unlike the knee and hip joint, the ankle joint complex does not, for the most part, combine movement in the horizontal plane with movement in the sagittal plane within the same joint. Dorsiflexion and plantar flexion at the talocrural joint takes place in the sagittal plane. Pronation and supination at the subtalar joint takes place in the horizontal plane (Reigger, 1988). This may possibly explain the fact that idiopathic ankle joint OA is much rarer than that of the knee or hip. A recent epidemiological study of ankle arthritis reports that only 7% of cases of ankle arthritis were idiopathic, whereas 70% were post trauma and 12% due to rheumatoid disease (Saltzman et al, 2005). This is in direct contrast to hip and knee arthritis where the primary cause is idiopathic (Altman, 1986). It may be that a joint which is less mechanically complex, with only one degree of freedom, may demonstrate less wear than the more biomechanically intricate joints at the hip and knee.

2.2.vi The knee joint

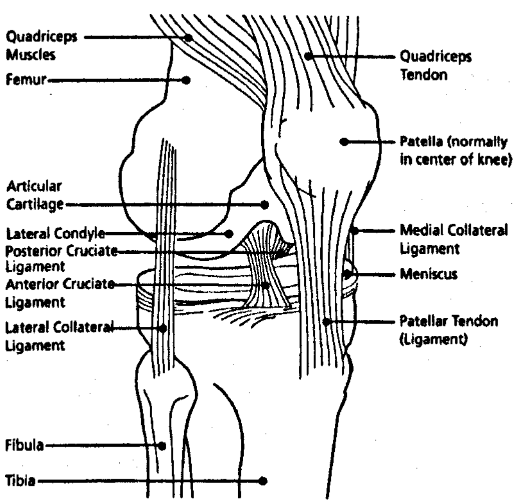

Figure 13 - The knee joint

The knee joint (Figure 13) has the greatest surface area and is most complex joint in the body (Palastanga et al, 1994). It is situated between the body's two longest lever arms (Figure 13). It comprises two condylar joints between the medial and lateral condyles of the femur and the medial and lateral plateaux of the tibia and a gliding joint between the patella and the patellar surface of the femur (Snell, 1986). It is a synovial hinged joint with most movement taking place in the sagittal plane but with some rotation in the transverse plane. Additionally, there are accessory movements within the joint during movement. Weber and Weber described the mechanism of the femur rolling backwards on the tibia during flexion and forwards during extension as early as 1836.

The knee has very strong ligamentous support both within and outside the synovial capsule. The intracapsular anterior and posterior cruciate ligaments cross each other within the joint cavity and form the main bond between femur and tibia (Snell, 1986). The anterior ligament prevents posterior displacement of the femur on the tibia. The posterior cruciate prevents anterior displacement of the femur on the tibia. The cruciates are the key contributing structures to overall joint stability (O'Connor et al, 2003). The lateral collateral ligament is cordlike and attaches to the lateral condyle of the femur and the head of the fibula. The medial collateral ligament is a broad flat band, attached above to the medial condyle of the femur and below to the medial surface of the shaft of the tibia. It is also attached to the edge of the medial meniscus. The collateral ligaments help prevent sideways movement of the femur on the tibia. In addition the ligaments act together to stabilise the joint. This is particularly noticeable in full extension when all the ligaments twist and tighten and the knee becomes a mechanically rigid structure (O'Connor et al, 2003). The close integration of all these elements is vital to the smooth function of the knee (Welsh, 1980). The extended knee is held firmly and rotation of the tibia and femur occurs concurrently. In cases of ligamentous laxity, the knee may hyperextend or bend backwards. It is then said to be in a locked position (Snell, 1986) being held in place by stretched ligaments without muscular contribution.

The knee differs from other joints in that it has two menisci, medial and lateral. They are load bearing structures which offer an improved contour for femoral articulation by deepening the articular surfaces of the tibial condyles and thereby appear to act as shock absorbers.

The major movements of the knee joint are flexion and extension in the sagittal plane. The muscles involved in flexion are biceps femoris, semitendinosus, and semimembranosus, assisted by gracilis, sartorius and the popliteal muscles (Palastanga et al, 1994). Flexion is limited by contact of the soft tissues at the back of the leg with the thigh. Extension is carried out by quadriceps femoris. Extension is limited by ligaments. Medial rotation is performed by sartorius, gracilis and semitendinosus, lateral rotation by biceps femoris. Rotation occurs in the transverse plane and the ligaments described above provide stability in extension (Palastanga et al, 1994).

2.2.vii The hip joint

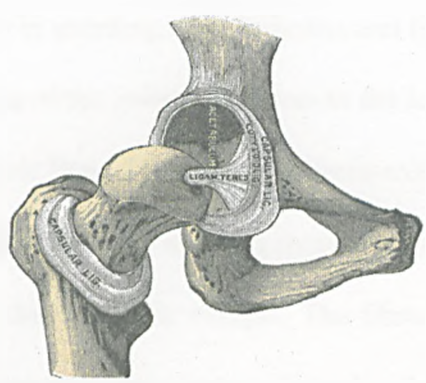

Figure 14 - The hip joint

The hip joint is the most stable joint of the body (Nordin and Frankel, 1989). It is a ball and socket joint, but when standing erect the femoral head is not completely covered by the acetabulum, the anterosuperior aspect being exposed. The ball is the hemispherical head of the femur and the socket is the cup shaped acetabulum (Palastanga et al, 1994) (Figure 14). The hip has a wide range of movement and its' strength largely depends on the shape of the bones and on the very strong ligaments. It must be capable of supporting the entire weight of the body, as in standing on one leg, and also of allowing stable transference of the weight, particularly during movement of the trunk on the femur as occurs during walking and running. It is, therefore, the pivot upon which the upper part of the human body is balanced, particularly in gait (Palastanga et al, 1994).

The iliofemoral ligament is attached to the anterior inferior iliac spine above and to the intertrochanteric line of the femur below. It helps prevent overextension in standing. The pubofemoral ligament is attached to the superior ramus of the pubis and below to the lower part of the intertrochanteric line. This ligament limits extension and abduction. The ischiofemoral ligament is spiral in shape and is attached to the body of the ischium near the acetabular margin. The fibres pass upwards and are attached to the greater trochanter. This also limits extension. The transverse acetabular ligament is formed by the acetabular labrum as it bridges the acetabular notch, this converts the notch into a tunnel through which the blood vessels and nerves enter the joint. The ligament of the head of femur is attached to the head of the femur and to the transverse ligament – it lies within the joint and is enclosed in the synovial membrane (Snell, 1986).

Flexion at the hip joint is performed by iliopsoas, rectus femoris and sartorius, aided by the adductor muscles (Palastanga et al, 1994). Extension is performed by the gluteus maximus and the hamstring muscles. Gluteus medius and minimus, sartorius, tensor fasciae latae and piriformis all work in abduction. Adduction is performed by adductor longus and brevis, the adductor fibres of the adductor magnus and assisted by pectineus and gracilis. Lateral rotation is performed by piriformis, obturator internus and externus, superior and inferior gemelli, quadratus femoris and gluteus maximus. The anterior fibres of gluteus medius and minimus and tensor fasciae latae are responsible for medial rotation. Both ligaments and muscles have to work more strongly in extension to maintain the upright posture (Palastanga et al, 1994).

2.3 GAIT

For the purposes of this study the terms 'gait' and 'walking' are considered to be interchangeable. Strictly speaking, gait refers to the manner of progression, whereas walking is used to describe the process of locomotion (Jones and Barker, 1996). In this study the term "gait" will be used. The earliest truly scientific approach to the study of gait was in the classic 'De Motu Animalum' published in 1682 by Borelli who was a student of Galileo. Borelli (1682) measured the centre of gravity of the body and described how balance is maintained in gait by constant forward movement of the supporting area, i.e. the feet (Whittle, 1991). Gait is usually a smooth, well co-ordinated activity using a repetitious sequence of limb motion to move the body forward while simultaneously maintaining balance (Perry, 1992). It is by far the most common daily activity exerting the greatest repetitive forces through the joints of the lower limb (Morrison, 1970).

The lever system of the long bones in the lower limbs is responsible for transmitting body weight (Isman and Inman, 1969) allowing forward progress. This system operates through the foot and ankle complex which is multi-functional. It is one of the most dynamic structures of the skeletal system (Palastanga et al, 1994), strong enough to support the weight of the body on ground contact but supple enough to absorb shock. It is malleable to accommodate uneven surfaces and yet also resilient to provide the "spring" in gait (Beckett et al, 1992). In the non-weight bearing position the foot moves on the leg in an open chain movement. In weight bearing the leg moves on the foot and the movement is said to be a closed chain. The talocrural joint is the fulcrum of sagittal movement of the lower limb and the forces acting at the ankle, when transmitted upwards along the long lever arm of the lower limb, are greatly increased.

During gait, for the main part, motion takes place in the sagittal plane but rotation in the transverse plane also plays an important role (Planes of Motion - Figure 15). The axes of motion in the foot and ankle are, however, aligned obliquely to the cardinal planes of the body. The ankle can be said to function using simple hinge joint motion but the anatomical orientation is complex (Oatis, 1988).

Movement in the sagittal plane allows the body's centre of mass to move along a horizontal trajectory (Evans, 1990). However, transverse plane movement is also necessary. Rotation of the pelvis about a transverse axis facilitates advancement of the lower limb. In order to keep the trunk, head and eyes facing in a forward direction, rotation of the cervical and lumbar spine must occur in the opposite direction. In order to step in a forward direction, the hip externally rotates and the subtalar joint supinates. The top and bottom of the body rotate in the same direction which is opposite to the direction in which the pelvis moves. These rotational movements are scarcely perceptible in contrast to the large sagittal movement but without these movements neither the eyes nor the feet would move in a straight line. After ground contact and during weight acceptance the subtalar joint pronates and the hip joint internally rotates as the pelvis reaches a neutral position. The pelvis then once again rotates about a transverse axis, this time in the opposite direction (as the contralateral limb moves forward). The subtalar joint then resupinates and the hip extends. At the talocrural joint movement is almost all in the sagittal plane (Norkin and White, 1995). The inherent capacity of the hip, knee and subtalar joint for rotatory movement can be utilized to increase stride length (Evans, 1990).

The amount of rotation at each joint is small, but since walking is the main weight bearing activity of the body the effects of the forces that this rotation produces can be significant over time. Gait is usually observed in the sagittal plane where these transverse movements are not apparent and their significance had not always been recognised.

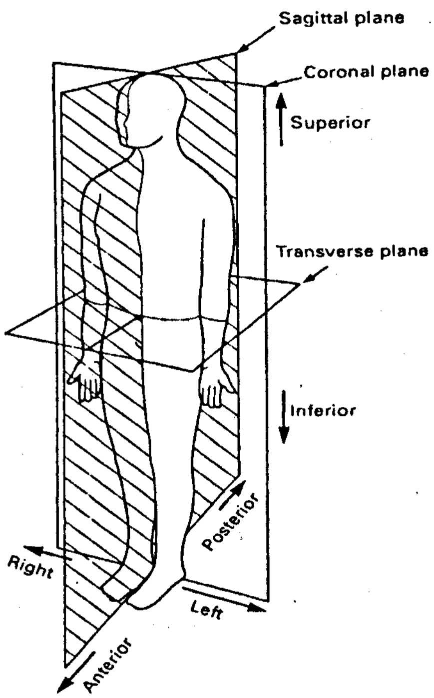

Figure 15 - Planes of motion

As a cyclical activity, gait can be analysed in one cycle to represent a whole period of activity. One full gait cycle is the interval of time from heel strike of one foot to the next heel strike by the same foot. The gait cycle consists of 60% stance phase and 40% swing phase (Nuber, 1988; Root et al, 1977). The stance phase is when the foot is in contact with the supporting surface and the swing phase when the lower extremity is advancing forward to renew ground contact. Initial contact to midstance is the most demanding part of the gait cycle as, in addition to weight acceptance, the foot and lower limb have to perform three other separate functions: shock absorption on contact, balance and smooth progression of forward movement (Perry, 1992).

2.3.i Sagittal plane movement at the ankle joint complex

The contact and weight acceptance phase begins when the heel strikes the ground and continues until the entire foot is on the ground. Midstance extends from foot flat until the heel lifts off the ground. As soon as the foot is flat on the ground, the ground reaction force (GRF) begins to move forwards along the foot (Whittle, 1991) (Figure 16). The stage of the gait cycle from heel contact to foot flat is sometimes called the initial rocker or heel pivot. The talocrural joint is the fulcrum of movement with body mass moving directly over it (Geiringer, 1995). As the GRF moves forwards, the heel lifts and propulsion occurs and extends until the foot leaves the ground

(Figure 16). The GRF has a magnitude equal to bodyweight at the point of application - between the foot and the ground (Nordin and Frankel, 1989).

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Figure 16 - Direction of ground reaction force (GRF) at different stages of the gait cycle
^Reproduced from Gait Analysis. Michael Whittle. 19911

2.3.Ü Transverse plane movement at the ankle joint complex

In addition to this sagittal movement at the talocrural joint, transverse movement in the subtalar joint occurs (Dannenberg and Guiliano, 1999). When the heel strikes the talus is in a supinated position but moves almost immediately into pronation. This causes a shift of the GRF away from the lateral half of the plantar foot to the medial half caused by the medial deviation of the talar head crossing the vertically directed line of force (Kirby and Green, 1992). With this movement, the foot becomes supple to adapt to the ground surface and also to act as a shock absorber. In late midstance, resupination occurs at the same time as external rotation of the weightbearing limb (Fu and Feldman, 1990). The GRF moves forward and laterally during midstance then, as the medial arch stability develops, the weight is transferred medially in preparation for propulsion. Body weight passes over the foot from mid-stance to push off (Kirby and Green, 1992).

2.3.iii Biomechanics of the hindfoot during normal gait

At heel strike the foot is plantarflexed and the calcaneus is inverted, indicating that the subtalar joint is in a supinated position, thus giving a rigid platform for weight acceptance (Tiberio, 1987). Tibialis anterior, extensor digitorum longus and the extensor hallucis longus all decelerate the foot to prevent it slapping the ground. The foot then moves into dorsiflexion and pronation to become a flexible unit to accommodate changes in the ground surface and to absorb the shock of gait - closed chain pronation (Harradine, 2003). Soleus then reacts quickly to restrain the rate of ankle dorsiflexion and thus controls forward progression also simultaneously contributing to stability. The calcaneus becomes everted, the head of the talus slides medially and plantarflexes and the navicular drops (Root et al, 1977). Motion at the subtalar joint and tibial rotation are interdependent in the weight bearing foot (Norkin and Levangie, 1982; Durrell, 1995). This is a consequence of the tight fit of the talus into the talocrural joint mortice, because the talus is wider anteriorly. At foot flat with weight acceptance through to midstance, the foot remains a mobile adapter to ground changes thereby improving balance. At the end of midstance, the foot is starting to resupinate. The actions of soleus and gastrocnemius prevent additional movement of the talocrural joint so the heel rises as the tibia continues to advance (Perry, 1992). Progression and stability are both served by the normal balance between mobility and muscular control of the two plantar flexor muscles.

The plantar fascia, which is stretched during pronation, rebounds to assist resupination; this is part of the windlass effect (Hicks, 1953) (see Figures 11 and 12). The calcaneus inverts and there is an upward movement of the navicular. The talus is pushed up and out and the tibia, which is locked in the mortice of the talocrural joint, follows into external rotation. Peroneus longus and tibialis posterior then pull the foot up into close packed position, stabilising the first ray, thereby allowing it to plantarflex as bodyweight progresses forward. This closed packed position converts the foot to a rigid lever for push off, able to withstand forces which can reach many times body weight during this phase of the gait cycle. The hallux may then extend and toe off occurs on this rigid lever.

2.3.iv Interdependence of lower limb biomechanics in gait

Mechanically, the contact or weight acceptance phase of gait is the most important, because this is when the lower limb needs to absorb the ground reaction force by joint motion and eccentric muscle work. Normally, at initial contact or heel strike, the foot is plantar flexed and the subtalar joint is in a supinated position. This provides a rigid platform for weight acceptance (Tiberio, 1987). The knee moves into full extension and external rotation and the femur rolls forward on the tibia. The hip joint is flexed and also externally rotated. The rigidity caused by the supinated foot and the extended knee is necessary to accept body weight. Almost immediately, however, the knee flexes 15 – 20 degrees, controlled by the action of the quadriceps muscles. At the same time the tibia internally rotates while the subtalar joint pronates and the hip also moves into internal rotation as it moves into extension. All these mechanisms serve to transmit and diffuse ground reaction forces and also allow the foot to adapt to uneven surfaces. Knee extension is then initiated in conjunction with re-supination of the subtalar joint and continues during midstance to push off while the hip is extending. The knee joint at this point demonstrates a varus moment which is the dominating moment demonstrated in normal gait.

It is no chance occurrence that after heel strike and during weight acceptance, the knee and hip flex and inwardly rotate when the subtalar joint pronates and then, when the subtalar joint supinates, the knee and hip extend and externally rotate (Fu and Feldman, 1990). The synchronous actions of the knee hip and subtalar joint, during the contact and midstance phases, are interdependent motions and the rotation of the tibia and femur are obligatory actions for normal kinetics of both joints (Tiberio, 1987). Body weight passes over the foot from midstance to push off and the contralateral limb moves forward.

2.4 PATHOPHYSIOLOGY RELATED TO FOOT POSTURE

2.4.i The Supinated Foot

The supinated foot is associated with diminished pronation (Cornwall and McPoil, 1999). This influences the amount of internal rotation of the lower limb. At heel strike, the mortice of the talocrural joint holds the tibia in external rotation when the foot is supinated and the knee is extended. At this time the femur is in external rotation. After initial acceptance of body weight, immediately following heel strike, if pronation of the subtalar joint is diminished, the knee remains extended and the hip remains externally rotated as the pelvis moves in a posterior direction in the transverse plane. This results in a rotatory torque at the hip joint, as, in normal gait, the hip would be in an internally rotated position at this time.

The supinated foot is also, anecdotally, associated with less than the normal range of dorsiflexion which means less than 10° to 15° (Kirby and Green, 1992). After weight acceptance, diminished dorsiflexion inhibits body weight from passing over the foot from the midstance to the push off phase, it cannot pass over the extended knee and must therefore pass over the extending hip. The hip is at this time in an externally rotated position. Additional upwards trunk movement on the same side may be observed as the body weight progresses over the hip. Additionally, with insufficient pronation initially, the shock absorbing effect is decreased or lost. It also results in a lack of some degrees of knee flexion which normally occurs with pronation (as described in 2.3.iv) so the shock absorbing mechanism of knee flexion is also decreased. The hip joint which is the more proximal joint in the closed kinetic chain will therefore have increased shock.

2.4.ii The Pronated Foot

After initial heelstrike, the foot moves into dorsiflexion and pronation in order to become a flexible unit which accommodates changes in the ground surface and to absorb shock. Pronation should be present for the first 25% of the midstance phase. Resupination should then follow. When the foot remains pronated to midstance, the major abnormality that occurs is that the ground reaction force remains in the medial side of the plantar foot. The vertically directed line of force, acting through the tibia and talus during weightbearing activities, is shifted medially in relation to the weight bearing plantar structures of the foot (Kirby and Green, 1992).

The shift in the line of force means resupination and external rotation of the tibia, which should occur in the push off phase of gait, are prevented. This is considered abnormal as it produces an internal rotation moment of the tibia in the weight bearing knee, at the same time as the contralateral pelvic advancement produces an external rotation moment of the femur (Tiberio, 1987). The knee is then placed under significant axial torsion load. Over time, by excessive repetitive loading of the soft tissue structures in the knee joint as the result of this biomechanical predisposition the capacity of the tissues to adapt is exceeded and a cellular and inflammatory vascular response results (Bogdan et al, 1987). Excessive pronation of the midfoot can alter foot posture. A pronated foot, with calcaneal eversion or valgus, is frequently found in the hyperpronation syndrome in athletes (Kannus, 1992).

Excessive, or prolonged, pronation can lead to lowering of the medial arch and can occur as a result of general inherent ligamentous laxity, decreased ligament tensive resistance or increasing loads, e.g. obesity (Kirby and Green, 1992). Obesity is a known risk factor for MCOA (Sharma et al, 2001).

2.5 CONCLUSION

In conclusion, the biomechanics of the foot and ankle have an important and close relationship with those of the knee and hip during gait, particularly after the initial heel strike and during the mid-stance phase of the gait cycle.

CHAPTER 3. OSTEOARTHRITIS

3.1. BACKGROUND

OA is a major public health problem. As estimated by the World Health Organisation, it is one of the major causes of impaired function which reduces health worldwide (Wluka, 2006). It is a major cause of pain and disability and an important health care burden. The societal burden is expected to increase with the increasing prevalence of obesity and the ageing of the community (Hunter and Felson, 2006). Affecting mainly the knee and hip joints, it occurs in up to 25% of people of 65 years of age (Bush et al 2003). It is, by far, the most common disease to affect the synovial joints (Pendleton et al, 2000). The development of OA is a multifactorial process in which mechanical factors have a central role (Hunter and Felson, 2006).

It is characterised, in particular, by defects or abnormalities of articular cartilage, changes in the joint capsule, subchondral bone and bony margins of the joint (Altman and Dean, 1989). However, there are no agreed criteria for OA knee in population studies (Spector et al, 1993). The radiographic scoring of Kellgren and Lawrence (1957) has been the system most used in the past.

The Kellgren–Lawrence grading scale: grade 1, doubtful narrowing of joint space and possible osteophytic lipping; grade 2, definite osteophytes and possible narrowing of joint space; grade 3, moderate multiple osteophytes, definite narrowing of joints space, some sclerosis and possible deformity of bone contour; grade 4, large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour.

There is some correlation between radiographic disease severity, symptoms and functional limitations. However, the relationship is not strong and this is the main difficulty in attempting to establish a single definition (Moskowitz et al, 2001). Spector (1993) suggests that the Kellgren and Lawrence grade 3 and the presence or absence of a definite osteophyte read by a single observer with an atlas are the best methods of defining OA of the knee for epidemiological studies.

The clinical signs are:

1. Joint pain which is usually worse after use
2. Pain at night or after rest (usually a sign of more advanced disease)
3. Minimal joint stiffness, bony swelling and crepitus
4. Radiographic finding of osteophytes, subchondral schlerosis and joint space narrowing
5. Lack of chemical evidence of a systemic inflammatory process.

The criteria for classification of idiopathic osteoarthritis of the knee defined by American College of Rheumatology (Altman et al, 1986) combines both clinical, radiographic and laboratory scores and gives a fairly comprehensive view of the disease (Figure 17).

Clinical and laboratory	Clinical and Radiographic	Clinical ± -
Knee pain	Knee pain	Knee pain
+ at least 5	+ at least 1 of 3	+ at least 3 of 6
- Age > 50 years	Age > 50 years	Age > 50 years
- Stiffness < 30 minutes	Stiffness < 30 minutes	Stiffness < 30 minutes
- Crepitus	- Crepitus	- Crepitus
- Bony Tenderness	+ Osteophytes	- Bony Tenderness
- Bony Enlargement		- Bony Enlargement
- No palpable warmth		No palpable warmth
- ESR < mm/hour		
- RF < 1:40		
- SF OA		
92% sensitive 75% specific	91% sensitive 86% specific	95% sensitive 69% sensitive

ESR = erythrocyte sedimentation rate (Westergren)

ESR 95% limits)	Age (years)		
	20	**55**	**90**
Men	10	14	19
Women	15	21	23

RF = rheumatoid factor

SF OA signs of OA (clear, viscous, or white blood cell count < 2,000/mm^3)

+ Alternative for the clinical category would be 4 of 6, which is 84% sensitive and 89% specific.

Figure 17 - Criteria for classification of idiopathic osteoarthritis of the knee defined by American College of Rheumatology

Although it is traditionally considered a disease of the elderly, being relatively rare before the age of forty, OA is not an inevitable consequence of aging. There is no evidence that the normal joint, subject to normal stresses, will break down during the life span of an individual (Ogata et al, 1997). Regular use does not appear to precipitate OA. In fact, the relationship between habitual physical activity and OA in aging women is shown to be favourable (White et al, 1991).

The incidence of OA appears to be greater in the developed world, but these statistics may change. Increased life expectancy in some third world countries may contribute to the future incidence of OA, as well as more comprehensive reporting and indeed more request for medical help. Until now most studies have been carried out in the developed world and there are only a few studies on the prevalence, pattern or clinical course of OA in the tropics or in even less developed areas (Adebajo, 1995).

In the UK, most patients with OA will be managed in the community and primary care setting (Peat et al, 2001) and this is where strategies to prevent or modify the condition will have to be targeted. OA sufficiently severe to consider joint replacement still represents a minority of all pain and disability in the older patient. Currently therapy is divided into categories of physical, pharmacological, surgical and psychological measures to provide relief (Altman and Dean, 1989).

3.2 AETIOLOGY OF OA

Although the occurrence of OA is commonplace, the aetiology is complex, embracing both biomechanics and biochemistry (Felson et al, 2000). It is most likely that OA is the result of an acquired process initiated much earlier in life through mechanical, genetic or other origins (Felson et al, 2000). Lower limb weight bearing joints are particularly susceptible to local biomechanical factors such as muscle weakness and joint laxity (Felson et al, 2000). These local factors are specific to the joint site and in some instances to the joint compartment (White et al, 1991). This concurs with Sharma's view that OA can be viewed as the result of local factors acting within the context of joint susceptibility (Sharma, 2001). It is also acknowledged that significant mal-alignments may produce increased risk of OA (Tetsworth and Paley, 1994). The important part played by mechanical axis deviation around the knee in OA knee has been acknowledged (Guichet et al, 2003). The part played by the foot during the gait cycle in lower limb biomechanics has not featured in studies on knee alignment in MCOA.

The disease is marked by changes in articular cartilage which becomes yellowed, soft, pitted, uneven, fissured and ulcerations may develop. Subchondral bone may develop cysts while marginal osteophytes develop at the periphery of the joint (Altman and Dean, 1989). Related changes in the surrounding capsule, synovium and periarticular structures are often noted.

It appears that the regeneration which occurs in cartilage in everyday life is inadequate in OA (Altman and Dean, 1989). Interestingly, normal cartilage lacks innervation so defects in cartilage, although a major manifestation of the disease radiographically, are not the source of pain which is a major presenting symptom. Possible sources of pain are joint capsule distention, stretching of periosteal nerve endings and possibly synovial inflammation (Oddis, 1996). In some cases of severe inflammation the clinical signs appear superficially similar to rheumatoid arthritis. However, the symptoms are often observed in a single joint reinforcing the view that mechanical factors play a significant role in the initiation of the disease (Felson et al, 2000; Sharma, 2001).

There have been suggestions that knee OA, particularly tibiofemoral OA, is on the increase (Dieppe, 2000; Wluka, 2006). Rogers and Dieppe (1994) undertook a comprehensive survey of skeletons from a number of ancient

English burial sites. They found that hip OA was more common than knee OA in our ancestors, and that most of the knee OA in older times was due to patella femoral joint disease, rather than tibiofemoral joint disease. Current prevalence data shows that tibia femoral OA is approximately twice as common as hip OA, affecting some 10% of those over the age of 50 and a significant proportion of younger adults (Felson, 1990). This is interesting as obesity is also on the increase (Mazzocchi and Traill, 2005) and there are links with obesity and OA knee (Sharma et al, 2000). Body mass index (BMI) has been shown not to be associated with onset and progression of OA hip, but to be positively associated with OA knee (Reijman et al, 2007). A recent systematic review has shown that weight reduction in patients with knee OA reduced the physical disability and relieved pain (Christensen et al, 2007). Obesity has been linked to pronated feet in children (Bordin et al, 2001; Garcia-Rodriguez et al, 1999) and also in adults (Sachithanandam and Joseph, 1995). Where ankle dorsiflexion is 10° or more, allowing body weight to pass over the foot, there may an increase in susceptibility to subtalar overpronation. Pronation is associated with obesity, which is also associated with MCOA. There may, therefore, be a link between ample dorsiflexion, pronated feet and MCOA.

Over forty years ago Trueta (1963) focused the discussion of the aetiology of osteoarthritis on biomechanical changes occurring in the deep chondral layers and subchondral bone in the degenerative joint. He argued that uneven pressures experienced by the subchondral bone in the degenerative joint produced a vascular change that altered the nutritional supply of the deep cartilage layer which caused fatal damage to the deep chondral cells. As a result of this the cartilage eventually underwent fibrillation and disintegration (Eckhoff, 1994). Knecht et al (2006) reviewed the mechanical qualities of articular cartilage and also concurred with the concept that the breakdown of the cartilage matrix preceded the fibrillation and erosion of the cartilage surface. They suggested using arthroscopy to assess early cartilage changes as a means of early detection.

In reviewing papers on this subject, Radin et al (1991) found that there was support for the concept that loading affects the stiffness of the deep chondral layers. High shear stresses have been found to cause splitting and degeneration of the cartilage base (Eckhoff, 1994). Eckhoff (1994) argues that rotation is the force which leads to asymmetry of pressure and altered patterns of shear stresses with the potential to cause degeneration of the deep chondral layers.

The effects of foot posture on supination and pronation are related to the rotary stresses imposed by the leg on the weight bearing foot (Stagni et al, 2003). Early studies (Hicks, 1953; Isman and Inman, 1969) indicate that the subtalar joint acts as a mitred hinge, that is, as a directional torque transmitter. Where the timing of supination and pronation are not synchronous with the rotational elements of lower limb gait this may have an effect on the loading of deep chondral layers of cartilage in the hip and knee joint.

Trueta (1963) also found that it was the unsatisfactory adaptation of the femoral head to its socket which leads to problems of hip OA. The femoral head is most exposed in positions of external rotation of the femur. External rotation of the femur and tibia are linked to supination of the foot.

3.3 THE WAY FORWARD

Various physical aspects of the musculo-skeletal system, alignment, muscle strength, joint laxity and proprioception have been the focus of research into lower limb OA (Hurley and Scott, 1998; Sharma et al, 1999; Felson et al, 2000; Sharma et al, 2000). These studies may encourage the development of strategies to prevent or modify the course of the disease. It has also been suggested that attention should be directed to the correction of the underlying mechanical abnormality rather than to the development of pharmacological or biological agents (Brandt et al, 2006). This is significant from an economic as well as from a medical perspective. The cost of the condition has risen over recent decades accounting for up to 2.5% of the gross national product for USA, Canada, UK, France and Australia (March and Backmeier, 1997).

Non pharmacological and nonsurgical management, such as patient education, physical therapy, weight management and orthoses are strongly recommended as the way forward (Pendleton et al, 2000; Dieppe et al, 1995; Hochbberg et al, 1995).

The effect of foot postures on the biomechanics of gait and the relevance of this to lower limb OA has not been fully investigated. The aim of this current work is to increase the knowledge base through examining the feet of patients with MCOA and hip OA.

3.4 MEDIAL COMPARTMENT OSTEOARTHRITIS OF THE KNEE

The most frequently affected joint in the knee is the medial compartment (Keyes et al, 1992). MCOA occurs spontaneously in younger adults as well as the more elderly. The predominance of MCOA most probably results from the high medial compartment forces which occur during weight bearing activities such as walking (Morrison, 1970; Schipplein and Andriacchi, 1991). This is by far the most common daily activity exerting the greatest repetitive forces through the knee. During walking, the normal forces acting on the leg produce a varus torque (i.e. a torque tending to adduct the knee into varus) (Andriacchi, 1994). This varus torque is directly associated with the compressive force across the medial aspect of the knee, which is nearly 2.5 times the force through the lateral aspect of the knee (Morrison, 1970; Schipplein and Andriacchi, 1991). However, a recent study indicates that the knee adduction moment is unrelated to the pain and disability associated with MCOA (Maly et al, 2006).

This varus torque is, however, a normal part of the biomechanics of gait (see 2.3.iv). It may be that abnormal biomechanics may be the cause of increased loading and subsequent symptomatic changes in the joint. It is also acknowledged that significant malalignments may produce increased risk of OA (Tetsworth and Paley, 1994).

Localisation of OA to the medial compartment was noted as early as 1968 when the Swedish radiologist Ahlback observed that most cases of primary OA of the knee started in the medial compartment and progressed within that compartment through three radiological stages without progressing elsewhere in the knee. Similarly, Hernborg and Nilsson (1977) recorded the natural history of OA knee and found that 90% of the lesions revealed by radiography were confined to the medial compartment. A study which examined 46 medial tibial plateaus (White et al, 1991), found that, in every case, the cartilage and bone erosion was centred anteriorly on the plateau and the posterior cartilage was intact. Figures 18, and 19 demonstrate the preservation of the posterior section of the medial compartment and the lateral compartment in Kellgren and Lawrence grade 4 MCOA.

Figures 18, 19 – Radiographs showing anterior-posterior and lateral view of a left MCOA

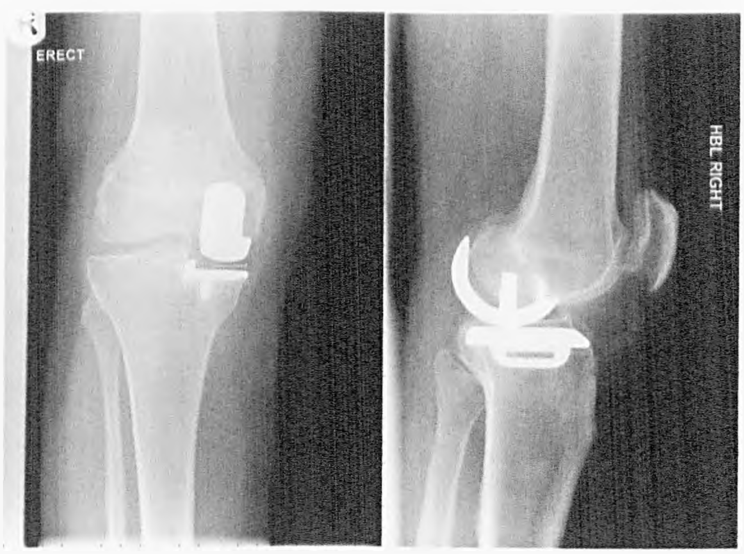
The preservation of the posterior section of the medial compartment and the fact that the cruciate ligaments were intact explains why the varus deformity was observed in these patients only when the knee was extended. In sitting (Figures 20 and 21) the unworn cartilage acts to preserve the knee joint space and subsequently the deformity does not become fixed. The consistency of these findings led to the description of medial compartment OA as a separate clinical entity.

Figures 20 and 21 - Correction of the varus deformity in sitting

3.4.i Surgical treatment of MCOA

Until the introduction of the Unicompartmental Knee Arthoplasty (UKA) thirty years ago, the treatment of choice for younger patients with MCOA knee was a high tibial osteotomy (HTO). An HTO induces valgus re-alignment of the femoro-tibial angle by wedged osteotomy of the tibia. By altering the biomechanics of the knee, through realigning the joint surfaces, static as well as dynamic loads on the medial articular surface are reduced while, at the same time, lateral loading is increased (Spahn, 2004). The knee varus torque is reduced resulting in a decrease in both knee pain and disease progression (Kettlekamp et al, 1976). Corrective osteotomies are mostly performed at the level of the proximal tibia ("high tibial osteotomy") (Spahn, 2004). The relative success of this procedure reinforces the suggestion that there is a strong mechanical contribution to MCOA (O'Connor et al, 2003). However, the results of HTO deteriorate with time (Lonner, 2003) and by 5 years, 37% may require a total knee arthroplasty (TKA), and by 10 years, 50% (Naudie et al, 1999; Nagel et al, 1996). As conversion to TKA has inherent difficulties (Mont et al, 1994) HTO in this country is usually reserved for a small group of carefully selected younger patients who have higher demands and when extended longevity is required (Moskovitz et al, 2001). The presence of patellofemoral OA also leads to poorer outcomes (Madan and Rushforth, 2002).

Currently, in many orthopaedic centres, the UKA is being used in selected cases as an alternative to HTO and TKA. "Anteromedial osteoarthritis is a distinct clinicipathological entity; its radiographic features enable it to be diagnosed from lateral radiographs; its anatomical features render it suitable for treatment by unicompartmental arthroplasty" (White et al, 1991). UKA is widely used in Europe and America. Metal backed UKAs with a meniscal bearing system have been used for 30 years. UKA is a bone stock and cartilage preserving procedure. It is less invasive than TKA, preserving the cruciate ligaments and giving better range of movement and more normal physiological function (Laurencin et al, 1991). In addition, less bone stock is removed in this procedure and both revision UKA and TKA are possible, in contrast to the difficulties after a HTO. In comparing UKA with TKA, many patients report that the knee with the UKA feels better and more normal than the TKA (Moskovitz et al, 2001). The Oxford UKA has been shown to last for ten to fifteen years (Murray et al, 1998) which is comparable to the length of time of a TKA lasts. It is also suitable for subsequent conversion to TKA if necessary.



Figures 22 and 23 - Radiographs showing Medial Oxford Unicompartmental knee, frontal and sagittal views right leg

One of the most frequently used unicompartmental prothesis is the Oxford UKA. The prosthesis design employs a spherical metal femoral component and a flat metal tibial base plate with a keel, separated by an unconstrained fully congruous high density polythene bearing (O'Connor et al, 2003) (Figure 22 and 23). The polythene meniscal bearing, concavely spherical above and flat below, can maintain congruity between the metal femoral condyle and the metal tibial plateau while allowing them complete freedom to rotate and slide upon one another. The main reason for employing meniscal bearings is to diminish polythene wear (Goodfellow, 2003).
The most recent surgical innovation, utilising a minimally invasive technique (Figure 24) and allowing accelerated discharge following UKA, has been the subject of a randomised controlled trial (Reilly et al, 2005). Patients' satisfaction and attitude to this procedure was also a subject of study (Barker et al, 2006). The hospital in which these studies were carried out has now adapted the procedure to a protocol and this has been adopted as part of standard care (Jenkins et al, 2006).

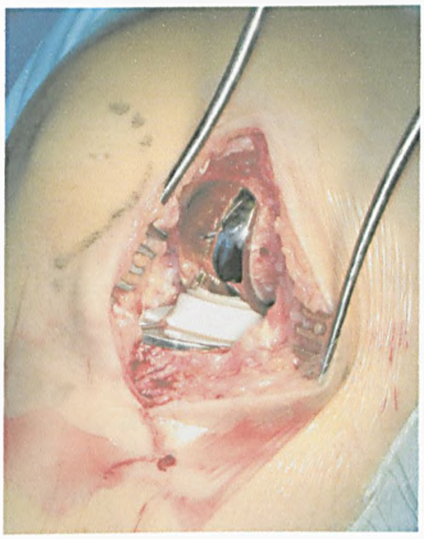


Figure 24 - Oxford Unicompartmental Knee Arthroplasty demonstrating small incision

A ten to fifteen year survival rate reported for the Oxford UKA (Murray et al, 1998) is not significantly different from the best rates for total knee replacement. Patellofemoral OA is not a contraindication and older patients are also suitable for this procedure. Fluoroscopically controlled radiographs at a mean follow-up time of 11.4 years (10-14) of 29 medial UKAs showed no change in the appearance of the lateral compartments leading to suggestions that medial compartment OA can be considered as a focal disorder of the knee (Pandit et al, 2006).

3.5 HIP OSTEOARTHRITIS

OA is the most common disease of the hip joint in Caucasian adults (Dieppe, 1995). It usually starts insidiously but in few cases can start abruptly (Jorring, 1980). Those patients who present with secondary arthritis due to congenital hip disease tend to be the younger patients and show a slow deterioration (Hartofilakidis and Karachalios, 2003). The mean age of patients with idiopathic OA tends to be higher but patients undergo a much more rapid excacerbation of symptoms. Joint pathology can precede symptoms by years and the start of pain may be associated with minor trauma in an already diseased joint (Dieppe, 1995). Early physical signs include restriction of internal rotation and abduction of the affected hip, with pain at the end of range. Superolateral wear of the acetabulum has been identified in hip OA as a local mechanical factor (Murray, 1998). The earliest radiographic sign seen in idiopathic OA is limited wear of the articular cartilage at the superolateral part of the joint space and, as a result, narrowing of the joint space (Hartofilakidis and Karachalios, 2003) (Figure 25).

Figure 25 - Radiograph of right hip showing Grade 4 Osteoarthritis

There is evidence that maintaining a full range of joint motion and strong muscles may reduce the risk of the disease progressing as well as greatly decreasing pain and disability (Dieppe, 1995). Heel lifting as a conservative therapy for hip OA (Ohsawa and Ueno, 1997) has been suggested, but this has not met with much critical approval as yet. This treatment did not change the natural course of hip OA but was suggested as a simple and effective treatment for relief of hip pain for those unable or unwilling to take pain inflammatory drugs (NSAIDs) have been widely used for pain relief but the side effects have recently received much adverse publicity. For very severe pain or disability, the surgical option is usually recommended.

3.5.i Surgical treatment of hip OA

Total hip arthroplasty (THA) (Figure 26) remains the mainstay of treatment most often performed to relieve pain and restore function in patients who have extensive damage to the hip joints as a result of OA, rheumatoid arthritis, avascular necrosis, traumatic arthritis, some hip fractures and benign or malignant tumours (Trudelle-Jackson, 2002). OA accounts for 70% of elective cases (Siopack and Jergensen, 1995.

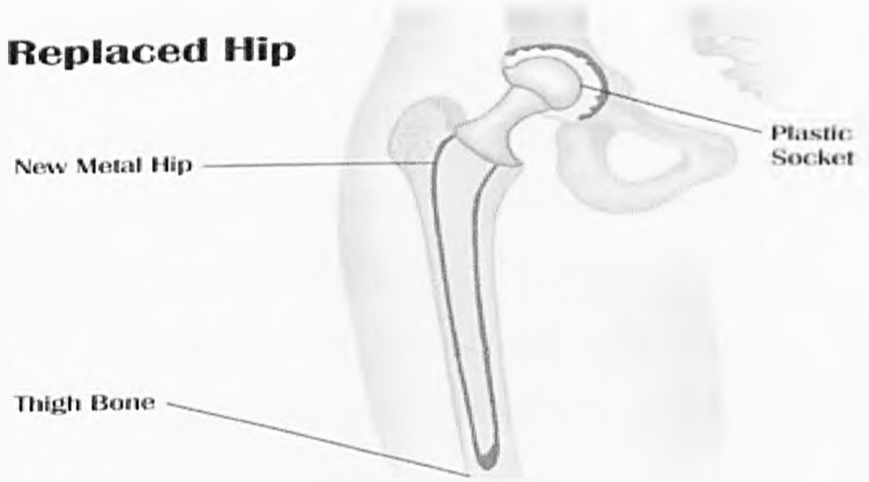


Figure 26 - Total Hip Arthroplasty

Osteotomy or fusion are rarely considered in Britain or North American such is the success of the THA. However osteotomy remains a viable alternative to joint replacement for the relief of pain, particularly when economic factors are dominant and it is still widely used in many parts of the world with less highly developed health economies (Amstrutz and Kin, 1992). THA is not a new procedure but it continues to evolve with improvements in implant design, biomaterials, and surgical technique.

CHAPTER 4. RELIABILITY OF MEASUREMENTS OF FOOT POSTURE AND JOINT RANGE OF MOTION

4.1 INTRODUCTION

The range of motion measurements of the foot and ankle complex which are undertaken in the following studies were selected as a result of careful consideration of the literature. These measurements needed to be precise and accurate. Therefore, before commencing the data collection of foot posture and range of motion, the reliability of the methods of measurement was tested.

4.1.i Measurement Reliability

Reliability of joint measurement refers to the amount of agreement between successive measurements of the same joint. There are two types of reliability that are of interest: intra-tester and inter-tester. Intra-tester reliability refers to the amount of agreement between measurements of the same joint by the same tester. (Norkin & White, 1995). Inter-tester reliability refers to the agreement of two or more testers measuring the same entity. Since almost all measurements in these studies were taken by the author, intra-tester reliability was tested on the outcome measures used in the studies.

Papers have been published on the reliability of goniometer measurements (Watkins et al, 1991; Gogia et al, 1987; Rothstein et al, 1983) and experience shows that both the position of the limb and the alignment of the goniometer are important (Norkin & White, 1995). Therefore, a protocol was established for the goniometric measurement of talocrural dorsiflexion.

Similarly, standardised methods for the other measurement tools were established. These protocols are described below.

The intra-tester repeatability of the Foot Posture Index, talocrural dorsiflexion, calcaneal angle and navicular height in sitting were examined to establish the reliability of these measures in a clinic based setting.

4.2 METHOD

4.2.i Subjects

Subjects for this study were 20 healthy volunteers from within the hospital, 16 female and 4 male. The minimum age was 25, maximum 55, mean age 34.11 (S.D. ± 10.43). There were no exclusion criteria applied to the volunteers as intra-tester reliability would not be affected by foot or ankle pathology.

4.2.ii Equipment

1) The Foot Posture Index (Redmond et al, 2006)
2) Protractor (Helix, Made in England)
3) A Gollenhon extendable goniometer, model 01335 (Layfayette Instrument Company, Lafayette, Indiana, USA)
4) Ruler in centimeters (Helix, Made in England).

4.2.iii Measurements

a) The Foot Posture Index score
b) Talocrural dorsiflexion in degrees
c) Calcaneal angle in degrees
d) Navicular Height in sitting in centimetres

(a) <u>The Foot Posture Index</u>

The FPI is made up of a composite score of 6 clinical features. These are:

1. Talar head palpation
2. Supra and infra lateral malleolar curvature
3. Calcaneal frontal plane postion
4. Prominence in the region of the talonavicular joint

5. Congruence of the medial longitudinal arch
6. Abduction/adduction of the forefoot on the rearfoot

Full explanations of each of these clinical criteria are detailed in the guidelines published by the author of the FPI (Appendix 3). Normal values are given as 0 to +5, the pronated foot +6 to +9 (highly pronated +10) and the supinated foot -1 to -4 (highly supinated -5 to -12).

Protocol : All observations were made with the subject in relaxed standing with double limb support. They were asked to take several steps on the spot and then to relax and stand still, with their arms by their side and looking straight ahead. Foot posture was assessed visually and palpated, the data recorded on a standardised form and the summary score calculated.

(b) **Talocrural dorsi flexion**

Figure 27 - Talocrural dorsiflexion

For this study dorsiflexion was measured using a Gollenhon extendable goniometer, model 01335.

Protocol : The volunteer was seated and the knee flexed by the physiotherapist to 45 degrees. This is sufficient to negate the effects of gastrocnemius shortening. The volunteer was then asked to hold the position and to dorsiflex the talocrural joint. A line was drawn horizontally along the lower border of the shaft of the 5th metatarsal. A marker was made on the lateral side of the leg midway between the anterior and posterior aspects of the tibial plateau. A second marker was made midway between the anterior and posterior aspects of the ankle at the level of the malleolus. A line was drawn to connect these two markers. The arms of the goniometer were placed on these lines and the fulcrum on a dot which was drawn approximately on the centre of the lateral malleolus. Every effort was made to maintain STJ neutral and to prevent the use of trick movements to gain increased dorsiflexion range.

(c) <u>The calcaneal angle – standing calcaneal inversion/eversion measurement</u>

Figure 28 - Calcaneal angle

Calcaneal angle was measured using a plumb line and a protractor (Helix, Made in England)

Protocol : The calcaneal angle was measured with subjects weightbearing in relaxed stance. To achieve as normal a standing position as possible the volunteer was asked to march on the spot for four steps and then relax. A plumb line was dropped bisecting the lower limb and marked three times equidistantly from mid-gastrocnemius region to floor. A line was drawn to join these marks. The examiner then sat behind the opposite foot, in order to accommodate the medial curve of the calcaneus. A line was drawn bisecting the calcaneus. The angle between the two constructed reference lines was measured.

(d) Navicular height

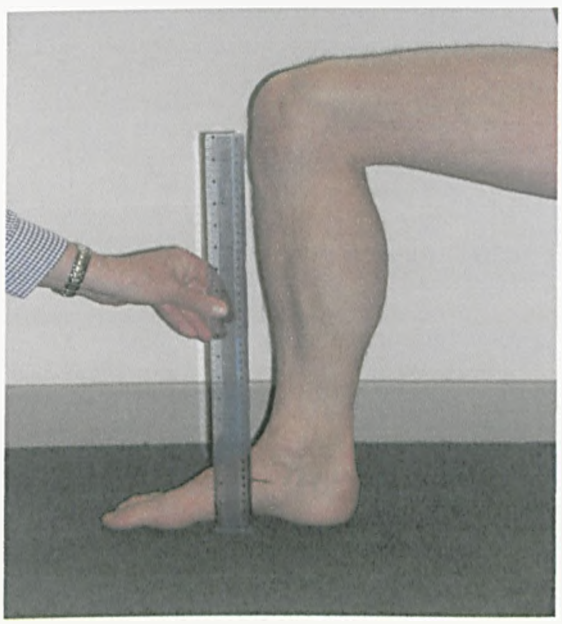


Figure 29 – Navicular Height in sitting

Navicular height in sitting was measured using a Ruler (Helix, Made in England) which was divided into centimetre and millimeter increments. Protocol : The volunteer was seated in a chair with the knee bent to 90 degrees, the ankle also at 90 degrees (using blocks if necessary) and the knees parallel. The examiner marked the skin using a horizontal line on the navicular tuberosity on each foot. A ruler was used to measure the distance between this point and the supporting surface (navicular height in sitting). This was recorded in centimetres.

4.2.iv Reliability Testing Procedure

The design sought to replicate the clinical situation in which these measurements would be taken. In the clinic right or left legs would be measured depending on the site of the lower limb osteoarthritis. In the reliability study the allocation of either right or left limb was randomly allocated using a computer generated randomisation list. For goniometric measures, after setting the angle of the goniometer, it was handed to a recorder to read the range of motion. This ensured that the tester did not recall the measurements taken. All other measurements were recorded on a standardized data sheet which was stored by an independent observer. One week later, the measurements were taken again and recorded on a new recording sheet which was again given to an independent observer. All data was entered onto an SPSS data base by the independent observer.

4.3 DATA ANALYSIS

The concept of reliability is complex and different statistical methods can be used to demonstrate aspects of reliability (Bruton et al, 2000). An interclass correlation coefficient ($ICC_{2,1}$) which reflects both systematic error and random differences in test scores is generally accepted as the preferable method of quantifying reliability (Guyatt et al, 1987). This along with the Bland and Altman agreement test (1986) allows useful interpretation of the data and gives a level of reliability that can indicate if differences between tests are clinically acceptable. Neither test alone provides sufficient information and it is recommended that both are used in reliability studies (Rankin & Stokes, 1998, Chinn, 1991).

4.3.i Intra-Tester Variation

Statistical analysis was performed using Bland and Altman's method of assessing reliability (Bland & Altman, 1986) and by the Intraclass Correlation (Shrout & Fleiss, 1979, Bland & Altman, 1996). The Intra-class correlation coefficient (ICC) is a single index calculated using variance estimates obtained through ANOVA and thus reflects both degrees of consistency and agreement among ratings. However, it tends to give a high level of agreement in cases where the between – subjects variance is large and it does not give an indication of the magnitude of disagreement between measurements. The Bland & Altman method indicates a range of error and any bias in measurements. It also presents the data in a way that is easily interpreted visually. Bland & Altman plots of the difference between the first and second measurements versus the mean of the two measurements were constructed for intra-tester reliability for each of the four methods of measurement.

4.4 RESULTS.

4.4.i Intra-tester Reliability

Calculations of reliability according to ICC and Bland & Altman method are shown in Tables 1 and 2.

Bland & Altman plots of the difference in range versus the mean range are shown in Figures 30 – 34.

Table 1 - Intra-rater repeatability using Intraclass Correlation Coefficients

Intra-rater measures	Sum Squares Within Subjects	Total Sum of Squares	I.C.C
FPI	0.40	10.00	0.97
Talocrural Dorsiflexion	0.22	67.50	0.98
Calcaneal Angle	0.40	8.00	0.98
Navicular Height in sitting	0.02	0.41	0.98

Table 2 – Results for Bland and Altman method of intra tester repeatability

Intra Rater Reliability	Mean difference	Standard Deviation Difference	Std.Error Mean	95% C.I.for mean difference	Reliability Coefficient	95% limits agreement
Foot Posture Index (score)	-0.20	1.01	0.22	-0.67, 0.27	2.02	-2.99, 1.77
Dorsiflexion (degrees)	-0.15	2.66	0.59	-1.39, 1.09	5.32	-5.36,5.06
Calcaneal Angle (degrees)	-0.20	0.89	0.20	-1.39, 1.09	1.78	-1.95,1.55
Navicular Height Sitting (cms)	-0.12	0.21	0.05	-0.11, 0.08	0.42	-0.42,0.39

The mean differences for repeated measures were all close to zero. The error standard deviation was higher for the dorsiflexion.

There was no trend in the data, showing that the size of measurement error did not increase or decrease with the total range of motion.

Interactions between subject and tester were searched for manually by examining the cases where either tester or subject showed outliers on the data plots against raw data. No suggestions of any such interactions was found.

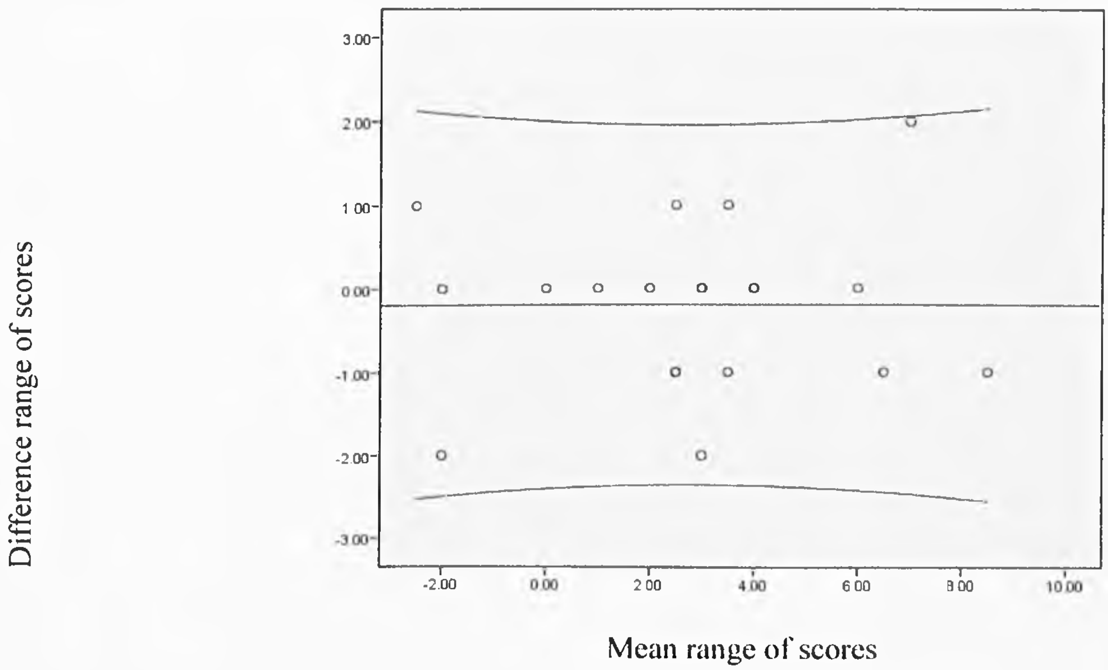


Figure 30 – Bland and Altman plot of Foot Posture Index intra-tester results

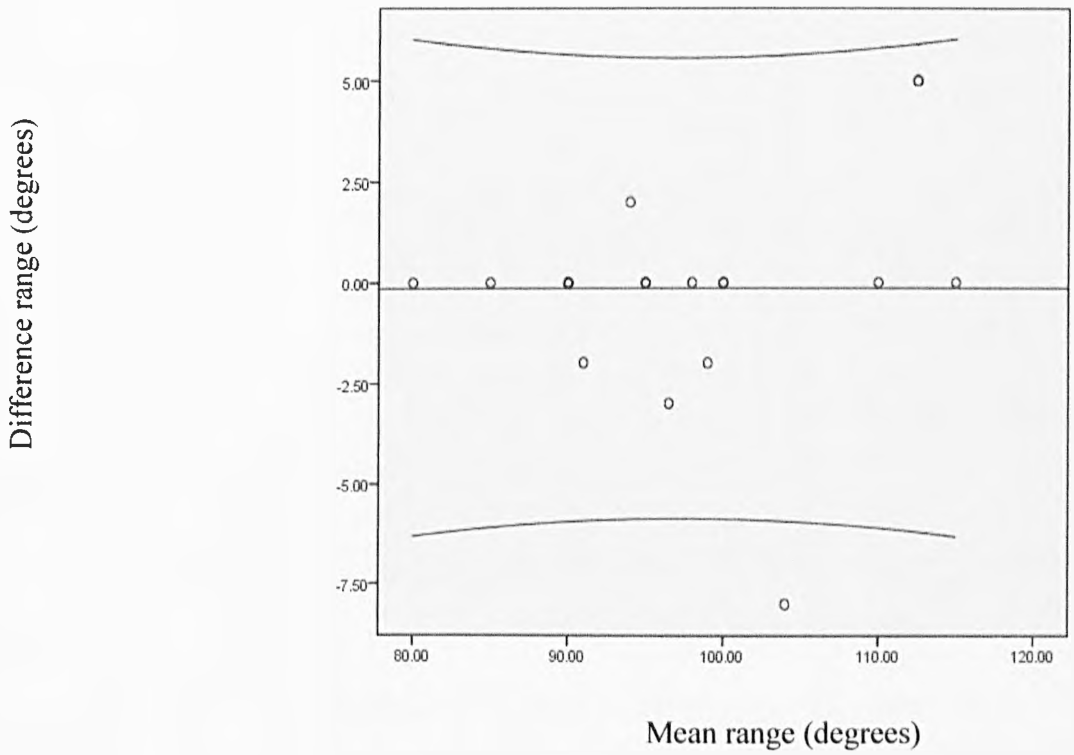


Figure 31 - Bland and Altman plot of Dorsiflexion measurements intra-tester results

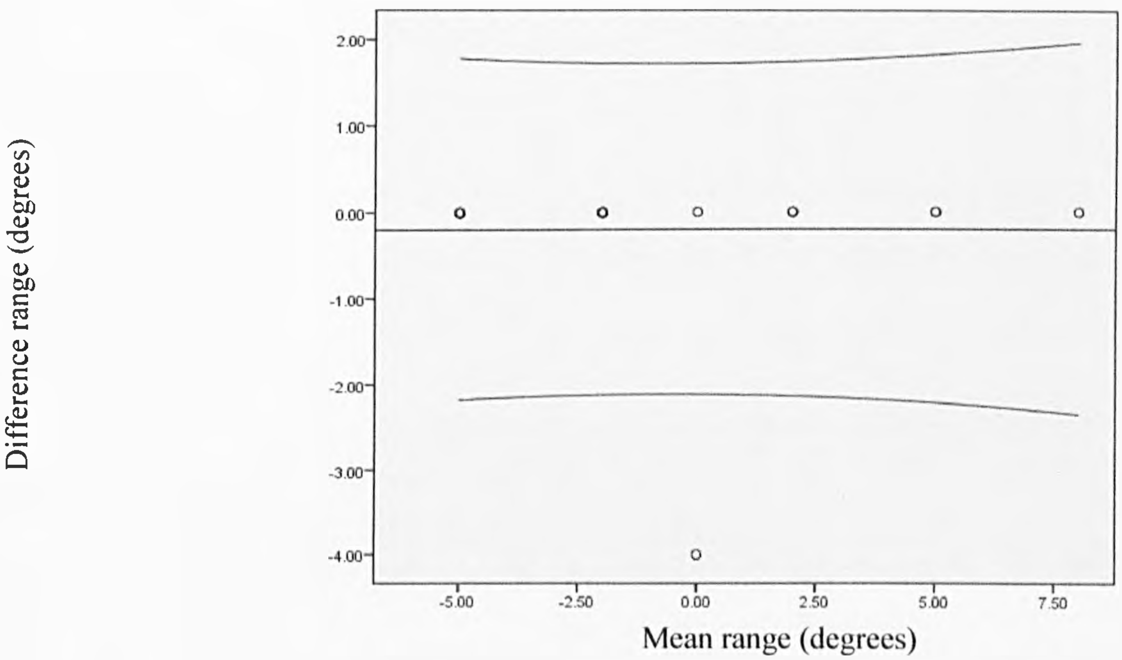


Figure 32 – Bland and Altman plot of Calcaneal Angle measurement intra-tester results

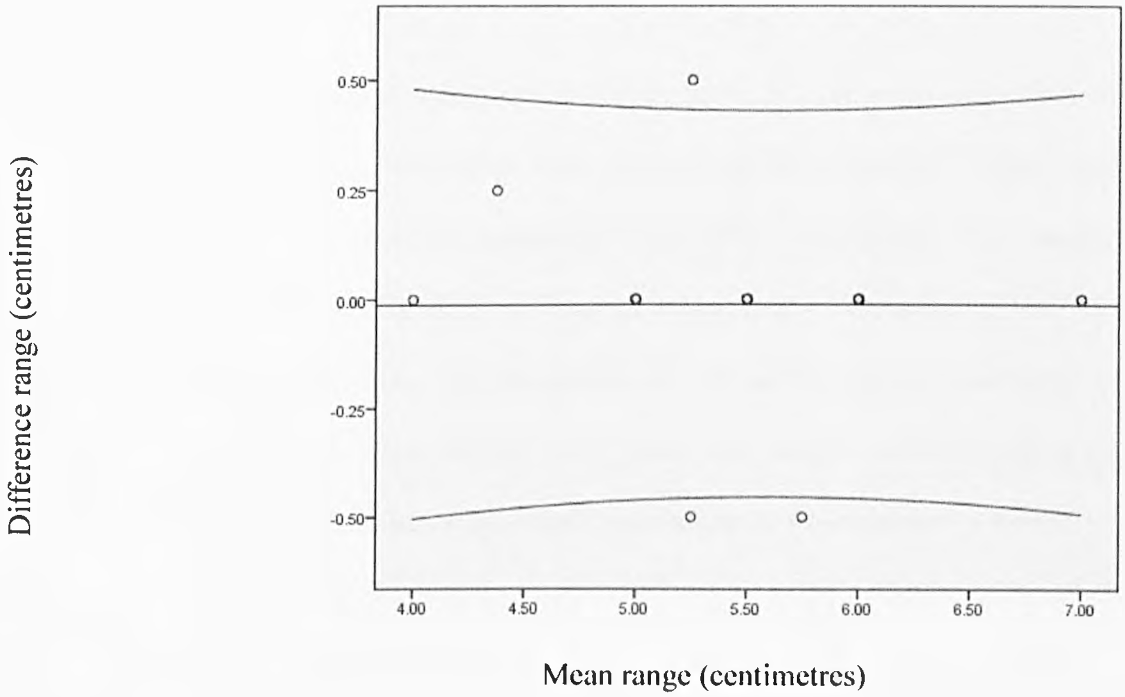


Figure 33 – Bland and Altman plot of Navicular Height in Sitting measurement intra-tester results

4.5 DISCUSSION

There is a need to demonstrate that clinical measurements are accurate and reliable. This study showed that the foot and ankle complex measurements taken by the author demonstrated a high level of reliability. It is probable that the reliability of the methods of measurement were good because standardised protocols were established for each of the measures under investigation. Patient positioning, tools used, and the marking of anatomical landmarks with pen were established before commencement of the test-retest. It has been suggested that the position of the patient significantly contributes to the measurement error in measurements of passive knee extension (Watkins et al, 1991). Errors may, however, still occur in identifying the anatomical landmarks, and by error in reading the goniometer. These sources of error are likely to be present irrespective of the method of measurement and represent the true clinic based situation.

Bland & Altman's method of assessing reliability was chosen as it was felt to be the best method of comparing agreement between the measurements, avoiding the errors in interpretation that can arise from the use of correlation coefficients (ICC). ICC is the ratio of between subject's variance to the sum of error variance and subject variance. If the between subjects variance is high, that is, the data comes from a heterogeneous sample, then the reliability will inevitably be high. ICC is also difficult to interpret clinically, as it gives no indication of the magnitude of disagreement between measurements. However, ICC has the advantage of being easy to understand and is useful when multiple sets of observations are taken (Bruton et al, 2000). In accordance with the suggestions of Rankin & Stokes (1998) and Bruton et al (2000) both the intra-class correlation coefficient and Bland & Altman's method were calculated.

The results presented here show that high levels of ICC were achieved with all methods of measurement with values varying between 0.97 and 0.98. These figures taken alone, would suggest good reliability with all methods. However, as there was a large degree of heterogeneity within the sample, these figures are likely to be falsely inflated. The reliability measured by the Bland & Altman method is thought to be more reliable in this sample.
It is difficult to separate all the components of variation that occur in the clinical setting, but it was felt that the assumptions made in the data analysis were robust. The level of reliability achieved with the goniometer was influenced by two outliers. This may have occurred as a result of the tester being unable to prevent the subtalar joint pronating to enhance the amount of talocrural dorsiflexion. Although attempts were made to retain the subtalar

joint neutral position, this is difficult to achieve as the movements are closely linked biomechanically. Given that the 95% limit of agreement for dorsiflexion was 10°, it was considered necessary in subsequent studies to measure talocrural dorsiflexion three times and take the mean. It was felt that this would improve the reliability of the measurement. All other measurement protocols were considered sufficient for the purposes of use in the observational studies in this thesis.

4.6 SUMMARY

The repeatability of range of motion measurements taken was acceptable with reservation as discussed above.

CHAPTER 5. DIFFERENCES IN THE FEET AND ANKLES OF PATIENTS WITH DIFFERENT SITES OF LOWER LIMB OSTEOARTHRITIS – A PROSPECTIVE OBSERVATIONAL STUDY

5.1 INTRODUCTION

The clinical impression that differences exist in the foot types of patients with medial compartment osteoarthritis of the knee (MCOA) and osteoarthritis (OA) hip was investigated in a prospective observational study. In an observational study, the researcher collects information on the measurements of interest, but does not influence events (Altman, 1999). Differences in foot type would be of interest because of the interdependence of lower limb, foot and ankle biomechanics and related pathophysiology which is discussed in Chapter 2.

The measurements of the foot and ankle complex undertaken in this study were as a result of a careful consideration of the literature.

5.2 FOOT AND ANKLE MEASUREMENTS

5.2. i Talocrural Movement

There is a wide range of variability reported in talocrural plantar and dorsiflexion. This presents a dilemma for clinicians who try to assess the normality of their patients' range of movement. In a study which attempted to establish normative data for passive talocrural plantar flexion/dorsiflexion flexibility it was demonstrated that, in a large cohort of 300 male and female healthy subjects aged 15 to 34 years, the variation in dorsiflexion was wide ranging (Moseley, 2001). Using a torque controlled procedure the range varied from 4.5 to 39.5 degrees (Mean 18.1°, Standard Deviation 6.9 °). The scores were normally distributed about the mean. Moseley et al (2001) indicated that for most subjects normal range was 10 – 30 degrees but that there was a small group at either end of the spectrum exhibiting either minimal or maximal dorsiflexion.

At birth talocrural dorsiflexion has been reported as being limited only by apposition to the tibia (Waugh, 1983). This is not confirmed by consultations with paediatric physiotherapists by the researcher, who found that expert practitioners reported a wide range of dorsiflexion almost from birth. By age 11 it appears to already have become fixed. Bennell (2001) demonstrated that even with a 12 month training programme at ballet school it was not possible to increase the range of dorsiflexion in 11 year old novice dancers. These young dancers learn dance techniques and perform stretches but would not be actively working on points (dancing on toes with toe blocks in shoes) at this young age, so the function of the gastrocnemius and soleus muscles and subtalar joint would not be compromised (personal communication with Janet Briggs, Physiotherapist at the Royal Ballet School, London). Boone (1981) demonstrated, in the only paper which gives figures for dorsiflexion in age bands 13-19, 20-29, 30-39, 40-54, 61-69; that while remaining fairly constant in early life, dorsiflexion decreases in the over sixty age band by approximately 50%.

Clinical methods of assessing talocrural joint dorsiflexion are often found to be unreliable and consequently their validity has been questioned. However, Elveru et al (1988) investigated the intertester and intratester reliability of goniometric measurements at the talocrural joint and subtalar joint (STJ). Intraclass correlation coefficients (ICCs) for intratester reliability of talocrural dorsiflexion and plantarflexion were 0.90 and 0.86 respectively. These data suggest good intratester reliability for both plantar and dorsiflexion is possible providing there is careful adherence to a standard measurement protocol.

Visual Estimation is a common form of non-goniometric measurement (Miller, 1985). The majority of clinicians visually estimate joint angle as part of clinical assessment. It has been shown to be a reliable method for studying knee flexion and extension in patients with rheumatoid arthritis (Marks et al, 1978), however, a later study (Watkins et al, 1991) suggests that the use of a gonoimeter improves reliability. For ankle movement goniometric measurement is also considered superior to visual estimation (Croxford et al, 1998).

The talocrural joint should normally allow the foot to dorsiflex 10 degrees beyond perpendicular to the leg when the knee is fully extended (Whittle, 1993). If there is less than 10 degrees then the subject may be considered to have an equinus condition (Kirby, 1997). This may be due to soft tissue involvement, such as a short gastrocnemius muscle, an osseous blocking of joint motion (Whittle, 1993) or it may be due to hyperextension of the knee which results in a functional rather than true lack of dorsiflexion.

The amount of skin creasing around the anterior aspect of the talocrural joint is a helpful indication of lack of dorsiflexion. When only a few wrinkles are visible at the end range of dorsiflexion this would usually indicate a range of

1 – 2 degrees. When a patient has greater than 10 degrees of dorsiflexion deep skin creases are visible.

Reported values of normal plantar flexion varied from 40 – 65 degrees and for dorsiflexion between 10 and 30 degrees (Elveru et al, 1988).

5.2.ii Calcaneal Angle

The second measurement used in this study was the calcaneal angle relative to the lower leg (Saunders, 1982) which has been reported to provide information about motion at the subtalar joint (Jonson 1997). The intratester reliability for measuring relaxed calcaneal stance position when tested by Evans et al (2003) was only moderate. Standard error of measurement (SEM) scores ranged from 0.9° to 6.2°. Gheluwe et al (2002), however, found that the intrarater intraclass correlation coefficients (ICCs) were >0.8. It has been shown that there is significant correlation between this commonly used static rearfoot alignment measurement and frontal plane radiographic parameters (Lamm, 2005). It is also the most common method of rearfoot analysis (Guichet et al, 2003). The calcaneal angle of the ideal well balanced foot measures between 0 and 2 degrees of calcaneal inversion. The calcaneal angle of a pronated foot measures greater than 2 degrees of calcaneal eversion (McPoil and Cornwall, 1994; Coplan, 1989).

5.2.iii Navicular height

The third measurement used was of the highest point of the medial longitudinal arch (MLA) in the sagittal plane. This is one of the simplest methods of providing a clinician with quantifiable information regarding foot structure (Williams, 2000). The prominent navicular bone represents the highest point of the MLA. It is usually visible as the most prominent point on the inner side of the foot, or if not, can be palpated by drawing the hand along the foot. This measurement has good reported intrarater reliability ICC > 0.74 (Evans et al, 2003). The agreement between clinical and radiographic measurements of navicular height was reported to yield ICCs of 0.874 (Williams, 2000). High intrarater reliability has also been reported when navicular height is used as a means of assessing the resting STJ position (Ator, 1991). Sell (1994) advocates the use of weight bearing navicular height as also having a high intratester reliability and further suggest that both calcaneal angle and weight bearing navicular height are reliable and acceptable for clinical and research purposes.

5.3 SUBTALAR JOINT NEUTRAL

The subtalar joint (STJ) neutral position is one in which the foot is neither pronated or supinated (Root, 1971). Root (1971), the principle innovator in modern podiatric biomechanics, introduced the STJ neutral position concept. It is frequently quoted in studies of the foot and the STJ neutral position is considered by many to be significant. However, while this was part of a major contribution to the development of foot biomechanics much recent thinking has progressed and STJ neutral position is no longer considered to be necessary for all basic foot measurements. McPoil (1985) described the following method for placing the subtalar joint in neutral. The patient stands on a firm surface. The therapist palpates the talus medially and laterally using thumb and forefinger while asking the patient to rotate the lower limb to the left and right, causing an accompanying pronation and supination of the talus. When the talus is felt equally on both sides the talonavicular joint is congruent and the foot is considered neutral. However, there is poor intertester reliability for this measurement. Tiberio (1988) states that measuring talocrural dorsiflexion with the STJ in neutral does give a more accurate measure but this was described with the subjects lying prone and the ankle joint being passively dorsiflexed. Considering the patient age group in this study, sitting would be the most comfortable position to measure talocurural dorsi and plantar flexion. To achieve STJ neutral would, however, require two testers or assessors to perform the measurements. The literature suggests that the method of measuring talocrural dorsiflexion chosen for this study and described below was fit for purpose (Elveru et al, 1988).

5.4 AIMS

This study was carried out to examine the foot and ankle characteristics of patients with OA hip, patients with MCOA and a healthy control group in order to determine whether or not differences existed between these groups.

HYPOTHESIS

H_1 Patients with osteoarthritis of the hip and patients with medial compartment osteoarthritis of the knee have different foot postures.

NULL HYPOTHESIS

H_{O1} There is no difference in the foot posture of patients with medial compartment osteoarthritis of the knee and patients with hip osteoarthritis

5.5 METHODS

This study was performed with the approval of the Oxfordshire Research Ethics Committee (04.OXA.017)) and the hospital Research and

Development Committee. The Nuffield Orthopaedic Centre NHS Trust acted as research sponsor and provided indemnity.

5.5.i Setting

The study was carried out in a specialist orthopaedic hospital where usual clinical practice included a visit to a pre-admission clinic ten to fourteen days before surgery. At this clinic physiotherapists routinely examined affected joints, as well as the joints above and below in order to plan post-operative rehabilitation (Bullock-Saxton, 1994). Whereas patients were usually examined by the surgeon supine on an examination couch, the physiotherapist examined a patient in standing to record any leg length discrepancy, valgus/varus alignment of the knee, and gait. Differences in foot type were more easily observed in standing and walking.

5.5.ii Participants

Patients awaiting elective hip replacement or medial compartment knee arthroplasty were contacted prior to attendance at a pre-admission clinic to inform them about the study and to ask them to consider participating in the trial. Consecutive patients prior to hip (HOA group) or medial compartment knee arthroplasty (MCOA group) were recruited. These patients were scored as having grade 4 OA (Kellgren and Lawrence, 1957) by the two operating orthopaedic consultants (Professor David Murray and Mr. Chris Dodd) who state that all patients demonstrated bone on bone contact with complete erosion of the hyaline cartilage on radiographic examination (Goodfellow et al, 2006).

Interested patients who had agreed that they wished to participate in this study, were given written information about the study and gave written consent (Appendices – incl copies of info form, consent & letter approval) Age matched volunteers (C) were also recruited from a poster in the hospital asking for recruits and were also consented and measured. There were 60 subjects in each of the three groups. Any patients/volunteers with a history of previous accident or operation on the affected limb, neurological problems or currently wearing orthotics were excluded from the study. Measurements for this study were taken by the author, an experienced musculoskeletal physiotherapist, experienced in joint measurement.

5.5.iii Measurements of the foot and ankle complex

Four measurements were taken of the foot on the side to be operated.

Talocrural plantar/dorsi flexion

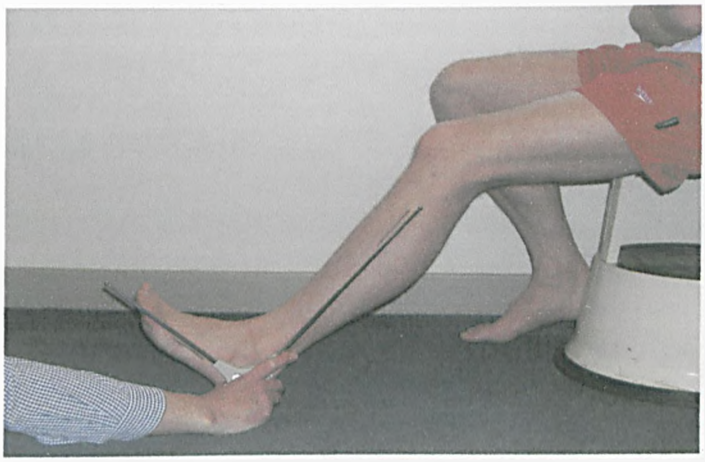


Figure 34 - Talocrural plantar/dorsiflexion

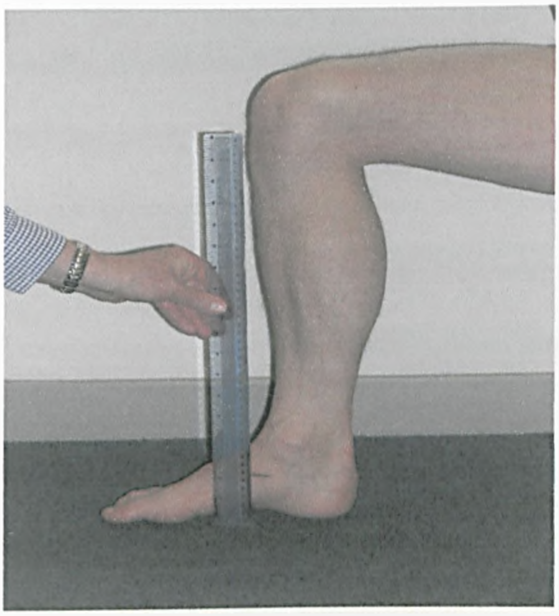
For this study dorsiflexion and plantar flexion were measured using a long arm universal goniometer. The method is described in section 4.2 b. The influence of STJ movement was recognised and every attempt was made to maintain a STJ neutral position and to prevent the use of trick movements to gain increased dorsiflexion range. The measures were each carried out three times and the mean score was recorded.

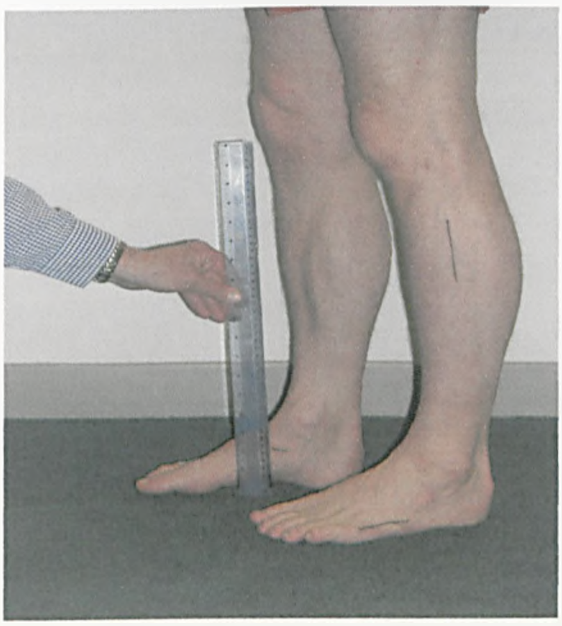
Calcaneal angle – standing calcaneal inversion/eversion measurement

Figure 35 – Calcaneal angle

The calcaneal angle was measured weightbearing in relaxed stance. This was the position in which the differences between patient groups were initially observed. The method used to measure calcaneal angle is described in section 4.2c.

Navicular height





Figures 36 and 37 – Navicular Height in sitting and standing

Navicular height was measured using the method described in section 4.2d.

5.6 FOOT TYPE

Finally, in addition to these measurement, all subjects were asked whether they knew what foot type they had e.g. "Do you have flat feet or do you have a high arched foot ?". They were also asked whether this had altered at any time. If there had been a change, they were asked whether the arch had become flatter or whether it had become higher.

5.7 STATISTICAL ANALYSIS

Power Calculation

The primary outcome measure selected was talocrural dorsiflexion. Boone (1981) reported that, based on normal values for people ages 61 – 69 years, 4 ° is a clinically significant difference (δ).

Using normal values, the standard deviation used was based on 4.6 (S). Altman's nomogram (Altman 1991) was used. A sample size calculation indicated that for 90% power and p value of 0.05, 56 participants in each group would be needed to detect a difference of 4° in ankle dorsiflexion (Std Diff = $\delta/S = 4/4.6 = 0.86$). To allow for drop out and non compliance 60 patients in each group were recruited.

Data Analysis

Summary statistics were used to describe the population of the study. No significant differences in the groups was seen in respect of age or sex. A one sample Kolmogorov-Smirnoff test was carried out to test for normality of the dorsiflexion, plantar flexion, calcaneal angle and navicular height in sitting and standing measures.

Primary Analysis

As the data was normally distributed and these were continuous measures, parametric statistics were used to investigate the differences between groups. A One Way Analysis of Variance (ANOVA) was carried out and post hoc analysis was undertaken using Bonferroni multiple comparisons to determine where significant differences occurred.

Secondary Analysis

Multiple regression was used to analyse inter group differences in dorsiflexion while controlling for age and sex.

The statistical package used was SPSS 12.0 for Windows.

(SPSS Inc, 233 S Wacker Drive, Chicago, IL 60606)

5.8 RESULTS

The demographic details of all three groups are presented in Table 3.

Assessment of any differences between the groups was analysed using ANOVA and the results are presented in Table 4.

Multiple regression analysis to investigate factors that contributed to differences are presented in Table 5.

Table 3 – Demographic details of all participants

	Sex (% total)	Mean Age	Standard Deviation	Minimum Age	Maximum Age
Group 1 HOA n = 60	31 male (52%) 29 female (48%)	45	+/- 9.11	45	85
Group 2 MCOA n = 60	25 male (42%) 35 female (58%)	42	+/- 8.09	42	67
Group 3 C n = 60	28 male (47%) 32 female (53%)	40	+/- 12.18	40	92

HOA - Patients with hip osteoarthritis,
MCOA - Patients with knee osteoarthritis
C - Healthy Controls

Table 4 - ANOVA of dorsiflexion, plantar flexion, calcaneal angle, navicular height in sitting and standing of the 3 groups, HOA, MCOA and C

	Group	Mean Values	Standard Deviation	F	p value
Plantar flexion (degrees)	HOA MCOA C	51.22 50.72 52.13	+/- 11.70 +/- 11.49 +/- 10.94	.239	.788
Dorsiflexion (degrees)	HOA MCOA C	2.62 10.07 8.4	+/- 4.86 +/- 4.29 +/- 3.71	49.284	.000 *
# Calcaneus to floor angle (degrees)	HOA MCOA C	-2.67 2.02 -.25	+/- 2.58 +/- 2.04 +/- 2.93	50.851	.000 *
Navicular Height (sitting) (cms)	HOA MCOA C	5.69 5.22 5.28	+/- .74 +/- .94 +/- .89	5.374	.005 *
Navicular height (standing) (cms)	HOA MCOA C	5.18 4.69 4.73	+/- .76 +/- .83 +/- .98	5.979	.003 *

HOA - Patients with hip osteoarthritis
MCOA - Patients with knee osteoarthritis
C - Healthy Controls
Negative calcaneus to floor angle indicates an inverted calcaneus (supinated footPositive calcaneus to floor angle indicates an everted calcaneus (pronated foot)
* Significant at $p < 0.05$

There were statistically significant differences between HOA (the hip group), MCOA (the knee group) and C (the controls) for measures of ankle dorsiflexion, calcaneal inversion/eversion and navicular height but not for plantar flexion of the ankle . Bonferroni multiple comparisons confirmed the differences in calcaneal angle and dorsiflexion between patients with hip OA and MCOA.

Table 5 – Multiple regression analysis

Coefficients a*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	15.446	2.754		5.609	p<.001
	gender	.851	.720	.079	1.181	p<.239
	age	-.060	.035	-.115	-1.704	p<.090
	group	-2.862	.437	-.439	-6.542	p<.001

a* = Dependent Variable: dorsiflexion

$r^2 = 21.8\%$

Multiple regression analysis for dorsiflexion/gender/age, indicated that most of the further variance between groups was due to age though this did not reach statistical significance at the p = 0.05 level.

Significant differences in foot characteristics between the groups has been demonstrated so the null hypothesis can be rejected.

5.9 DISCUSSION

This study has shown a measureable difference in the foot characteristics of patients with stage IV OA hip, stage IV MCOA and a healthy control group. The patients with hip OA had a low range of dorsiflexion and an inverted calcaneus, characteristics of a supinated foot. The mean value of dorsiflexion range in this group was 2.62 degrees. 10 degrees of dorsiflexion is considered to be the minimum required for normal smooth gait (Kirby and Green, 1992). Patients with MCOA had a high range of dorsiflexion and an everted calcaneus, characteristics of a pronated foot. The mean value of dorsiflexion range in this group was 10.07 degrees. This is only just over the minimum required for normal gait. The healthy control group had a mean value of 8.4 degrees of dorsiflexion. This is less than required for normal smooth gait. The normal group had a mean age of 64.92 years which may indicate that the older population has less dorsiflexion than the average age group, supporting the findings of Boone et al (1981) that up to 50% of range of dorsiflexion may be lost in subjects over the age of 60.

The findings also concur with a recent study by Burns and Crosbie (2005) who noted significantly less ankle dorsiflexion in feet with pes planus than pes cavus. This association is further explored in Chapter 7.

However, the question remains whether the foot influences the site at which lower limb OA develops, or whether these changes are secondary to OA and develop as compensatory mechanisms.

Many patients and controls in the study were unable to state whether they had either high arched or low arched feet currently, or whether this had changed in the recent past. However, almost without exception, subjects cited family members either parents, siblings or children, with similar feet although they were not able to define type of foot.

Group HOA were the most aware. 45% stated they had always had high arches and none could recall having flat feet as children. In addition, a search of the literature does not reveal a condition of acquired high arches, except where it is associated with neurological problems such a Charcot Marie Tooth syndrome, muscular dystrophy, syphilis or other neurological conditions. There were no subjects in the study with a diagnosis of any neurological problem.

In a study which examined talocrural dorsiflexion with different age groups (Boone 1981); it was noted that dorsiflexion decreases with age which concurs with the results in this observational study. The lack of adequate dorsiflexion range in patients with OA hip found in the data may be age related. However, the ample range of dorsiflexion in patients with MCOA who were of a similar age suggests that age may not be the only factor which influences dorsiflexion.

In Group KOA, 18% of patients stated that they had flat feet in childhood sufficiently pronounced to require medical attention. Acquired flat foot is a recognised condition (Van Boerum, 2003) in the adult population. However, from a mechanical viewpoint, if the varus deformity which is typical of MCOA knee influenced the hindfoot characteristics, it would favour the development of a supinated foot position rather than a pronated one. This is because the varus knee would appear to pull the calcaneus into an inverted position drawing the foot outwards.

Whilst undertaking the measurements it was noted that the feet of all subjects varied greatly in all dimensions. The measurement of navicular height was felt to be rather two-dimensional. Some feet were very round and thick and the measurements were higher, while other much flatter and thinner feet had smaller measurements although the relative arch height could be similar. The differences in navicular height would also be less for the smaller thinner foot although relatively speaking there was a greater difference. Therefore the difference was not utilised. The measurement of navicular height, whether in sitting or standing, also seemed to reflect the size and shape of the foot as well as the orientation (high or low arched). In a recent publication it has been noted that navicular height was significantly associated with foot length ($r = 0.57$; $p < .01$) and foot width ($r = .54$; $P < .01$), indicating that if comparisons are to be made between subjects, navicular height will need to be corrected for shoe size (Menz et al, 2003).

Also the measuring of the calcaneal angle with a varus knee deformity had to be accommodated by having the patients seated. It was suggested to draw the line bisecting the calcaneus using a set square from the floor up rather than a plumb line from the knee down (Coplan 1989), but it was felt that this measurement would be affected by the varus angle of the knee, therefore this method was not used and the knee down protocol was chosen instead.

5.10 CONCLUSIONS

This study has shown a measureable difference in the foot characteristics of patients with stage IV OA hip, stage IV MCOA and a healthy control group. There is a highly significant difference in the range of dorsiflexion and in the calcaneal angle and a less significant difference in navicular height in both sitting and standing. The results of this study, therefore, support the hypothesis H_1. The patients' feet appear to represent the two ends of the continuum of normal range. As has been demonstrated (Hogan and Stahell, 2001) the general population do not conform to either of the two extremes.

The differences in range of talocrural dorsiflexion between the two patient groups and the control group is particularly noteworthy. Talocrural dorsiflexion has not featured in previous attempts to classify foot types and to relate foot structure to foot and lower limb function (Kaufman et al, 1999; Lawrence et al, 1998; Cavanagh et al 1997). The significant differences found in this study might suggest that it has a role to play and as it is a relatively reliable measurement (Cornwall and McPoil, 1999) it should be considered for inclusion in future studies.

5.11 FURTHER WORK

Having noted that the feet of patients with MCOA were significantly pronated compared to patients with HOA and a control group, the next step was to study the effect of a correction of the varus deformity of MCOA on the foot characteristics of these patients. If MCOA and the varus deformity had a part to play in the development of the pronated foot, then the major correction of this deformity at the time of surgery to replace the joint with the Oxford Unicompartmental Knee Arthroplasty might demonstrate a change in the foot characteristics.

CHAPTER 6. OXFORD UNICOMPARTMENTAL ARTHROPLASTY OF THE KNEE – PRE AND POST OPERATIVE ALIGNMENT AND ITS INFLUENCE ON THE FOOT AND ANKLE

6.1 INTRODUCTION

The feet of patients with MCOA have been shown to be significantly pronated compared to the feet of patients with hip osteoarthritis and those of a healthy control group. It has not been shown that pronated feet can influence the development of MCOA, or whether MCOA influences the development of the pronated foot. However, a clinical sign of MCOA is a varus deformity of the knee which would appear to favour the development of a supinated rather than a pronated foot (Figure 38). A varus deformity of the knee would appear to pull the talus outwards to a more supinated position as it is held in the mortice of the tibia and fibula.

Figure 38 - Showing the varus deformity associated with MCOA

If, however, the varus deformity did have a part to play in the development of the pronated foot then the major correction of this deformity that occurs when knee replacement surgery is undertaken using the Oxford Unicompartmental Knee Arthroplasty (UKA) might demonstrate a change in the foot. The next step, therefore, was to study the effect of a correction of the varus deformity of MCOA on the foot characteristics of these patients.

To be suitable for Oxford UKA, the varus malalignment seen in MCOA must be correctible and not a life long deformity. Stress x-rays taken before surgery are used to decide whether a UKA or total knee arthroplasty is required (White et al, 1991). If alignment can be achieved by stress i.e. pulling the lower leg into valgus then the deformity is judged to be correctible and suitable for an Oxford UKA. The deformity is also corrected by flexing the knee to 90° (White et al, 1991) as the unworn parts of the cartilage are then in contact.

The varus deformity present in MCOA is largely, therefore, a problem of lack of cartilage and bone in the medial compartment in the area which is in contact during weight bearing (Sharma et al, 2001) (Figure 39). While sitting, the areas of cartilage which are in contact are intact. This helps to maintain the length of the cruciate ligaments, and the medial and lateral collateral ligaments, which are not surgically lengthened during the joint replacement procedure.

Figure 39 - Radiograph of left knee showing MCOA grade 4

6.2 AIMS

The purpose of this phase of the study was to assess the effect of the correction of the varus alignment, an essential part of an Oxford UKA, on foot characteristics. A prospective observational study which utilised pre- and post-operative measures of foot and ankle characteristics and varus/valgus knee angle was conducted.

HYPOTHESIS

H_1 Surgical correction of the varus deformity associated with MCOA has a measurable effect on the foot characteristics of patients.

NULL HYPOTHESIS

H_{O1} Surgical correction of the varus deformity associated with MCOA has no effect on the foot characteristics of patients

6.3 MATERIALS AND METHODS

This study was performed with the approval of the Oxfordshire Research Ethics Committee (04.OXA.017) and permission was obtained from the hospital Research and Development Committee. All participants gave informed consent before participation.

6.3.i Intervention

Knee joint replacement surgery using the Oxford UKA implant (see Chapter 3).

6.3.ii Clinical Setting

This study was carried out in a specialised orthopaedic hospital where usual clinical practice includes a visit to a pre-admission clinic 10 – 14 days before surgery and 6 to 8 weeks post operatively to a follow-up clinic. At these clinics, physiotherapists routinely examine affected joints, with patients standing and walking to record any leg length discrepancy, valgus and varus alignment of the knee and gait patterns.

6.3.iii Participants

Fifty-five patients who consented to participate in the study were measured during their visit to the pre-admission clinic. Patients had all been given a date for surgery and were confirmed as having MCOA stage 4 (Kellgren and Lawrence, 1957) by the two operating orthopaedic consultants (Professor David Murray and Mr. Chris Dodd). At six to eight week post operative review the same measurements were repeated. All pre-operative measurements were taken by the author.

Exclusions: Any patients with a history of previous trauma or operation to the affected limb or neurological problems were excluded.

6.3.iv Procedure

Five measurements were taken. Four of these are described in the Descriptive Study, Chapter 3. These are plantar and dorsiflexion of the talocrural joint, calcaneal angle and navicular height in sitting and standing. In addition, the valgus/varum alignment of the knee was measured (Figure 40).

Valgus/Varus alignment

Patients were measured barefoot in relaxed standing. Patients were asked to take 4 – 5 steps on the spot and then relax into their normal stance. A Gollenhon extendable goniometer, model 01135 (Layfayette Instrument Company, Layfayette, Indiana, USA) was used. The fulcrum was placed centrally over the patella with the upper arm aligned to the anterior superior iliac spine and the lower arm aligned with the long axis of the tibia (Figure 40).

Figure 40 - Demonstrating measurement technique for valgus/varus alignment

6.3.v Data Analysis

Sample size calculation

The American Knee Society Score was used as the primary outcome measure to inform a sample size calculation. It is a reliable validated measurement tool employed in knee assessment pre and post knee surgery (Insall et al 1989). It differentiates between objective/subjective measurements of the knee and knee function. This is because knee function tends to deteriorate as the patient ages, but this does not necessarily indicate a change within the knee itself. The objective measurements are range of motion, stability and flexion contracture, extension lag and malalignment.

Pain is the subjective measure. Malalignment is dealt with as a deduction. An 8° difference in alignment will lead to a deduction of 20 points.

The score is rated :

Excellent 85 -100

Good 71 - 84

Fair 61 - 70

Poor below 60

Therefore an 8° difference in valgus/varus alignment would change the score sufficiently to demonstrate a clinically significant change.

Using normal values, the standard deviation used was based on 8° (S). Altman's nomogram (Altman 1991) was used to calculate sample size. This indicated that for 90% power and p value of 0.05, 55 in each group (n= 55) would be needed to detect differences of 8° in correction of varus deformity. 55 patients were recruited.

6.3.vi Statistical Analysis

The pre and post operative measurements are shown in Table 6. As the varus and valgus knee measurement scores were not normally distributed, a Wilcoxon signed ranks test was used to analyse the significance of the changes (Table 7). This is the non-paramentric alternative to the repeated measures t-test which, instead of comparing means, converts score to ranks and compares them at Time 1 and Time 2.

The statistical package used was SPSS 12.0 for Windows.

(SPSS Inc, 233 S Wacker Drive, Chicago, IL 60606)

6.4 RESULTS

There were 55 patients in total, 24men, and 31 women aged 42 to 86 years.

Table 6 - Pre and Post operative measurements

	Pre-op Mean	Standard Dev.	Post - op Mean	Standard Dev.
Plantar flexion	52.654	±12.743	52.564	± 12.396
Dorsi flexion	9.836	± 5.388	10.181	± 5.319
Navicular height in standing	4.596	± 0.905	4.395	± 0.864
Calcaneal Inversion	0.291	±1.409	0.254	±1.442
Calcaneal eversion	3.036	± 2.538	3.509	±2.456
Knee Varus alignment	4.16	±3.060	0.563	±1.813

Table 7 – Wilcoxon signed ranks test for significance of change in pre and post operative measurements

a) knee varus and valgus measurements

b) talorcural dorsiflexion measurements.

c) plantar flexion measurements.

d) calcaneal angle measurements.

e) navicular height in sitting measurements.

f) navicular height in standing measurements.

	Knee Varus Valgus	Talocrural Dorsiflexion 1 Dorsiflexion 2	Talocrural Plantar Flexion 1 Plantar Flexion 2	Calcaneal Angle 1 Calcaneal Angle 2	Calcaneal Angle 1 Calcaneal Angle 2	Navicul Height Navicul Height 1 (si)
Z	-.543(a)	-.656(a)	-.144(b)	-1.657(a)	-.276(b)	-1.4
Asymp. Sig. (2-tailed)	p = <.001	p =<.512	p = <.886	p = <.097	p = <.783	p = <.14

a Based on negative ranks.

b Based on positive ranks.

c Wilcoxon Signed Ranks Test

The Wilcoxon signed ranks test revealed a statistically significant ($p<.001$) difference in the varus/valgus alignment of the knee following an Oxford UKA. The results are presented in Table 7. However, there was no formal test for reliability carried out for this measurement and, as the SD value is over twice that of the mean (Mean: 0.563; SD: 1.813), the varus values recorded may be outside the measurement error for this variable. Before surgery a range of 14 degrees varus to 7 degrees valgus was observed (Mean varus/valgus orientation = 4.16 degrees varus alignment). Post surgery a range of 7 degrees varus to 12 degrees valgus was recorded (Mean varus/valgus orientation = 4.40 degrees valgus alignment). The degree of change varied depending on the amount needed to correctly align each knee's mechanical axis. The Wilcoxon signed ranks test also showed that there was no statistically significant change in the other measures. It was also noted that the foot and ankle measurements are not different from the measurements obtained in Chapter 5.

The null hypothesis was accepted as there was no change in foot characteristics. The pronated foot posture which these 55 patients demonstrated remained unchanged even after the clinically and statistically significant change in knee alignment from varus to valgus. Therefore, although it cannot be assumed that the foot posture influenced the development of the MCOA, this study does not support the hypothesis that the varus deformity has a major influence on the foot posture of these patients. However, it must also be acknowledged that the 6 to 8 week post operative period is relatively short and the full effects of the re-alignment may not be present at this time. It is proposed to continue this study by observation at 1 year post surgery to further assess if any re-alignment has occurred as a consequence of replacement surgery.

6.5 DISCUSSION

The importance of the intrinsic deviation of alignment (mechanical axis deviation) around the knee, in understanding knee arthritis and asymmetric loading of other joints leading to degenerative arthritis, has been acknowledged (Guichet et al, 2003). However, the part played by the foot during the gait cycle has not featured in studies on knee alignment in MCOA or in operative alignment aims. For example, *"Planning for knee replacement requires as a standard procedure the evaluation of the mechanical axis alignment. The use of the hip-ground line for calculation of the mechanical axis deviation is applicable to adults"* (Guichet et al, 2003). Since the foot is a moveable object, not a static platform, it would seem that this approach is likely to lead to inaccuracy. This is particularly relevant as the foot adjusts in frontal, sagittal and transverse planes of movement, during the gait cycle.

Malalignment of lower limbs is a frequent cause of consultation in paediatric orthopaedic clinics. It is acknowledged that even in patients with few symptoms, significant malalignments may produce increased risk of osteoarthritis in adulthood (Tetsworth and Paley, 1994). Varus or valgus malalignment, which has been present from an early age, increases the risk of medial and lateral OA progression respectively (Cerejo et al, 2002; Sharma, 2001).

However, the varus deformity of MCOA results from recent arthritic changes in the medial compartment, rather than being a cause of the disease and this comparative study is very specifically directed at MCOA. To be suitable for Oxford UKA the deformity must be correctable and this is verified by stress X-ray (Chapter 3). All the patients in this study did undergo an Oxford UKA.

Varus deformity, it has been noted, has some effect on the pattern of progress of degeneration (Ritter et al, 2004). Acquired malalignment has been observed at almost all stages of MCOA (Sharma et al, 2001). The correction of the malalignment in these patients did not cause a change in foot characteristics 6 to 8 weeks after surgery. The foot characteristics are therefore fairly robust. In addition, from an observational viewpoint, a knee demonstrating varus alignment would appear to supinate the foot rather than increase pronation.

The effect on the biomechanics of gait of an overpronated foot, as discussed in chapter 2, might lead to deterioration of the cartilage in the medial compartment of the knee. Since the varus deformity in MCOA is due to lack of cartilage in the medial compartment there may be a link. This study lends some weight to the argument that the foot characteristics influenced the development of MCOA, although this it still does not mean that a causal relationship can be assumed.

6.6 CONCLUSION

This prospective observational study has shown the foot and ankle characteristics of patients with MCOA remain unchanged in the early stages following Oxford UKA. It also indicates that patients with MCOA have foot and ankle characteristics which are related to pronation, which confirms the results of the previous study (Chapter 5). The pathophysiology of pronated and supinated feet is discussed in Chapter 2. Therefore, if patients with

MCOA present with these foot characteristics, it is arguable that it may be clinically appropriate to give them advice and/or treatment. However, before advice or treatment can be given, clinical assessment is necessary.

The measures of clinical status used in the two observational studies, goniometer, protractor and ruler while useful, do not define foot posture. The next stage of this thesis, therefore, was the assessment of suitable clinical measurement tools to assess foot posture.

CHAPTER 7. CLINICAL OUTCOME MEASURES FOR THE FOOT

7.1 INTRODUCTION

The first component of this thesis focused on the measurement of the feet of patients with osteoarthritis (OA) of the lower limb. Currently, clinical assessment of the foot is not routinely undertaken in the examination of patients with lower limb OA. If this were to be introduced, there would be difficulty in selecting suitable clinical outcome measures, as there are a wide variety of these which focus on different aspects of foot assessment and no consensus about which ones should be used. This second part of the thesis, therefore, focuses on clinical outcome measures for the foot which would be suitable for use by physiotherapists.

The measures used for the foot and ankle complex in the descriptive observational studies (Chapter 5 and 6) enabled differences in foot and ankle characteristics in patients with different sites of lower limb OA to be observed. Of the original measures used, the measurement of talocrural dorsiflexion is straightforward and uses a goniometer which is part of the normal physiotherapy repertoire. The navicular height measurement, though satisfactory, is not ideal because it appears to be a rather one dimensional measure of a three dimension entity, i.e. the width and length of foot is related to the navicular height and differences between feet might be as much a result of these other dimensions, as arch height which it is purporting to measure. The calcaneal angle requires the use of a protractor and a plumb line, which, while not usual physiotherapy tools, are not unduly complex. However, while these measures are useful for research purposes, and arguably could translate to the use in the clinical setting, there are alternatives which may prove more suited to this purpose.

The diversity of reported measures is an indication that there are difficulties in recommending any one single, simple, objective and quantitative measure (Urry and Wearing 2001). For this reason, a literature review of the current clinical outcome measures for the foot was carried out.

7.2 CLINICAL OUTCOME MEASURES FOR THE FOOT

The results of the literature review are listed below.

- The Foot and Ankle Osteoarthritis Outcome Score (FAOS) is a patient self reported questionnaire which considers pain and disability due to a variety of foot and ankle related problems. FAOS content is based on the Knee injury and Osteoarthritis Outcome Score (KOOS) and its content validity and reliability has been reported based on a sample of 213 patients with lateral ankle instability (Roos et al, 2001). The FAOS consists of 5 subscales : (i) pain, (ii) other symptoms, (iii) function in daily living (ADL) and (iv) foot and ankle related quality of life (QOL). Patients are asked to respond to the questions based upon their experiences during the previous 7 days. A normalised score is calculated for each subscale and the result can be plotted as an outcome profile. It is patient administered, is considered user friendly and takes about 10 minutes to fill out. FAOS has, thus far, been reported for use in patients 20 – 60 years old.

- Foot Function Index (Saag et al, 1996): a validated and reliable instrument for measuring foot pain, disability and activity restriction in patients with rheumatoid arthritis. It has also been validated for use as an outcome score to report the results of treatment of patients with foot and ankle disorders (SooHoo et al, 2006). This is a self report questionnaire in three parts. It is used to ascertain patient assessment in the domains of activity limitation, function and disability. It comprises 23 items and scoring is based on a visual analogue scale.

- Ankle Osteoarthritis Scale (Domsic and Saltzman, 1998): a modification of the Foot Function Index developed to be used for measuring symptoms and disability among subjects with ankle osteoarthritis. It is a patient completed, body part and disease specific scale. 2 sub scales (pain and disability) are composed of nine items. Individual items scored on a visual analogue measure each give sub scales a total score and the overall score. A higher score indicates greater pain or disability. Criterion validity was tested using the WOMAC (a disease specific scale for osteoarthritis) and SF-36 (a general health survey) and a high degree of concordance was shown for related subscales (Domsic and Saltzman, 1998). Construct validity using a physical measure of ankle function demonstrate sensitivity of the instrument to the degree of joint dysfunction (Domsic and Saltzman, 1998).

- The American Orthopaedic Foot and Ankle Scale (Kitaoka et al, 1994) provides a standard method of reporting clinical status of the ankle and foot. The system incorporates a physical examination with patient report to provide numerical scales to describe function, alignment and pain. It was designed for use among all patients with foot or ankle dysfunction. Its reliability for the hallux and toes has been demonstrated (Baumhauer et al, 2006) and the subjective component has also been validated and its reliability tested (Ibrahim et al, 2007). It is widely used but limitations have been reported on the scoring scales (SooHoo et al, 2003). In both the hallux and the lesser toe metatarsophalangeal-interphalangeal scales, the presence of callus is questioned.

- The Manchester Disability Index (Menz et al, 2006): a validated patient self report questionnaire, suitable tool for assessing foot pain in community dwelling older people where its reliability has been confirmed. It is a four-factor structure representing the constructs of functional limitation, pain intensity, concern about appearance and activity restriction. There is no published report on validity or reliability.

- Foot and ankle disability index (Martin et al, 1999): A validated and reliable self report questionnaire developed for use among elderly individuals with rheumatoid arthritis. It uses functional scales that comprise 23 items which measure pain, disability and activity restriction. Scoring is based on a visual analogue scale. It was designed to assess functional limitations related to foot and ankle conditions. It was also found to be responsive to improvements in function after rehabilitation for subjects with chronic ankle instability. (Hale and Hertel, 2005).

In addition, there are systems of measurement for arch height:

- Arch Height and Arch Height Ratio (Franettovitch et al, 2007) which utilises videotape images of the medial aspect of the foot and a software programme to calculate the measurements. This is too complex and therefore too time consuming for normal clinical use. There are no published reports of reliability or validity.

- Arch Height Index Measurement System (Richards et al, 2003) a measure of dorsal height normalised to foot length which utilises a specially devised heel cup and set of sliding callipers with subjects on an adjustable chair using a 3cm thick platform under heel and metatarsals. This is again a complex system which has not appeared in further studies.

There are many other suggestions of methods to assess arch height, some purely observational others, including radiographs. Many of them are novel measurements devised by individual authors and not utilised by other researchers or clinicians. A study which reviewed a number of possibilities (Williams and McClay, 2000) suggests that the most reliable and valid method of clinically assessing arch height is to divide the dorsum arch height at 50% of foot length by a truncated foot length (difference between 10% weight bearing and 90% weight bearing). This again is not an outcome measure which could be utilised easily in a clinical situation to give rapid feedback. Similarly, there are also various footprint measures which have been suggested (Queen et al, 2007; McPoil and Cornwall, 2006; Urry and Wearing, 2001). These also require complex measurements and calculations which again would be very time consuming and require considerable mathematical skills.

In spite of the variety of clinical outcome measures, none of the above was considered suitable for the purpose of either examining the gait of patients with lower limb OA or to establish foot postures. Patients with lower limb osteoarthritis do not, for the main part, have foot problems, they present with extremes of normal range rather than pathologies. As a result of the literature search, however, two final tools which appeared to have clinical utility were selected for further study: the F-Scan System and the Foot Posture Index.

7.3 SELECTED CLINICAL OUTCOME MEASURES

7.3.i The F-Scan system

This is a dynamic, electronic, system of foot measurement. It is possible that static measurements may not totally reflect the rear foot movement which occurs during a dynamic activity such as walking (Cavanagh et al, 1997).

Complex gait analysis in the gait laboratory provides this information, but it is an expensive and time consuming procedure and is not available for general use. Relatively speaking, the F-Scan system is inexpensive. The reliability of this system has been demonstrated by several studies (Mueller et al, 1994; Mueller and Strube, 1996; Rose et al, 1992; Koch, 1993). The F-Scan is used in podiatry for assessment of the diabetic foot and also for biomechanical assessment. It is not a usual part of the physiotherapist's repertoire but might prove to be a suitable tool as it is relatively quick to use and could be incorporated within the normal time frame used for clinical assessment.

7.3.ii The Foot Posture Index (Redmond et al, 2006)

The measurement techniques utilised in Chapters 5 and 6 are mainly rear foot measurements. The Foot Posture Index (FPI) was considered worthy of attention because it is a three dimensional measure, developed to address a need for a clinical tool that measures foot posture in multiple planes and anatomical segments. The FPI aims to quantify the degree to which a foot can be considered to be in a pronated, supinated or neutral posture (Redmond et al, 2006). In a number of independent evaluations of reliability, the PFI has proven reliable in varied clinical settings (Intraclass correlation coefficients = 0.62- 0.91) (Evans et al, 2003; Noakes and Payne, 2003; Yates and White, 2004). It has been subjected to evaluation against the Rasch statistical model (Keenan et al, 2007) which confirmed its construct validity. Its usefulness in the physiotherapy assessment and treatment planning of lower limb OA has not been established, therefore further investigation was needed.

7.3.iii Further Work

As a result of the literature review, a further study using the two clinical outcome measures described above, the F-Scan system and the FPI, was carried out with a cohort of patients with hip OA and MCOA and a control group of healthy volunteers.

This was designed to test the clinical utility of the outcome measures in a physiotherapy clinical setting and would also serve to re-affirm, or disprove, the results of the descriptive study in Chapter 5. The FPI would also, if used with the goniometric talocrural dorsiflexion measurement, allow the relationship of dorsiflexion to foot posture which was noted in Chapter 5 to be further examined.

7.4. THE F-SCAN STUDY

7.4.i. Introduction to the F-Scan

In this study, the F-Scan system was used to examine the centre of pressure and the areas of peak pressure of the feet of patients with hip OA, MCOA and healthy volunteers during gait. From the literature, it appeared that these outcome measures would provide useful data. In addition, since the system is not a usual part of the physiotherapist's repertoire, this study aimed to assess its clinical utility in a physiotherapy department.

7.4 ii -Scan in-shoe pressure measurement system hardware

To measure the parameters evaluated in this study, in-shoe sensors were used. The sensor consists of a bipedal, thin (.007in or 0.18mm) shoe insole (Figure 41) composed of sensor cells on which the entire plantar surface of the foot rests, leading to a transducer (Figure 42) connected to an interface board of a laptop computer. The sensor attaches to a cuff unit which is attached to the lower leg with a Velcro strap (Figure 43). A 9.25m cable attaches the sensor to the computer. The sensor measured the plantar pressure at the interface between the foot (with sock) and the shoe.

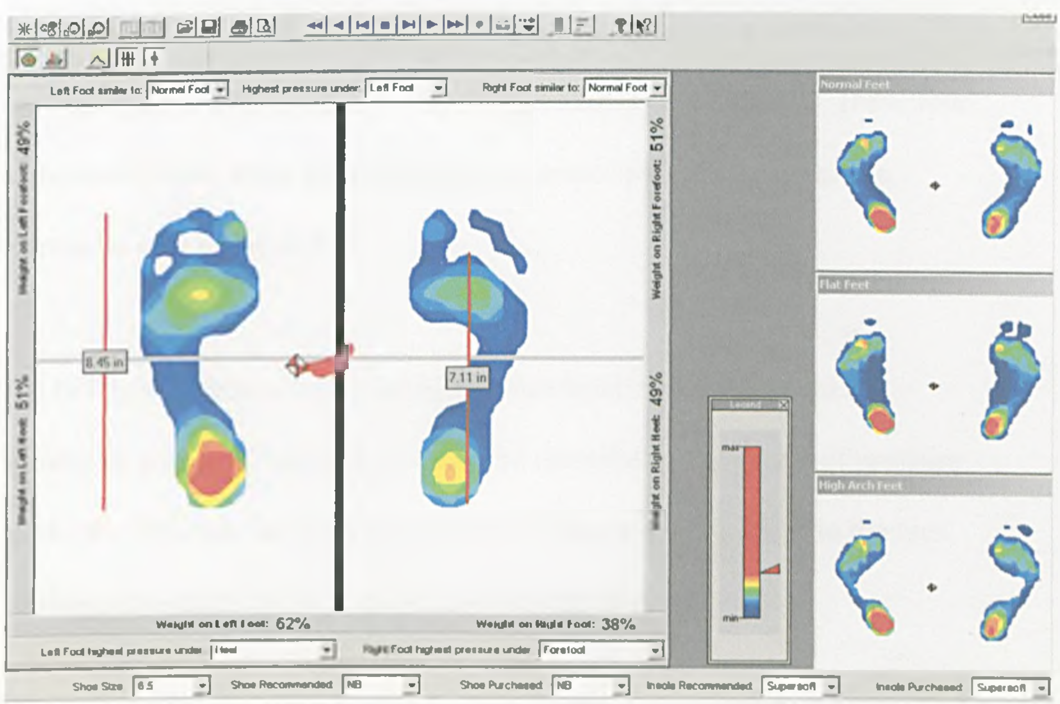
Figure 41 - The F-Scan Sensor

Figure 42 - The F-Scan Transducer

Figure 43 - The F-Scan Transducer attached to the sensor in patient's shoe

7.4.iii F- Scan Software

Once the pressure recordings are made by the insole sensor and stored, the F-Scan software allows for a detailed evaluation of the data. F-Scan recordings from separate trials can be analysed individually or compared side by side. With single trial analysis, the data can be displayed in 3 different ways.



T

Figure 44 - Showing F-Scan images on screen in gait mode of Flat, Normal and High arch Feet with Colour legend.

(1) In the gait mode there is a display of two-dimensional representation of the plantar pressures detected by the sensor as a function of time viewed

sequentially from heel strike to toe-off (Figure 44). Increasing pressure is depicted by colour changes in this mode. The plantar force in the forefoot, midfoot, hindfoot and the total area of the foot as a function of time is also graphically displayed in this mode.

(2) In the pressure area display mode the pressure/time relationship inside of four defined areas (boxes) on the sensor can be analyzed. These four areas can be of various sizes, from 15 x 15 mm to 105 x 105 mm and can be moved about to analyze pressures in various areas of the sensor. These four adjustable boxes allow the investigator to assess plantar pressures in a particular area of the foot.

(3) In the peak force display mode, the maximum force registered at a particular portion of the gait cycle can be identified. The centre of pressure path (the path that the maximum pressure follows from the heel to the toes during a single gait cycle) can be measured as well.

7.4.iv Centre of Pressure (COP)

The F-Scan system incorporates calculation of the Centre of Pressure (COP). COP identifies the geometric centroid of the applied force distribution (Rogers and Cavanagh,1984). When a subject is standing every point of the foot that is in contact with the ground will have some pressure or force applied to it. (Pressure is defined as force per unit area. The System International (SI) unit of force is the Newton and the SI unit of pressure is the pascal.)

All of these forces from different locations can be averaged to arrive at a single force that is equal to the sum of the magnitudes of all the smaller forces acting at a single point called the centre of pressure (Fuller, 1999). Thus the COP is defined as the point at which there is no moment from all of the applied forces. This concept was demonstrated by Hicks as early as 1953. (ref)

The path of COP has become a useful tool for clinicians because it is an easily described visual representation of foot movement. During gait, the location of the COP will change over time at different phases of the gait cycle. The path of COP is created by plotting the change of location of COP at regular time intervals during the entire stance phase of gait (Rogers, 1988). A normal progression begins on the heel, slightly laterally to the midline, along the midline of the foot up to metatarsal heads then medially to under the first or second toe (Katoh et al, 1983).

COP is different from peak pressure and the area of COP in the foot may not actually be in contact with the ground. During gait, the path of COP may be under the medial arch where there is no ground contact (Fuller, 1999). Root et al (1971) have stated that excessive pronation or supination of the foot during walking will affect the COP. The path of COP or force line has been used to describe abnormal foot movement during gait (Brand et al, 1981; Grundy et al, 1975). The flat or overpronated foot results in a medial shift in the loading of the foot during heel-off. This implies that the medial support structures of the foot experience increased loading in the presence of a flatfoot (Imhauser et al, 2004).

7.4.v Plantar Pressure

Plantar pressure data has been recognised as an important element in the assessment of the diabetic foot, but it may also provide an indication of foot and ankle function during gait (Cavanagh et al, 1992). Assessment of plantar pressure can be included as part of gait analysis. If pressures appear atypical in certain areas of the foot, attempts can be made to modify this through a treatment regime using orthoses, gait retraining and exercise regimes.

7.5 AIMS

The aim of this exploratory study was to look at the feet of the three groups, patients with hip OA, patients with MCOA and healthy controls, using the F-Scan, to establish whether they displayed any statistically different characteristics. It also aimed to assess the utility of the F-Scan in a clinical setting when used with a cohort of patients with hip OA, MCOA and a control group of healthy volunteers.

HYPOTHESIS

H_1 Patients with OA hip, patients with MCOA and a group of healthy volunteers have different foot characteristics as measured by the F scan..

NULL HYPOTHESIS

H_{O1} There is no difference in the foot characteristics of patients with OA hip, patients with MCOA and a group of healthy volunteers

7.6 MATERIALS AND METHODS

This study was performed with the approval of The Mid and South Buckinghamshire Local Research Ethics Committee (06/Q1607/1) and the permission of the hospital Research and Development Committee. All subjects gave informed consent before participation.

7.6.i Design

This was an exploratory study on a cohort of patients with hip OA, MCOA and a control group of healthy volunteers.

7.6 ii Setting

The study took place from January 2006 to January 2007 in a specialised orthopaedic hospital where usual clinical practice includes a visit to a pre-admission clinic 10 – 14 days before surgery.

7.6. iii Sample size calculation

Assuming normal distribution, a sample size calculation using Altman's nomogram (Altman, 1991) was carried out which indicated that for 90% power and an alpha value of 0.05, 19 feet in each group was needed to detect a clinically significant difference of 2.2 psi (δ) in plantar pressure. The calculation was based on previously reported statistics from a sample with a SD of 2(S) (taken from Randolf et al, 2000). (Std Diff = δ/S = 2.2/2 = 1.1). To allow for attrition and non compliance the sample size was set at 20.

7.6.iv Participants

Twenty patients with X ray and clinical evidence of stage IV hip OA immediately prior to total hip arthroplasy, twenty patients with X-ray and clinical evidence of stage IV MCOA immediately prior to Oxford unicompartmental knee arthroplasty (UKA) and twenty age matched healthy volunteers, who served as controls, consented to participate.

7.6.v Exclusion criteria

Any patients/volunteers with a history of previous accident or operation on the affected limb, neurological problems, diabetes or currently wearing orthoses were excluded from the study.

7.6. vi Measurement method

All participants underwent the same procedure.

(a) Height was measured to the nearest 0.1 cm. Weight was measured without shoes to the nearest 0.1 kg on a scale which is subject to regular calibration. Body Mass Index (BMI) was calculated as kg/m^2 and recorded.

Recommendations from research based specifically on this system and manufacturer's guidelines have been utilised to develop the measurement protocols. (Mueller and Strube, 1996; Rose et al, 1992).

(b) A separate new sensor was used for each subject as it has been shown that pressure measurements decline when several trials are run on one single sensor (Rose et al, 1992). A paper template was taken of the inner shape of the shoe and the computerized F-Scan sensor was cut 5 mm smaller than this. Trimming of the sensors was performed as per the manufacturer's guidelines. Care was taken to ensure that the 0.0 coordinate on the sensor still corresponded with the centre of the foot. The paper template was recommended (Raspovic et al, 2000) to decrease manipulation of the sensors, which has been demonstrated as a factor which can affect system accuracy (Mueller and Strube, 1996; Rose et al, 1992). One pair of sensors was used per person and at all times sensor manipulation was kept to a minimum.

Patients were given a pair of shoes and socks. Ten pairs of the same shoes were used in English sizes 3 – 12 (NIKE All Court Canvas) in order to control plantar pressure variability associated with shoe construction. These shoes have a flat midsole which means that there is no heel raise or medial support. Same brand socks were also supplied for each participant in either small, medium or large size.

The sensors were placed in each shoe. The participants then put the shoes on with the use of a long handled shoe horn and were then asked to walk the required 10 steps. This also allowed the sensors to adjust to moisture and temperature within the shoe and to allow the patient time for familiarization with the system. This is recommended by the manufacturer and is called "conditioning" the sensor. Calibration was then performed according to the manufacturer's guidelines: the patient was weighed and this force was applied to the insole by the subject standing on the insole and lifting the opposite leg to apply all the body weight through one sensor.

After these preparatory procedures, recordings with the F-Scan commenced. Participants were asked to walk at their normal speed and a recording of 7 steps was made. For analysis the first and last step were disregarded so that normal cadence was established. The 3 steps which were most uniform were selected for analysis. Although walking cadence may have an effect on peak plantar pressures (Zhu et al, 1995) the patients in this study had difficulties walking due to deformity and pain. Patients were encouraged to walk at their normal pace. It was hoped this would lead to a recording of normal plantar pressures for each individual.

In a subset of patients the presence/absence of callus was document, as this feature was only noticed once data collection had already commenced.

All subjects were measured by the author.

7.7 DATA ANALYSIS

7.7.i The line of centre of pressure (COP)

The F-Scan system calculates the line of COP and this is shown on the screen image. For analysis, each image was printed out and a line defined as the foot axis was drawn from the tip of the second toe to the centre of the heel (van Schie and Boulton, 2000). It was then scored. If the line of COP fell mostly medial to the foot axis a score of 1 was given; if it fell mostly laterally, a score of 2 was given; for those feet where the line of COP coincided with the foot axis, a score of zero was given.

7.7.ii Area of peak plantar pressure

It was planned to capture the variations in plantar pressure using the F-scan assessment boxes as described in the literature (Rose et al, 1996). These allow detailed analysis of various compartments of the foot. Rose et al (1996) used boxes of a fixed area for all subjects in order to maintain this as a constant. However, in practice, it was quickly evident that the size of participants' feet varied to a very large extent. Consequently, the area in each box in relation to the foot as a whole was not uniform. For this reason it was deemed appropriate to utilise another method of assessing the variations in plantar pressure..

The foot was divided firstly, into medial and lateral aspects and, secondly, into toes and rest of foot. The F-scan has a facility to bisect the screen image both vertically and horizontally. These divisions appeared to allow more accurate analysis of equal areas of each of the participant's feet. The percentage pressure was calculated by the F-Scan system. The dimensions were set using the F-Scan software and remained constant for all data. Summary statistics were used to describe the population of the study. No significant differences in the groups was seen in respect of age or sex. A one sample Kolmogorov-Smirnoff test was carried out to test for normality of the Tekscan output.

7.7.iii Primary Analysis

As the data was normally distributed and these were continuous measures, parametric statistics were used to investigate the differences between the groups. A one way analysis of variance (ANOVA) was carried out and post hoc analysis was undertaken using Bonferroni multiple comparisons to determine where significant differences occurred.

The statistical package used was SPSS 14.0 for Windows.

(SPSS Inc, 233 S Wacker Drive, Chicago, IL 60606)

7.8 RESULTS

The characteristics of each clinical group are presented in Table 8. Analysis of differences between the groups are presented in Table 9.

Table 8 – Descriptive Characteristics

Group	Mean age, SD, range	Sex (% of population)	BMI, mean, SD, range
Group 1 : Hip OA	64, ± 6.9, 42-76	7 male (35%) 13 female (65%)	28.1, ± 3.4, 23-35
Group 2 : MCOA	63, ± 8.7, 45-79	9 male (45%) 11 female (55%)	29.4 ± 6.3, 21-41
Group 3: Controls	56, ± 7.3, 46-73	4 male (20%) 16 female (80%)	24.9, ± 2.9, 21-31

KEY: Group 1 – Patients with osteoarthritis of the Hip – Hip OA
Group 2 – Patients with medial compartment osteoarthritis of the knee - MCOA
Group 3 – Healthy volunteers –control

Table 9 - ANOVA of body mass index, centre of pressure, percentage of pressure on medial aspect of foot, percentage of pressure on toes of the Groups 1,2 and 3

	Group	Mean Values	Standard Deviation	F	P value
Body Mass Index (BMI)	Hip OA MCOA Control	28.100 29.400 24.950	±3.354 ±6.336 ±2.928	5.238	p = .008
Centre of Pressure	Hip OA MCOA Control	1.500 1.400 1.600	±0.827 ±0.882 ±0.753	0.295	p = .745
Percentage of pressure on medial aspect of foot (Pascal)	Hip OA MCOA Control	41.700 % 43.775 % 40.000 %	±3.049 ±4.813 ±3.986	4.434	p = .016
Percentage of pressure on toes (Pascal)	Hip OA MCOA Control	11.800 % 14.625 % 12.175 %	±3.499 ±4.196 ±3.847	3.162	p = .050

KEY: Group 1 – Patients with osteoarthritis of the Hip – Hip OA
Group 2 – Patients with medial compartment osteoarthritis of the knee - MCOA
Group 3 – Healthy volunteers –control

Post Hoc Bonferroni results indicate that most of the significant difference in BMI lies between the control group and the two patient groups. In all three groups the line of COP was slightly lateral. Patients with MCOA had the most medial line although this was not significant. There was a significant difference between the peak pressure on the medial side of the foot, with the MCOA group having the highest score and the hip OA group having the lowest, with the control group between these points. Most of the significant difference between toe and rest of foot pressure lies between patients with hip OA and patients with MCOA, again with the control group score lying between the other two.

In the course of the study an interesting, but unforeseen, feature of the feet of patients with lower limb OA became evident. It was noted initially because one patient observed that the line of COP ended in a spiral on the F-Scan screen on same area of the foot where he had a problem with callus. After this, the termination of the line of COP was observed with the remaining patients. The numbers are small and the result not statistically significant but, nevertheless, the spiral area at the end of most of the remaining lines of COP corresponded to areas of callosity in the foot. Foot callus has been seen as significant (Soohoo et al, 2003). The on- screen images are shown below.

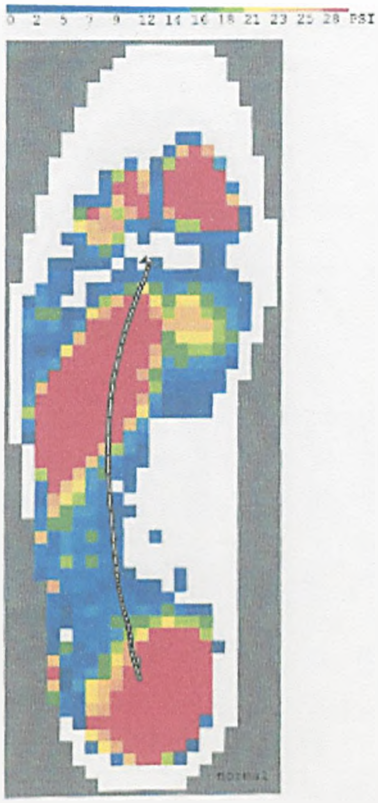


Figure 45 - Showing the plantar aspect of a normal right foot with Centre of Pressure line, showing weight passing from heel to lateral aspect and push off from hallux

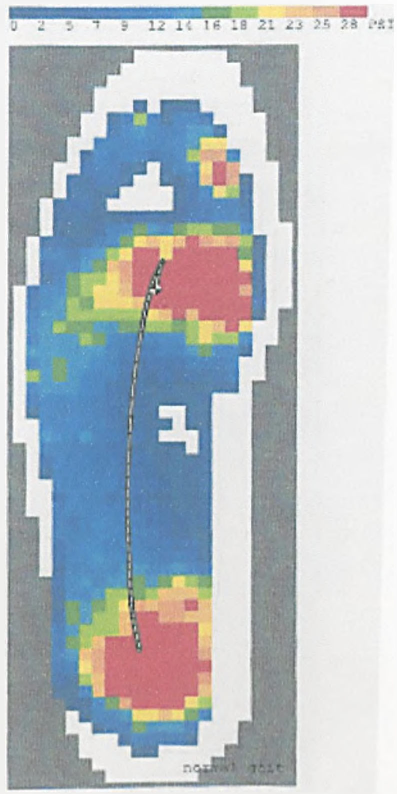


Figure 46- Showing the plantar aspect of a pronated right foot with Centre of Pressure (COP) line, showing weight on the 1st metatarsal phalangeal joint with little push off from hallux and with twist at end of COP line

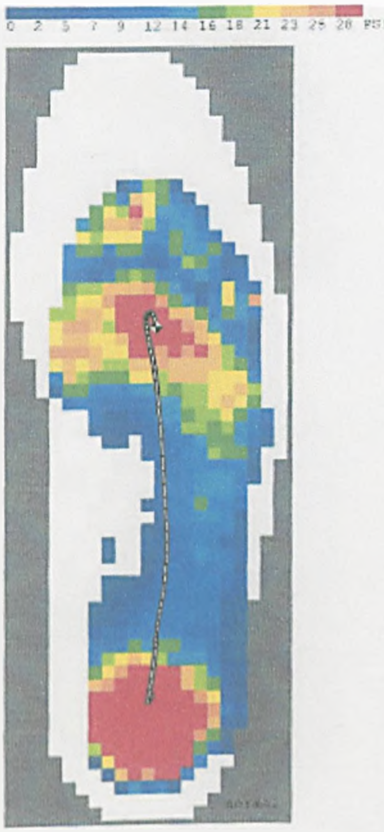


Figure 47 - Showing the plantar aspect of a pronated left foot with Centre of Pressure (COP) line, showing weight on 2nd metatarsal phalangeal joint with little push off from hallux and with a twist at end of COP line (This patient has a painful 1st metatarsal phalangeal joint or hallux valgus)

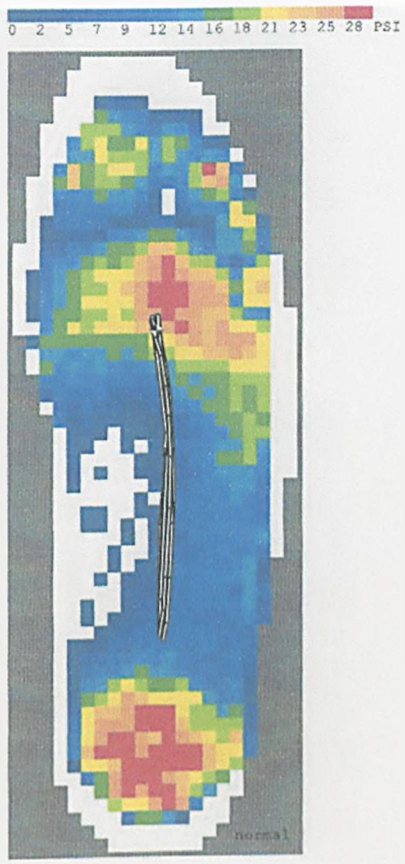


Figure 48 - Showing the plantar aspect of a supinated left foot with Centre of Pressure (COP) line, showing weight on 2nd/3rd metatarsal phalangeal joint with no push off from hallux and with twist at end of COP line (This patient has callous under these joints)

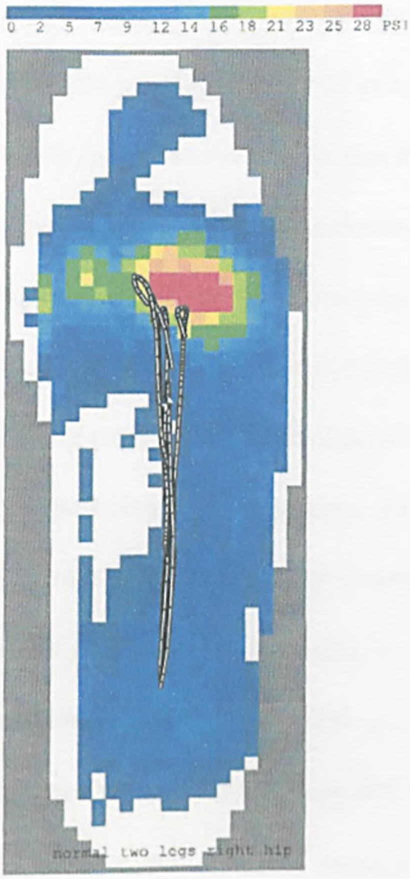


Figure 49 - Showing the plantar aspect of a supinated foot with Centre of Pressure (COP) line, showing weight on 4th/5th metatarsal phalangeal joints with no push off from hallux and with twist at end of COP line (This patient has callous formation under 4th /5th metatarsals and corn between)

7.9 DISCUSSION

A potentially important source of mechanical stress on the tissues of the knee and hip is an abnormal gait pattern (Orlin and McPoil, 2000). In a study which looked at the variance in dynamic plantar pressure derived from radiographs of static measurements only 35% of the variance could be explained by these measurements. This implies that the remaining 65% could be attributed to the dynamics of gait (Cavanagh et al, 1997). Atypical loading patterns may be reflective of risk factors for, or predictors of, lower limb pathology. Gait patterns may be influenced by different foot types. Extremes of either foot type, supinated or pronated, might result in changes in gait pattern which are sufficient to disrupt the normal closed chain functioning of the lower limb and loading of the foot. The F-scan system was used to attempt to detect differences in gait patterns of patients with hip OA, MCOA and a control group of healthy participants.

The F-scan system is relatively new. The design of the device suggests that the data obtained could reasonably be expected to accurately reflect the pressures on the foot while walking in shoes. The reproducibility, durability and variability of the system were evaluated by Rose et al (1992), Young (1993) and Randolph et al (2000). Other advantages of the system include that it is relatively easy to fit the insole to the subject's shoes and that the study can be conducted in a relatively short time, less than 1 hour per subject. A limitation of the pressure sensor is that its' properties may change over time which could produce unreliable data (Cavanagh et al,1992). Efforts were made to ensure the reliability of the F-Scan as used in this study by giving each subject a new sensor and ensuring good fit and minimal manipulation on insertion in the shoes. This does add to the expense of the system. The sensors are quite brittle and easily creased and this leads to distortion of the results. Care taken when trimming the sensor, when placing it in the shoe and allowing the participants to walk for 10 steps before recording may also help to minimise the effects of bending (Mueller and Strube, 1996; Rose et al, 1992).

Nicopoulos et al (2000) argued that the calibration might be inaccurate and that bending and temperature effects might lessen the overall reliability of the system. Since that time the calibration has been incorporated into the software package.

Mueller and Strube (1996) state that when rank ordering of measures is indicated then the F-scan is reliable. This means that the F-Scan can be used to compare one measurement to another measurement but it is not a diagnostic tool for making absolute decisions e.g. identifying a threshold for injury or pain. The purpose of this study was to assess relative differences between the groups, not for absolute decision about clinical classification.

7.9.i The line of centre of pressure

This study did not find significant differences in the centre of pressure (COP) line. The F-scan images did indicate a difference between the two patient groups which was apparent at the time of measurement but this did not reach significance level when analysed using the method of assessing the position of the line of centre of pressure as described in data analysis. This was the most precise measurement available given the differences in foot dimensions. The line of COP curved so using straight lines might not be sufficiently accurate and with additional software it might be possible to give a more precise percentage of the foot area/pressure on either side of the COP. Currently there is no such software available.

Although there are differences in the feet of all three groups, the patients' feet do not demonstrate serious pathologies. The hip and knee groups demonstrated foot characteristics which were at either end of the spectrum of normal. It is likely that the foot strives to keep the line of centre of pressure within normal range, in order to maintain balance and as normal a gait as possible. However, maintenance of the line of centre of pressure within normal limits might contribute to stress in other joints of the lower limb.

The main difference in the line of COP that was observed was the termination of the line. The COP line could be seen on screen for each individual step or averaged over the three steps. For most of the normal feet the line simply terminated but in many of the patients in this study it terminated in a spiral line. The site of this spiral line varied from patient to patient. This feature of the feet of the patients with lower limb OA had not been foreseen. In the American Orthopaedic Foot and Ankle Society clinical rating system (Kitoaka et al, 1994), mentioned earlier in this chapter, symptomatic and non-symptomatic callus on both the hallux and the 5th metatarsal are given scores.

In many of the patients with MCOA the spiral end to the line of COP was around the first metatarsal phalangeal joint (MPJ) and examination of the skin at this point revealed callus formation. The reason for the spiral at the end of the line of COP might be the failure of the foot to resupinate resulting in a lack of windlass effect. If the first MPJ is loaded then it cannot extend and this might result in a rotary moment occurring at this point. This would explain the callus formation as the skin would be compressed and the foot would twist on that area. In an unpublished MSc thesis (Durrell, 1995) which looked at the feet of young athletes the formation of callus under this joint in pronated feet was noted. This link between increased pressure and callus formation was also proposed by Hunt (1985) and Giallonardo (1988). The end of the line of COP may tend to become convoluted in an area where compression and rotary forces occur.

However, not all pronated feet demonstrated increased callus around the first MPJ. In some cases, a painful hallux valgus appeared to cause unloading of the first MPJ and the callus appeared under the second MPJ joints. This was also the area of a convoluted end to the line of COP.

This is something which requires further study. The position of the callus could reflect the different coping mechanisms patients with pronated feet have adopted to compensate for lack of resupination. Alternatively, there may be another explanation, or the finding may be mere artefact.

The patients with supinated feet displayed different tendencies. The line of COP was slightly more lateral at the end but also convoluted. Some demonstrated calluses at third and fourth metatarsal levels. This was a similar site to the patients with pronated feet and painful hallux but the areas of maximum pressure in the supinated feet were more lateral and this difference was observable on screen. Others demonstrated callus formation between fourth and fifth metatarsals and several of these patients stated that they had corns between their toes. These patients demonstrated forefoot varus and appeared to roll out on the lateral border of the foot.

The areas of callus formation at the end of the COP line in some patients were very interesting as they concurred with the hypothesis that the rotary component of gait is disturbed by changes in the supination/pronation/resupination cycle. This may result in an upwards effect on the knee and hip joints but may also have a downward effect on the skin of the sole of the foot. As the observation about callus formation was noted only after the data collection had started, it was not possible to collect the additional data on all patients. Thus a subset of approximately one third of the patients had their feet examined for callus formation, making it clinically interesting but insufficient in numbers to assess statistical significance. It may be an interesting area for further research.

7.9.ii Areas of Peak Pressure

Mueller and Rose (1996) used F-scan assessment boxes for detailed analysis of various compartments of the foot. In that study there were five subjects who did not have any complaints of foot problems. It did not give any details of subjects, whether male or female, or height or weight and given that the boxes were utilized, it is probable that they were all the same sex and roughly the same size. In this study there were men and women of various heights and it may be this fact which made the use of boxes impractical.

A research software package was not available at the start of this study, but has since been introduced. In future it may be possible to utilise this or to develop another method to grade the box sizes according to foot dimensions in such a way that they could be used to give a more accurate description of the percentage pressure in specific areas. This would improve the validity/reliability of the results. This problem was similar to that perceived with the use of navicular measurement in Chapter 4. The complexity of measurement of the foot may be a reason why so little research into the relationship of the foot and lower limb OA exists. The use of a marker at the joint such as a flat button which would be easily identified on screen might also help with accurate analysis.

A new method for measuring areas of peak pressure was therefore devised. The foot was divided into medial and lateral aspects, by splitting the screen vertically; and toes and rest of foot, by splitting the screen horizontally. Previous research indicates that a supinated foot is likely to demonstrate elevated pressure under the forefoot and rearfoot (Morag and Cavanagh 1999). Loading medially or laterally has been shown to be associated with the arch index, indicating a pronated or supinated foot (Menz and Morris 2006). These previous findings are supported in this study (Table 10). Patients with hip OA put less pressure on the toes and more on the lateral aspect of the foot, in keeping with the findings for a supinated foot. Patients with MCOA put more pressure on the medial aspect of the foot and more on the toes. The control group appeared to fall between the two other groups.

This study indicates that there is a significant difference in the percentage peak pressure areas of patients with hip OA and MCOA and the healthy control group.

7.9.iii Body Mass Index

The differences in BMI were significant. A high BMI is usually associated with MCOA but not hip OA (Reijman et al 2007), but in this case both patients with hip OA and MCOA had a higher BMI than the control group. The MCOA group did have the highest BMI and the heaviest individual participant but most difference was between the two patient groups and controls. This may be due to the relative inactivity of the two patient groups as both patient groups had restricted mobility due to pain from lower limb OA.

7.9.iv Toe-in toe-out gait patterns

An important aspect of gait which the F-scan does not indicate is toe out or in-toe gait. However, the equipment does have the facility to allow video images to be synchronised with the on screen images of foot pressures when walking. The gait pattern of people with MCOA has been shown to demonstrate less external foot rotation than a control group (Teichtahl et al, 2003) and it has been suggested that an externally rotated foot will decrease the peak adduction moment acing on the knee (Andrews et al, 1996; Guichet et al, 2003). In contrast, the toe out gait is the pattern of gait associated with a supinated foot which according to this thesis is associated with hip OA. The use of a video with the F-scan may therefore increase its clinical utility especially in gait assessment and re-education.

7.10 UTILITY OF THE F-SCAN SYSTEM

The F-Scan System is a sophisticated electronic system. The examination takes about one hour to complete and the system allows patients and therapist access visual data of the foot in motion.

It is commonly used clinically by podiatrists to assess high pressure areas in diabetic feet and the effects of orthoses on pressure distribution (Albert and Rinoie 1996). In this study, the F-scan demonstrated a significant variance in dynamic plantar pressure between the three groups, patients with hip OA, patients with MCOA and a healthy control group. Since differences in pressure distribution might indicate a potential source of mechanical stress on the knees and hips (Orlin and McPoil, 2000) this is useful information. It also allows both patient and therapist an insight into the areas of maximum pressure and the line of centre of pressure, both of which can be influenced by footwear, orthoses and gait. If attempts were made to normalise gait patterns of patients with lower limb OA using orthoses, then the F-Scan could be used to determine whether changes made had the intended effect.

The F-Scan requires training in its use and care in carrying out the procedure. With regular use, however, for clinical work, the system is reasonably straight forward.

7.11 THE FOOT POSTURE INDEX STUDY

7.11.i Introduction to the Foot Posture Index

The Foot Posture Index (FPI) was used as a clinical outcome measure to determine the foot posture of patients with hip osteoarthritis (OA), patients with medial compartment osteoarthritis of the knee (MCOA) and a control group of healthy volunteers. The intention was to determine whether the three groups demonstrated different foot postures. In addition, the utility of the FPI to orthopaedic physiotherapists in a clinical setting was assessed.

In addition, the previous clinical measurement of talocrural dorsiflexion was utilised to determine if there was a correlation between talocrural dorsiflexion and foot posture. This relationship has been visually noted in Chapter 4 but the use of the FPI would allow for a more scientific correlation to be established. It was not attempted to establish a correlation between calcaneal angle and foot posture as the calcaneal angle is part of the FPI.

The FPI, by measuring the foot posture in multiple planes and anatomical segments, gives a clear indication of which foot type an individual has and where precisely the foot differs from the norm (Redmond et al, 2006).

7.12 AIMS

The aim of this exploratory study was to look at the feet of the three groups, patients with hip osteoarthritis (OA), patients with medial compartment osteoarthritis of the knee (MCOA) and a control group of healthy volunteers, using the FPI to establish whether they displayed any statistically different characteristics. It also aimed to assess the utility of the FPI in a clinical setting when used with a cohort of patients with hip OA, MCOA and a control group of healthy volunteers.

HYPOTHESIS

H_1 Patients with OA hip, patients with MCOA and a group of healthy volunteers have different foot characteristics demonstrated by the FPI.

NULL HYPOTHESIS

H_{O1} There is no difference in the FPI of patients with OA hip, patients with MCOA and a group of healthy volunteers

7.13 MATERIALS AND METHODS

The study was performed with the approval of The Mid and South Buckinghamshire Local Research Ethics Committee (06/Q1607/1) and the hospital Research and Development Governance Unit permission was obtained. All participants gave informed consent.

7.13.i Design

This was an observational study carried out on a cohort of patients with lower limb OA and a group of healthy volunteers.

7.13.ii Setting

The study took place from January 2006 to January 2007 in a specialised orthopaedic hospital.

7.13.iii Statistical Analysis

Power Calculation

The primary outcome measure was the Foot Posture Index (Redmond et al 2006). A 5 point difference was assumed to be a clinically significant difference (δ). The standard deviation was based on the standard deviation of a normal group 3.99 (S). A sample size calculation using Altman's nomogram (Altman 1991) was carried out which indicated that for 80% power and a p value of 0.05, 20 feet in each group was needed to detect a difference of 5 points in the FPI (Std Diff = $\delta/S = 5/3.99 = 1.25$).

Data Analysis

Descriptive statistics were noted for age and gender and BMI (Table 12). The FPI scores were not normally distributed, therefore a Kruskal-Wallis test was used as it is the non-parametric alternative to a one-way between-groups analysis of variance (ANOVA). It allows comparison of scores of a continuous variable for three or more groups. Scores are converted into ranks and the mean rank for each group is compared. It is appropriate as, in this instance, there are different people in each of the three groups.

The statistical package used was SPSS 14.0 for Windows.
(SPSS Inc, 233 S Wacker Drive, Chicago, IL 60606)

7.13.iv Participants

Twenty patients with X ray and clinical evidence stage IV osteoarthritis of the hip immediately prior to total hip arthroplasty, twenty patients with X-ray and clinical evidence of stage IV osteoarthritis of the medial compartment of the knee immediately prior to Oxford unicompartmental knee arthroplasty (UKA) and twenty age matched healthy volunteers who served as controls were consented.

7.13.v Exclusion criteria

Any patients/volunteers with a history of previous accident or operation on the affected limb, neurological problems, diabetes or currently wearing orthotics were excluded from the study.

7.13.vi Measurement procedures

All participants underwent the same procedures

Talocrural dorsiflexion

Talocrural dorsiflexion measurement was carried out utilising the same procedure as in Chapter 4 except that a Gollenhon extendable goniometer, model 01335 (Layfayette Instrument Company, Lafayette, Indiana, USA) was used rather than a universal goniometer. This was now the instrument used by all physiotherapists in the pre-admission clinic.

Foot Posture Index

The FPI is made up of a composite score of 6 clinical features. These are:

7 Talar head palpation

8 Supra and infra lateral malleolar curvature

9 Calcaneal frontal plane postion

10 Prominence in the region of the talonavicular joint

11 Congruence of the medial longitudinal arch

12 Abduction/adduction of the forefoot on the rearfoot

Check numbering

Full explanations of each of these clinical criteria are detailed in the guidelines published by the author of the FPI (Appendix 3). Normal values are given as 0 to +5, the pronated foot +6 to +9 (highly pronated +10) and the supinated foot -1 to -4 (highly supinated -5 to -12).

All observations were made with the subject in relaxed standing with double limb support. They were asked to take several steps on the spot and then to relax and stand still, with their arms by their side and looking straight ahead. Foot posture was assessed and the summary score calculated.

The measurements were all taken by the author, who was also responsible for recruitment, so blinding was not possible. Additionally, the gait of patients with hip OA and those with MCOA are distinctive, as is the varus deformity of most patients with MCOA.

7.14 RESULTS

Table 10 describes the baseline characteristics of the study population. The groups were not significantly different in terms of age and distribution of sexes. The Kruskal-Wallis Test revealed a statistically significant difference in FPI and dorsiflexion scores across the three groups (Table 2). A Mann-Whitney U test revealed significant differences in FPI between each of the three groups (p=0.001). This indicates differences in foot types between the three groups so the Null Hypothesis can be rejected.

A Box and Whiskers plot demonstrates the actual FPI scores of the three groups graphically (Figure 50). It demonstrates that patients with hip OA had a low negative median FPI score which indicates a supinated foot. The range of scores was narrow. Those with MCOA had a high positive median score which indicates a pronated foot. The range of these scores was also narrow. All FPI scores for the control group lay between those of participants with Hip OA and MCOA, indicating a wide variety within this normal range.

The relationship between the FPI scores and talocrural dorsiflexion measurement was investigated using the Spearman correlation coefficient. There was a moderate positive correlation between the two variables (rho = 0.57, p =0 .001). A low degree of dorsiflexion was associated with a supinated foot. A high degree of dorsiflexion was associated with a pronated foot.

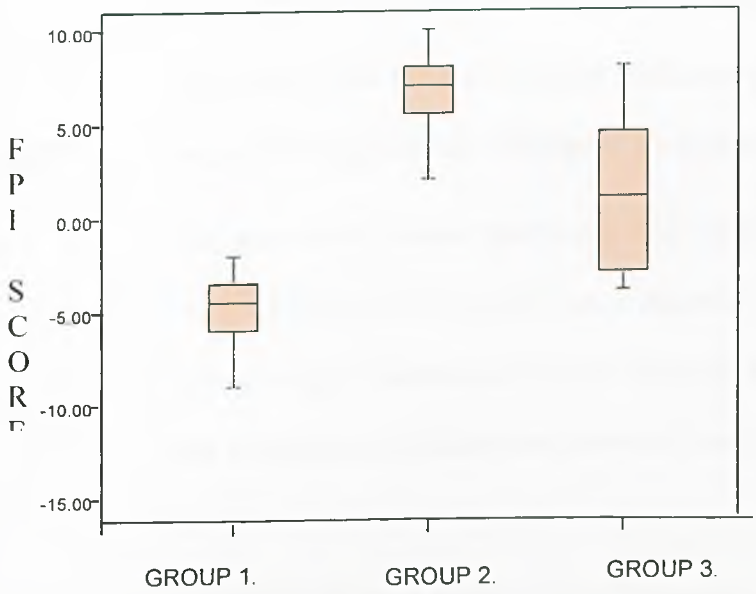
Table 10 – Demographic characteristics of study population

Group	Number Participants	Age Mean, SD, (Range)	Sex Number (% total)
1. Hip OA	20	64 ± 6.9 (50-74)	7 (35%) male 13 (65%) female
2. Medial Compartment Knee OA	20	63 ± 8.7 (46-79)	9 (45%) male 11 (55%) female
3: Control	20	56 ± 7.3 (42-68)	4 (20%) male 16 (80%) female

Table 11 – Comparison of Foot Posture Index and Dorsiflexion Range of Movement

	Group	Mean, SD	Chi - Square	df	p value
Foot Posture Index Score *(-12 to +10)*	1: Hip OA 2: MCOA 3:Control	-4.85±2.739 7.0±3.075 1.0±3.993	39.076	2	p=0.001*
Dorsiflexion *(30 to - 45 degrees)*	1: Hip OA 2: MCOA 3:Control	-2.60 ±5.215 9.10±-6.389 7.45±4.718	27.611	2	p=0.001*

*Kruskal-Wallis test



Key: Group 1 – Patients with OA hip
Group 2 – Patients with MCOA
Group 3 – Healthy controls

Figure 50 – Box and Whisker plot illustrating the differences in FPI scores for the three groups

7.15 DISCUSSION

The results demonstrate a significant difference in means of the FPI for each group. They indicate that the patients with hip OA and patients with MCOA are at opposite ends of the spectrum and the control group have a mean score which is between the two. This is graphically demonstrated in the box and whisker plot which clearly illustrates the fact that patients with hip OA have a negative, narrow range of scores indicating supinated feet. The patients with MCOA have a narrow range of positive scores indicating pronated feet. The range of FPI scores for the healthy volunteers was greater than either of the other two groups indicating a wide variety within normal range. This supports the findings of the initial study (Chapter 5).

The correlation between the dorsiflexion and FPI scores is significant and it has not been the subject of previous research. It has been noted that the normal range of dorsiflexion is very wide and that normal foot postures can also vary greatly but until now there has been no association demonstrated

7.16 UTILITY OF THE FOOT POSTURE INDEX

The FPI is an easy to use tool and which takes 10 – 15 minutes to complete the examination. It yields a numeric score which can be recorded so progress or deterioration through natural history of the condition can be noted. It also allows for assessing the results of therapeutic modifications, such as foot orthoses, or treatment programmes of muscle strengthening, stretching and gait re-training. The FPI has been the subject of physiotherapy in-service training in the orthopaedic hospital where the study was carried out and has been found to be user friendly.

Besides giving a foot posture score, the Foot Posture Index gives multiplanar information on the foot which allows for a more in depth assessment and, therefore, a more tailored treatment plan. By considering different planes separately and breaking the foot into separate areas it considerably eases the process of foot examination. The most notable differences within the patient groups were that patients with hip OA demonstrated both forefoot varus and normal forefoot. Patients with pronated midfoot sometimes demonstrated normal or supinated hindfeet i.e. a bulging navicular with an inverted calcaneus. Management of these conditions would be assisted with reference to the FPI.

The use of the FPI index to assess the foot posture of patients with lower limb OA would appear to be useful. Calcaneal angle is part of the FPI but talocrural dorsiflexion is not. Normal physiotherapy practice is to measure joints above and below the area being treated and it would appear good practice to include talocrural dorsiflexion measurements as well as the FPI in assessment of patients with lower limb OA.

Table 13 illustrates the comparative properties of the clinical outcome measures used in this thesis. Talocrural dorsiflexion, calcaneal angle and navicular height measurements are discussed in Chapter 4.

Table 12 - Clinical Outcome Measures

Talocrural dorsiflexion	Reliability	Construct Validity	Ease of Use	Cost
Using Goniometer	√	Untested	1	Time only
Calcaneal angle Using protractor	√	Untested	2	Time only
Navicular Height in sitting And standing	√	Untested	1	Time only
F-Scan system	√	Untested	3	£1200 plus insoles
Foot Posture Index	√	√	2	Time only

(Ease of use applies to a physiotherapist :

1. Part of normal training
2. With 1 – 2 sessions of additional training
3. More than 2 sessions of training + supervision during initial use.)

The F-Scan system would be useful clinically, particularly if physiotherapists were to use orthoses to try to normalise different foot postures, as it is necessary for these adjustments to be carefully monitored. The F-Scan allows monitoring of the foot in motion. The basis of this thesis is that small differences in feet and gait may be related to different sites of lower limb OA. It follows, therefore, that even small changes which are produced by the use of orthoses, must be the subject of thorough scrutiny.

The use of the Foot Posture Index is recommended in the clinical assessment of patients with lower limb OA. It is easily accessible, inexpensive and user friendly and could be incorporated into usual physiotherapy practice without adding excessive time to the examination. It examines the different areas of the foot, forefoot, midfoot and hindfoot and therefore gives an indication of different planar movements. It has been shown to be both reliable (Noakes and Payne, 2003) and have construct validity (Keenan et al, 2006). In practice it has value as a teaching tool as the manual, freely available from the internet, explains each of the factors with illustrations and by using the FPI the physiotherapist is able to more easily properly observe and assess the foot.

7.17 FURTHER WORK

Having established that a difference does exist in the feet of patients with lower limb OA and having examined methods of clinical measurement, it would then be logical to look at interventions which might alter the foot characteristics of these patients to bring them closer to the norm. Currently, there is only one biomechanical intervention which is recommended for patients with MCOA. This is the use of a lateral wedge to the foot. This would not be an obvious intervention if the patient already had a pronated foot. It was thought necessary, therefore, to carry out a systematic review of the literature on lateral wedges to see what benefits, if any, this approach brought to patients with MCOA.

CHAPTER 8. THE BIOMECHANICAL AND CLINICAL EFFECTS OF LATERAL WEDGES – A SYSTEMATIC REVIEW OF THE LITERATURE

8.1 DEFINITION

A systematic review is one that has been prepared using a systematic approach to minimise biases and random errors which is documented in a materials and methods section. A systematic review may, or may not, include a meta-analysis (Eggar et al, 2001).

A systematic review should contain a clearly focused question and be conducted to an explicit and reproducible methodology which strives to avoid the subjectivity and selection bias of traditional reviews (Main, 2003).

8.2 INTRODUCTION

Differences in the foot postures of patients with different sites of lower limb OA have been demonstrated (Chapter 3). Clinical tools for the assessment of the feet of these patients have been shown to be effective in demonstrating these differences (Chapter 5). A biomechanical explanation of why these differences might influence the development of specific sites of arthritis has been postulated (Chapter 2). Patients with MCOA have been shown to demonstrate pronated feet. In the world of sports medicine, physiotherapy and podiatry the treatment for the over-pronating foot is a **medial** wedge orthotic (Cornwall and McPoil, 1995; Kelaher et al, 2000; Vincenzino et al, 2000). However, orthopaedic literature advocates the use of a **lateral** wedge for the treatment of MCOA.

In patients with MCOA, it might be argued that the biomechanics of the foot and ankle complex may be altered by the varus deformity of the knee which is a late symptom of MCOA. However the prospective observational study of patients pre and post-operative unicompartmental knee arthroplasty (Chapter 4) indicates that the foot posture is robust and not altered by the significant change to knee alignment which occur as a result of surgery.

Most studies on the use of the lateral wedge focus on the effect on the knee and there are none which describe the foot type to which the wedge is being applied. Given that there is a possibility that the use of a lateral wedge may further compromise an already pronated foot and considering the results of the research in this thesis, a comprehensive, systematic review was undertaken to evaluate all available literature to determine whether evidence exists to support the claims that lateral wedges have a part to play in the conservative management of MCOA.

8.3 BACKGROUND

As early as 1975 there was a reference to lateral wedging as a conservative treatment for MCOA in Japanese (Tomastur, 1975); but it was in 1987 that Yasudi and Sasaki (Yasuda and Sasaki, 1987; Sasaki and Yasuda, 1987) first published in English two papers suggesting the biomechanical and clinical advantages of this approach. These papers are widely quoted: EULAR recommendations for the management of Knee Arthritis (Pendleton et al, 2000); Osteoarthritis: New Insights: Part 2: Treatment Approaches (Felson et al, 2000) and in Conferences with Patients and Doctors in JAMA (Lonner, 2003).

Although a Cochrane Review (Brouwer et al, 2005) has recently been completed it focused principally on knee braces and only considered three studies on lateral wedges. Cochrane Reviews have stringent quality criteria for selection of articles (Main, 2003) which is usually helpful. However, in this case, it eliminated many of the most frequently cited sources of evidence for lateral wedges available for clinicians including the two papers named above. In addition, two of the studies examined looked at two simultaneous interventions, lateral wedges and a subtalar strap. The subtalar strap was in the form of a figure of eight bandage around the hindfoot. It is applied in such a way as to encourage supination and inhibit pronation whereas a lateral wedge would encourage the opposite effect. In addition, evidence exists that both taping and strapping have proprioceptive effects (Simoneau et al, 1997; You et al, 2004; Robbins et al, 1995). Since it is not possible to assign the effects derived from the two studies to either the wedge or the subtalar strapping it was, therefore, decided that a comprehensive systematic review of all the available literature on lateral wedges used on their own would be useful.

Systematic reviews can save resources and prevent unnecessary research occurring in areas where conclusive evidence already exists. Despite the limitations of the approach, systematic reviews are advocated as the best available approach to summarise and synthesise date (Main, 2003) and are considered a major advance in the objective review of evidence (Crombie and McQuay, 1998).

8.4 BIOMECHANICAL BASIS FOR THE USE OF LATERAL WEDGES

Normal gait demonstrates an almost continuous external varus moment about the knee with the exception of a small, brief, valgus moment at initial contact (Harrington, 1993; Johnson et al, 1980). Even those individuals with valgus deformity of the knee will have a varus moment throughout stance (Johnson et al, 1980; Noyes et al, 1996). This is part of the normal biomechanics of gait (see 2.5.v). Although present in all individuals, it is this dominating varus moment and subsequent increased medial compartment joint load that is thought by many researchers to be partly responsible for the greater incidence of OA in this compartment (Goh et al, 1993; Schipplein and Andriacchi, 1991). However, a recent study (Maly et al, 2006) indicates that the knee adduction moment is unrelated to the pain and disability associated with MCOA. Nevertheless, given the importance that some researchers place on the knee varus torque in the progression of MCOA, conservative means to attempt to reduce this torque by means of an in-shoe lateral wedge constitute a seemingly logical conservative treatment (Kerrigan et al, 2002).

8.5 PROTOCOL

The protocol was developed using the model suggested by Egger, Smith and Altman (2001). Figure 51 demonstrates the eight steps recommended for the conduction of a systematic review.

Step 1 Formulate Question for Review

Step 2 Definition of Inclusion and Exclusion Criteria

Step 3 Location of Studies

Step 4 Selection of Studies

Step 5 The Assessment of Study Quality

Step 6 Data Extraction

Step 7 Analysis and Presentation of Results

Step 8 Interpretation of Results

Figure 51 - The eight steps for the conduction of a systematic review

(Adapted from Egger and Smith, 2001)

The question for this review was formulated as a result of one of the initial literature searches looking at conservative methods of treatment for MCOA. No previous comprehensive systematic review of the research was available, although several narrative reviews were located (Pollo, 1998; Rouillon, 2001; Nadler and Nadler, 2001; Marks and Penton, 2004). The Cochrane Review was not comprehensive and looked only at randomised controlled trials, whereas much of the literature involved biomechanical trials. The question was discussed and refined at the "Systematic Reviews" module at the Department of Continuing Education at Oxford University in September 2004 under the supervision of Dr. Mike Clarke. The question was "Does evidence exist to support the use of lateral wedges as part of the conservative management of MCOA and have the biomechanics of the foot been considered in use of these wedges?"

8.5.i Inclusion/Exclusion Criteria

As there were a limited number of studies available, it was decided that all studies would be considered eligible for this review if they investigated the use of lateral wedges, either biomechanically or clinically, in a normal or patient with knee OA population (but not patients with neurological problems). All types of data, methods and outcome measures were included. Studies which included subtalar elastic strapping were not included as it was felt that this strapping would compromise the effect of the lateral wedges by provoking a proprioceptive response or a sensory stimulus which opposed the effect of the wedge,..

8.5.ii Search Strategy For Identification of studies

The searches were first carried out in May 2003 and were repeated in July 2004. Search dates were 1975 – 2004 where available and there was no restriction on language. The searches were carried out by the author and the documents retrieved were reviewed by the author, Dr. Karen Barker and Dr. Delva Shamley.

Studies were initially sought in all languages from the following databases:

MEDLINE
EMBASE
CINAHL

Allied and Complimentary Medicine

PubMed

EBSCP HOST

PEDro (Physiotherapy Evidence Database)

The free text term "lateral wedge" was used.

This retrieved 63 articles but only 7 were relevant. Other types of wedges were given such as wedging for high tibial osteotomy etc. In addition to the 7 relevant studies, another 5 were located (Toda, 2001; Toda et al, 2001; Toda et al, 2002; Toda and Segal, 2002; Toda et al, 2004). These involved the use of a subtalar elastic strap as well as a lateral wedge.

The search was expanded using:

#1 lateral*wedge* OR orthotic* OR orthos* OR insole*

#2 osteoarthri* OR oa

#3 knee*

#4 #1 AND #2 AND #3

#5 Orthotic Devices [MeSH] AND Osteoarthritis, Knee [MeSH]

This retrieved a further 34 articles but brought the total number of relevant articles to 12.

ClinicalTrials.gov was also searched for trials in progress. This revealed two current randomised controlled trials (RCTs) taking place in the USA which are described.

Cochrane and other Systematic Reviews were searched for in Database of Abstracts of Reviews of Effects in the National Electronic Library for

Health. This revealed a current Cochrane Review which was completed during the course of this review.

8.5.iii Studies not retrieved

A hand search of the reference lists of the relevant studies revealed a further study which was in Japanese (Tomastur, 1975). This study pre-dated the other research and a translation was not sought since the English abstract of the study did not indicate that translating this article would make a useful contribution to the review. A previous review (Marks and Penton, 2004) mentions a study which was part of the proceedings of the 13th Biennial Congress of the South African Rheumatism and Arthritis Association, Cape Town, 1992 which did not appear in the above searches. It is not certain whether this was published or not but it was not attempted to obtain further details because it was already more than ten years since its presentation and it was similar to other studies in that patients were reviewed from 4 to 21 months, there was no control or comparison group, outcome assessment and allocation was not blinded, adherence was not assessed and the role of competing interventions was not addressed.

8.5.iv Selection of Studies

Titles and abstracts of all retrieved records were screened to identify obvious exclusions and full reports were obtained for the remainder. Each of these was then assessed. Twelve reports were considered suitable, but two of these described the same randomised controlled trial with the same sample population, assessed at different times and thus the data was only included once. A total of 11 studies could be considered for the review.

In addition to the Cochrane Review (Brouwer et al,2005) already mentioned, four other reviews (Pollo, 1998; Nadler, 2001; Rouillon, 2001; Marks and Penton, 2004) were retrieved. These are discussed in the results section.

In the eleven studies identified as suitable for inclusion in the systematic review, the research methodologies employed were dissimilar and the conclusions were very varied. The topic is, however, very specific, and so all studies on the effects of lateral wedging on MCOA were included. It was felt that the total number of articles was sufficiently limited to justify this approach.

8.5.v Data Extraction:

Data extraction was performed using a paper data extraction form and appraisal tool. This form was based on the CONSORT statement (Altman et al, 2001) and the Critical Appraisal Skills Programme (CASP).

Data extraction sheet and appraisal tool headings based on CONSORT statement and CASP guidelines

INTRODUCTION

- Theoretical Background
- Clearly focused question:

METHODS

- Study type
- Suitable recruitment

1. Suitable subject characteristics
2. Suitable selection criteria
3. Appropriate number of subjects – sample size
4. Randomisation

- Details of interventions and how they were administered
- Clearly specified objectives and hypotheses
- Clear definition of outcome measures
- Blinding

RESULTS

- Recruitment and loss to follow up
- Appropriate and precise outcome measures:
- Statistical methods: normal distribution, confidence interval
- Conclusions drawn from evidence

DISCUSSION

- Interpretation of results from hypothesis
- Extent of generalizability
- Possible bias/confounding factors
- Interpretation in context of current evidence

- Data extraction was carried out by the author and two independent investigators, Dr. Karen Barker and Dr. Delva Shamley.

8.5.vi Assessment of methodological quality

US Preventative Service Task Force Guide to Clinical Preventative Services

Quality of evidence

1 evidence from at least one properly designed randomised controlled trial

2 evidence obtain from well-designed controlled trials without randomisation

2a evidence from well-designed cohort or case control studies, preferably from more than one centre or research group

2b evidence from multiple time series with or without the intervention, important results in uncontrolled experiment could also be considered

3 Opinions of respected authorities, based on clinical experience, descriptive studies or reports of expert committees

Strength of recommendations

A Good evidence to support the intervention

B Fair evidence to support the intervention

C Insufficient evidence to support the intervention

D Fair evidence against the intervention

E Good evidence against the intervention

The US Preventative Services Task Force guide to clinical preventative services (1996) was employed to assess methodological quality, above. This guide can encompass all different types of study included in the review and gave a graded assessment of quality.

8.5.vii Data analysis and presentation of results

Meta analysis was neither possible, nor considered appropriate, because we found only one randomised controlled trial. This and the heterogeneity among the other studies with respect to duration, procedures and outcome measures meant that a brief narrative account of the results on a study-by-study basis was most appropriate. This decision was supported by discussion at the "Systematic Review Module" with Dr.M.Clarke.

8.5.viii Interpretation of results

The initial interpretation of the results of the review was undertaken by the author. The accuracy, meaningfulness of the interpretation was discussed with Dr. Karen Barker and Dr. Delva Shamley to ensure the appropriateness of the findings. Summary information on the studies is presented below in tables for ease of reference: Table 6 – descriptive, Table 7 – qualitative information.

8.6 RESULTS

Table 13 - List of studies (b) biomechanical and (c) clinical

	Date and Author	Country	No. of Subjects	Subject Characteristics	Gender (M)(F)	Age	Length of study	Outcome Measures
1b	**1987 Yasudi and Sasaki**	**Japan**	**10**	**Bilateral MCOA**	**(F)**	**51-63 mean (57.3)**	**Single intervention**	**X rays**
2b	**1995 Giffin et al**	**Canada**	**7**	**MCOA**	**(M)**	**25-58**	**Single Interventio n**	**X rays EMG Ground reaction force**
3b	**1997 Ogata et al**	**Japan**	**A:40 B: 38 C:10**	**No arthritis Medial COA Lateral COA**	**26(M) 62(F)**	**A:60 B:62 C::63 (mean)**	**Single interventio n**	**Accelero-meter**
4b	**2000 Crenshaw et al**	**U.S.A.**	**17**	**No arthritis**	**Not given**	**27.7**	**Single interventio n**	**Motion Analysis System**
5b	**2002 Kerrigan et al**	**U.S.A.**	**15**	**MCOA**	**8 (M) 7 (F)**	**Not given**	**Single interventio n**	**Laboratory walkway**
6b	**2002 Maly et al**	**Canada**	**12**	**MCOA**	**9 (M) 3 (F)**	**46-70**	**Single interventio n**	**Questor Gait Analysis**
1c	**1987 Sasaki and Yasudi**	**Japan**	**? 149 ? 162**	**MCOA**	**(F)**	**45-85 Or 40-72**	**Not clear**	**Patient report on pain and function**
2c	**1991 Wolfe and Brueckmann**	**U.S.A.**	**55**	**Aging athletes**	**Not given**	**Not given**	**Not given**	**Phone interview**
3c	**1991 Tohyama et al**	**Japan**	**?85, 62 or 52**	**Early MCOA**	**9 (M) 52(F)**	**37-84 Mean 57**	**7 – 12 years**	**Patient report on pain, X-ray,walking scores**
4c	**1993 Keating et al**	**U.S.A.**	**85**	**OA and MCOA**	**37 (M) 48 (F)**	**37-83 Mean 59.6**	**4-24 months**	**HSSS**
5c	**2001/2004 Maillefert et al/ Phan et al**	**France**	**156 (A=82 wedge B=74 neutral Insoles**	**MCOA**	**A=28M 54F B=13M 61F**	**A=64 B=65.6**	**2001 – 6 months 2004 – 2 years**	**2001 – Womac 2004 – Womac and X-rays**

Table 14 - Data extraction sheet and appraisal tool headings based on CONSORT statement and CASP guidelines

Studies

INTRODUCTION	1b	2b	3b	4b	5b	6b	1c	2c	3c	4c	5c
Theoretical Background	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Clearly focused Question	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
METHODS											
Study type clearly defined	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Subject characteristics precisely defined	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Selection critieria defined	N	Y	N	Y	Y	Y	N	N	N	N	Y
Sample size suitable for study type	Y	Y	Y	Y	Y	Y	N	Y	?	Y	Y
Randomisation	N/A	N/A	N/A	N/A	N/A	N/A	N	N	N	N	Y
Intervention details	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y
Clearly specified objectives/hypotheses	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
Clearly defined outcome measures	N	Y	Y	Y	Y	Y	N	N	N	Y	Y
Blinding	N/A	N/A	N/A	N/A	N/A	N/A	N	N	N	N	Y
RESULTS											
Recruitment and loss to follow up	N/A	N/A	N/A	N/A	N/A	N/A	N	N	N	N	Y
Precise outcome measures	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
Precise statistical methods	N/A	N/A	N/A	N/A	N/A	N/A	N	N	N	N	Y
Conclusions drawn from evidence	N	N	N	Y	Y	Y	N	N	N	Y	Y
DISCUSSION											
Interpretation of results from hypothesis	N	N	N	N	Y	Y	N	N	N	Y	Y
Extent of generalizability	N	N	N	N	Y	Y	N	N	N	Y	Y
Possible bias	N/A	Y	Y	Y	N	N	Y	Y	Y	Y	N
Interpretation in context of current evidence	N	N	N	N	Y	Y	N	N	N	Y	Y

Y = yes   b = biomechanical   N/A = not applicable

N = no   c = clinical

8.6.i Biomechanical Studies

1b. The Mechanics of Treatment of the Osteoarthritic Knee with a Wedged Insole. Yasuda K, Sasaki T (1987).

The mechanical effects of standing on a wedged board while balancing on one leg were examined in this study. The results state that putting a wedge under the foot will alter the angle of that limb in relation to the supporting surface but no other clear findings emerge.

Methodological quality 2bC

2b. Application of a Lateral Heel Wedge as a Non-surgical Treatment for Varum Gonarthrosis. Giffin et al (1995).

This study evaluated the effect of the use of a 12.5mm heel wedge tapering to 6.35mm at the forefoot worn in shoes both statically and dynamically. It was found that there were no statistical differences in linear parameters or in free gait speed between conditions. There was a small varum to valgum shift in the femoral-shaft-tibial angle but alignment of the leg remained in a relative varum position. No statistical differences were noted in either anterior/posterior ground reaction forces or in EMG profiles between the wedged and non-wedged condition for vastus lateralis and medialis.

Methodological quality 2bC

3b. The effect of wedged insoles on the thrust of osteoarthritic knees. Ogata et al (1997).

The biomechanical effects of a lateral/medial wedge on the lateral/medial thrust (sideways movement) of normal and MCOA knees were examined in this study. There were three groups: Group 1 - 40 subjects with normal knees; Group 2 – 38 subjects with a total of 50 OA knees demonstrating a lateral thrust; Group 3 – 10 subjects with 10 OA knees demonstrating a medial thrust. The thrust at the knee was measured using an accelerometer while walking for 10 gait cycles on a walkway wearing the participants own shoes. Most of Group 1 demonstrated lateral thrust which was reduced with a lateral wedge. In all of Group 2 the lateral thrust was reduced by the lateral wedge, especially those subjects with early OA. In all of Group 3 the medial thrust was reduced by medial wedges. The main objective of this study was to evaluate biomechanical effects rather than clinical efficacy and it did demonstrate a difference in the first peak of medial/lateral acceleration after heel strike in many, but not all, of the knees tested. However, it then assumed that this was equivalent to clinical improvement which is not the case. The pain reduction claimed was not defined.

Methodological quality 2bC

4b. Effects of Lateral-Wedged Insoles on Kinetics at the Knee. Crenshaw et al (2003).

Three-dimensional gait analysis was used in this study to examine the kinetics of the use of lateral wedges with **healthy subjects.** Kinematic data was collected for one side of each subject (randomly selected) using five-camera high resolution Motion Analysis system and an AMTI OR6-5 force platform. Subjects walked up and down 8 metre walkway without and with lateral wedged insole with 5° angle along full length of insole. No differences were noted in velocity cadence and stride length or in hip, knee or ankle kinematics. Kinetics at knee demonstrated reduced external varus moment.

Methodological quality 2bD

5b. Effectiveness of a Lateral Wedge Insole on Knee Varus Torque in Patients with Knee Osteoarthritis. Kerrigan et al (2002).

This study used gait lab analysis to determine whether a lateral wedged insole reduced knee varus torque. Subjects were examined under 5 conditions.

1) in their own shoes

2) own shoes and non-wedged insole 3.175mm thick on affected side

3) own shoes and 5° lateral wedge on affected side

4) own shoes and non-wedged insole 6.35mm thick on affected side

5) own shoes and 10^{o} lateral wedge on affected side

Subjects were required to walk across a 10 m laboratory walkway and the order of testing was randomized. A reduction in knee varus torque was noted with both wedged insoles compared with non wedged insoles in early and late stance. The effects of this on pain were not analysed nor the effect on progression of MCOA knee.

Methodological quality 2bB

6b. Static and dynamic biomechanics of foot orthoses in people with medial compartment knee osteoarthritis. Maly MR et al (2002).

A biomechanical study using repeated measures to examine the effects of lateral wedges and a modified orthosis on gait. Subjects were exposed to 3 conditions:

1) own shoes

2) own shoes with 5^{o} valgus heel wedge

3) off the shelf orthosis modified to maintain rearfoot in 5^{o} valgus.

Subjects were required to walk on force plate for dynamic measures and order of testing was randomized. The study produced no evidence that lateral wedges altered lower limb static alignment and found that the adduction moment was unaffected by altered footwear

Methodological quality 2bD

8.6.ii Clinical Studies

1c. Clinical Evaluation of the Treatment of Osteoarthritic Knees Using a Newly Designed Wedged Insole. Sasaki T, Yasuda K (1987).

This aimed to examine the clinical effects of a treatment with lateral wedges. All patients were prescribed Indomethacin 600 mg/day and were also given one of 3 types of wedged insole: in shoe, shoe type, Japanese sock type. It is very difficult to validate any claims made in the conclusion of this study because patient numbers vary throughout. Clarification was not sought from the original researchers because the work was completed more than 20 years ago.

Methodological quality 3C

2c. Conservative treatment of genu valgus and varum with medial/lateral heel wedges. Wolfe SA, Brueckmann FR.(1991).

This study hypothesizes that the shifting of weight from one side of the foot to another by the use of a wedge will reduce pain in the knee. All patients were prescribed aspirin/aspirin like substances or low dose nonsteroidal anti-inflammatories + 1/8 inch medial or lateral wedges to be placed in shoe. Pain reduction noted but use of anti-inflammatories and aspirin increased.

Methodological quality 3C

3c. Treatment of osteoarthritis of the knee with heel wedges. Tohyama et al (1991).

The aim of this study was to examine pain and walking ability changes with the use of lateral wedges. It was not stated if the study was retrospective or prospective. Forty-nine patients were treated with analgesics + lateral wedges, 13 with analgesics alone. The main findings were differences in pain scores in first and second follow up, differences in walking ability in first follow up (time to follow-up not given) no difference in radiographs. All knees deteriorated and there was no significant difference between groups. There is no mention of how long or how often the wedges are worn and since this is an exclusively female Japanese population, this may be important. No significant outcomes were stated.

Methodological quality 3C

4c: Use of Lateral Heel and Sole Wedges in the Treatment of Medial Osteoarthritis of the Knee. Keating EM et al (1993).

The Hospital for Special Surgery scoring system was used in this study to evaluate lateral wedge use because Japanese scoring systems had been used in previous studies. There were five groups of patients: graded according to Sasaki and Yasuda's Modification of Ahlback's Classification of Medial Knee Osteoarthritis (see figure below). The interventions were: non steroidal anti-inflammatory drugs (except where contra-indicated) + removable in shoe wedges of 1/4 inch heel elevation and 3/16 sole elevations for patients in Groups 1 to 3. Patients in groups 4 to 5 could either have heel wedges or tibial osteotomy. Follow up period was on average 12 months but ranged from 4 to 24 months. HSS and HSS pain scores improved but authors note that this may be due to placebo effects.

Methodological quality 3C

Sasaki and Yasuda's Modification of Ahlback's Classification of Medial Knee Osteoarthritis

Grade I	Osteophytes only, no narrowing of joint space
Grade II	Decrease in medial joint space on standing roentgenogram of less than one half the lateral joint space
Grade III	Decrease in medial joint space of more than one half the lateral joint space
Grade IV	Obliteration of the medial joint space, with bone attrition of less than 1 cm
Grade V	Obliteration of the medial joint space, with major bone attrition of more than 1 cm

Figure 52 - Classification used in Keating's study (4c)

5c(1): Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis: a prospective randomized controlled study. Maillefert et al (2001).

This prospective randomized controlled study compared the effects of a neutrally wedged insole (control) with lateral wedge insoles and reports results after 6 months. It was multi-centred (5) and double blinded. Patients were randomly assigned to two groups. A podiatrist carried out randomization after screening for exclusion criteria related to foot function. Exact details are not given. Group 1 was given bilateral laterally elevated insoles and Group 2 bilateral neutrally wedged insoles. Patient assessment of disease activity, Womac index subscales (Wolfe et al, 1999) and concomitant treatment were used to measure outcome. No significant differences but some decrease in concomitant drug therapy in Group 1 was noted. Interestingly, the changes observed were less than what would be considered normal for the placebo effect and although not significant, the neutral group had better response in terms of Womac scores.

5c(2). Laterally elevated wedged insoles in the treatment of medial knee osteoarthritis: a two-year prospective randomized controlled study. Pham et al (2004).

This study reported on the same subjects as 5c (1) at two years and also included radiographic follow up. No significant differences were noted between groups.

Methodological quality 1C

8.7 STUDIES CURRENTLY BEING UNDERTAKEN

The literature search also revealed that two randomised controlled trials are currently being carried out in the US. Both are sponsored by National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS).

8.7.i Randomized trial of a wedged insole for treatment of osteoarthritis of the knee

Contact information: Joel A. Block, MD and Rush University Medical Center, Section of Rheumatology, Chicago, Illinois 60612, USA.

Study type: interventional

Study design: treatment, randomized, double-blind, active control, crossover.

No of patients enrolled : 109, enrollment period closed August 2004
Anticipated duration: 36 month treatment period.

This is an efficacy study. The results of this trial may give more information but it will be some time before results are disseminated.

8.7.ii Clinical Effects of Altered Biomechanics in Knee Osteoarthritis.

Contact information: Joyce P. Goggins, MPH and Boston University Medical Center, Boston, Massachusetts, 02118, USA.

Study type: interventional

Study design: treatment, randomized, double blind, active control, parallel assignment.

No of patients enrolled: 90, enrollment period closed November 2004.

This is an efficacy study.

8.8 PREVIOUS REVIEWS

There have been five previous reviews but these were not comprehensive.

- Bracing and heel wedging for unicompartment osteoarthritis of the knee, Fabian Pollo (1998) This article is principally concerned with knee bracing but gives a short description of the studies of Yasudi and Sasaki (1987). It also mentions Keating et al (1993) and quotes his reservation that ankle joint problems might arise.

- Orthèses, semelles et reeducation fonctionnelle: existe-t-il des solutions aux problèmes biomèchaniques de l'arthrose du member inférieur? O. Rouillon (2001). This article is concerned with knee bracing and functional reeducation. It mentions that most work on insoles has been done by Japanese researchers and that there is some evidence that the interventions might reduce pain. However, Rouillon found no study with rigorous methodology and no radiological evidence that lateral wedged insoles have an effect on the progression of the disease.

- Assistive devices and lower extremity orthotics in the treatment of osteoarthritis, R. Nadler and S Nadler (2001). This article focuses on arthritis of the lower limb, not exclusively the knee and has only a single paragraph on wedged insoles. It mentions Sasaki and Yasuda (1987) and Crenshaw et al (2000) and concluded that the results of these studies suggest that lateral wedges "are effective as a conservative treatment for patients with mild medial compartment degeneration".

- Are foot orthotics efficacious for treating painful medial compartment knee osteoarthritis ? A review of the literature. R. Marks and L. Penton (2004). This is a fairly comprehensive review on the use of lateral wedges. Overall, it finds in favour of the use of lateral wedges but suggests they might need to be "specifically designed to overcorrect for any prevailing joint malalignment or crafted in light of the precise magnitude of the prevailing osteoarthritic varus deformity". It also suggests that researchers "might also focus on examining the efficacy of wedged insoles in well-designed prospective trials, with adequate outcome measures".

- Braces and orthoses for treating osteoarthritis of the knee, Brouwer et al (2005). The Cochrane Review included three studies. Two of these combined lateral wedges with sub-talar strapping (Toda, 2001; Toda et al, 2004). This review finds only limited evidence that a lateral wedged insole decreases NSAID intake and has greater compliance compared with a neutral insole. It also found that there was limited evidence that a strapped insole has more adverse effects than a lateral wedged insole; this may indicate that the strapping does indeed have a different effect.

8.9 DISCUSSION

It is almost 30 years since the publication of the first English reports of the two Japanese trials. During this time, the rigor and standards of clinical trials have changed and what was previously considered an acceptable study may not meet the tighter specifications required today. In addition, the applicability of the four Japanese studies to a more general population is questionable. Racial differences in gait and foot type have been considered significant by diverse authors (Igbigbi and Msamati, 2002; Chen et al, 2003; Cho et al, 2004). In particular, Chen (2003) suggests that significant racial differences in gait may possibly explain differences in prevalence of knee arthritis in Chinese women. Furthermore, Sasaki and Yasuda's (1987) observation that elderly Japanese women do not wear shoes indoors and wear wooden clogs or sandals outdoors makes the use of insoles problematic, is important as it makes the length of time that the women in their study wore the lateral wedges unclear.

It has been stated that the magnitude of change that a lateral wedge can bring about in the static mechanical axis of the lower limb i.e. a more upright position is small in comparison to the static realignment that can be achieved by the high tibial osteotomy surgery (Maly, 2002). However, small changes at the end of a long lever may have significant changes further up the lever arm and the effects of the wedges on the hips has not been investigated.

Also, as the normal biomechanics of gait in patients with MCOA is compromised due to pain and varus deformity, further disruption by the use of a wedge to accentuate pronation and retard supination may provoke degenerative changes in a previously well balanced foot and ankle (Friedlander, 1989). The use of a lateral wedge which moves the pattern of gait further from the normal in a pronated foot is therefore questionable.

Overall the results of this review suggest that, based on current evidence, there are no major or long term beneficial effects with the use of lateral wedges. The X-ray results indicated that lateral wedges do not alter the normal course of MCOA, neither do they result in any change in observed radiological severity. There is limited evidence to suggest that their use may reduce varus knee torque and provide some temporary pain relief to patients with MCOA. However, the only randomised controlled trial (RCT) did not support the positive findings of other studies. (A second paper on this RCT was published with results at two years (the first was at six months post intervention). The fact that it did not make it very obvious might have led to the assumption that there were two RCTs which did not support the use of lateral wedges). Currently, two further RCTs are being carried out but the results have not yet been published.

At the present time the use of lateral wedges in the conservative management of medial compartment knee arthritis is not supported by the available literature and the biomechanics of the foot and ankle during gait appear not to have been considered in the current body of research.

8.10. UPDATE

This systematic review was completed in 2004 and submitted and accepted for publication in The Knee : "A systematic review of lateral wedge orthotics – how useful are they in the management of medial compartment osteoarthritis?" The Knee,
13: 177-183, 2006.

Of the two randomised controlled trials (RCT) which were being carried out in the US, one is still ongoing "Randomized trial of a wedged insole for treatment of osteoarthritis of the knee. Contact information: Joel A. Block, MD and Rush University Medical Center, Section of Rheumatology, Chicago, Illinois 60612, USA" and will be completed in December 2008.

The other "Clinical Effects of Altered Biomechanics in Knee Osteoarthritis. Contact information: Joyce P. Goggins, MPH and Boston University Medical Center, Boston, Massachusetts, 02118, USA" has now been published as "A Randomised Crossover Trial of a Wedged Insole for

Treatment of Knee Osteoarthritis" (Baker et al, 2007). The result of this RCT is discussed below.

A new RCT is currently recruiting patients. "Wedged Orthoses and Knee Osteoarthrtis" sponsored by the University of Delaware started in February 2002. Contact information: Todd D. Royer, PhD, Principal Investigator, University of Delaware, Newark, Delaware, 19716 (email: royer@udel.edu).

Study type: interventional

tudy design: treatment, randomized, single blind, placebo control, single group assignment, efficacy study

This study is still recruiting patients.

The trials published since the publication of the systematic review are itemized in the table below and graded, as before, using the US Preventative Service Task Force Guide to Clinical Preventative Services (1996).

Table 15 - List of recent studies (b) biomechanical and (c) clinical

	Date and Author	Country	No. of Subjects	Subject Characteristics	Gender (M)(F)	Age	Length of study	Outcome Measures
6b	2005 Kakihana et al	Japan	26	13 healthy controls, 13 patients with bilateral knee OA	13 (F) 13(F)	64±2.3 63.3±5.6	Single intervention	Gait lab 3D motion analysis, Femoral/ tibial/talar angle by X-ray
7b	2007Kakihana et al	Japan	70	51 patients with bilateral MCOA, 19 healthy controls	51 (F) 19(F)	65.5±3.8 67.1±4.2	Single intervention	Gait lab 3D motion analysis, Hip/Knee/ Ankle (HKA X-ray Kellgren & Lawrence classification
8b	2006 Shimada et al	Japan	42	23 patients with bilateral MCOA (46 knees), 19 healthy controls (38 knees)	6 (M) 17 (F) 5 (M) 14 (F)	67±8.7 66.4±9.3	Single intervention	Gait lab 3D motion analysis, X-ray Kellgren & Lawrence classification
6c	2005 Rubin and Menz	Australia	30	Patients with MCOA	21 (M) 9 (F)	58±11.6	6 weeks	Pain using Visual Analogue Scale
7c	2006 Fang et al	USA	28	Community dwelling adults with knee OA	18 (M) 10 (F)	67±11	4 weeks	Pain, stiffnes functional status WOMAC, OA Index
8c	2007 Baker et al	USA	86	Unilateral & Bilateral MCOA	29 (M) 57 (F)	68 (mean)	16 weeks	Pain, WOMAC, Medications

W. Kakihana et al have published two similar trials on lateral wedges. These are:

6b. Effects of laterally wedged insoles on knee and subtalar joint moments. Kakihana W, Akai M, Nakazawa K, Takashima T, Naito K, Torii S. (2005). The biomechanical effects of walking with 0° and 6 ° lateral wedges while walking over a force platform were examined in this study. The conclusion was that although the 6 ° was more effective than the 0 ° in reducing varus moment at the knee, the lateral wedge did not consistently reduce the knee joint varus moment in patients with knee OA. It suggests that a larger study should be carried out.

Methodological quality 2C

7b. Inconsistent knee varus moment reduction caused by a lateral wedge in knee osteoarthritis. Kakihana W, Akai M, Nakazawa K, Naito K, Torii S. (2007).

The biomechanical effects of walking with 0° and 6 ° lateral wedges while walking over a force platform were examined in this study. This study had a larger sample size but the conclusion was similar in that although the 6 ° was more effective than the 0 ° the lateral wedge did not consistently reduce the knee joint varus moment in patients with knee OA.

The knee joint varus moment not reduced in 18% of patients, nine patients actually had an increase. It suggests that indications and limitations of lateral wedge treatment should be confirmed by an RCT.

Methodological quality 2C

8b. Effects of disease severity on response to lateral wedge insole for medial compartment knee osteoarthritis. Shimada S, Kobayashi S, Wada M, Uchida K, Sasaki S, Kawahara H, Yayama T, Kilade I, Kamei K, Kubito M, Baba H (2006). The biomechanical effects of walking with lateral wedges (no further information on wedge available from study) while walking over two forceplates were examined in this study. They concluded that although kinetic and kinematic effects of lateral wedged insoles were not correlated they did reduce the lateral thrust in the first acceleration peak in gait but only for Grades I and 2 knee OA.

Methodological quality 2C

6c. Use of laterally wedged custom foot orthoses to reduce pain associated with medial knee osteoarthritis: a preliminary investigation. Rubin R, Menz HB (2005). Patients were issued with a custom molded foot orthoses with a 5 ° lateral wedge. Patient report at 6 week follow up indicated pain reduction in all patients, more in those with mild to moderate MCOA.

Methodological quality 3C

7c. Effects of footwear on medial compartment knee osteoarthritis. Fang MA, Taylor CE, Nouvong A, Masih S, Koa KC, Perell KL (2006). This is described as an uncontrolled pilot study. Twenty- eight patients wore 4° lateral wedges in shock absorbing shoes for 4 weeks. The conclusion stated is that all patients with varying Kellgren and Lawrence grades of MVOA report a reduction of pain, stiffness and functional impairment at 4 weeks. The authors suggest that the shoes may also have had a confounding effect.

Methodological quality 3C

8c. A Randomised Crossover Trial of a Wedged Insole for Treatment of Knee Osteoarthritis. Baker K, Goggins J, Xie H, Szumowski K, LaValley M, Hunter DJ, Felson DT (2007). (RCT which was in progress during systematic review under title "Clinical Effects of Altered Biomechanics in Knee Osteoarthritis")

Double-blind, randomized, crossover trial designed to detect a small effect of treatment. Patients were randomized to receive a 5° lateral wedge or neutral insole for 6 weeks, a 4 week washout period was then followed by the other treatment. The result of this RCT was that "The effect of treatment with a lateral wedge insole for knee OA was neither statistically significant nor clinically important".

Methodological quality 1E

Additionally, an unpublished PhD thesis "Efficacy of Lateral Heel Wedge Orthotics for the Treatment of Patients with Knee Osteoarthrtis" (Wallace 2006) which is available on the internet, concludes that further studies would be necessary to determine the efficacy of lateral heel wedges over a prolonged period.

The findings of these further studies do not contradict the original conclusions that were published by the author (Reilly et al 2006, Appendix 2).

CHAPTER 9. DISCUSSION, CONCLUSION, AND SUGGESTIONS FOR FURTHER RESEARCH

9.1 DISCUSSION

9.1.i Synopsis of study and findings

A clinically observed difference in the feet of patients with different sites of lower limb OA was the starting point of this thesis and its overall purpose was to explore the foot posture of patients with lower limb OA both experimentally and clinically.

The prospective observational study (Chapter 5) revealed differences in foot characteristics between two groups of patients with different sites of lower limb OA and a control group of healthy volunteers. There were 60 patients in the hip OA group who demonstrated lack of adequate dorsiflexion and calcaneal inversion. These characteristics are linked to a supinated foot (Figures 3 and 4). The 60 patients with MCOA demonstrated a good range of dorsiflexion and calcaneal eversion. These characteristics are linked to a pronated foot (Figures 5 and 6). The control group did not demonstrate either extreme. The observational study was published (Appendix 1) and was the first study to compare the foot characteristics of patients with hip OA and MCOA.

A further observational study (Chapter 6) was conducted which assessed a group of 55 pre and post-operative patients with MCOA. It was noted in this study that, after Oxford unicompartmental knee arthroplasty, although there is a significant correction of the knee varus deformity, a late onset sign of MCOA, the feet remain unchanged. This suggests that the foot characteristics are relatively robust. However, the short time frame, 6 to 8 weeks post-operative, does not allow firm conclusions to be made. Nevertheless, biomechanically the varus deformity might be more likely to contribute to a supinated foot. The study lends some weight to the argument that pronated feet do not occur as a result of the varus deformity associated with MCOA, but a causal relationship still cannot be assumed.

As a difference in the foot characteristics has been noted, examination of the feet might usefully be included in physiotherapy assessment of patients as part of the conservative management of lower limb OA. If the patient does exhibit deviant foot characteristics, it is possible to address this. One of the major problems till now has been the lack of a simple, objective and quantitative outcome measure (Urry and Wearing 2001). Currently, there is no standard practice for physiotherapy examination of the foot in an orthopaedic setting for patients with lower limb OA. Therefore, an investigation into clinical outcome measures for foot posture was carried out

(Chapter 7). After consideration of the available clinical outcome measures, two were selected for further investigation.

The F-Scan system was used for the first time to compare the feet of patients with lower limb OA. The results clearly demonstrated different pressure distribution under the foot of patients with hip OA, those with MCOA and the control group. Also observed were different sites of callous formation on the soles of the patients with hip OA and MCOA. These were particularly interesting as failure of the subtalar joint to act as a torque converter might result in a rotation moment in the foot which could be the cause of this callous formation (Chapter 7).

As complex analysis in the gait laboratory is an expensive and time consuming procedure and is not available for general use, the F-Scan may be a more affordable substitute. The F-Scan equipment was found to be useful but was also time consuming and further training would be required before a physiotherapist could incorporate routine use of the equipment into usual clinical and research practice.

The Foot Posture Index (FPI) was also the subject of study and was used to compare the feet of patients with lower limb OA, again this was the first time that this clinical outcome measure had been used with this cohort of patients. The results once again clearly demonstrated clinical differences between the feet of patients with hip OA, MCOA and the control group of healthy volunteers. A correlation between talocrural dorsiflexion, and foot posture was noted by use of the original measurements and the FPI which confirmed the visual observations noted in Chapter 5. The value of the FPI as a simple clinical measurement tool for physiotherapists was indicated. Because of the multiple segments and multiple planar movements in the foot most clinical outcome measures are too complex for clinical situations. The ease of use of the FPI makes it a useful adjunct to traditional clinical assessment methods which use goniometers and protractors for measuring angles and also adds to clinical management by giving a score which can be utilised to monitor treatment outcomes. At present, visual assessment is the usual method employed in foot examination but even this is rarely undertaken. If treatment of abnormal foot postures is to be undertaken, it is essential that careful assessment is carried on both for planning and monitoring treatment. This study has been accepted provisionally for publication by Physiotherapy.

Currently, the only biomechanical intervention in the conservative management of MCOA is the lateral wedge. However, none of the studies which looked at the use of lateral wedge orthoses considered the posture of the foot to which these were being applied. Only the effects on the knee and signs and symptoms of MCOA were considered. As normal gait biomechanics in patients with MCOA are compromised due to pain and varus deformity, further disruption by the use of a wedge without considering the foot may provoke degenerative changes even in a previously well balanced foot and ankle (Friedlander 1989). Therefore, a systematic review (Chapter 8) was carried out as part of this thesis to examine this practice as, if lateral wedging produced a very positive effect, then the significance of the biomechanics of the foot in MCOA would be questionable. The review demonstrated that none of the studies presented clear evidence of benefit or damage. The increased adduction moment which the deformity produced needs to be considered but the adduction moment is not the only influence on the knee during gait. This was the first systematic review of the use of lateral wedges to be published (Appendix 2).

9.1.ii Significance of pronated or supinated foot

In orthopaedic medicine there is a tendency to be joint focused. In textbooks, the joints are listed individually in chapters but there is often no overall view of the body in motion (Apley and Solomon, 1997). Similarly, in the Medical Student Information Pack (current 2007) from the Trauma and Orthopaedic Department of University Hospitals Coventry and Warwickshire NHS Trust, while the key skills included the focused examination of the major joints, they do not include gait assessment. This may explain why studies on the use of lateral foot wedges focus only the effect on the knee and not on the foot.

In contrast to orthopaedic medicine, in biomechanical podiatry the connection between foot biomechanics and lower limb pathology is routinely examined. "Why might a given foot type be associated with one set of pathologies but not another?" (Song et al, 1996). Song suggests that the reason could be that different foot types function differently biomechanically and any deviation from the norm would therefore upset biomechanical alignment of the lower extremities. He postulates, specifically, that individuals with planus, rectus and cavus foot types have distinctly different lower limb biomechanics when walking at their comfortable cadence (Song et al, 1996).

Normal gait produces movement mainly in the sagittal plane but rotation in the transverse plane is also an essential element of normal gait (Chapter 2). This occurs at the lumber and cervical spine allowing the head to remain forward facing. It also occurs at the hip, knee and subtalar joint which allows progression in a straight line. The subtalar joint acts as a torque convertor (Tiberio, 1987).

It is the timing of subtalar joint pronation and supination which is crucial as it needs to be synchronized to ensure smooth movement (McPoil and Cornwall, 1994). The amount of rotation at each joint is small but since walking is the main weight bearing activity of the body the effects of the shear forces that disturbances in the sequence of rotation can produce could accumulate and be significant over time (Eckhoff, 1994).

Patients with hip OA demonstrated a supinated foot (Chapter 7). A supinated foot is one which demonstrates an insufficiency of pronation, which may in turn lead to an external rotation moment at the hip joint (Chapter 2). In normal gait, the hip joint extends and inwardly rotates at the same time as the pelvis inwardly rotates proximally and the subtalar joint pronates distally. The rotation is synchronised. The knee is extended at this point in the gait cycle so the lower limb rotates as a whole. Where there is lack of pronation or if the timing of pronation is too short, the tibia remains externally rotated and, as the knee is extended, the femur also remains externally rotated. The pelvis, however, does continue to move into internal rotation as the contralateral lower limb moves forward. This results in an external rotation moment at the hip joint.

Additionally, the supinated foot noted in patients with hip OA could also lead to a decreased shock absorbing effect (Chapter 2). It has been shown that when a supinated foot pronates following heelstrike it does so for a much shorter period than a normal foot (Cornwall and McPoil, 1999). Normal pronation is a shock absorbing movement and it is accompanied by dorsiflexion of the talocrural joint and knee flexion which increases the shock absorbency (as described in 2.3.2.2.). These accompanying movements would also be diminished in a supinated foot, leading to an overall lessening of the shock absorbing mechanisms of gait.

This thesis also proposes that patients with MCOA have pronated feet (Chapter 7). As discussed in Chapter 2, this may lead to external rotation moment, at the mid-stance phase of gait in the medial compartment of the knee. In the normal foot, after initial pronation, resupination occurs. When the foot remains pronated the major abnormality that occurs is the apparent shift of the ground reaction force away from the lateral half of the plantar foot to the medial half. The shift in the line of force means that the resupination and external rotation of the tibia which should occur in the pushing off phase of gait are prevented (Whittle, 1991). This is considered abnormal as it produces an internal rotation moment of the tibia in the weight bearing knee at the same time as the contralateral pelvic advancement produces an external rotation moment of the femur (Tiberio, 1987). As a consequence, the knee is then placed under significant axial torsion load (Chapter 2). Over time, excessive repetitive loading of the soft tissue structures in the knee joint as the result of this biomechanical predisposition, exceeds the capacity of the tissues to adapt is exceeded and a cellular and inflammatory vascular response results (Bogdan et al, 1978).

It is interesting to note that idiopathic OA is much less common at the two joint complexes where transverse and sagittal plane movement are separate i.e. the ankle joint complex (Saltzman et al, 2005; Martin et al, 2007) and the elbow joint (Soojian and Kwon, 2007; Pomerance et al, 2005). Ankle joint complex and elbow joint OA tend to be the result of trauma rather than idiopathic OA. This may add to the evidence that it is the simultaneous combination of movements in different planes which is subject to mistiming and that this results in the shearing stresses and therefore predisposes to OA.

Foot characteristics and the biomechanics linked to pronated and supinated foot postures could, therefore, play an important role in the biomechanics of the knee and hip after the initial heel strike and during the mid-stance phase of gait.

9.1.iv Significance of findings

This research is thought to contribute to the field of study in several ways.

Firstly, a difference in the foot posture of patients with different sites of lower limb OA has been noted. In an area where there is no evidence-based literature, this study has added to the sparse evidence base using observational techniques. OA is a multi-factorial problem but the differences in foot posture has not previously been observed. Although no causal relationship has been established, nevertheless, in view of the current high incidence of lower limb OA and the subsequent increase in demand for joint replacements, any new information is worthy of consideration. There are possibilities that it might lead to improved assessment and possibly add to the treatment options in conservative management.

The investigation of clinical tools for the measurement of these differences has also added to the evidence-based literature since no guidelines or methods of measurement currently exist. The introduction of clinical tools is a significant step towards future research, providing the opportunity to establish base line scores upon which future research can be based.

The association between talocrural dorsiflexion and foot posture which was noted in the FPI study (Chapter 7) has also added to the evidence base literature. This has not previously been studied and is significant because dorsiflexion is limited by bony apposition at the talocrural joint (Chapter 2) as well as soft tissue restriction, e.g. shortened achilles tendon.

The systematic review has drawn attention to the fact that the only recommended biomechanical approach to the conservative management of lower limb OA has not produced any long term benefits. Perhaps, if the foot was considered, then a biomechanical approach which took account of the foot of the patient could be developed.

It was evident that there was little information in the public domain about the feet of patients with lower limb OA and that there was a need to try to generate and document knowledge in this area. The lack of supporting evidence derived from research for much physiotherapy practice is a recognised problem (Appleby et al, 1995). Observations from clinical practice can be used to develop theories and ideas, which can then be evaluated in a systematic way. This study has made a contribution towards providing evidence-based information.

9.2 LIMITATIONS OF THE THESIS

Perhaps the main limitation of the thesis is that the measurements and assessments were almost all carried out by the author who, though attempting at all times to be objective, may have introduced observer bias to the research

The patients in this study attended the same specialist orthopaedic hospital. They are fairly representative in age and gender of patients with lower limb OA but there was very little ethnic diversity so the findings cannot be universally applied. As discussed in Chapter 8, racial differences in gait and foot type have been considered significant by diverse authors.

The analysis of the outcomes from the F-Scan equipment was not carried out as originally planned from a review of the literature. In practice, the techniques employed in some previous studies did not appear suitable for the study conducted in this thesis (Chapter 7) and other means of analysis were adopted. These were selected with reference to other studies on the F-scan system.

9.3 CONCLUSION

The differences in foot posture in patients with lower limb OA has been examined and the Null Hypothesis can be rejected. Differences in talocrural dorsiflexion, calcaneal angle and foot posture in patients with hip OA, patients with MCOA and healthy controls has been noted (Chapter 5). In addition, an association between pronated and supinated feet and the amount of talocrural dorsiflexion has been demonstrated (Chapter 7). These differences are statistically and clinically significant and it is possible that the biomechanics and pathophysiology of these different foot postures may contribute to lower limb OA. However, a causal relationship cannot be established without a longitudinal study. Nevertheless, if foot and ankle assessment were included in the routine examination of patients with lower limb OA, it might lead to an improvement in conservative management and treatment. Attempts could be made to normalise feet which display either extremely pronated or supinated tendencies by use of stretches, gait re-education or othotics. The clinical measurement tools which have been examined in this thesis would aid the physiotherapist in this. Careful assessment of the foot before and after the use of orthotics is recommended. As the systematic review has demonstrated, the application of lateral wedges without careful assessment of the foot has not been shown to be beneficial in the conservative management of OA.

In view of the high incidence of lower limb OA any improvement in conservative care which might alleviate the symptoms is worthy of consideration.

9.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Further studies are needed to confirm the findings of this thesis. To establish a causal link between foot posture and the site of lower limb OA, longitudinal studies would need to be carried out and this could take many years. Another possible route would be to study the foot posture of the offspring of patients with hip OA. There have been many studies indicating a strong family link in hip OA (Lanyon et al,2000; Ingvarsson et al, 2000; Spencer et al, 2005). In the first descriptive study (Chapter 5) patients stated that although they did not know which type of foot they had, it did resemble the feet of other family members. The Foot Posture Index and talocrural dorsiflexion measures would be useful clinical measures for this research.

It has been demonstrated that dorsiflexion of the talocrural joint diminishes with age (Boone et al, 1981) (Chapter 5). A study which examined whether a programme which incorporated Achilles tendon stretching for patients with hip OA who had less than adequate dorsiflexion helped to restore some lost movement would be interesting.

The F-Scan demonstrated a significant difference in dynamic plantar pressure between the three groups which may indicate a difference in biomechanics. Biomechanical podiatrists and sports physiotherapists recommend wedging to alter foot biomechanics. These regimes are applicable to lower limb overuse injuries and their use in the treatment of lower limb OA would need to be carefully monitored, particularly in view of the deformities which accompany OA and the subsequent deviation from normal biomechanics which ensues. The F-Scan system does allow for the clinical monitoring of the line of COP and high pressure areas in the individual foot and for this purpose would seem very useful. The Foot Posture Index would also enable changes in foot posture as a result of the use of othoses to be monitored.

In late stage lower limb OA there are accompanying deformities which further complicate the biomechanics of gait. It may be that orthotic devices would be most useful in the treatment of early OA before the development of the deformities.

The F-Scan study revealed callosities on certain areas of the foot which appeared to be specific to different foot types and different sites of lower limb arthritis. Further exploration of the effect of orthoses on both the foot callous formation and lower limb OA might reveal some interesting outcomes.

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