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The Foot, Our Base of Support

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THE FOOT, OUR BASE OF SUPPORT

by

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This Independent Study, submitted by Sandra G. Lunde in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Chairperson, Physical Therapy)

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Department	Physical Therapy
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Signature Sandra G. Lunde

Date 3/27/93

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ABSTRACT

The purpose of this independent study was to consolidate information on biomechanics of the foot and ankle and the possible effects on the rest of the body of faulty mechanics. A literature search and specialized continuing education contributed to improved working knowledge of the significance of variations of the normal biomechanics. The physical therapist relates to the patient through complaints of foot pain, or through foot evaluation to get to other sites of pain. A thorough evaluation process, shoe recommendations, stretching, and/or strengthening exercises, and orthotic evaluation are the results of study.

INTRODUCTION

The foot, as the primary base of support, can be a source of both direct and indirect problems. Feet may cause many hours of discomfort, and appear to have been a somewhat neglected or misunderstood area of medicine. Various disciplines look at the foot from different perspectives, and the physical therapist is a logical member of the health care team to look at the foot in relation to motion.

Cailliet[1] describes the normal foot as having the following: a) no pain, b) normal muscle balance, c) absence of contracture, d) central heel, e) straight and mobile toes, and f) three sites of weight bearing while standing and during the stance phase of walking.

Donatelli[2] names the foot as the terminal joint in the lower kinetic chain that opposes external resistance. Gray[3] labels the foot the interface between the total body function and the weight-bearing surface. Thus, the right joint/motion function (arthrokinematics) allows the lower limb to accommodate the forces of weight bearing.[2]

Many forces are distributed and dissipated through the foot and leg during the stance phase of gait. Many articulations make up the foot, and these are basically divided into rearfoot, midfoot, and forefoot. Donatelli[2] lists the functional joints of the foot as the ankle (talocrural), subtalar, midtarsal (transverse tarsal), the tarsometatarsal (TMT), and the metatarsophalangeal (MTE) joints.

Motion is divided into a straight line movement-translation, which happens when the line of force passes through the center of an object; and perpendicular, which is a rotation in an arc around a fixed axis. Movement is also described by a plane. In the foot, these are frontal (coronal), sagittal, and transverse planes. Inversion and eversion happen in the frontal plane. Dorsiflexion and plantarflexion are in the sagittal plane, and abduction and adduction are in the transverse plane. The joints of the foot are basically hinges. True hinge joints allow 1^0 of freedom, thus 2^0 of freedom to the joint. The midtarsal, subtalar, and talocrural joints, and the first ray (first metatarsal and first cuneiform) and fifth ray (fifth metatarsal) all provide movement in the three body planes, and their axes of motion are oblique to these planes. McPoil and Brocato[4] state that efficient function of the foot depends on its ability to act as loose adapter, a shock absorber, a torque converter, and a rigid lever during the gait cycle.

The closed kinetic chain of the foot and ankle occurs at each phase of stance, from heel strike to push-off. Donatelli[2] reports that the ankle, subtalar, and midtarsal joints are dependent on each other during the stance phase of gait. The ankle plantarflexes right after heel strike, causing internal rotation and adduction of the tibia and talus. The subtalar joint pronates, with forward displacement of the talus and navicular. The calcaneus everts for maximal range of the midtarsal joint. The articular surfaces of the navicular and cuboid are more parallel to each other, producing a supple forefoot. During midstance, the tibia advances over the talus in closed kinetic chain dorsiflexion. During push-off, the subtalar joint supinates, producing a pivotal movement of the cuboid and calcaneus, stabilizing the cuboid. A fixed cuboid acts as a fulcrum for the peroneus longus muscle, facilitating plantar flexion of the first ray, or first metatarsal, in push-off.

Magee[5] considers observation of ambulation important for history and evaluation, and states that, in standing, fifty to sixty percent of the weight is normally taken on the heel, and forty to fifty percent is taken on the metatarsal heads. The foot forms an angle (Fick angle) that is about 12 to 18^0 from the sagittal axis of the body, developing from 5^0 in children. During movement, the foot is subjected to high loading, and anything that goes wrong may cause a change in walking pattern. The cumulative force to which each foot is subjected during the day is the equivalent of 1.4 million pounds in a person who weighs about one hundred ninety pounds and walks about eight miles a day. In walking, the foot is subjected to forces 1.2 times the body weight; in running, two times the body weight; and in jumping, from a height of two feet, five times the body weight.[5] Gait patterns should be observed for abnormalities or substitutions. Here, tight muscles could be sighted and the person taught a program for stretching, or weaknesses noted for a strengthening program.

METHODOLOGY

This paper will review inspection of the foot, its bony structure, ligaments, muscles, and soft tissue. Review of shoe styles and support is also a goal of this paper. Further understanding of how to fashion foot orthoses for simple problems is important, as is the mastery of biomechanics, and how that impacts total ambulation.

Review of current literature and attendance at workshops on the topics of foot and ankle biomechanics, shoe selection, and orthotics will be the methods used to gather information.

ANATOMY

Bones and Joints

Two chief functions of the lower leg, foot, and ankle are propulsion and support.[5] For propulsion, these segments act as a lever; for support, they act like a rigid structure holding up the whole body. Magee[5] defines the functions of the foot as including:

1. Acting as a base of support that is sufficient to provide the necessary stability for upright posture with minimal muscular effort,
2. Providing a mechanism for rotation of the tibia and fibula during the stance phase of gait,
3. Providing flexibility to adapt to uneven terrain[5,6],
4. Providing flexibility for absorptions of shock by becoming a rigid structure in the pronated position[5,6],
5. Acting as a lever during push-off.

The foot is made up of 26 bones; the talus, calcaneus, navicular, medial cuneiform, middle cuneiform, lateral cuneiform, cuboid, five metatarsals, and fourteen phalanges (Figure 1). The joints are the talonavicular, talocalcaneal (subtalar), calcaneocuboid, tarsometatarsal (5),

Figure 1-1. Bones of the Foot, Lateral View

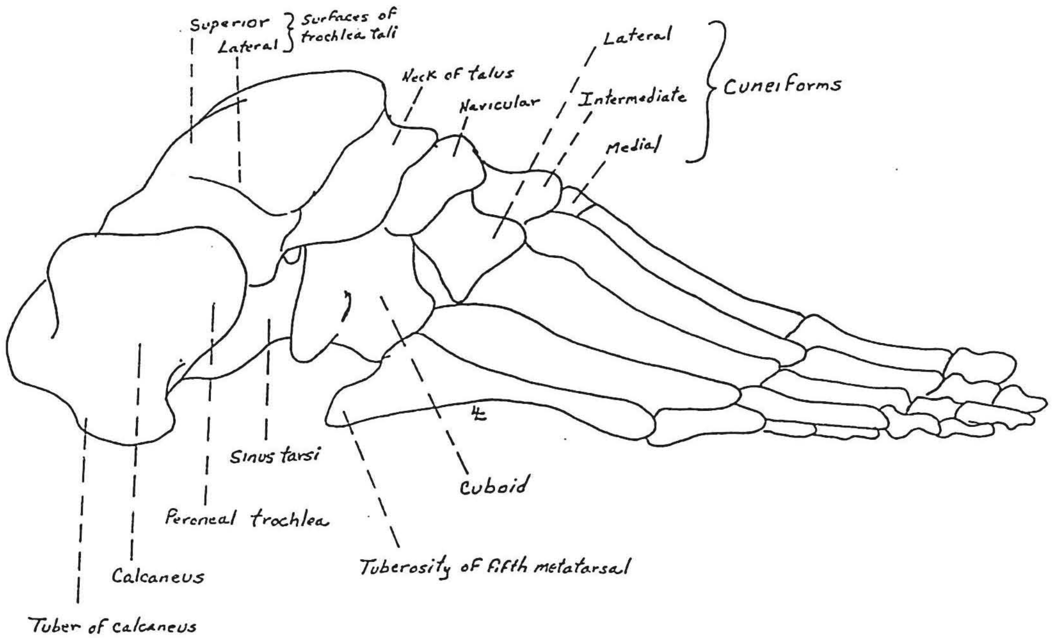


Figure 1-2. Bones of the Foot, Medial View

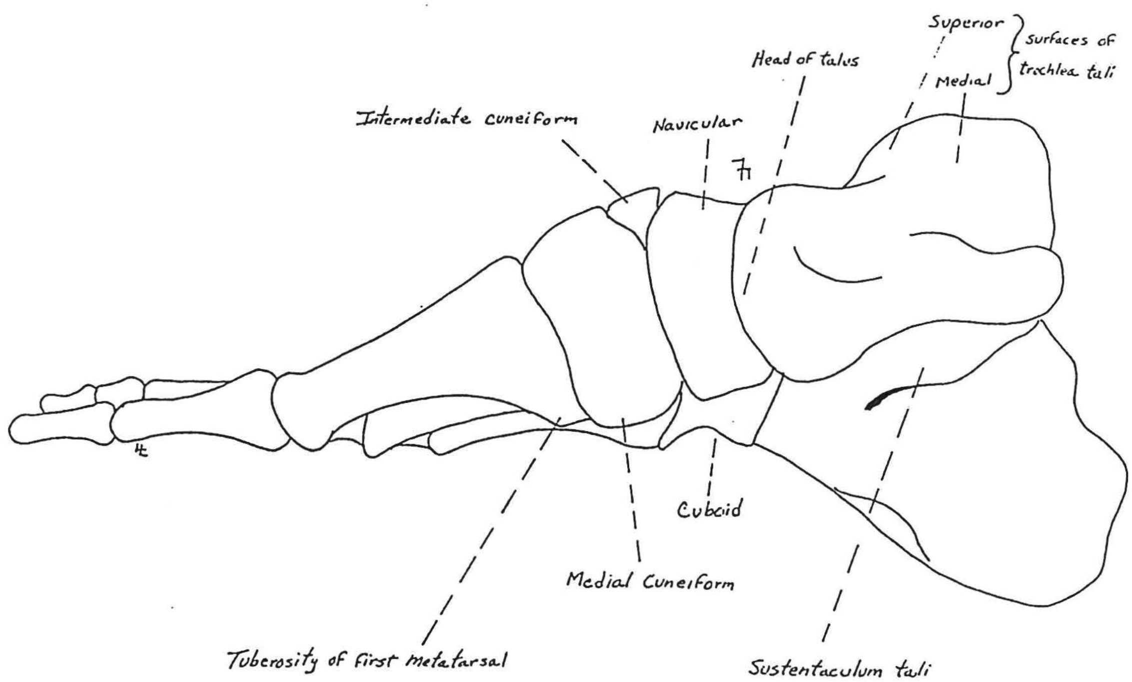


Figure 1-3. Bones of the Foot, Dorsal View

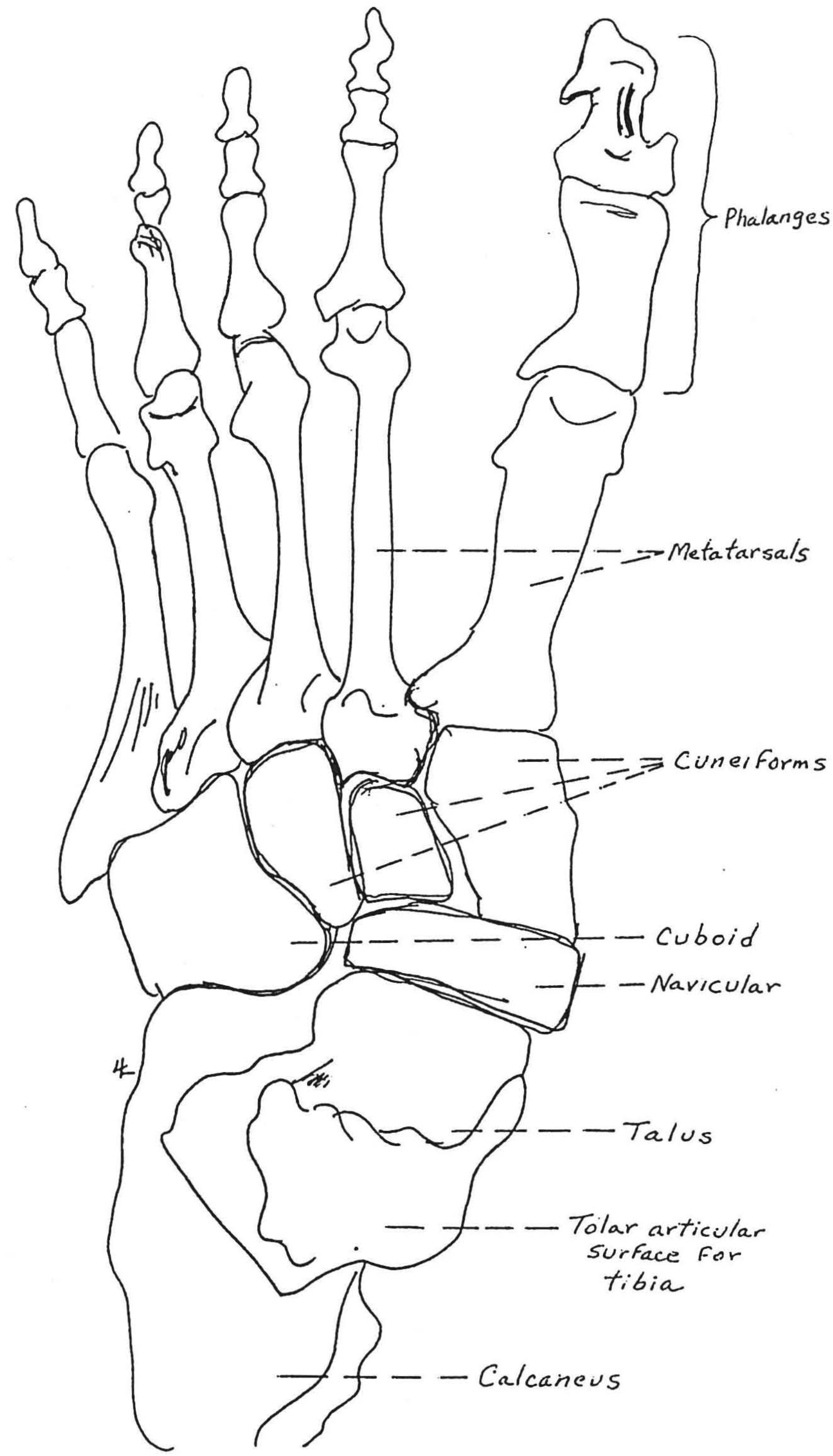
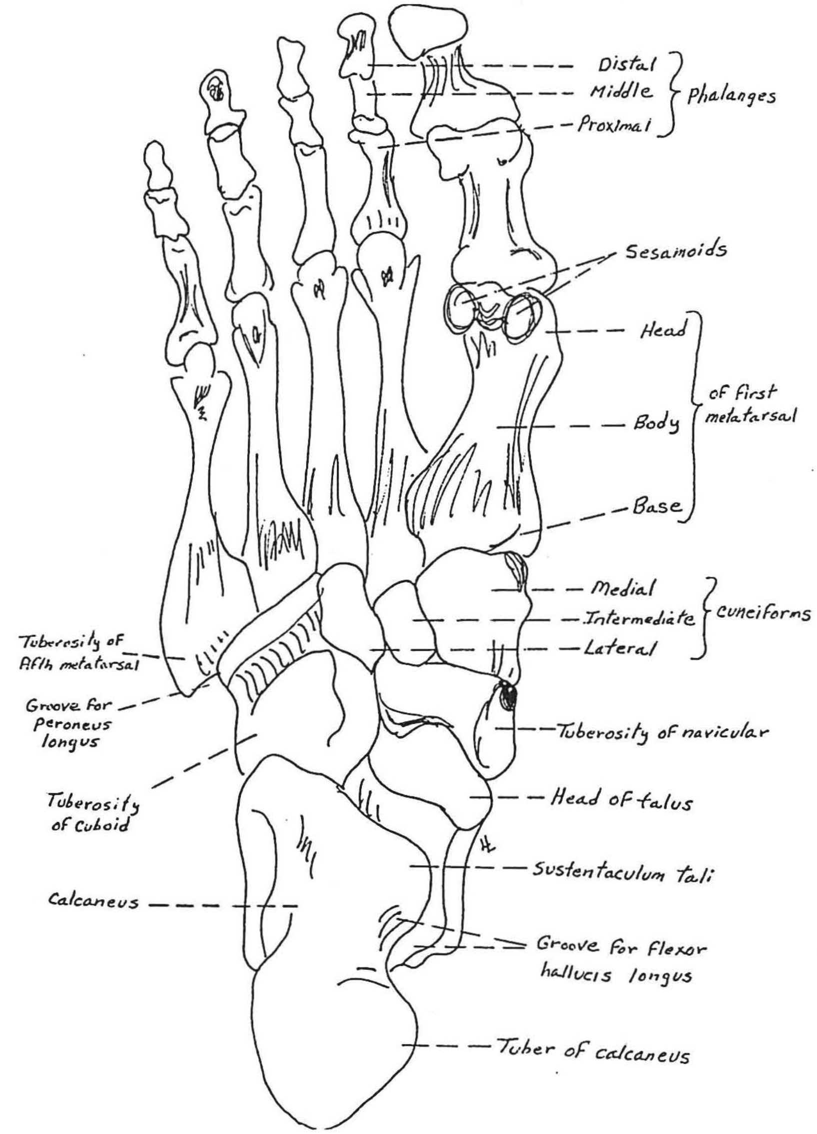
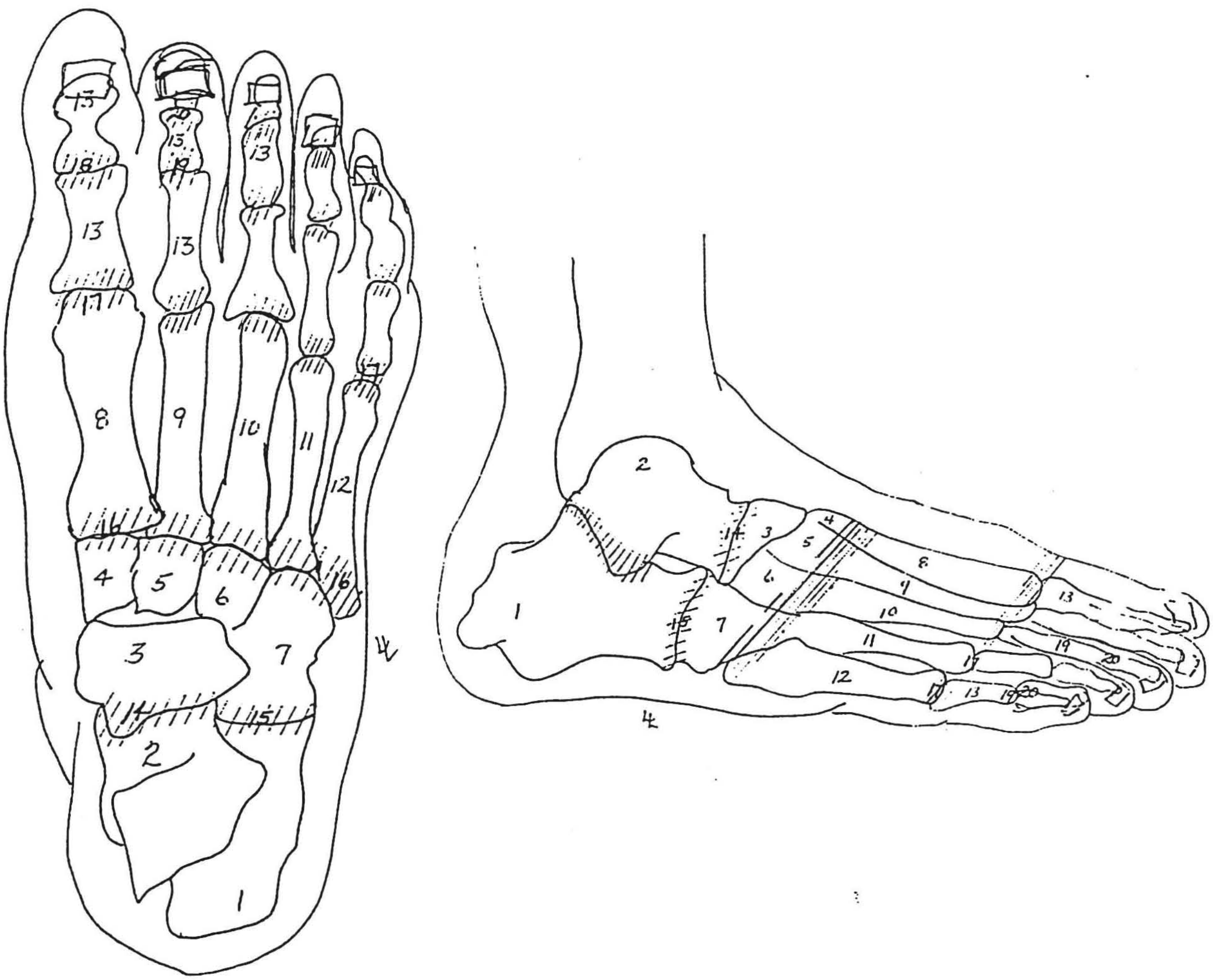


Figure 1-4. Bones of the Foot, Plantar View



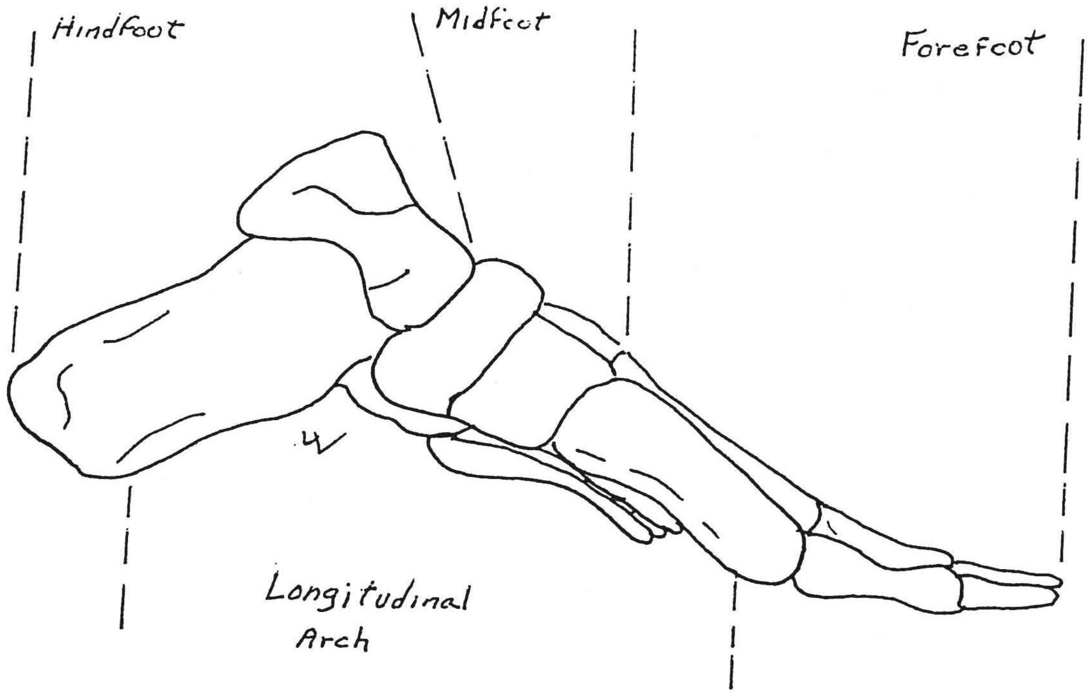
metatarsophalangeal (5), interphalangeal joints (IP), proximal (PIP), and distal (DIP) (Figure 2). The ankle joint is the talocrural and is made up of the tibia, fibula, and talus. The tibia and fibula have to come apart for the talus to come through[3]. This joint controls what happens in the foot. The subtalar joint responds to the proximal joints and is the torque converter from the leg to the foot. The midtarsal (transverse tarsal) or talonavicular and calcaneocuboid is the most dynamic joint in the foot. The tarsometatarsal will do the work and get the foot to the floor if the subtalar joint is in the wrong place. The talus is convex anterior/posteriorly and concave mediolaterally. The hindfoot is made up of the talus and os calcis. The midfoot is made up of the navicular, three cuneiforms, and the cuboid. The forefoot includes five metatarsals, phalanges (two for the great toe, three for the other toes).[7] The foot has a longitudinal arch and a transverse arch (Figure 3). The medial longitudinal arch consists of the calcaneus, talus, navicular, first cuneiform, first metatarsal, and the sesamoid and is 15-18 mm. from the ground.[8] The lateral longitudinal arch consists of the calcaneus, cuboid, and the fifth metatarsal, and is about 6 mm. off the ground. The transverse arch has all the metatarsal heads on the ground during quiet standing.

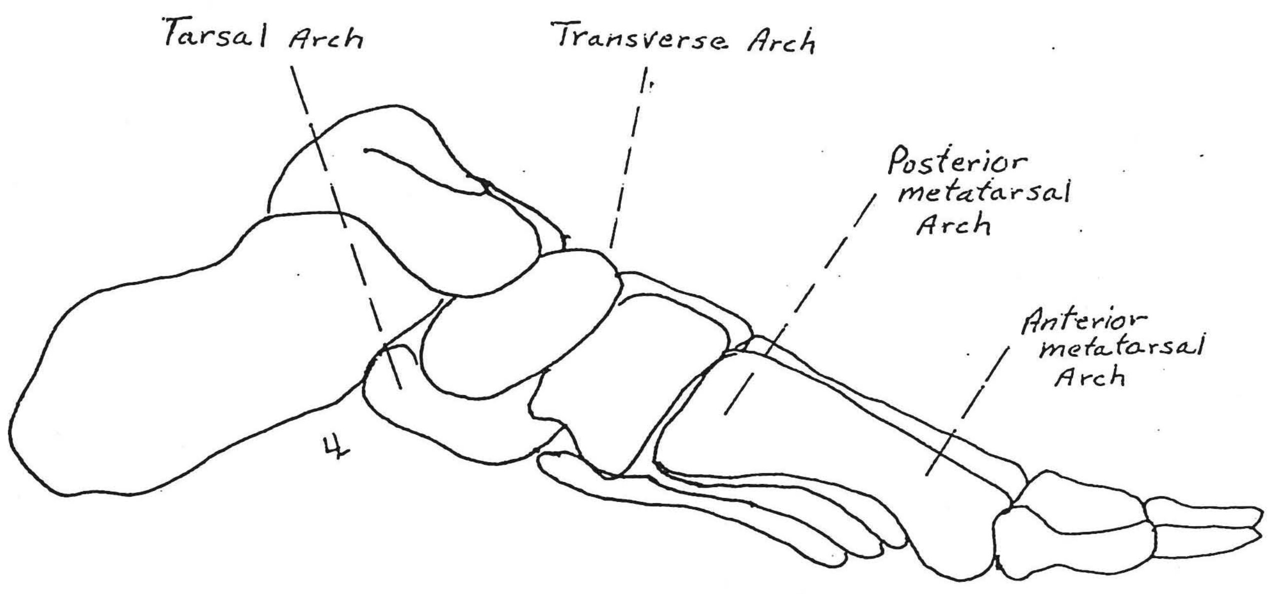
Figure 2. Foot Bones and Joints, Dorsal and Lateral View



[1.Calcaneus; 2.talus; 3.navicular; 4.medial cuneiform; 5.middle cuneiform; 6.lateral cuneiform; 7.cuboid; 8.first metatarsal; 9.second metatarsal; 10.third metatarsal; 11.fourth metatarsal; 12.fifth metatarsal; 13.phalanges; 14.talonavicular joint; 15.calcaneocuboid joint; 16.tarsometatarsal (TMT) joint; 17.metatarsophalangeal (MTP) joint; 18.interphalangeal (IP) joint; 19.proximal interphalangeal (PIP) joint; 20.distal interphalangeal (DIP) joint; 21.talocalcaneal (subtalar) joint.]

Figure 3. Divisions and Arches of the Foot, Medial View





The rearfoot, midfoot, and forefoot function as a unit during the stance phase of gait. Alterations in any one of these structures will influence the function of the entire foot and ankle during the stance phase. The interdependency and interrelationship of the rear-, mid-, and forefoot are established by muscle and connective tissue structures. Movement of one joint will influence movement of the other joints in the foot and ankle. The soft tissue structures establish an interdependency of the foot and ankle to the entire lower limb. Therefore, alterations in the mechanics of the foot and ankle can influence the functions of the lower limb.[5]

Planes of Motion

Translation is movement of an object in a straight line that occurs when the line of force passes through the center of the object.[2] Rotation is movement of an object in an arc around a fixed axis.[2] It occurs when the line of force does not pass through the center of an object. Rotational motion is always perpendicular to the axis of rotation.[2]

Primary planes of motion in the foot and ankle are the frontal, sagittal, and transverse planes.[2] Frontal plane movements are inversion and eversion. The sagittal plane movements are dorsiflexion and plantarflexion. The transverse plane movements are abduction and adduction. The joints of the foot and ankle function as hinges. Motion must occur perpendicular to the axis; if not, partial dislocation or impingement may occur. A true hinge joint provides 1^0 of freedom, or movement, in one plane. The IP joints of the toes provide 1^0 of freedom, or movement, in one body plane. The MTP joints have two independent axes of motion. Each axis provides 1^0 of freedom, therefore giving the joints 2^0 of freedom. The midtarsal, subtalar, talocrural joints, and the first and fifth rays all provide movement in the three cardinal planes.[2]

A part of the static foot maintained in an inverted position is described as being in varus, and an everted position as being in valgus.[3,9] The suffixes -ion or -ing describe a motion, and -ed or -us the resulting position or deformity. Thus, a bunion is hallux abducto valgus.[3,10]

Supination and pronation describe simultaneous motion in all three primary planes. Supination is a combination of adduction/inversion/plantarflexion. Pronation involves abduction/eversion/dorsiflexion. With the exception of the sagittal plane (dorsiflexion and plantarflexion), the terminology used to describe primary plane motion at the ankle differs from that of the foot. In the frontal plane at the ankle, tilting toward the midline is adduction. In the transverse plane, at the ankle, the motion is that of internal and external rotation.[9]

The ankle, subtalar and midtarsal joints, and the first and fifth rays have axes of motion that are oblique to the body planes (Figure 4). On the first ray axis, dorsiflexion/inversion is not a triplane motion. It has its own axis, so a callus will form under the first MET head from pronation.[3]

Hypermobility is a motion occurring at a time when it should not. When hypermobility occurs, and there is abnormal compensation, the primary problem must be found.[3]

Figure 4. Obliquity of Ankle Axis, Palpated at Tips of Malleoli

Patient History

The following list of questions must be answered in order to establish the essential data base via patient history.[3,4,5,9]

1. Age and sex of the patient.
2. Usual activity, or pastime, and what stresses involved.
3. History of previous injury or affliction (systemic conditions such as diabetes, gout, psoriasis, and collagen diseases may manifest themselves first in the foot).
4. What type of shoes does the patient wear? Heels? Condition? Orthotics? Tell the patient not to wear new shoes to the exam. Check usual wear pattern and support. Be aware of the interaction between the foot and the ground. Tests may tell how far the shoe moves, but not how far the foot moves in the shoe.
5. What effect on the foot problem does walking on different terrains have?
6. Does activity make a difference? Pain after activity suggests overuse, during activity suggests stress on the injured structure.

7. Occupation--does patient stand alot and on what surfaces?

8. What was the mechanism of the injury?

9. Are symptoms improving, becoming worse, or staying the same? Ascertain the type of onset and the duration and intensity of symptoms.

10. What are the sites and boundaries of pain and abnormal sensation? Is this a dermatome pattern, peripheral nerve track, or another painful structure?

11. Did the patient notice a transient or fixed deformity of the foot and ankle at the time of injury? Was there any transitory locking (e.g., a loose body)?

12. Was the patient able to continue the activity after the injury? If so, the injury was probably not too severe, as long as there was no loss of stability.

13. Was there any swelling or bruising? How quickly and where did it develop? What type of swelling--blood, synovial, purulent, intracapsular/ extracapsular?

14. What are the qualities of pain--aching, burning, sharp, dull, continuous, intermittent?

15. Any precipitating factors, aggravating factors, or relieving ones? Has there been any previous therapeutic intervention?
16. Radiation?
17. Areas of recurrent callus formation and the location of previous ulceration or skin breakdown.
18. Numbness, stiffness, weakness, instability, rate of progression of deformities.
19. Pending litigation or Worker's Compensation?
20. Current medications, allergies, bleeding history, previous reactions to anesthetic agents (regional or general)?
21. Acute or chronic (repetitive) stress?
22. Is the injury bony, musculotendinous, or ligaments?
23. Is the patient at risk or not at risk (likelihood of repeat or recurrent injury)?
24. How is the injury staged?
    I. Does not interfere with recreation or sports, but is symptomatic.
    II. Symptomatic and affects performance.
    III. Stops performance.

Giallonardo[10] used a SOAP note format for the evaluation process to review subjective and objective data and assess dysfunction of the foot and ankle. Patient history provides subjective data. Inspection, palpation, and measurement provide objective data. Assessment of the dysfunction, and foot orthoses if present, leads to proper setting of treatment goals. Each treatment plan should be based on a goal. Reassessment of the goals should also be a significant part of the treatment planning process.

Physical Examination

The physical exam must be systematic and competent.[3,11] An exam of the spine, pelvis, hip, and knee must be included in order to interpret specifics of the foot/ankle exam. A working knowledge of anatomy, physiology, and biomechanics is necessary. The ankle is not a simple hinge joint. The anterior-widened, wedge-shaped talus within the talofibular mortise is the link between the leg and the foot. As such, the mortise is pivotal in all loads that are transmitted.

The physical exam includes:

1. General inspection and alignment of the foot and ankle in static, dynamic, and passive weight-bearing postures.
2. Inspection of the foot in pronation and supination.
3. Alignment of the leg and heel (heel--os calcis axis and the tibial axis determine leg/heel alignment and whether heel [rearfoot] valgus or varus is present). Bisect the lower third of the leg and compare it to the calcaneus.
4. Alignment of the heel and forefoot (forefoot held in neutral and ankle at 90^0). Medial and lateral

borders of the talus are palpated equally. Normally, about 5^0 of supination are present.

5. Hind-, mid-, and forefoot mobility. Forefoot to rearfoot relationship. Bisect of calcaneus compared to lines of metatarsal heads.
6. Comparison of above with contralateral side (if normal).
7. Walking or running gait exam often needed for evaluation, especially with more chronic foot and ankle problems. Normal float or airborne phase with running precedes an impact load of two to three times body weight. Walking, by comparison, constantly features a weight-bearing extremity. The normal unlocking mechanism at the subtalar joint that permits adaptation of the foot to the surface, as modified by shoes or orthoses, allows pronation absorption of the impact.

In the past, after the patient identified the site of the symptoms, and the practitioners differentiated the source of the symptoms, treatment was initiated. More is needed. The exam must go on to further review. Torsion relationship, why the person toes in or out, must be determined. Open-chain flexibility is determined by checking the joints in different positions to decide structural or functional disability. Closed-chain, or functional flexibility, shows in motion or symmetry. Observe the patient from the front, side, and back. Most biomechanical exams turn out to be home programs with stretching.[3]

NORMAL BIOMECHANICS

The Gait Cycle

Biomechanics is 95% timing and 5% motion and strength.[3,6,11] It is a static-type science that examines each motion, or phase of motion, separately.[3] It is a science that helps us understand the totality of the human organism and the relationship or interaction that the various body parts, segments and systems, have with each other that contribute to the ability or inability to locomote. In normal gait:

At heel strike, the foot is in supination and hits the ground on the lateral condyle of the heel. The foot then collapses to foot flat and the calcaneus everts so the knee can flex.

At mid-stance, the foot is essentially neutral while progressing into the position of pronation. The knee goes into a relative valgus position. External rotation of the tibia on the femur occurs, with internal rotation of the femur at the hip joints. If stopped now, the motion is supination, but the position is pronation.

At push-off, the forefoot is pronated so the medial aspect of the foot and great toe may be positioned to function with maximal push-off power. Heel-off is the key and should be neutral.

From footstrike to mid-stance, pronation allows the foot to become loose and mobile, in order to be an effective adapter and shock absorber.[12] After the foot has landed firmly and is bearing the full weight of the body, the directions of foot movement reverses. The arch starts to rise and the foot starts to roll upward and outward, becoming very rigid and stable, in order to lift the weight of the body and move it forward.[6] If there is a deformity, orthotics can bring the ground up to meet the foot, so the deformity doesn't meet the ground.

As the pelvis externally rotates, the femur externally rotates, the tibia externally rotates, and the foot supinates. The peroneus longus grabs the base of the first ray to pull it into the ground. Some people feel better in high heels because the subtalar and first ray are locked up and more stable, mimicking the shoe motion.

During the first 25% of stance, the foot goes into pronation because it unlocks and is flexible to adapt to the ground. It then starts to supinate, become rigid, and provides the stabilization. In excess pronation, there is pain from muscle overuse. In excess supination, the forces are absorbed in the sacroiliac joint.[3]

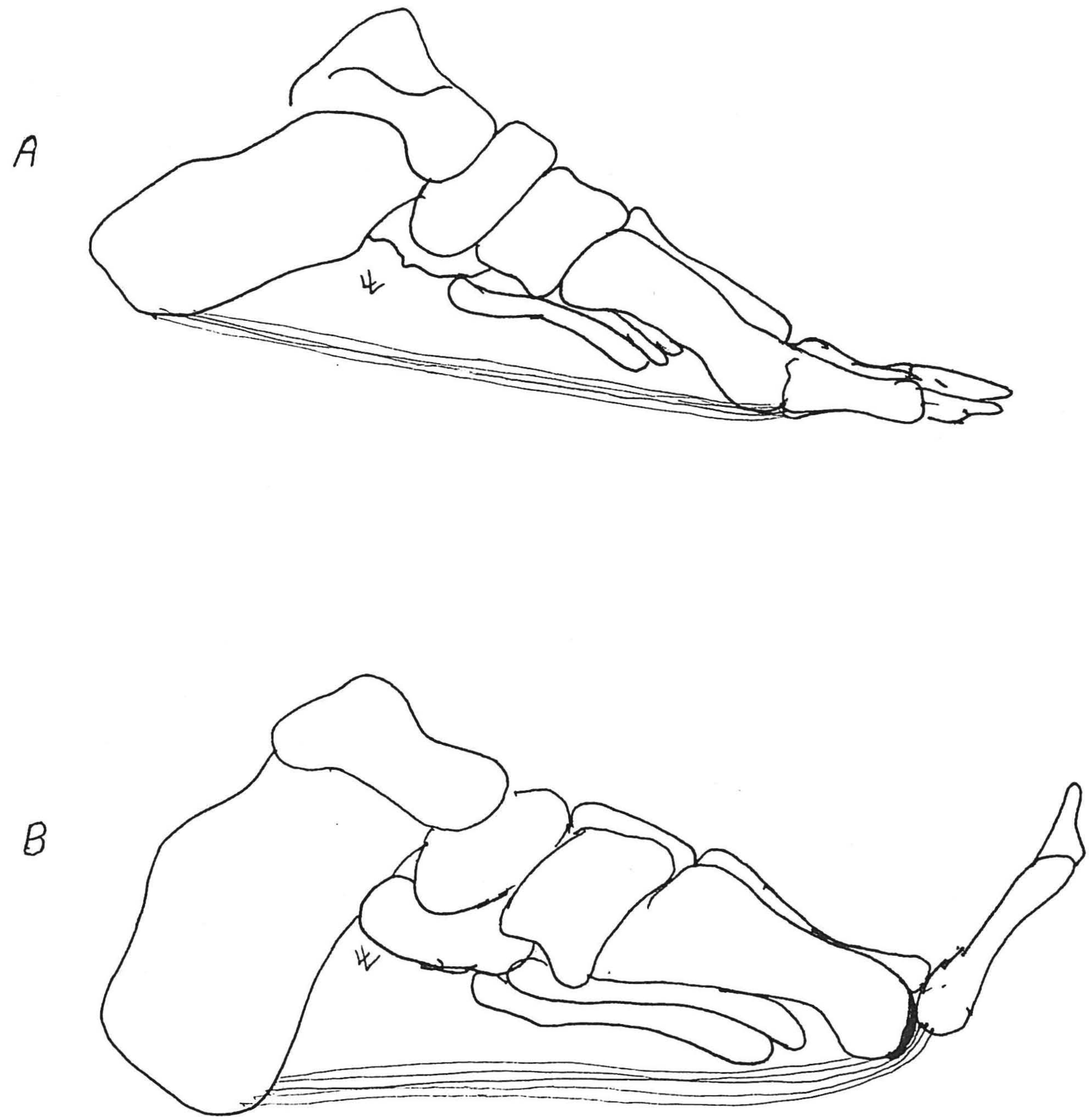
During gait, the rearfoot converts the torque of the lower limb. Transverse rotation of the lower extremity is converted into sagittal, horizontal, and frontal plane movement. The rearfoot influences the function and movement of the mid- and forefoot. It is made up of the talus and calcaneus. The talus articulates with the calcaneus on facets parallel to the ground for additional balance and adaptation.[5] When the talus cannot be felt to poke out on either side, then the subtalar joint is in neutral. When the subtalar is in neutral, the mid-tarsal cannot be pronated and the heel will go into varus.

The midfoot transmits movement from the rearfoot to the forefoot and promotes stability. Movement and function are dependent on mechanics of the rearfoot. It is made up of the navicular and cuboid. The midtarsal joint is the major articulation of the midfoot, formed by the approximation of these two bones, which articulates with the talus and calcaneus (Figure 2).

The forefoot adapts to the ground as the terrain changes, adjusting to the uneven surface. The accommodation is dependent on the normal mechanics of the rearfoot. It includes the cuneiforms, metatarsals, and phalanges. The hallux is the most prominent of the phalanges.[5]

In the loading response of gait, the loading is on an outstretched limb, with two-foot stance. In mid-stance, the body passes over and the contralateral limb is off the ground. In the terminal stance, the body continues to pass over. As the toes dorsiflex, they tighten the plantar aponeurosis to elevate the longitudinal arch (Figure 5).

Figure 5. Diagramatic Representation of the "Windlass Mechanism"



[The windlass mechanism--dorsiflexion of the toes tightens the plantar aponeurosis.]

Closed and Open Kinetic Chain

During weight-bearing, the subtalar joint locks, and the foot and ankle become a rigid lever. This facilitates and leads to push-off at the end of the weight-bearing phase. The foot can strike normally at the lateral rearfoot, the midfoot, or the forefoot, but it should be smooth, symmetric, and silent. It is necessary to look at all the components of gait, including symmetry and upper body posture, to find any abnormal stress present.[11] Symmetry, specific limp, and posture may suggest either foot or ankle problems or other proximal problems.[11] For example, over-pronation can lead to shin splints, patellofemoral incongruity, iliotibial band knee, and hip symptoms. Both foot and ankle problems, on the other hand, can often be corrected by changes fed proximally by or through the foot and ankle with orthoses or appropriate shoes, or both, or by a change in gait. Similarly, a spinopelvic angle caused by a leg length discrepancy, abnormal leg length, or pelvic tilt can be helped by an appropriate lift or orthosis.[11]

Sixty percent of the normal walking cycle is spent in the stance phase, or closed chain, (25% in double stance, with both feet on the ground) and forty percent is in swing phase, or open chain. From ipsilateral heel strike to ipsilateral heel strike, there are three functional tasks involved: Weight acceptance, single limb support, and swing limb advancement.[11] There are also eight sub-phases: Initial contact, loading response, mid-stance, terminal stance, pre-swing, initial swing, mid-swing, and terminal swing. The most important joint motions during the gait cycle occur at the hip, knee, and ankle joints during the sagittal plane. More subtle motions occur in the foot and pelvic areas in all three planes.[13]

The components of step length are terminal swing on the reference leg and terminal stance on the contralateral. This requires 30^0 of hip flexion, full knee extension, and pelvic rotation in the reference limb. In the trailing limb, there is apparent hyperextension of the hip, 5^0 backward pelvic rotation, ankle-lock, weight shift to the metatarsal heads, with resultant heel rise. If any actions are missing, there is a shortened step length. The only muscles that are working in single-limb support are the calf and hip abductors. Weak plantar flexors will not hold the tibia, so the patient may go into genu recurvatum. Forefoot pain may produce this response.[11] Excess plantar flexion may cause the pelvis to retract.

ABNORMAL BIOMECHANICS

Pain and Posture

Some difficulties that may interfere with normal body mechanics include:

1. A rigid plantarflexed first ray pushes the foot back outward. It does not dorsiflex and let the other rays come down. (Normal mobility of the first ray is one thumb's width into dorsiflexion and one thumb's width into plantarflexion.)
2. On evaluating the lower quarter, a weakened component (such as the back) may no longer be able to absorb forces from normal foot and ankle motion.
3. Zero to 25% of gait should be pronation and 75% resupinating.
4. A heel whip may cause bunions or hallux valgus.
5. If pronation is structural (arch problems), no exercise can correct it.
6. What occurs at the rearfoot should occur at the forefoot.
7. Torque demand causes the body to kick-in or turn on to compensate. Because of deficits or pathology, torque advantages may not be used.[3]

8. In examining a shoe, if the crease at the forefoot is not straight across, but oblique, this may indicate markedly reduced motion at the first metatarsal joint. If fusion or partial fusion are present (hallux rigidus), toe-off comes from the last four toes. Normally, the first metatarso-phalangeal joint has 70-90^{0} of dorsiflexion for toe-off.[12]

9. Most gait problems in stance phase result in pain and cause the patient to walk with an antalgic gait. The patient tries to get off the involved extremity as fast as possible and may try to avoid the painful component completely. Stance phase may also be affected by shoes.[14]

10. At heel strike, foot pains may be from a heel spur. The patient may hop onto the involved foot to avoid heel strike.

11. At foot flat, weak or non-functioning dorsiflexors may cause foot slap. Ankle fusion may prevent foot flat until mid-stance.

12. In mid-stance, weight is normally borne evenly on all aspects of the foot. Rigid pes planus (flat foot) or subtalar arthritis may cause patients to develop pain when walking on uneven ground; fallen arches may cause painful calluses over the

metatarsal heads, and corns on the toes may be painful in stance, since they rub on the shoe.[14]

13. In push-off, if the patient has osteoarthritis or fused MTP, he may push off from the lateral side of the foot, eventually causing pain. Corns or calluses may develop secondary to the pressure and adding pain.

14. In swing phase, the ankle dorsiflexors work to allow the foot to clear, so these muscles need to be normal strength.[14]

Gait Deviations

During weight acceptance, the causes[13] of <u>forefoot</u> or <u>foot-flat contact</u> rather than normal heelstrike might be plantarflexion contracture or knee flexion contracture, combination greater than 30^0; compensation for weak quadriceps to avoid normal loading response; weak dorsiflexors that have the effect of losing the heel rocker, decreasing forward momentum of the tibia or decreasing shock absorption. <u>Foot slap</u>[13] during weight acceptance is most likely due to weak dorsiflexors with the same significance as foot-flat. <u>Excess plantarflexion</u>[13] during weight acceptance may be due to plantarflexion contracture or spasticity, with a decreased forward momentum of the tibia. During single limb support, excess plantarflexion is compensatory for decreased motor control of plantarflexors or quadriceps, and interferes with progression over the ankle and forefoot rocker. Impaired proprioception or pain may be the cause of excess plantarflexion in single limb support and decrease the contralateral step length and decrease shock absorption. Neutral (without 10^0 of dorsiflexion) may appear like knee hyperextension or pelvis retraction. <u>Excess plantarflexion</u>[13] during swing limb advancement may be due to weak dorsiflexors, plantarflexion contracture or spasticity, or impaired proprioception. This interferes with foot clearance during mid swing and interferes with foot position for weight acceptance. Excess ankle dorsiflexion[13] during weight acceptance may be compensatory for excessive hip and knee flexion, weak quadriceps that are not meeting the high demand, and creates more hip and knee flexion, increasing the torque demand on the hip extensors and quadriceps. Excess ankle dorsiflexion[13] during single leg stance may be due to weak plantarflexors, compensatory to create contralateral step length when normal heel rise is not present, or intentional to decrease the demand at loading response on the opposite limb, or compensatory for excessive hip and knee flexion. This creates a decreased contralateral step length during the terminal stance and interferes with heel rise. Excess varus[13] during weight acceptance may be a spastic anterior tibialis, posterior tibial, or soleus and cause a poor position for weight acceptance. During single leg stance and swing leg advancement, cause may be varus contracture, impaired proprioception, or weak peroneals or toe extensors, with the significance of a rigid foot resulting in decreased shock absorption. Excess valgus[13] during weight acceptance is probably a valgus contracture creating a poor position. During single leg stance, impaired proprioception may be the reason, with rotated tibia. During swing leg advancement, weak soleus, tibialis posterior, or compensatory for plantar flexion contracture may result in a deforming force, give a poor posture for stance stability, and decrease stability for forefoot rocker (SLS). Heel off[13] during weight acceptance is most likely plantarflexion contracture or spasticity and, during single leg stance, knee flexion contracture with tibial advancement. Significance is loose heel rocker during loading response, decreases forward momentum, decreases weight bearing surface for stable base of support, decreases shock absorption (LR), and increases pressure on the metatarsal heads. No heel off[13] during single leg stance is weak plantarflexors during terminal stance, compensatory for MT head pain, or inadequate toe dorsiflexion range during terminal stance with the significance of interference with progression over forefoot rocker and decreased step length. During swing leg advancement, cause of no heel off is probably inadequate toe dorsiflexion range (pre-swing) and decreases contralateral step length. Drag[13] during swing leg advancement is likely due to inadequate knee and hip flexion, dorsiflexion or impaired proprioception, and interferes with forward momentum and step length. This is also dangerous on uneven terrain. Contralateral[13] vaulting during swing leg advancement is compensatory for inadequate knee and hip flexion, dorsiflexion of swing limb, or compensatory for increased leg length of swing limb, causing increased energy demand on the calf muscles. When the toes are held up[13] during swing leg advancement, this is compensatory for weak anterior tibialis or hyperactive toe extensors. This may cause skin irritation, calluses on the dorsum of the toes from rubbing against the shoe. Inadequate extension[13] during single leg stance or swing leg advancement may be toe flexion contractures or spasticity, or forefoot pain (terminal stance, pre-swing) and interferes with progression over the forefoot rocker, decreases forward momentum, and decreases contralateral step length. If the toes are clawed[13], this may be hyperactive toe flexors or extensors, or a muscle imbalance of the long toe extensors and intrinsics. This interferes with progression over the forefoot rocker, decreases forward momentum, and decreases the contralateral step length. The team states that walking is an automatic behavior, so effecting a change is difficult.

SHOES

The following factors are important when considering proper shoe selection.

1. Shop for shoes at the end of the day when your feet are their largest, and wear the socks you will wear with the shoe.
2. Try on both shoes, because people's feet are often different sizes. Buy for the larger foot.
3. Test the shoes by hopping on each foot on a non-carpeted floor to check cushioning, running a few steps and stopping quickly to see if the foot slips, check for a thumbnail's width between longest toe and end of the shoe, being sure the heel counter is snug.
4. Test for flexibility by rising up on toes and seeing that the forefoot bends easily. Be sure the shoe is not concave between arch and heel.
5. Look for defects in workmanship and look at the shoe on a flat surface.
6. Know the motion-control problems by looking at current wear of the owner's shoes.

7. Board-lasted shoes may be better for people who over-pronate. The upper of the shoe is fastened to a stiff fiber board.
8. Slip-lasted shoes may be better for "runners" who supinate. Shoe upper is stitched to the sole in one piece. Larger stabilizer at the outside of the heel than the inside also helps.
9. Combination-lasted shoe (fastened to a fiber board in the heel and sewn in one place around the forefoot). If the fit is right, both pronators and supinators can use this type of shoe. The shoe's last may be identified by looking at the stitching under the insole.
10. Focus on buying a shoe that feels good on your feet and provides the right mix of stability, cushioning, and flexibility, not by the fancy words describing the contents of the sole.[13]
11. Be sure the foot is measured for correct sizing.
12. Be wary of the high-fashion shoes, avoid pointed toes.
13. Small family or independent shoe stores may provide better service for the best fit. Choose professional shoe-fitters over shoe salesmen.
14. Buy leather shoes. There is more similarity to human skin. Leather is moldable and breathes to allow exchange of moisture and absorption.

15. Shoes do not usually cause foot problems, but may aggravate them. Shoes can also protect the feet from shock, friction, and stress that might otherwise be intolerable.
16. Rotate your shoes at least every day, but even during the day.
17. Orthopedic or corrective shoes often do not correct.[6]
18. Problems caused from wearing high-heeled shoes are:
    a. Weight shift to the front of the foot (normally 40% front, 60% rear) or 80% or more of the body weight.
    b. Squeezing the foot into narrow toes.
    c. Aggravating dormant problems such as hammertoes, bunions, corns, and calluses.
    d. Shortened calf muscles causing muscle imbalance and leading to such things as shin splints and Achilles tendinitis in the athletic female.
    e. Weakened ankle because of the altered position.
    f. Poor posture through the knees, hips, and lower back, leading to pain at any or all of those joints.[6]

When adding orthotics, put them in new shoes.[15]

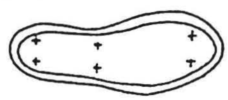
Last or Construction / What's the Difference?

"Lasts" can refer to either the form the shoe is built around or the type of construction used in making the shoe. Below is an explanation of the two.

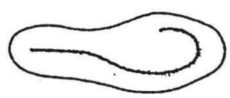
Last Construction

The last construction of a shoe is important in determining its overall support. Here is a description of the different types of last constructions and their primary uses and advantages:

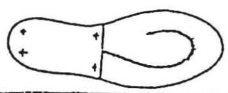
Board Lasted - The upper section is pulled over the last and cemented to a flexible innersole board. This method provides stability and is especially good for larger individuals.



Slip Lasted - The upper is stitched closed on the underside and slipped onto the last (looks like the inside of a moccasin). This method provides flexibility and lightness.



Combination Lasted - This method combines board and slip lasting. It is board lasted in the rearfoot for stability and slip lasted in the forefoot for flexibility. Many athletic shoes are combination lasted.



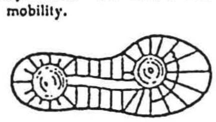
Lasts

The last is the form the shoe is built around. It is what determines the basic shape of a shoe. The shape of a shoe contributes to a shoe's support characteristics and fit characteristics. The following are the different types of lasts:

Straight Last - This type of last is usually preferred by overpronators.

Semi-curved Last - This type of last is usually preferred by individuals who want a supportive last, but do not want the bulky feeling of a straight last.

Curved Last - This type of last is usually preferred by an individual looking for a shoe with good lateral support. Shoes built on this type of last are usually preferred by underpronators who want a shoe with added mobility.



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ORTHOTICS

The biomechanical/functional definition of an orthotic is that it be capable of controlling functional pathology of the foot and lower extremity by maintaining the subtalar joint around neutral.[15] The goals and requirements include:

1. Conforms exactly to the foot.
2. Sufficiently rigid for control.
3. Controls abnormal compensation.
4. Allows normal function.
5. Stands up to stress--can be easily adjusted.
6. Comfortable--patient compliance.

The shell includes many types from flexible to rigid, including accommodative, semi-rigid, and biomechanical. Another component is the post, a wedge on the medial or lateral side of the orthotic, designed to support or control movement.[2] The post may be built into the shell--intrinsic, or added onto the shell--extrinsic. A varus post or medial wedge is thought to control eversion of the calcaneus and internal rotation of the tibia directly after heel strike.[2] The varus post also controls pronation. In the rearfoot, timing is controlled, as is the rate of deceleration and function, away from end range. Forefoot posting holds the abnormal forefoot in a normal or nearly normal relationship to the rearfoot and the supporting surface.[2] Forefoot varus, supported with a medial wedge, is not destructive to the foot, by itself, but the excessive pronation at the subtalar joint, and the resultant hypermobility, can be destructive to the foot and to the rest of the lower kinetic chain during propulsion.[2]

The cover of the top of the module, or shell, covers metatarsal heads, sulcus, and toes. If the orthotic needs to go to the end of the shoe, the extension is placed distal to the module.[16] Special additions may include a deep seat, a high medial phalange, a lateral clip, a heel raise, a lateral phalange, metatarsal pads, arch reinforcement with softer material, and balance for lesions.

Heel lifts are sagittal plane corrections for ankle joint equinus, as opposed to forefoot and rearfoot posts, which are frontal plane corrections. The heel lift can reduce compensatory pronation of the subtalar joint, whether the limitation in ankle joint dorsiflexion is caused by bony, soft tissue, or postural factors.[2]

Biomechanical orthotics may be useful in reducing the excessive weight bearing for adults.[2] These orthotics are not designed to change or correct foot abnormalities, but are designed to reduce pain and improve function of the foot during the stance phase of gait.[2] In children, orthotics are prescribed to control excessive rearfoot movement in the stance phase of gait.[2] Rigid materials are most commonly used to control movement.[2] Research continues to find valid and reliable methods to help determine how orthotics alter foot function during the stance phase of gait.

In a biomechanical orthotic, the first ray may be cut out to allow the ray to plantarflex and enhance the "windlass action" (Figure 5).

SUMMARY

Understanding the foot and ankle are important to the physical therapist because of the direct or indirect effects foot abnormalities can have on pain. Beyond localized foot pain are the possibilities of knee, hip, back, or neck pain related to gait patterns, standing posture, or compensation for foot deformities. Shoe recognition and, at least, an understanding of the function of orthotics allow an avenue to pursue for the relief of structural problems or pain. After conducting a full evaluation of stance and gait, as well as structure, follow-up treatment may include exercise or accommodation to treat the compensation for the deformities. This could encompass flexibility training, modalities, proprioception, joint mobilization, or control of stresses.

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