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MSc EXERCISE AND HEALTH

"Foot pressure adaptations in normal and pronated males after inclined walking on treadmill"

Mavrea Evgenia

MSc Thesis: “Foot pressure adaptations in normal and pronated males after inclined walking on treadmill”

MSc Candidate: Mavrea Evgenia

Supervisor Professor: Giakas Ioannis

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Abstract

Pronation is associated with hypermobility and instability of the foot. During walking it can alter lower limb biomechanics through the coupling of subtalar pronation and tibial rotation that occurs in closed kinetic chain. It is, hence, correlated with the development of several overuse syndromes that mainly affect the foot and the knee joint. The most common interventions for overpronated subjects are orthotics, inserts and taping. These have a positive impact in the proper alignment of the foot posture, decrease plantar pressure medially and shift the center of pressure laterally.

The aim of the present study is to identify alterations in plantar pressures of normal and pronated individuals during inclined walking on treadmill and reveal potential use of inclined walking as a therapeutic intervention.

Twenty-nine healthy male subjects participated in the study. According to Foot Posture Index score they were divided in two groups: foot pronators and normal (control) group. The navicular index was measured in both groups and then the subjects walked on treadmill with their comfort speed, while in-shoe plantar pressures were recorded. The subjects first walked straight, then with 2˚ and 4˚ left gradient and finally with 2˚ and 4˚ right gradient.

As far as center of force is concerned, both groups showed statistically significant changes in the shift of center of force trajectory in both left and right foot with the normal group representing greater impact. Regarding peak plantar pressure, in both groups walking with inclination 4 degrees resulted in higher numerically changes than 2 degrees. In both groups the right foot (dominant) decreased medial plantar pressure in the rearfoot, midfoot, rearfoot of in all parts when the treadmill was lifted from the left side. Meanwhile, when the treadmill was lifted from the right side, the left foot also showed diminished plantar forces, but did not have the same consistency in the results.

In conclusion, the findings of the study show that inclined walking can alter the gait pattern in both normal and flatfoot individuals. Further research is necessary in the future.

Key words: foot posture, pronation, inclined walking, plantar pressure, center of force

Περίληψη

Προσαρμογές στις πελματικές πιέσεις μετά από επικλινή βάδιση σε άτομα φυσιολογικά και με βλαισοπλατυποδία

Η βλαισοπλατυποδία συνδέεται με αυξημένο πρηνισμό στην υπαστραγαλική άρθρωση και οδηγεί σε υπερκινητικότητα και αστάθεια όλων των αρθρώσεων της ποδοκνημικής. Κατά τη διάρκεια της βάδισης η βλαισοπλατυποδία μπορεί να προκαλέσει εμβιομηχανικές αλλαγές, εξαιτίας της στροφής που προκαλεί στην κνήμη ο πρηνισμός του άκρου ποδός σε κλειστή κινητική αλυσίδα. Για το λόγο αυτό έχει συνδεθεί με την ανάπτυξη συνδρόμων υπέρχρησης κυρίως στην άρθρωση της ποδοκνημικής και του γόνατος. Οι πιο συχνές παρεμβάσεις σε άτομα με βλαισοπλατυποδία είναι τα ορθωτικά πέλματα, οι ενθέσεις έσω υποδήματος και οι τεχνικές περίδεσης. Αυτά επιδρούν στη σωστή ευθυγράμμιση του ποδιού, μειώνουν την πελματική πίεση στο εσωτερικό του και μεταφέρουν το κέντρο πίεσης στην εξωτερική επιφάνεια.

Σκοπός της παρούσας έρευνας είναι να αξιολογήσει τις αλλαγές στις πελματικές πιέσεις φυσιολογικών ατόμων και ατόμων με βλαισοπλατυποδία κατά την επικλινή βάδιση σε διάδρομο και να αποκαλύψει τη δυναμική της σαν θεραπευτική παρέμβαση.

Στην μελέτη έλαβαν μέρος 29 υγιείς άνδρες. Σύμφωνα με το σκορ του Foot Posture Index χωρίστηκαν σε δύο γκρουπ: φυσιολογικοί κ με πλατυποδία. Στη συνέχεια, μετρήθηκε ο Δείκτης Σκαφοειδούς και στα δύο γκρουπ και περπάτησαν στο διάδρομο στη φυσιολογική τους ταχύτητα ενώ καταγράφονταν οι πελματικές πιέσεις. Οι δοκιμασίες περιλάμβαναν βάδιση σε ευθεία, με κλίση 2˚ και 4˚ αριστερά και τέλος με κλίση 2˚ και 4˚ δεξιά.

Σχετικά με το κέντρο πίεσης, και στις δύο ομάδες παρουσιάστηκαν στατιστικά σημαντικές διαφορές στη μετατόπιση της τροχιάς του κέντρου δύναμης τόσο στο δεξί όσο και στο αριστερό πόδι με τα φυσιολογικά άτομα να σημειώνουν μεγαλύτερες αλλαγές. Σε ότι αφορά τις πελματικές πιέσεις, στη βάδιση με κλίση 4 μοίρες εμφανίστηκαν αριθμητικά μεγαλύτερες διαφορές από ότι στις 2 μοίρες και στα δύο γκρουπ. Τόσο στα φυσιολογικά άτομα, όσο και στους πλατύποδες το δεξί πόδι (κυρίαρχο) μείωσε τις πελματικές πιέσεις στην εσωτερική επιφάνεια του οπίσθιου, του μέσου, του πρόσθιου ή και όλου του ποδιού όταν ο διάδρομος είχε ανυψωθεί από αριστερά. Ταυτόχρονα, όταν ο διάδρομος είχε ανυψωθεί από τη δεξιά πλευρά, το αριστερό πόδι παρουσίασε επίσης μείωση των πιέσεων, αλλά δεν εμφάνισε την ίδια συνέπεια στα αποτελέσματα.

Συμπερασματικά, τα ευρήματα της μελέτης δείχνουν πως η επικλινής βάδιση μπορεί να αλλάξει το πρότυπο βάδισης τόσο σε φυσιολογικά, όσο και σε άτομα με πλατυποδία. Περαιτέρω έρευνα είναι αναγκαία στο μέλλον.

Λέξεις κλειδιά: στάση ποδιού, βλαισοπλατυποδία, πρηνισμός, επικλινής βάδιση, πελματικές πιέσεις , κέντρο πίεσης

Introduction

The foot is one of the most complex structures of the human body. It consists of numerous bones, ligaments and muscles that are necessary for the high demands of everyday and sport activities.

Foot posture plays an important role and must be observed by the therapist in weight bearing position, in order to reveal potential variations from neutral posture. Foot pronation is a triplanar motion, but mostly refers to pronation of the subtalar joint that can lead to hypermobility and instability of the foot. During walking, pronation can cause alteration of biomechanics through the coupling of pronation and tibial rotation that occurs in closed kinetic chain. For this reason, it is associated with the development of overuse syndromes and injuries in the foot and the knee joint, such as medial tibial syndrome, plantar fasciitis and patellofemoral syndrome. Secondarily, pronation can also have deep impact in the hip joint and the spine.

Most common treatments in order to prevent injury or reduce symptoms are orthotics, in-shoe wedges or taping. These aim at correcting of the malalignment of the subtalar joint and reducing the pronation of the foot and the rotation of the tibia. Furthermore, their goal is to eliminate medial foot pressure and change the center of pressure and the muscle activation during weight bearing activities.

Purpose of the study

The purpose of the present study is to evaluate the changes in plantar pressure of normal and pronated men while walking on treadmill with inclination 2 and 4 degrees.

Importance of the study

Previous studies have shown that orthotics, in-shoe wedges or taping can help reduce foot pronation and consequently the injuries that relate to it. However, all studies contain interventions in the subjects' shoe and to our knowledge there is no previous research that explores inclined walking on treadmill.

The present study could be the beginning of investigating the impact of inclined walking not only in the foot, but in the whole kinetic chain. In addition, if it proves to be beneficial, inclined walking programs could be integrated with other interventions and be part of rehabilitation protocols. In other words, this study can have immediate clinical application in pronated subjects in order to correct malalignments and decompress the medial part of the foot. Also, it can be applicable in both athletic and non-athletic populations.

Study Hypothesis

The first hypothesis (H1) is that inclined walking compared to simply walking straight can move the center of pressure more medially or laterally, depending on the occasion, in both normal and pronated subjects. The second hypothesis (H2) is that pronated men can adapt to inclined walking, showing a more neutral foot posture as well as decrease in medial foot pressures. Finally, the third hypothesis (H3) is that inclined walking with 4 degrees' gradient results in greater changes of plantar pressure than 2 degrees.

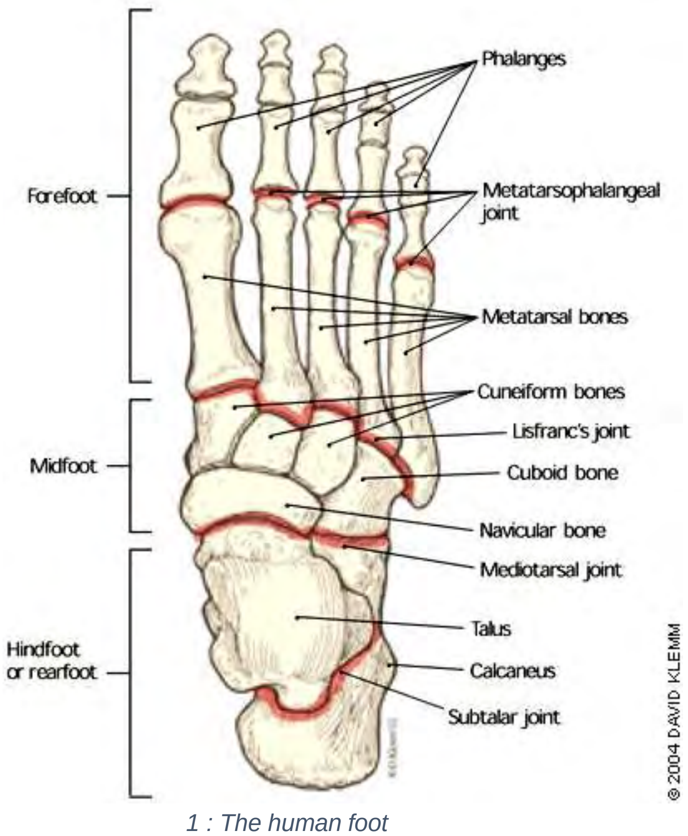
The null hypothesis (Ho) is that walking with inclination has no effect in foot pressure, posture and center of pressure and no significant differences between the two groups.

Literature Review

Basic Anatomy

The foot is a complex structure with 26 bones (plus the two sesamoids) that form 33 joints. It is divided in 3 parts: the hindfoot, the midfoot and the forefoot (Image 1). Also, it consists of over 100 muscles and their tendons and 3 layers of ligaments attached to the bones.

The hindfoot (or rearfoot) contains the distal tibiofibular, the subtalar and the talocrural joint. The tibiofibular syndesmosis is a joint composed of various ligaments and a fibrous membrane that spreads between the tibia and fibula, while the subtalar joint is composed by the head of the talus and the calcaneus. The talocrural joint is a hinge joint that is formed by the talus and the two malleoli and is firmly stabilized from the deltoid ligament medially and the anterior talofibular, posterior talofibular, calcanofibular ligament laterally.



1 : The human foot

The midfoot contains the talocalcaneonavicular, cuneonavicular, cuboideonavicular, the cuneocuboid and the three intercuneiform joints. Midtarsal joints in isolation allow only minor movements, but when they work together they allow significant amount of motion. Lastly, the forefoot contains the 5 metatarsals and the phalanges of the toes which create the tarsometatarsal, intermetatarsal metatarsophalangeal and interphalangeal joints and are responsible for the movements of the toes (Grey & Bannister, 1995).

The primary function of the foot is to support the human body and provide stability for upright posture. During daily activities, the foot must sometimes act as a rigid structure for effective propulsion and other times as a flexible structure in order to absorb the shocks and adapt to different terrains

In the frontal aspect of the foot the most important muscles are the longus, brevis and tertius peroneus, the anterior and posterior tibialis and the extensors of the toes, whereas in the posterior aspect the key muscles are the soleus, the gastrocnemius and the flexors of the toes.

The foot forms 4 arches: the medial longitudinal arch, the lateral longitudinal arch, the transverse arch and the metatarsal arch. The main functions of the arches are: body weight distribution, shock absorbing during several activities and protection of the soft tissues. The medial longitudinal arch is most commonly evaluated by clinicians as abnormality in its structure is linked with injuries. High arch is usually due to contraction of plantar muscles or ligaments or insufficiency of the flexors of the foot, whilst flat arch may be the result of instability of plantar ligaments or hypertonic muscles (Magee, 2014). When the foot is loaded the plantar aponeurosis prevents the arches from collapsing.

Plantar aponeurosis is thought to be the continuum of Achilles tendon. It starts from the calcaneal tubercle and extends to the proximal phalanges. It consists of the medial and lateral parts, also known as fascia, and the central thicker part (aponeurosis) (Chen et al., 2014).

Regarding the innervation of the foot, the spinal nerve roots O4 – I2 are responsible for the area, as well as the peripheral nerves: tibial, peroneal (superficial and deep), saphenous and sural. Blood is supplied to the foot complex by the tibial (anterior and posterior), the fibular, the tarsal, the plantar (medial and lateral) and the dorsal pedi arteries.

Basic biomechanics

The foot complex is designed to bear high shearing and compressive forces and interact with different terrains. In standing position it can take 4 times the body weight and in activities like running it can reach 13 times of the body weight (Brockett & Chapman, 2016). The normal weight distribution on the foot is 40% in the forefoot and 60% in the rearfoot in load situations, whereas both during walking as in static position this weight is transferred through the three arches. Consequently, its structure and biomechanics characteristics allow all these major forces and protect from often injuries.

In order to describe easily the human motion, the body is divided in three anatomical planes of movement: frontal, sagittal and horizontal or transverse. The frontal axis passes from left to right, the sagittal passes from posterior to anterior and the horizontal passes from inferior to superior. According to this, abduction/adduction of the foot takes place in the horizontal plane, dorsiflexion/plantar flexion in the frontal plane and inversion/eversion in the sagittal plane.

Range of motion (ROM) varies significantly between individuals and is affected but their everyday routine. ROM of dorsiflexion 20˚, plantar flexion 45˚, eversion 12 ˚and inversion 23˚. However, in daily activities rarely someone reaches the end of range of motion. For example, only 10˚ of dorsiflexion are required for normal walking.

Supination and pronation are combined triplanar movements that mostly happen in the subtalar joint. In open kinetic chain, supination combines inversion, plantar flexion and adduction, while pronation combines eversion, dorsiflexion and abduction. In closed kinetic chain, when the limb is loaded, during pronation and supination the talus is moving instead of the stable calcaneus. The proportional distribution of each of the coupled movements varies with the angle of the joint axis. Normal range of motion is 45-60˚ for supination and 15-30˚ for pronation.

Except of the physiological movements mentioned above, also occur several accessory movements in all the foot joints. These are mainly gliding and rotatory movements of very small range of motion.

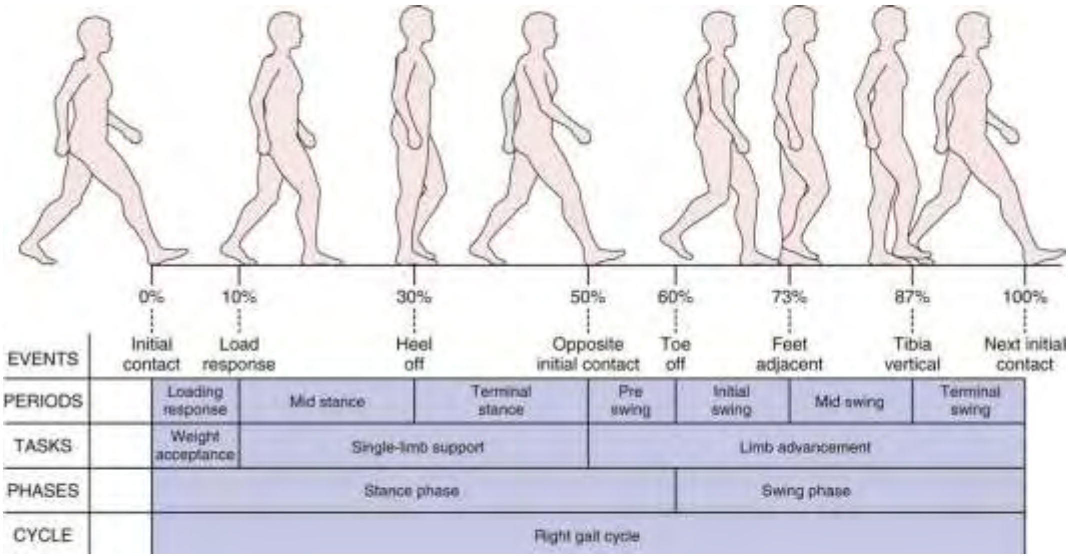
There are also two other axons of great importance: the subtalar joint and the midtarsal joint axon. Subtalar joint axis orientation is normally 40-45 degrees from vertical and 15-18 degrees inclined from the sagittal level. The orientation of the subtalar joint axis effects muscle moments, ligaments and ground reaction forces and if deviated it may be associated with various pathologies (Lewis, Kirby, & Piazza, 2007). Midtarsal joint consists of the talonavicular and the calcaneocuboid joints and is considered to be the functional communication between forefoot and rearfoot. For years, biomechanists described two axes of the midtarsal joint: the longitudinal and the oblique. This theory claimed that in pronated individuals these two axes are almost parallel, leading to a loose midfoot, while in supinated individuals they cross each other and cause locking of the midfoot. However, recent studies rejected this theory and proved with highly scientific methods that there is one triplanar axis 37,9 degrees from transverse and 29 degrees from frontal plane (Tweed, Campbell, Thompson, & Curran, 2008) ;(Nester & Findlow, 2006). The subtalar and midtarsal joint positions are highly relative to each other and affect the static and dynamic posture of the foot complex.

Gait cycle

Walking is a cyclic activity in which one stride follows the other. One gait cycle begins when the foot touches the ground and finishes when the same foot touches the ground again (Nelson, 1980). The gait cycle for each foot is divided in two phases: stance phase and swing phase. Stance phase consists the 60-65% of the cycle and has 5 subphases: initial contact, load response, midstance, terminal stance and preswing. The swing phase, on the other hand, has 3 subphases: initial swing, midswing and terminal swing (Image 2). There are two double support phases that each lasts 10%.

Running is a cyclic movement too, but unlike walking there is no double support and instead there is a phase where none of the foot touches the ground (recovery phase).

The foot has a significant role in gait cycle. The midtarsal joint is thought to be responsible for the foot being both flexible and rigid during different parts of the stance phase (Blackwood, Yuen, Sangeorzan, & Ledoux, 2005). At initial contact the heel strikes the ground supinated and in neutral position regarding plantar/dorsal flexion. This may vary, depending on the type of shoe and the surface of the ground. Then the whole foot gradually touches the ground performing plantar flexion and pronation and the medial longitudinal arch flattens and lengthens the foot. When the foot pronates it is associated with internal rotation of the tibia and on the contrary, when the foot supinates it is combined with external rotation of the tibia. Afterwards, the foot starts to supinate and perform plantar flexion again until the heel rises and the foot pressure comes on the toes and especially on the hallux for proper propulsion. In toe-off the foot becomes more rigid and tension increases in plantar aponeurosis. During swing phase, the lower limb accelerates, passes beneath the body and decelerates until it touches the ground again. The foot during swing phase is in a neutral position, but some small inversion / eversion movements can be noticed. (Image 3).



2: The phases of the gait cycle

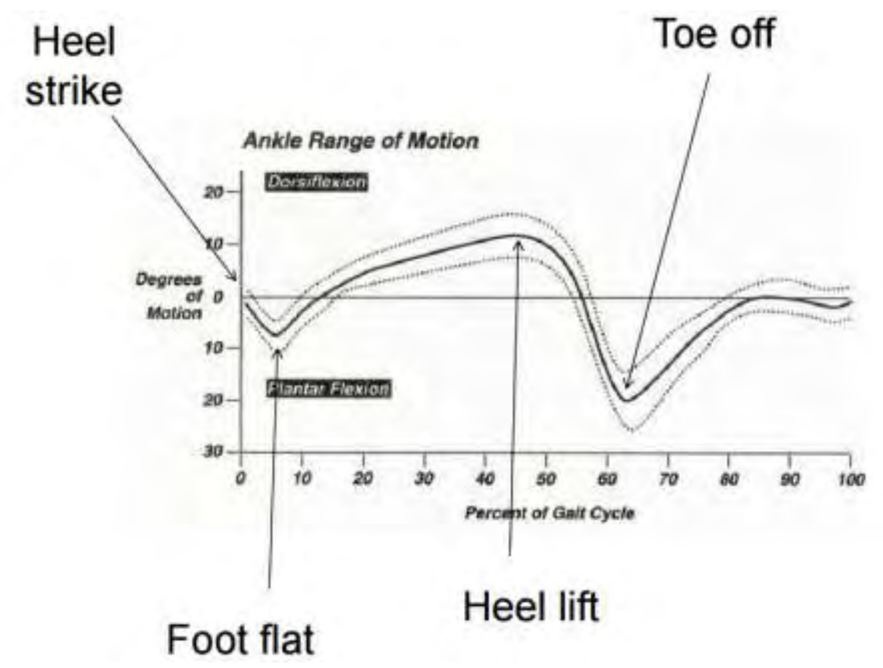
Concerning the muscle activity during gait, the hip, knee and pelvis muscles play a significant role to the effective transfer of body weight. As far as foot muscles are concerned, during stance phase synergy of agonist and antagonist muscles is necessary. At loading response, the ankle dorsiflexors contract eccentrically, at midstance the soleus muscle keeps the foot stable on the ground and before toe off the plantar flexors and the fibularis longus contract concentrically. Meanwhile, most foot muscles are active during initial and late swing subphase for proper acceleration and deceleration (Anderson & Pandy, 2003).

It is therefore understood that any muscular imbalance or variation from normal function of the foot joints can alter the gait pattern and result in excessive loading.

Gait analysis

Along with technological advances and development of innovative equipment a more detailed approach is available to professionals of engineering, medicine and biomechanics.

The analysis of human gait is accomplished through complex theoretical and computational methodologies that provide detailed information of the kinematics and dynamics. Biomechanists take lots of time-distance measurements during walking, like step length, stride length, stride width, cadence and velocity. Also, they use high definition cameras, force plates, pressure and motion analysis systems so they can identify joint position and calculate ground reaction forces, joint moments, foot pressures, power or energy. This way they can compare normal with pathological walking and analyze gait pattern in detail.



3: Ankle range of motion during gait

Foot Posture

Foot posture is examined in weight bearing position. The clinician should always begin with inspection and observation of the lower limbs, pelvis and spine for detection of general abnormalities, such as scoliosis, uneven weight bearing, varus/valgus knees etc. Then, the foot is observed in order to compare muscle tone in each side and soft tissues for swelling, scaring or other. If there are symptoms deriving from the foot complex, then the clinician can evaluate the foot in lying position too.

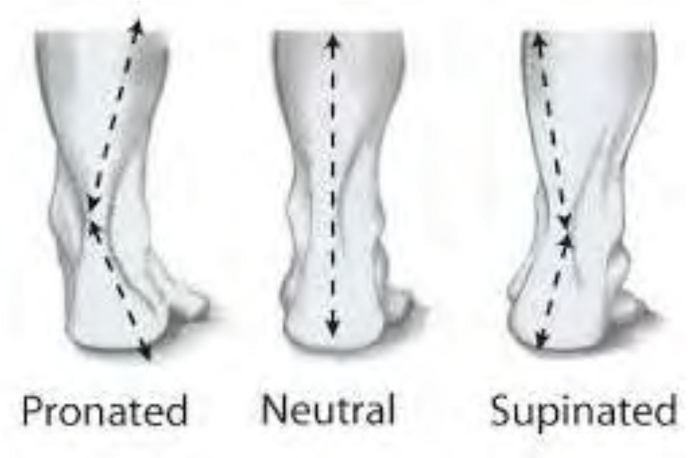
Feet are distinguished in three types: planus, rectus and cavus. Planus feet are low arched with valgus hindfoot and/or varus forefoot, rectus feet are well aligned in all axons and cavus feet are highly arched with varus hindfoot and/or valgus forefoot.(Hillstrom et al., 2013). Usually cavus feet are very rigid and planus feet are hypermobile, so they both result in lack of balance in weight bearing activities

(Magee, 2014). Also, planus feet appear with characteristically bulging of the navicular medially and calcaneus in a valgus alignment and this is the reason why diabetic patients with planus feet tend to ulcerate inwards. Epidemiological studies showed that only 10% of the population have rectus feet, while 5% are cavus and 85% are rectus.

Medical and biomechanical studies have adopted the terms overpronation and oversupination that, as mentioned earlier, refer to the triplanar motion of the subtalar joint, in order to describe excessive motion or duration of these combined movements.

Foot pronation is a combined movement that includes ankle dorsiflexion, rearfoot eversion and forefoot abduction. Although, pronation is a significant movement that happens normally in certain phases of walking, running or sport activities, a foot that remains excessively pronated cannot supinate properly and allow adaptation on uneven surfaces when needed.

Abnormally pronated (or overprnated or hyperpronated) foot is related with hypermobility of the joints of the foot, especially the subtalar joint (Brown, Rudicel, & Esquenazi, 1996) and may cause instability during weight bearing activities (Tsai, Yu, Mercer, & Gross, 2006). Mainly, pronation causes internal rotation of the tibia and increases strain in all the medial musculoskeletal structures. It accompanies with shifting the center of pressure medially, putting strain in muscles and ligaments and also lowering of the transverse and the medial longitudinal arch, so that the plantar surface almost touches the ground. Bilateral induced overpronation in standing position resulted in internal rotation of the shank and the hip and anterior pelvic tilt (Khamis & Yizhar, 2007), whilst unilateral overpronation was correlated with leg-length discrepancy (Rothbart, 2006). Pronation can be measured through the angle of the talus and can vary from 5 to 20^{o} (Kapandji, 1964).



4: Foot posture variations

Common injuries / pathologies

Variation from normal foot posture can influence the function of the foot and alter the mechanics of the whole lower limb through tibia rotation that occurs in closed kinetic chain. For this reason, it is thought to be one the predisposing factors that leads to pathologies of the lower extremity and the spine. Some of the most common pathologies that are linked to overpronation are described below.

Metatarsalgia

Metatarsalgia is an "umbrella" term used by clinicians to describe non-specific acute or chronic pain in the forefoot. It's origin may be systemic or regional disease or can be attributed to several biomechanical factors (Bardelli, Turelli, & Scoccianti, 2003).

Neutral foot put bigger pressure on the 2nd and 3rd metatarsals, while pronated foot put most of the pressure on the medial aspect of the foot and hence on the 1st metatarsal joint. This overloading explains why pronation is strongly associated with pain in the metatarsophalangeal joints, well as development of hallux valgus, hallux limitus and hallux rigidus (Golightly, Hannan, Dufour, Hillstrom, & Jordan, 2014) ;(Hillstrom et al., 2013).

Plantar fasciitis

Plantar fasciitis is considered to be the most common source of pain in the heel. Epidemiology in runners can reach 10%. The basic factor for appearance of the symptoms is altered foot biomechanics. Specifically, subtalar overpronation and flat medial longitudinal arch seem to put excessive stress to the fascia and lead to arousal of symptoms (Kwong, Kay, Voner, & White, 1988).

Although recent research is not clear about plantar fasciitis and foot pronation, Chang et al compared 22 healthy people with 22 chronic plantar fasciitis patients and found significantly greater total rearfoot eversion and first metatarsophalangeal joint dorsiflexion at the plantar fasciitis group, as well as changes in ground reaction forces and forefoot motion.(Chang, Rodrigues, Van Emmerik, & Hamill, 2014).

Achilles disorders

Several etiological mechanisms have been proposed for Achilles acute and chronic disorders (ruptures, tendinitis and tendinopathy}. Some of the most important are: overuse, footwear, training surfaces, poor lower extremity flexibility, steroid injections and altered foot biomechanics (Smart, Taunton, & Clement, 1980).

Achilles tendinopathy represents 9-15% of total running injuries. Main symptoms are: pain, swelling in the area, morning stiffness and disability during activities. Karzis et al assessed with Doppler ultrasonography Achilles tendon of normal and overpronated people at both weight and non-weight bearing activities. Results showed that overpronation may change the blood flow in Achilles tendon, particularly at mid-tendon, enhancing possibility of injury (Karzis et al., 2016). In another study that compared healthy and mid-portion tendinopathy runners, significantly greater sub-talar joint eversion displacement was observed at the tendinopathy group (Ryan et al., 2009).

Medial Tibial Stress Syndrome

Medial tibial stress syndrome (MTSS) is a very common exercise-induced injury, developing especially in runners and military officers (Moen, Tol, Weir, Steunebrink, & Winter, 2009). Patients usually describe a vague, diffuse pain of the lower extremity, along the middle-distal tibia associated with exertion (Galbraith & Lavallee, 2009). Etiology is still debated, but a lot of intrinsic and extrinsic risk factors have been recognized (Hamstra-Wright, Bliven, & Bay, 2015).

A systematic review with meta-analysis indicated that individuals with excessive foot pronation tend to develop MTSS (Neal et al., 2014). Also, great differences were found in external rotation and eversion of the subtalar joint of people with MTSS compared with healthy individuals (Akiyama et al., 2015). In fact, Tweed et al suggest that any runner with suspected MTSS should be statically and dynamically assessed for abnormal pronation and properly treated (Tweed, Campbell, & Avil, 2008).

Patellofemoral pain syndrome

Patellofemoral pain syndrome (PFPS) is characterized by anterior knee pain during activities, for example squat or stairs. It commonly affects runners and is reported in young ages. The 3 dominant causes for appearance of the symptoms are considered to be: malalignment of the patella, muscular imbalance and overuse (Thomeé, Augustsson, & Karlsson, 1999).

The compensatory internal rotation of the tibia due to overpronation is thought to be one of the reasons that patella maltracking occurs, moving laterally in specific (Tiberio, 1987). In addition, a recent study that assessed patients with PFPS showed that they have a more pronated posture and hypermobile foot compared to healthy individuals (Barton, Bonanno, Levinger, & Menz, 2010). However, Neal's systematic review included four studies about PFPS and indicated very limited evidence of pronation being a risk factor (Neal et al., 2014).

At this point, it is important to clarify that recent literature review supports no association between pronation and acute ankle injury, bone stress fractures or non-specific lower limb injury.

On the other hand, there are a lot of pathologies that can increase foot pronation as a compensation of the body. For example, idiopathic scoliosis is one of the most common pathologies that lead to increased foot pronation as counterbalance on the same or the opposite side. Moreover, knee osteoarthritis and specifically medial compartment osteoarthritis, can increase foot pronation due to greater abduction moment of the knee joint. These and many more other pathologies, along with poor muscular system and inappropriate shoes can influence gait pattern and lead to chronic syndromes.

Interventions

In the past years, orthopedics, podiatrists and physiotherapists are trying to relieve their patients from overuse syndromes linked with overpronation, as well as prevent injuries in athletes with abnormal foot posture. As the technology in screening and orthopedic devices is quickly developing, more and more therapeutic approaches are being used. The three most commonly described interventions to control static and dynamic posture of the foot are orthotics, inserts and taping.

Orthotics

Orthotics are devices that support, cushion or guide the motion of the foot. They are a common treatment for patients with excessive foot pronation, providing stability and relieving from the symptoms (pain and discomfort). They can be bought “off the self” or be custom made for a particular patient (Knudson, 2007).

“Off the self” orthotics are prefabricated and come in different shapes and sizes. Most commonly they are constructed with some degrees of supination and density depends on the body weight of the patient. They are usually bought in stores by the patient itself and are considered a cost effective solution. Ferber and Hettinga showed that they can influence kinematics and reduce plantar fascia strain, but they found no difference in medial longitudinal arch height (Ferber & Hettinga, 2016). Another study in 2009 took 41 people with foot, knee and back pain and showed that over-the-counter insoles brought relief and improved foot shape(Landsman, DeFronzo, Anderson, & Roukis, 2009).

On the other hand, custom made orthotics are prescribed by a physician, usually an orthopedic or podiatrist, and designed from specialists according to the three dimensional foot morphology of the patient. As shown in a recent study, customized supinated foot orthotics by an experienced podiatrist lead to reduction of pronation, change the center of pressure and result to a more lateral ground reaction force (Delacroix, Lavigne, Nuytens, & Chèze, 2014). Additionally, a research that compared custom made orthotics by a podiatrist with over-the-counter orthotics (both had a 5degree wedge), showed that they are both effective in displacing the center of pressure and knee load, but only custom made insoles reduced the ankle eversion moment. Also, Caravaggi et al, compared custom made, off the self and prefabricated with the safety shoe insoles in a group of workers. The results showed that only custom made orthotics decreased peak pressure and pressure-time integral (Caravaggi et al., 2016).

Lastly, shock absorbing insoles are also used by patients in order to decrease impact forces in the foot. These are also bought by the patient itself from the pharmacy, or the orthopedic store. They are constructed from soft materials (usually silicone) and are flat profile. A systematic review with meta-analysis in 2016 compared foot orthoses (custom made and prefabricated) with shock absorbing insoles regarding their ability to prevent injuries. The results indicated that orthotics are effective in preventing pathology development in the lower limb, but not soft-tissue injuries. On the contrary, shock absorbing insoles were not capable of preventing injuries (Bonanno, Landorf, Munteanu, Murley, & Menz, 2016).

Inserts

Shoe inserts have been used for many years and prescribed especially in sport populations. Their purpose is proper alignment of the foot, cushioning, shifting the center of pressure and reducing joint moments. Their disadvantage is that discomfort is often described by patients (Bennell et al., 2011). Inserts can be placed in the rearfoot, midfoot or more rarely in the forefoot, depending on the patient's symptoms and the corrections needed.

Lateral wedges are used vastly, especially in patients with knee osteoarthritis. A study that used 5 different EVA inserts showed that full lateral inserts reproduced changes in ankle inversion and path of center of pressure, but no significant changes in ankle and knee joint moments (Nigg et al., 2003). A later study by Leitch et al that used lateral heel wedges and conducted gait analysis and in-shoe plantar pressure measurements showed increased lateral heel pressure, shifted center of pressure and decreased knee abduction moment(K. M. Leitch, Birmingham, Jones, Giffin, & Jenkyn, 2011). While this sounded promising for patients with knee osteoarthritis, a systematic review with meta-analysis in 2013 presented that lateral wedges can reduce pain in patients with medial knee osteoarthritis, but are no better compared to other therapeutic interventions (Parkes et al., 2013).

In 1994, Johanson et al compared rearfoot, forefoot and both inserts in individuals with excessive pronation. They used Foot track analysis system to monitor calf-to-calcaneus and calcaneus-to-vertical angles and they found that rearfoot posting itself can control adequately foot pronation (Johanson et al., 1994).

Kim used arch pads into running shoes in order to study kinematics during walking and running. The results indicated that arch pads can eliminate foot eversion and thereby control pronation (Kim, 2012).

Taping

Taping techniques are used widely in the last decades from physiotherapists, especially in athletes. There are two widely known ways of taping according to the materials that are being used: rigid (or sports) taping and kinesiotaping.

Rigid adhesive tape is often applied to the foot in order to relieve symptoms and indicate whether orthotics would be useful or not for the patient. Many techniques have been described with Low Dye technique being the most popular among therapists.

Low Dye elevates the medial longitudinal arch, reducing pronation of the foot and extends above the joint of the ankle. Vicenzino et al showed that this taping technique has anti-pronation effect in both static and dynamic activities (Vicenzino, 2004). Yoho et al confirmed changes to medial arch height, but the tape had only short-term effects and no significant changes were detected after tape removal (Yoho, Rivera, Renschler, Vardaxis, & Dikis, 2012).

Kinesiotape, on the other hand, is an elastic adhesive and hypoallergic tape. Kinesiotaping is a very popular technique nowadays. However, recent studies comparing application of kinesiotape and sham kinesiotape showed no anti-pronation effect at a large group of subjects (Luque-Suarez et al., 2014) and no change in plantar pressure in amateur runners (Aguilar, Abián-Vicén, Halstead, & Gijon-Nogueron, 2016).

Methods

Subjects

The study sample consisted of 29 healthy male individuals that participated voluntarily and signed a consent form (Appendix A) after being thoroughly informed about the protocol.

Inclusion and exclusion criteria

In the study participated subjects with symmetrical right and left foot reporting no recent history of neurological or musculoskeletal disorders. Individuals with recent lower limb injury/surgery or individuals presenting instability, frailty or limping during walking were excluded from the study. Also, subjects with obvious leg length discrepancy (>5mm) were excluded.

Measurements

All volunteers were required to attend a single testing session at the physiotherapy clinic wearing similar type of training shoes. Firstly, they filled in an assessment sheet (Appendix B) about their anthropometric characteristics, previous history of injuries or trauma in the lower limbs and use of orthotics. Subsequently, the Foot Posture Index was filled in by the therapist and the arch index test and the foot pressure analysis were performed.

Foot Posture Index

In order to create the subgroups (normal group and pronated foot group) the Foot Posture Index (FPI) was used. FPI is a valid clinical tool that even novice examiners can use with good results (McLaughlin, Vaughan, Shanahan, Martin, & Linger, 2016). It consists of 6 validated observations of the foot (Appendix C). Three items of the FPI concern the rearfoot (palpation of head of talus, curves above and below the lateral malleoli and inversion/eversion of the calcaneus) and three the forefoot (bulging at the region of talonavicular joint, congruence of the medial longitudinal arch and abduction/adduction of the rearfoot)(Redmond, Crosbie, & Ouvrier, 2006).

The subjects were asked to stand still for approximately 2 minutes. They were looking straight ahead in a relaxed position with double limb support and arms relaxed at their side. The examiner was moving around assessing each foot separately from the frontal, transverse and sagittal aspect. Its item was graded with -2, -1,0,1 or 2 with negative values showing supination of the foot, zero values showing neutral foot and positive values showing pronation of the foot. Afterwards an overall score between -12 and 12 was estimated for each foot. Highly negative scores (-12 to 0) indicate supination, scores from 1 to 7 indicate normal foot posture and significant positive scores (8 to 12) show pronation of the foot(Redmond, Crane, & Menz, 2008). All measurements were executed by the same examiner because of the high inter-examiner reliability of FPI (Morrison & Ferrari, 2009).

Navicular index

A lot of clinical test have been described lately, in order to evaluate the plasticity and the height of the medial longitudinal arch. In the present study the navicular index was used (Buldt et al., 2015). This test is also performed with the patient in a standing position. It is very quick and can easily and reliably differentiate the flatfoot from the normal-arched foot (Roth, Roth, Jotanovic, & Madarevic, 2013). Each subject was asked to place one foot on a stool and the assessor measured the distance (in centimeters) between the navicular tubercle and the surface of the stool at first with the 1st toe relaxed and then passively extended by the therapist (Figure 4). Afterwards the difference of the two measurements is calculated.

5: Navicular index test

Foot Pressure Analysis

The F-Scan Versatek System (Tekscan Inc, Boston, MA) was used to measure plantar pressure within shoe. The Wireless edition of the system was used, so that data was transmitted directly to the computer via wireless internet connection. This way, the subjects were able to move freely without cabling altering their gait performance.

6: F-Scan Wireless System / Trimming of the sensors

Each insole was trimmed to the size of the subject's shoe and frequency set at 100 Hz before the test. Each F-Scan insole consists of 960 individual pressure-sensing locations, which means that has a spatial resolution of 4 sensors / cm2. The insoles are made from polyester and use resistance-based technology (Hsiao, Guan, & Weatherly, 2002). Before beginning each session sensors were zeroed and step calibration was performed as recommended by the manufacturer. The F-Scan Research 7.0 Software was used in order to collect and analyze the data.

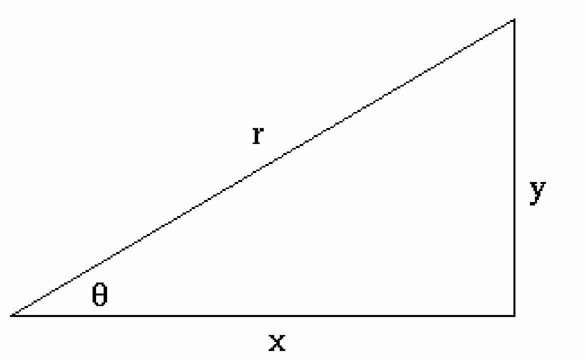
7: Step calibration

Strength Master (Model MA100CE) treadmill was used for the measurements. Subjects were asked to walk on treadmill with their comfort speed for one minute in order to get familiarized with the procedure and then they were assessed in 5 different conditions: 1. Simply walking 2. Walking with left gradient 2 degrees 3. Walking with left gradient 4 degrees 4. Walking with right gradient 2 degrees and finally 5. Walking with right gradient 4 degrees. Each test lasted 10 seconds.

8: Walking straight on treadmill

9: Plantar pressure measurement during inclined walking (4degrees left)

In order to create the treadmill's gradient, 4 wedges were constructed according to the width of the treadmill, using the trigonometric type: tan θ= y/x. (Figure 9). The wedges were put under the treadmill's foothold before each test.



10: Trigonometric type for manufacturing of wedges

Approval

The study was approved by the three-membered Bioethics Committee of University of Thessaly.

Statistical analysis

SPSS (PASW Statistics 18.0) was used for statistical analysis. Descriptive statistics have been used for the characteristics of the sample. Repeated measures two-way analysis of variance (ANOVA) was conducted in order to compare the center of force deviation between trials in the two groups. Level of significance (p) was defined at 0,05 to determine whether a significant relationship existed.

Microsoft Office Excel 2016 was used for the collection of data as well as the creation of tables and charts.

Results

Anthropometrics

All subject characteristics are summarized in Table 1. At the interview that followed 25 participants reported right and only 4 reported left as their dominant lower limb. Also, 5 of the subjects declared previous history of injury in the lower limbs, which included meniscical tears, sprained ankles, anterior cruciate ligament tears and hip dislocation. However, none of them occurred within the last two years. At last, 6 of the subjects reported to wear orthotic devices.

	Mean	Std. Deviation
Age	44,03	15,64
Height	1,76	,06
Weight	82,48	12,64

Table 1: Sample characteristics

FPI results

According to FPI scores the participants were separated in 2 groups. The normal (or control) group consisted of 16 individuals with total score from 2 to 7 and the foot pronation group of 13 individuals with scores from 8 to 12.

Navicular Index results

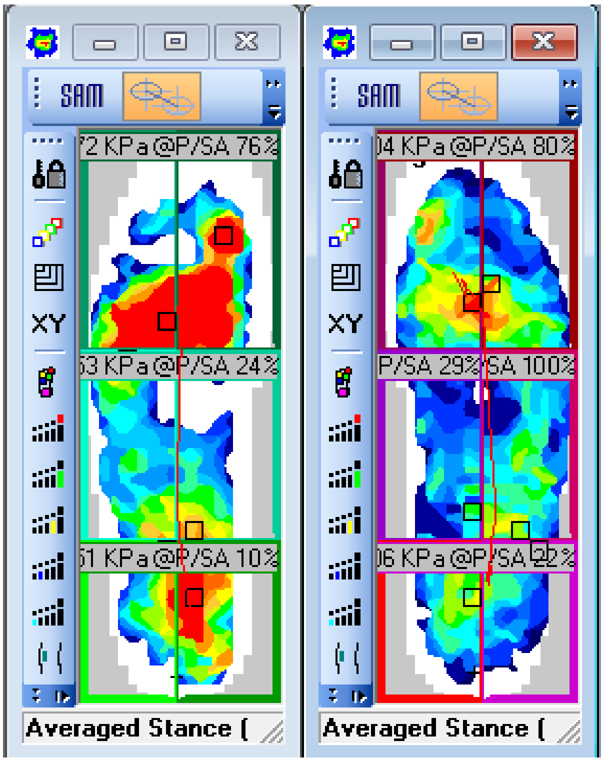
The navicular index did not present significant differences between the two groups. In the normal group the right foot had mean change 0,36 and the left 0,39. On the other hand, in the foot pronation group the right foot had mean change in the test 0,36 and the left foot 0,48. According to this, no correlation was found between FPI score and navicular index.

Foot pressure results

Three subjects (one from the control and two from the pronation group) were excluded from the results because of missing data. That was probably caused by poor collection of data from the sensors.

Peak force

The foot was divided in 6 parts: medial rearfoot, lateral rearfoot, medial midfoot, lateral midfoot, medial forefoot and lateral forefoot and its part was examined thoroughly during the five different walking trials. The peak force per weight was calculated for each condition.



11: Plantar areas selected for analysis of peak pressure (flatfoot subject)

Comparison of 1st and 2nd trial

At the second trial the treadmill was lifted 2 degrees from the left side. It was, thus, expected that the left foot would increase medial forces and the right foot would eliminate medial and increase lateral pressure.

In the normal group all but two subjects diminished plantar pressure in at least one region of the medial aspect of the right foot. Identical were the results of the left foot, with 13 individuals presenting higher medial forces.

As far as the pronation group was concerned, all but one participant presented decreased plantar pressures medially in the right foot and 5 of them reported decrease in all rearfoot, midfoot and rearfoot parts. In the left foot although changes were noticed, there were not following a specific pattern. Six out eleven subject increased medial pressure and only one of them in all parts.

Comparison of 1st and 3rd trial

During the third trial the treadmill was lifted 4 degrees from the left side. The results are similar as above, but plantar pressures presented wider changes.

In the normal group all subjects decreased medial pressure in the right foot, while in the left foot 9 participants showed higher values medially.

Even though changes in numbers are greater in 4 degrees compared with 2 degrees, the pronation group appeared similar alterations. In fact, the same subjects showed diminished values in the medial aspect of the right foot and 4 of them decreased pressure all the three medial parts. In the graphic below the regions were alteration occurred at the right foot are represented extensively. Regarding the left foot, only 7 males pronated and none of in all parts.

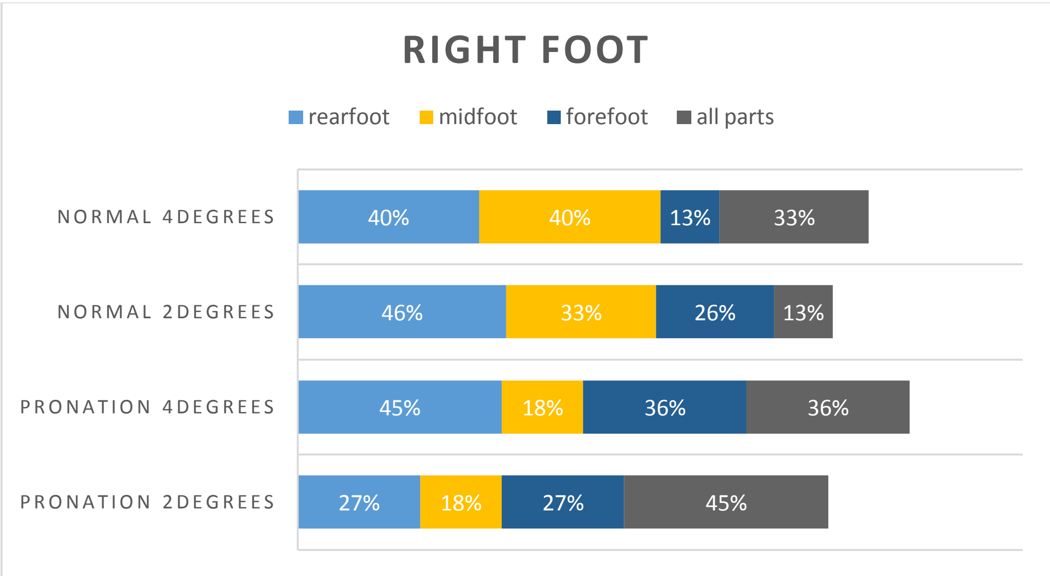


Table 2: Percentage of subjects that decreased medial pressure in the right foot during inclined walking

Comparison of 1st and 4th trial

The treadmill was lifted 2 degrees from the right side, so it was hypothesized that the right foot would pronate and the left foot would supinate. Exactly like in the previous efforts, normal individuals decreased medial pressure (13 out of 15) in the left foot, but only one increased supination in all three regions. Meanwhile, in the right foot 14 out of 15 subjects increased pronation.

All the pronated males lessened their plantar pressures medially in the left foot, but only two of them decreased force in all the three parts of the foot. In the right foot though, 5 males increased medial pressure in one part only and no participant seemed to pronate in all parts.

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Comparison of 1st and 5th trial

In the last trial the treadmill was lifted 4 degrees from the right side. As expected, the changes were numerically higher.

In the normal group the results showed that 75% of the subjects diminished medial pressure in the left foot. Also, all but one individual increased plantar forces in the medial aspect of the right foot.

In the pronated individuals 9 of the participants decreased medial forces in the left foot, but only 1 of them managed to lessen pressure in all the three medial parts. The exact numbers are shown in the following graph. In addition, in the right foot 6 males tended to pronate, but zero subjects raised values in all medial regions.

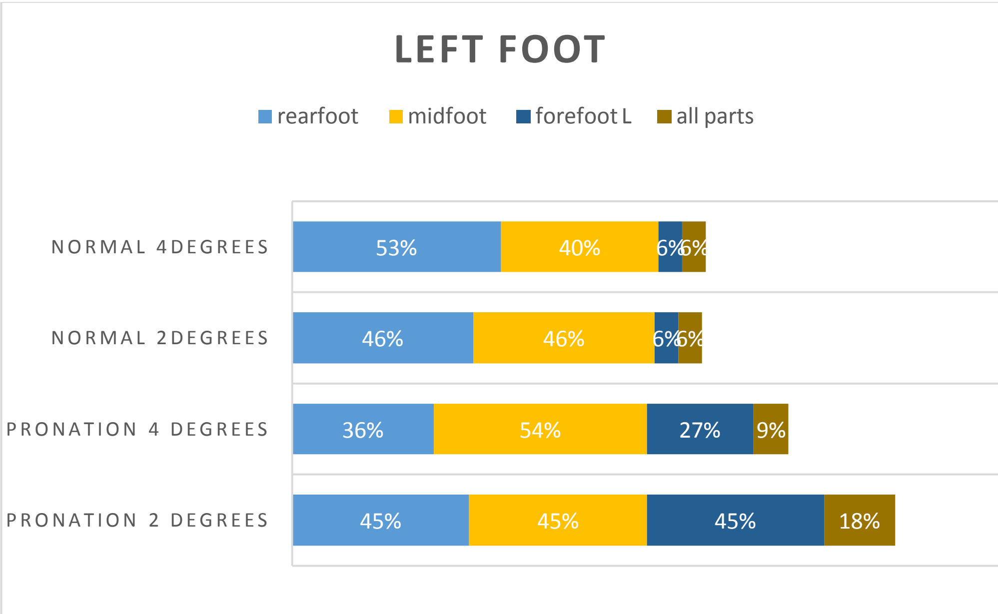
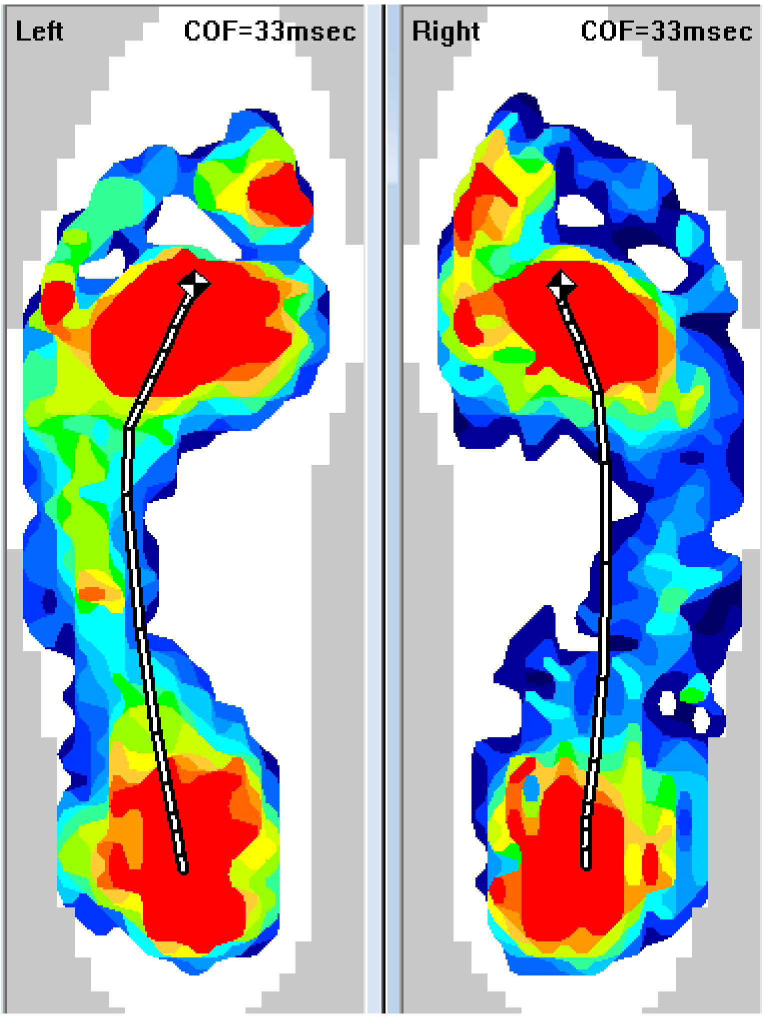


Table 3: Percentage of subjects that decreased medial pressure in the left foot during inclined walking

Center of Force

The averaged center of force trajectory deviation of the 3rd and 5th effort was calculated. These trials were selected because, as mentioned before, 4degrees resulted in grater changes in numbers. The first and the last stance were excluded from every trial and also some stances with incomplete data. Then, it was compared with the path of center of pressure at the neutral walking.



12: Center of force trajectory (normal subject)

Comparison of 3rd and 5th trial right

The maximum deviation of right foot's center of pressure from neutral walking was compared to the 3rd and 5th trial. As I was suspected, the path of the center of pressure moved from the lateral to the media aspect of the foot. Both normal and pronation group shifted the trajectory of center of pressure $F(1,24) = 5,93$, presenting statistically significant changes ($p<0,05$). The interaction between center of force deviation and groups failed to reach statistical significance $F(1,24) = 1,43$, $p>0$ 05. The control group, though, seemed to be more affected, as shown in the graphic below (Table 4).

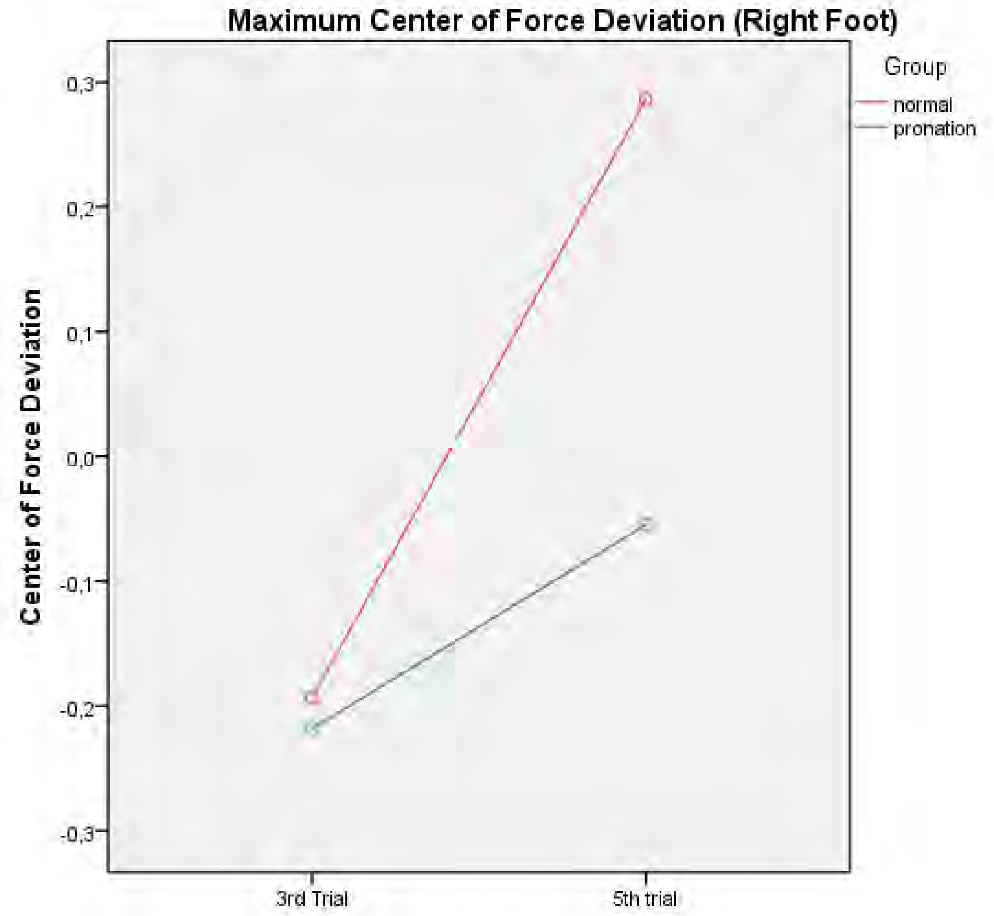


Table 4: Center of force deviation of the right foot from the 3rd to the 5th trial

Comparison of 3rd and 5th trial left

Similarly, the maximum deviation of the left foot's center of pressure was examined. This time the center of pressure trajectory moved from the medial to the lateral region of the foot. Results showed statistically significant differences in the change of center of force in both groups $F(1,24) = 5{,}48$, $p<0{,}05$. The interaction between center of force and group failed to reach statistical significance $F(1,24) = 1{,}22$, $p>0{,}05$. However, in the left foot, the same way as in the right, the normal individuals presented higher impact (Table 5).

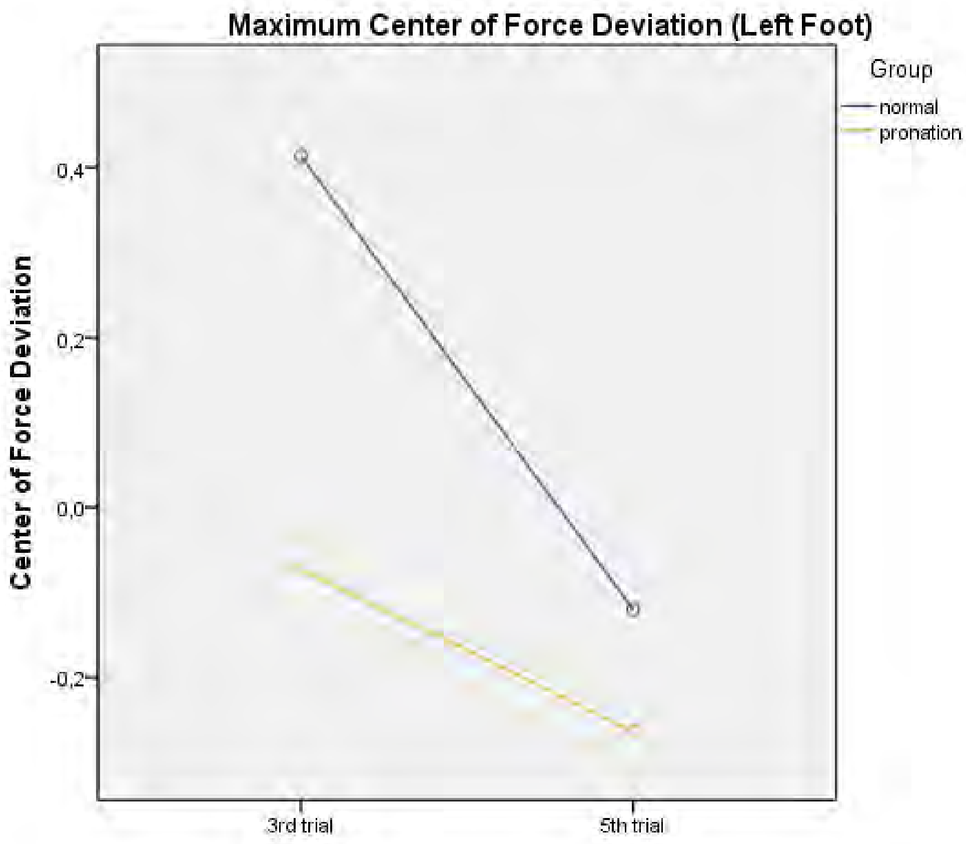


Table 5: Center of force deviation of the left foot from the 3rd to the 5th effort

Discussion

The present study was based on the fact that orthotics and shoe inserts are capable of shifting the center of pressure laterally when used in overpronated patients. The difference is that during inclined walking the whole foot is lifted by 2 or 4 degrees, while orthotics or inserts only correct one part of the foot (usually the rearfoot or midfoot). This means that the stimulus given to the subjects might have been very strong compared to usual interventions.

Moreover, many subjects were not used to walking on treadmill. As shown in a previous study there are significant differences between over ground and treadmill walking (Alton, Baldey, Caplan, & Morrissey) and this can influence the gait characteristics.

To our knowledge there is no similar study in arthrography. In the only study that used side inclination and measured center of pressure, the subjects had to execute side steps (like in a slope) and not walking. In this study postural stability was compared between side stepping with inclination and cross walking (Wang, Hsieh, Huang, Peng, & Su, 2009). Also, in a study by Hagins et al 8 dancers had to jump and land on inclined surfaces, in order to investigate the impact of inclined conditions in the lower limbs. In this study lateral inclination was found to result in greater changes in the knee and foot (Hagins, Pappas, Kremenic, Orishimo, & Rundle, 2007). However, no research or predictive simulation have been done with purpose to compare normal and flatfoot individuals during inclined walking.

The first hypothesis was confirmed, because inclined walking was able to move the center of pressure in both groups. It was hypothesized that inclined walking would force one foot to pronate and the other one to supinate. For example, when the treadmill was lifted from the left side, it was expected that the left foot would increase medial pressure and the right foot would supinate and lessen medial pressure. In fact, maximum center of force deviation was shifted statistically significant in the two groups with the normal group showing greater changes in both left and right foot. This can be happening due to a more refined neuromuscular system, allowing adaptations to different terrains and situations in normal individuals. Meanwhile, pronated participants might have made smaller changes because, as shown in previous studies, their foot is more unstable and locked in a position that does not allow sufficient degree of supination when needed.

The results are similar to previous papers that studied center of force displacement during walking. Leitch et al studied center of force shift in healthy and knee OA patients wearing lateral heel wedged shoes 4˚ and 8˚ and observed changes of the path laterally and anteriorly in both groups (Kristyn M. Leitch, Birmingham, Jones, Giffin, & Jenkyn). Also, a research by Delacroix et al confirmed that custom made insoles resulted in a more lateral center of pressure path and caused neutralization of the foot (Delacroix et al., 2014). However, this study used a force platform and not in-shoe measurements. As shown previously, the two methods result in different values in parameters like average peak pressure, average peak force, timing and center of pressure displacement and might lead to different deduction (Chevalier, Hodgins, & Chockalingam)

The second hypothesis was confirmed showing reduction in medial rearfoot, midfoot and forefoot plantar pressure in both foots. In the right foot the percentages are very high. However, in the left foot very few of the participants showed decrease in the medial pressures of all three parts. This could be explained by the fact that in most subjects the right foot is the dominant and is expected to have a more trained neuromuscular system and adapt quicker to changes. Also, it may be due to familiarization of the subjects with the procedure, because the left foot was always tested last.

The outcomes described above showed that both groups managed to alter their gait pattern in the same way. This could be very promising for future investigation in pronated groups of people. Specifically, if someone considers the fact that repetitive tasks can enhance motor performance through brain plasticity, one can assume that inclined walking as a therapeutic procedure can lead to long term results. On the other hand, the short duration of the efforts and the lack of follow up session cannot lead to such a conclusion yet. Moreover, we cannot ignore the fact that while one foot supinates, the other one pronates increasing the loads in an already strained area. Hence, inclined walking might be more suitable and safe for individuals with unilateral pronation.

The third hypothesis was confirmed. Even if both conditions resulted in alterations of plantar pressures, only minor numerical differences could be detected with 2˚ gradient, while 4˚ revealed greater changes in forces. It should also be mentioned that the participants themselves reported discomfort when walking with 4˚ inclination. This agrees completely with the findings of a previous study which compared different type of lateral wedge insoles in patients with knee osteoarthritis. It showed that insoles with lateral wedge 10˚ caused wider effects than 5˚, but also created discomfort in the subjects tested (Kerrigan et al.).

The null hypothesis was rejected. Even though results varied between the groups and the sample was very small, significant changes were noticed in both groups.

Limitations

Regarding the study limitations, all subjects knew they were being tested, and may have subconsciously altered their usual gait pattern. Furthermore, the participants were instructed to wear their training shoes, which means that not all shoes were identical. However, all shoes were of neutral type and the participants that used orthotics were asked to take them off their shoes.

Only men were recruited in the present study. The main reason was the large amount of data. It was avoided to add women, because adding sex as another variable could only complicate the statistical analysis. Also, we did not think that it would influence the final results as a study by Rodriguez et al demonstrated that there are no significant differences in foot posture between men and women, even though men possess longer and wider feet (Rodríguez et al., 2013).

Another limitation is that we did not use any radiographic measurements as described in other studies. On the contrary, only clinical measurements have been used in order to categorize the subjects in the two subgroups. A study by Murley et al, though, suggested that clinical measurements have significant correlation to radiographic angles and can be reliably used in research (Murley, Menz, & Landorf, 2009).

Recommendation for further research

Similar studies could be conducted in the future including a bigger sample, so that the results can be generalized in the population. A sample containing both men and women, could also be part of a later study in order to detect differentiation in sexes. Also, it would be useful to design a study with a sample of individuals with unilateral pronation as this group of people could be really benefited by inclined walking.

Moreover, it would be very interesting to watch potential changes by testing efforts with longer duration or by repeating the same tasks in the same or follow up session. This could reveal if familiarization or motor learning process influences the results.

Further research using kinematic evaluation is suggested in order to explore in detail the changes that occur in foot joints and the impact of inclined walking in the knee and hip joint angles and the spine. Also, the use of electromyography is required to detect possible changes in muscle activation. Previous studies showed that induced overpronation increased EMG activation of the temporalis and the masseter (Valentino, Fabozzo, & Melito, 1991), while no changes were detected in trunk and upper limb muscles (Ntousis, Mandalidis, Chronopoulos, & Athanasopoulos, 2013), but both conducted static measurements. It would be very interesting to watch muscle adaptations of the lower limb and the trunk during inclined walking.

Conclusions

Over the recent years there has been tremendous progress in the development of orthotics and other interventions in order to bring the static and dynamic function of the foot close to the ideal. Physicians, physiotherapists and orthopedic companies, based on research, are always looking up for ways to help people with overpronation and correct their gait pattern. Especially when it comes to athletic population, correcting malalignments and prevention of injuries is the keystone to maximize athletic performance.

The aim of the study was to detect alterations in plantar pressures of normal and pronated males comparing walking straight with inclined walking on treadmill in four different conditions. The results showed that both groups shifted the center of force statistically significant. Furthermore, both groups presented changes in their peak plantar pressures in one or more regions of the foot. The right foot (dominant) had higher consistency in both normal and flatfoot subjects. Lastly, the 4degree inclination resulted in numerically greater differences than 2 degrees in both foot as it was suspected

This was the first study to investigate the impact of inclined walking in pronated and normal individuals. The findings suggest that gait patterns can be altered by walking with side gradient in both groups. Further research is necessary in order to study kinematics and muscle activation that could reinforce the use of inclined walking in preventive and rehabilitation therapy.

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APPENDIX A – Consent Form

Τίτλος Ερευνητικής Εργασίας: Προσαρμογές στις πελματικές πιέσεις μετά από βάδιση σε πλάγια κλίση σε άτομα φυσιολογικά και με βλαισοπλατυποδία

1. **Σκοπός της ερευνητικής εργασίας**

Σκοπός της μελέτης είναι η αξιολόγηση των αλλαγών στις πελματικές πιέσεις μετά από βάδιση σε διάδρομο με πλάγια κλίση 2^o και 4^o και η διερεύνηση των διαφοροποιήσεων ανάμεσα σε άτομα φυσιολογικά και με βλαισοπλατυποδία.

Διαδικασία

Το φύλλο αξιολόγησης που καλείστε να συμπληρώστε αφορά τα ανθρωπομετρικά σας χαρακτηριστικά (ηλικία, ύψος, βάρος) και τυχόν τραυματισμούς ή παθήσεις των κάτω άκρων. Στη συνέχεια, θα υποβληθείτε σε κάποιες κλινικές δοκιμασίες βάση των οποίων θα χωριστείτε σε δύο ομάδες. Τέλος, με την καθοδήγηση ενός έμπειρου φυσικοθεραπευτή θα εκτελέσετε 5 δοκιμασίες πάνω σε δαπεδοεργόμετρο με ταχύτητα 5 m/sec (απλή βάδιση, βάδιση με κλίση δεξιά 2^o και 4^o και βάδιση με κλίση αριστερά 2^o και 4^o). Η κάθε δοκιμασία θα έχει διάρκεια 10 δευτερόλεπτα κατά τα οποία θα καταγράφονται οι πελματικές πιέσεις μέσω του συστήματος F Scan Versatek. Όλες οι μετρήσεις θα πραγματοποιηθούν στο φυσικοθεραπευτήριο την ίδια ημέρα.

2. **Κίνδυνοι και ενοχλήσεις**

Δεν υπάρχει κανένας κίνδυνος τραυματισμού κατά τη διάρκεια των δοκιμασιών. Παρ' όλα αυτά υπάρχει πρόβλεψη πρώτων βοηθειών και εκπαιδευμένο προσωπικό για κάθε ενδεχόμενο.

3. **Προσδοκώμενες ωφέλειες**

Με την συμμετοχή σας θα λάβετε αποτελέσματα από μία εξειδικευμένη εμβιομηχανική αξιολόγηση που θα σας δώσει πληροφορίες σχετικά με τη στάση και την κατανομή των πιέσεων στο άκρο πόδι. Η διερεύνηση των πελματικών πιέσεων κατά την πλάγια βάδιση θα βοηθήσει στην αναγνώριση παραγόντων που αποτελούν ρίσκο για τραυματισμό, καθώς επίσης και στην πρόληψη και αντιμετώπιση αυτών.

4. **Δημοσίευση δεδομένων – αποτελεσμάτων**

Η συμμετοχή σας στην έρευνα συνεπάγεται ότι συμφωνείτε με την μελλοντική δημοσίευση των αποτελεσμάτων της, με την προϋπόθεση ότι οι πληροφορίες θα είναι ανώνυμες και δε θα αποκαλυφθούν τα ονόματα των συμμετεχόντων. Τα δεδομένα που θα συγκεντρωθούν θα κωδικοποιηθούν με αριθμό, ώστε το όνομα σας δε θα φαίνεται πουθενά.

5. **Πληροφορίες**

Μη διστάσετε να κάνετε ερωτήσεις γύρω από το σκοπό ή την διαδικασία της εργασίας. Αν έχετε οποιαδήποτε αμφιβολία ή ερώτηση ζητήστε μας να σας δώσουμε διευκρινίσεις.

6. **Ελευθερία συναίνεσης**

Η συμμετοχή σας στην εργασία είναι εθελοντική. Είστε ελεύθερος-η να μην συναινέσετε ή να διακόψετε τη συμμετοχή σας όποτε το επιθυμείτε.

7. **Δήλωση συναίνεσης**

Διάβασα το έντυπο αυτό και κατανοώ τις διαδικασίες που θα ακολουθήσω. Συναινώ να συμμετάσχω στην ερευνητική εργασία.

Ημερομηνία: __/__/__

Ονοματεπώνυμο και
υπογραφή συμμετέχοντος

Υπογραφή ερευνητή

Ονοματεπώνυμο και
υπογραφή παρατηρητή

APPENDIX B - Assessment sheet

First name:

Last name:

Age:

Height:

Weight:

Injuries or pathologies in the lower limb: Yes No

Left: Right:

Use of orthotics: Yes No

APPENDIX C – Foot Posture Index

THE FOOT POSTURE INDEX©
FPI-6

Reference Sheet

The patient should stand in their relaxed stance position with double limb support. The patient should be instructed to stand still, with their arms by the side and looking straight ahead. It may be helpful to ask the patient to take several steps, marching on the spot, prior to settling into a comfortable stance position. During the assessment, it is important to ensure that the patient does not swivel to try to see what is happening for themself, as this will significantly affect the foot posture. The patient will need to stand still for approximately two minutes in total in order for the assessment to be conducted. The assessor needs to be able to move around the patient during the assessment and to have uninterrupted access to the posterior aspect of the leg and foot.

If an observation cannot be made (e.g. because of soft tissue swelling) simply miss it out and indicate on the datasheet that the item was not scored.

If there is genuine doubt about how high or low to score an item always use the more conservative score.

Rearfoot Score	**-2**	**-1**	**0**	**1**	**2**
Talar head palpation	Talar head palpable on lateral side/but not on medial side	Talar head palpable on lateral side/slightly palpable on medial side	Talar head equally palpable on lateral and medial side	Talar head slightly palpable on lateral side/ palpable on medial side	Talar head not palpable on lateral side/ but palpable on medial side
Curves above and below the malleoli	Curve below the malleolus either straight or convex	Curve below the malleolus concave, but flatter/ more shallow than the curve above the malleolus	Both infra and supra malleolar curves roughly equal	Curve below malleolus more concave than curve above malleolus	Curve below malleolus markedly more concave than curve above malleolus
Calcaneal inversion/eversion	More than an estimated 5° inverted (varus)	Between vertical and an estimated 5° inverted (varus)	Vertical	Between vertical and an estimated 5° everted (valgus)	More than an estimated 5° everted (valgus)
Forefoot Score	**-2**	**-1**	**0**	**1**	**2**
Talo-navicular congruence	Area of TNJ markedly concave	Area of TNJ slightly, but definitely concave	Area of TNJ flat	Area of TNJ bulging slightly	Area of TNJ bulging markedly
Medial arch height	Arch high and acutely angled towards the posterior end of the medial arch	Arch moderately high and slightly acute posteriorly	Arch height normal and concentrically curved	Arch lowered with some flattening in the central portion	Arch very low with severe flattening in the central portion – arch making ground contact
Forefoot abd/adduction	No lateral toes visible. Medial toes clearly visible	Medial toes clearly more visible than lateral	Medial and lateral toes equally visible	Lateral toes clearly more visible than medial	No medial toes visible. Lateral toes clearly visible

For further information, manuals and extra datasheets see: www.leeds.ac.uk/medicine/FASTER/FPI/

Foot Posture Index Datasheet

Patient name	**ID number**

	FACTOR	*PLANE*	SCORE 1 Date______ Comment______		SCORE 2 Date______ Comment______		SCORE 3 Date______ Comment______	
			Left *-2 to +2*	***Right*** *-2 to +2*	***Left*** *-2 to +2*	***Right*** *-2 to +2*	***Left*** *-2 to +2*	***Right*** *-2 to +2*
Rearfoot	Talar head palpation	*Transverse*						
	Curves above and below the lateral malleolus	*Frontal/ transverse*						
	Inversion/eversion of the calcaneus	*Frontal*						
Forefoot	Prominence in the region of the TNJ	*Transverse*						
	Congruence of the medial longitudinal arch	*Sagittal*						
	Abd/adduction forefoot on rearfoot	*Transverse*						
	TOTAL							

Reference values
Normal = 0 to +5
Pronated = +6 to +9, Highly pronated 10+
Supinated = -1 to –4, Highly supinated –5 to -12