

Biomechanics of the Foot and Ankle Under Static Conditions

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The purpose of this article is to discuss the static mechanics of the foot and ankle. First, the motions of the ankle and foot available during nonambulatory activities are described by reviewing the literature discussing the axes of motion for the ankle and joints of the foot. Conflicting terminology is presented and clarified, and a scheme for a reasonable terminology is presented. The role of the ankle-foot complex in closed and open kinetic chains is also discussed. Terminology describing structural and functional positions of the foot is presented, including definitions of the subtalar neutral position. A systematic format of terminology is offered to reduce the current inconsistencies. Finally, the weight-bearing area of the foot and muscle activity in quiet standing are reviewed.

Key Words: Ankle; Foot; Kinesiology/biomechanics, lower extremity; Lower extremity, ankle and foot; Tests and measurements, range of motion.

Anatomists, biomechanical engineers, and clinicians have studied the foot and ankle complex for centuries. Each discipline has provided its unique insight into the structure and function of this unit. The diversity of approaches, however, has also led to varying interpretations, resulting in considerable confusion regarding the operation of this complex. The purpose of this article is to discuss the basic biomechanical characteristics of the foot and ankle under static, or nonambulatory, conditions. Specifically, the motions of each joint and the combined movements of joints functioning as a unit will be presented. Terminology to describe joint motions and joint positions in the foot and ankle will also be defined to allay the confusion generated by the multidisciplinary, yet occasionally contradictory, treatises on the foot and ankle complex.

PLANES AND AXES OF MOTION FOR THE FOOT AND ANKLE

This section reviews the planes in which the foot and ankle move and the axes about which they rotate. In this section, it is assumed that the foot is free to move and the leg is fixed. The following section deals with motions that occur when the foot is fixed and the leg is free to move, such as in the stance phase of gait.

Perhaps the greatest source of confusion regarding the function of the ankle and foot arises from ignoring a basic discussion of planes and axes of motions that physical therapists first hear in their introductory courses in physical therapy. Figure 1 reviews the three cardinal planes of motion: 1) sagittal, 2) frontal (coronal), and 3) transverse planes. Rotation in a plane occurs about an axis perpendicular to that plane (Fig. 2). Hence, motion in the sagittal plane (flexion-extension) occurs about a medial-lateral axis, motion in the frontal plane (abduction-adduction) occurs about an anterior-

posterior axis, and motion in the transverse plane (medial-lateral [internal-external] rotation) occurs about a longitudinal axis (Fig. 3).¹⁻³

The motions of the ankle-foot complex are defined operationally by motions in these cardinal planes. Motion in the sagittal plane is known as *dorsiflexion* and *plantar flexion*. Motion in the frontal plane is known as *eversion* and *inversion*. Motion in the transverse plane is defined as *abduction* and *adduction*.³ Note should be made here that abduction and adduction in the foot are in a different plane from abduction and adduction throughout the rest of the appendicular skeleton. Perhaps one explanation for this difference is the orientation of the foot with the leg (ie, the foot lies at a 90° angle to the leg). Abduction of the foot occurs about an axis perpendicular to the plane of the foot. If the foot continued from the distal leg in a straight line, the abduction described above would occur in the more-familiar frontal plane (Fig. 4).

Although the motions of the foot and ankle are defined in terms of the cardinal planes, the true mechanical axes of the joints of the foot complex are *not* perpendicular to these cardinal planes. Thus, because motions occur in a plane perpendicular to the axis of motion, the motions of the foot and ankle occur in planes other than the cardinal planes. These motions occur in planes that pass through all three cardinal planes and are thus known as *triplanar motions* (Fig. 5).^{3,4}

The triplanar motions most commonly seen in the foot and ankle are those that combine dorsiflexion, abduction, and eversion in one direction and plantar flexion, adduction, and inversion in the opposite direction. That is, these two motions are pure rotations about an oblique axis resulting in the same end position as three separate rotations in the cardinal planes. Unfortunately, it is at this point that the terminology becomes remarkably inconsistent and confusing. In 1941, Manter used the terms "pronation" and "supination" to describe the motion in the subtalar joint (STJ) and transverse tarsal joint, noting that pronation was the simple rotation about a single axis resulting in dorsiflexion, abduction, and eversion and

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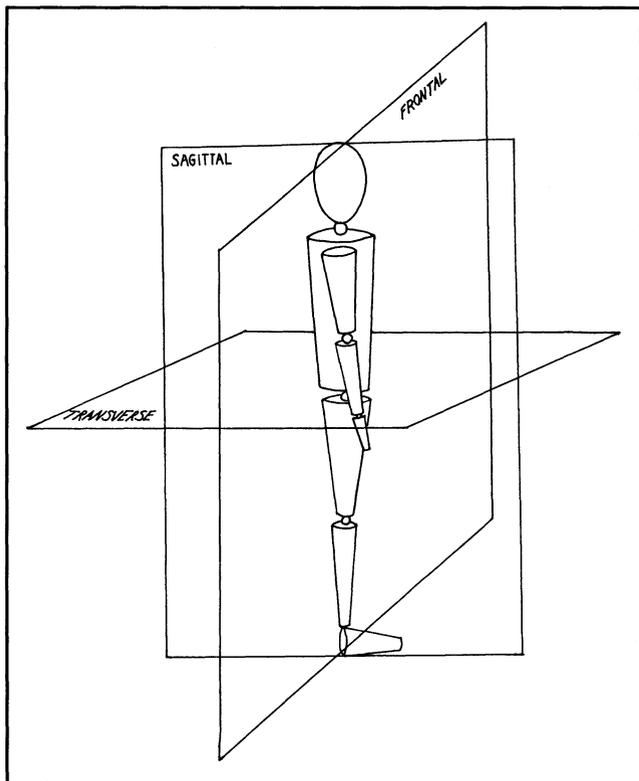


Fig. 1. The three cardinal planes of the body: 1) sagittal, 2) frontal, and 3) transverse.

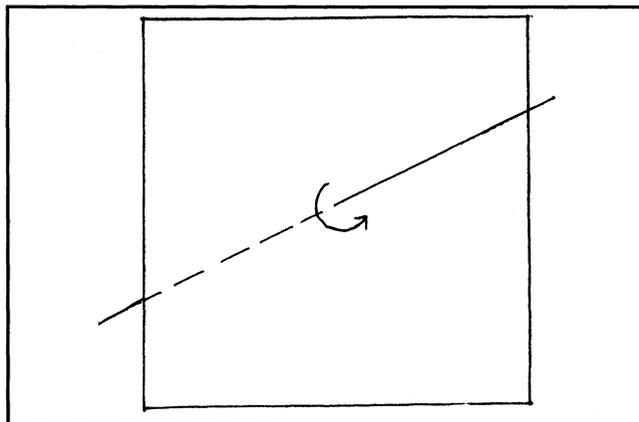


Fig. 2. Diagram indicating rotation in a plane about a perpendicular axis.

that supination was the rotation about an oblique axis resulting in plantar flexion, adduction, and inversion.⁵ Wright et al noted that pronation and supination, as used by Manter,⁵ were "traditional terms" to describe the triplanar motion in the foot.³ These articles implied a general agreement in terminology between the orthopedic and anatomy communities. More recently, however, variations in this terminology have surfaced in the orthopedic and physical therapy literature. Inman used the terms pronation and supination synonymously with the terms eversion and inversion, respectively (ie, to refer to rotations in the frontal plane).⁶ In contrast, other authors appear to reverse the use of pronation-supination and eversion-inversion.^{7,8} These authors used the terms inversion and eversion to mean the composite motions about oblique axes, and they used the terms pronation/supination to mean the rotations in the frontal plane. Some

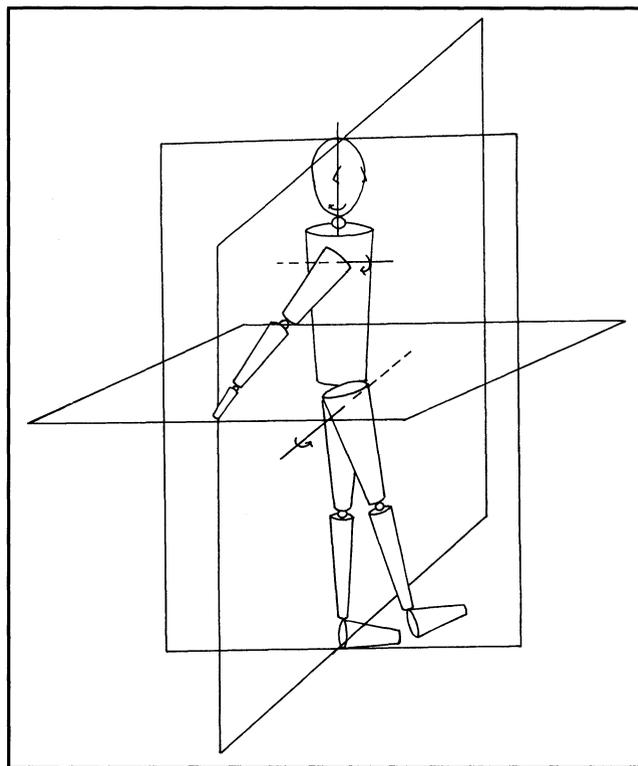


Fig. 3. Motions in the cardinal planes.

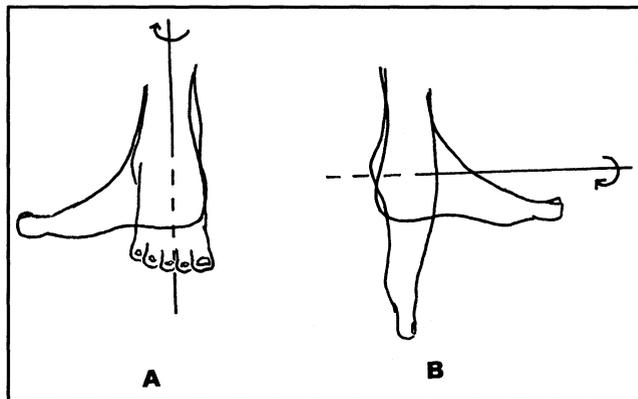


Fig. 4. Axis for abduction of foot (A) anatomically and (B) in frontal plane.

authors in physical therapy, however, have returned to the traditional usage.^{9,10} The podiatric literature appears to use the traditional terms of pronation and supination.⁴

This controversy still is unresolved. I recommend, however, the most widely used terminology, which also appears to have the longest historical tradition. This terminology also provides a consistent and logical description of the motion available anatomically. Thus, it is recommended that the triplanar motion of the foot and ankle be described in terms of pronation (dorsiflexion, abduction, and eversion) and supination (plantar flexion, adduction, and inversion). The individual motions of each segment of the ankle-foot complex will be described in these terms in the following sections.

Ankle Axis and Motion

Inman described the axis of motion at the ankle as passing just distal to the medial and lateral malleoli.⁶ This description

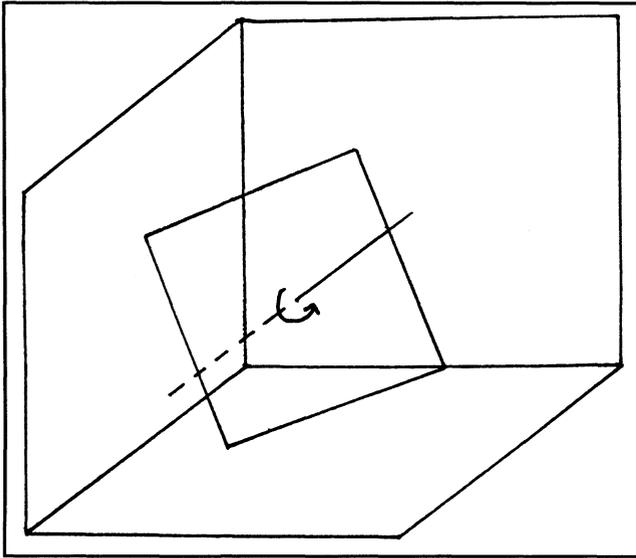


Fig. 5. Triplanar rotation intersecting all three cardinal planes.

means that the axis of motion is oblique to all of the cardinal planes of motion. Yet, the ankle joint is undoubtedly a hinge joint (ie, the motion is uniaxial). The axis is rotated laterally with respect to the knee joint and projects downward and laterally (Fig. 6).^{3,6,8} Thus, in keeping with this terminology, the ankle pronates by dorsiflexing, abducting, and everting. The ankle axis, however, is so close to the longitudinal axis of the foot that the eversion component is negligible. The axis is rotated about 20 degrees in the transverse plane and thus provides some visible abduction. Yet, the axis is closest to the mediolateral axis and thus contributes most to dorsiflexion.¹¹ The reverse for supination is also true (ie, the ankle contributes most to plantar flexion and has some visible adduction and negligible inversion). Although most anatomy texts acknowledge the obliquity of the ankle axis, they generally describe the available motion of the ankle as dorsiflexion and plantar flexion. In keeping with the accepted terminology, the motion should be described as pronation (albeit mostly dorsiflexion) and supination (albeit mostly plantar flexion).

Goniometric measurements imply that the motion of the ankle occurs in the sagittal plane (dorsiflexion/plantar flexion). From a clinical standpoint, this is a reasonable assumption because the most important functional contributions are those of dorsiflexion and plantar flexion. Clinicians, however, should note that a malalignment of the ankle joint could result in a change in the ankle's contribution to dorsiflexion, abduction, or eversion. Note that ankle motion is that motion between the talus and the tibia and fibula only. The moveable arm of the goniometer, therefore, should remain parallel to the lateral aspect of the heel to avoid confusion by contributions from the midtarsal region (Fig. 7). Several authors have reported the "normal" ranges of motion for the ankle joint.¹² With the exception of Boone and Asjen, however, the population from which the observations were made was not described. Reported values of normal plantar flexion varied from 40 to 65 degrees and for dorsiflexion varied between 10 and 30 degrees. This wide range of variability presents a dilemma for clinicians who try to assess the normality of their patients' ROM. This dilemma may be resolved with well-documented descriptive research to describe ROMs in various patient populations. Until these data are available, however, clinicians must use data from the opposite limb and develop

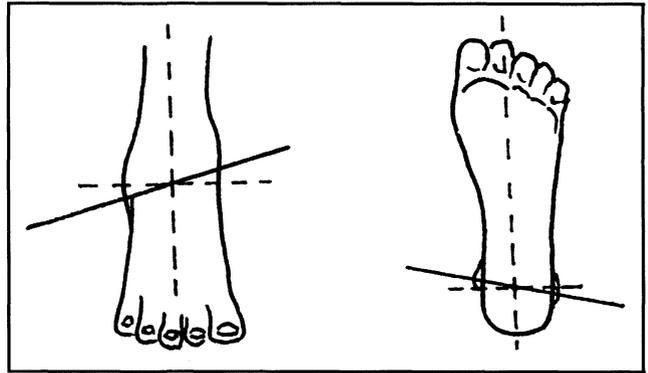


Fig. 6. Axis of ankle joint motion.

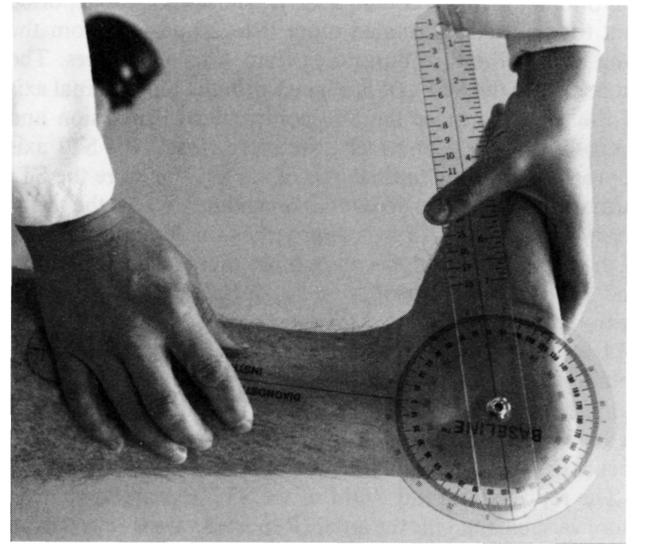


Fig. 7. Correct goniometer alignment for ankle motion assessment.

an understanding of the patient's functional requirements to determine whether the ROM is adequate.

Elveru et al investigated the intertester and intratester reliability of goniometric measurements at the ankle joint and the STJ.¹² In their study, 14 physical therapists took measurements of 50 different feet in patients with orthopedic problems. Intraclass correlation coefficients (ICCs) for intratester reliability of ankle dorsiflexion and plantar flexion were .90 and .86, respectively. The ICCs for intertester reliability for dorsiflexion and plantar flexion were .50 and .72, respectively. These data suggest good intratester reliability for both measures and acceptable intertester reliability for plantar flexion. Intertester reliability for dorsiflexion was poor. The need, however, for the intertester reliability of the absolute measures of dorsiflexion should be evaluated. Perhaps the ability to identify the presence or absence of a plantar-flexion contracture is more reliable and is adequate for clinical applications. Until research is performed to answer these questions, however, clinicians must use caution when comparing their ankle motions with those taken by other physical therapists.

Subtalar Joint Axis and Motion

In classic gross anatomy texts, the STJ is described as a gliding joint in supination.¹³ The calcaneus moves anteriorly, inferiorly, and medially under the talus. It moves posteriorly, superiorly, and laterally during pronation.⁸ Thus, the head of

the talus is readily palpated on its lateral aspect during supination as the calcaneus moves medially and can be palpated medially during pronation as the calcaneus moves laterally. It should also be noted that the osseous movements can be described as the talus moving on the calcaneus, in which case the motions are all reversed.

The STJ has also been described as a hinge, or uniaxial, joint.⁶ Its axis has been described as running downward, posteriorly and laterally (Fig. 8.)^{5,6} Thus, the motion of the STJ is triplanar, providing pronation and supination. The joint orientation, however, results in a more even distribution of composite motions than at the ankle.^{6,11} From a sagittal view, the axis is about 45 degrees from the horizontal plane (ie, halfway between the abduction-adduction and eversion-inversion axes). Inman, however, reported a wide variation in this orientation (greater than $\pm 22^\circ$).⁶ The author also reported that the STJ axis is rotated more than 20 degrees from the long axis of the foot but varies from 4 to 47 degrees. The more closely the STJ axis is aligned with the longitudinal axis of the foot, the more the STJ contributes to inversion and eversion (Fig. 9). Conversely, the more closely the STJ axis approaches the longitudinal axis of the leg, the more the STJ motion contributes to abduction and adduction. In the transverse view, as the STJ axis approaches the longitudinal axis of the foot, the motion becomes more eversion and inversion and decreases its contribution to dorsiflexion and plantar flexion. It should be noted that goniometric measurement of STJ motion actually represents only the eversion-inversion component of STJ pronation and supination because the goniometer is placed on the posterior surface of the hindfoot in the frontal plane, the plane in which eversion and inversion occur (Fig. 10).

The reported normal ROM of the STJ appears to be even more variable than for the ankle. Reported values of inversion excursion range from 5 to 50 degrees. Reported values of eversion vary from 5 to 26 degrees. Root et al, however, reported that pronation normally contributes two thirds of the total STJ motion.¹⁴ Like the ankle data, the populations in whom these measurements were observed are rarely described. Means and standard deviations also are seldom reported. Inman stated that total STJ motion is extremely variable from a total of 10 degrees to a total of 65 degrees, with an average total range of about 40 degrees.⁶ Inman's data, however, were collected using a specially designed goniometer to assess triplanar motion rather than by the standard clinical practice of assessing only frontal plane motion.

Elveru et al's study of the intratester and intertester reliability of STJ ROM measures raises serious questions about

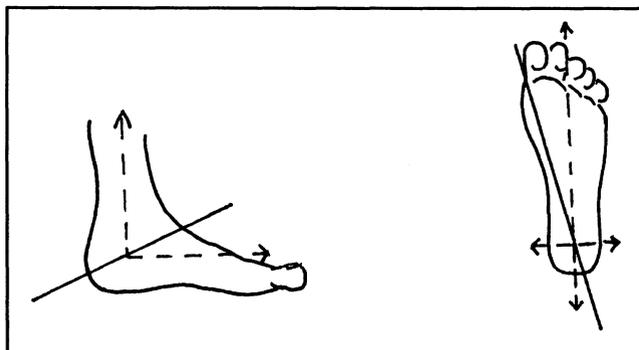


Fig. 8. Axis of subtalar joint motion.

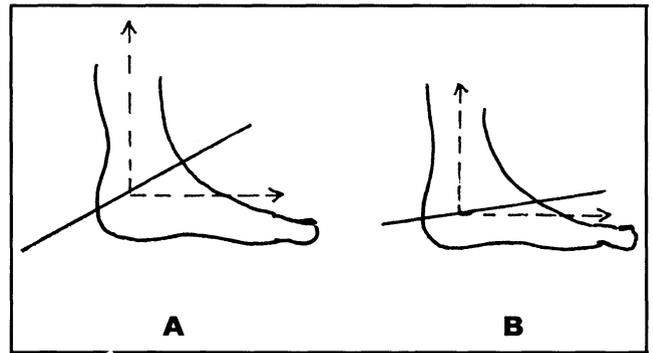


Fig. 9. Effects of change in subtalar joint axis orientation: (A) an oblique axis resulting in an even distribution of eversion during subtalar pronation; (B) a more longitudinally aligned axis favoring eversion during subtalar eversion.

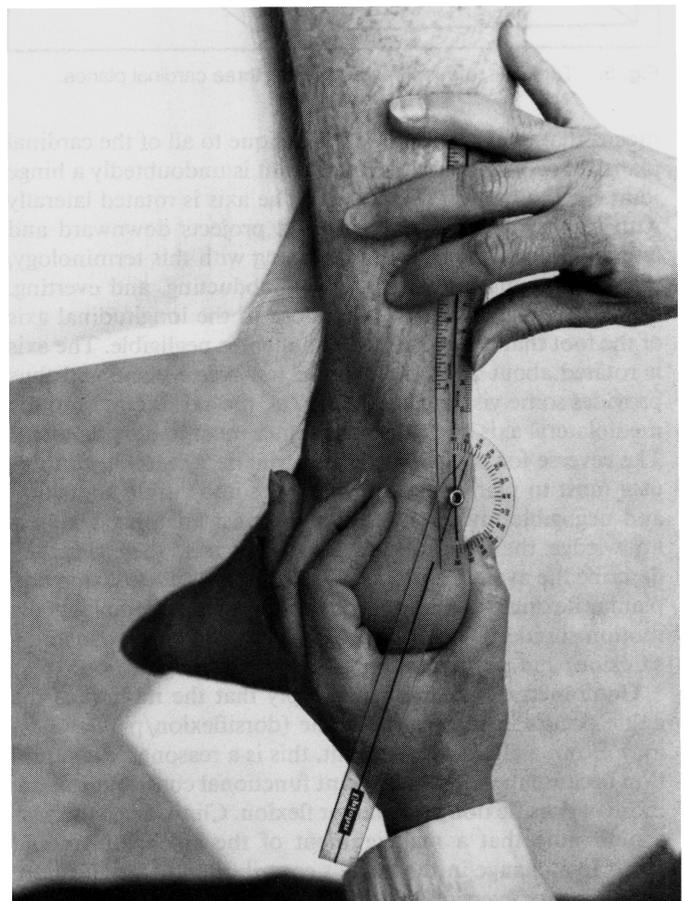


Fig. 10. Correct goniometer alignment for subtalar joint motion assessment in frontal plane.

these measures.¹² In their study, intratester ICCs were .74 for inversion and .75 for eversion. They, however, found intertester ICCs of .32 for inversion and .17 for eversion. These data suggest moderate intratester reliability but virtually no reliability among testers. Thus, clinicians again must take care to use these measurements appropriately; that is, they may be used with care to identify changes seen in an individual patient's status when measured by a single therapist. No conclusions, however, should be drawn by comparing measurements made by more than one tester.

Transverse Tarsal Joint Axes and Motions

The transverse tarsal joint is the functional articulation between the hindfoot (talus and calcaneus) and midfoot (navicular and cuboid). These articulations have been described anatomically as "plane" or "gliding" joints.¹³ Kapandji described the osseous movements of the transverse tarsal joint.⁸ In supination, the author reported that the navicular glides medially and inferiorly on the head of the talus. The cuboid follows the navicular, moving medially and inferiorly on the calcaneus. In pronation, these relative motions are reversed.

Other authors have considered the transverse tarsal region as a single functional unit, describing the movement of the unit as a segment rotating about its own axes. Two axes of motion have been described by investigators of this area.^{4,5,11} Unlike the ankle joint and the STJ, these axes appear to have little correlation with real anatomical landmarks. Rather, they appear to be mechanical constructs useful to describe the functional behavior of the region. The longitudinal axis is similar to the longitudinal component of the STJ axis,¹¹ providing eversion and abduction or inversion and adduction. The oblique axis is similar to the axis of the ankle and consequently contributes more to dorsiflexion and plantar flexion than to motions in the frontal and transverse planes.^{5,11} Thus, the transverse tarsal joint serves to amplify the motions of the ankle joint and the STJ. This function suggests that the loss of ankle joint or STJ motions can be compensated for, at least partially, by motion at the transverse tarsal joint.

Normal ROM of the transverse tarsal joint varies dramatically in the literature. Norkin and White reported 0 to 20 degrees of inversion and 0 to 10 degrees of eversion.¹ These measurements, however, were obtained by a method that appears to include tarsometatarsal motions as well as transverse tarsal motion. Root et al reported a minimum range of 4 to 6 degrees but did not report expected full ranges or the methods by which these data were obtained.⁴ There is no known standardized method to reliably measure discrete transverse tarsal joint motion in the clinic. Most clinicians who assess midtarsal mobility appear to use manual techniques to determine qualitative joint glides in this region. The reliability of such methods, however, should be evaluated.

The motions of the transverse tarsal joint and the STJ appear to be interdependent.⁵ As one joint moves into pronation, it appears to pull the other joint toward pronation. Conversely, supination at one joint appears to be accompanied by supination at the other. Pronation at both of these joints results in a flattening of the medial longitudinal arch and thus in a more flexible foot, whereas supination at both joints results in an elevation of the arch, causing the foot to become more rigid.^{9,15}

Tarsometatarsal Joint Axes and Motions

The tarsometatarsal joints of the foot are divided functionally into the first through the fifth rays. These joints have also been described anatomically as gliding joints, which means that their motion is translatory or planar.¹⁴ Root et al, however, described them functionally as rotatory joints whose motions occur about specific axes.⁴ The first ray is the functional unit between the first metatarsal and medial cuneiform bones. The axis of motion of this unit is directed in an anterior, lateral, and downward direction. This axis lies almost in the transverse plane but approximately midway between

the frontal and sagittal plane. The motion of the first ray is uniaxial and triplanar. Because of the orientation of its axis, however, the motion combines dorsiflexion and inversion or plantar flexion and eversion with negligible contributions to abduction or adduction. Thus, the motion of the first ray is different from pronation and supination but remains uniaxial and triplanar.

The second ray is the unit consisting of the second metatarsal and middle cuneiform. The third ray is composed of the third metatarsal and lateral cuneiform. The fourth ray is the fourth metatarsal alone. Root et al described their motion as pure dorsiflexion and plantar flexion but noted that the axes have not been identified experimentally.⁴

The fifth ray is formed by the fifth metatarsal only. Its axis of motion is similar to the oblique midtarsal axis and thus allows pronation and supination to occur between the metatarsal and the cuboid.

Normal ROMs apparently have not been reported for the tarsometatarsal joints. Root et al, however, indicated that the first ray should be able to plantar flex and dorsiflex equally on the second ray.⁴ Motion of the other rays appears less well defined, although these authors noted the importance of plantar flexion of these joints during dorsiflexion of the metatarsophalangeal joints.

Metatarsophalangeal and Interphalangeal Joint Axes and Motions

The metatarsophalangeal joints of the foot are condyloid, or biaxial, joints allowing motion in the sagittal and transverse planes. These axes pass through the head of each metatarsal. Thus, these joints provide pure dorsiflexion-plantar flexion and abduction-adduction in the cardinal planes of the body. The interphalangeal (IP) joints are hinge joints allowing pure flexion and extension on the sagittal plane.⁴

Reported motion of the metatarsophalangeal joints is also variable. Reported extension varies from 0 to 70 degrees to 0 to 90 degrees for the great toe and from 0 to 40 degrees to 0 to 90 degrees for the other toes. Reported flexion is less variable: 0 to 45 degrees to 0 to 50 degrees for the great toe and from 0 to 40 degrees to 0 to 50 degrees for the lesser toes. Interphalangeal flexion of the great toe has been reported as 0 to 90 degrees with no extension. Reported IP flexion for the lesser toes is 0 to 30 degrees to 0 to 35 degrees (proximal IP flexion greater than distal IP flexion) and extension of the distal IP joints is 0 to 60 degrees.¹

EFFECTS OF MOTION OF THE FOOT AND ANKLE ON THE LOWER EXTREMITY WITH THE FOOT FIXED ON THE GROUND

The preceding discussion has considered only the motion of the foot and ankle in space as the ankle-foot complex would move with the subject in a nonweight-bearing position. This construct is known as an *open kinetic chain* (ie, the distal end of the limb is free to move in space). During weight-bearing activities, however, the foot is fixed on the ground, and the more proximal segments are more free to move. In this situation, the foot is functioning in a *closed kinetic chain* in which it is relatively fixed by the ground and the superincumbent weight above. Under this circumstance, movement of the foot will cause the tibia and fibula to move, which, in turn, will tend to force the femur into rotation unless the twisting force or torque is absorbed at the knee joint.

Thus, motion of the foot and ankle must also be considered in terms of the resulting motion at the leg. Pronation and supination are triplanar motions. When these motions occur with the foot fixed, therefore, the resulting motion of the leg must also be triplanar. Pronation with a fixed foot results in inward rotation, medial deviation, and a slight forward inclination of the leg, whereas supination produces the opposite results. Pronation on the fixed foot, therefore, tends to flex the knee, whereas supination tends to result in knee extension.^{6,11,16} The movements of the leg, if not absorbed at the knee, can be transmitted up the thigh, resulting in medial rotation of the femur with pronation and lateral rotation with supination.

TERMINOLOGY FOR POSTURES OF THE FOOT

Another source of confusion when discussing the function of the foot is the description of the structural alignment of the foot as well as the functional alignment during weight-bearing. The use of the *subtalar neutral position* (STN) provides consistency in positioning the foot before assessing structural, or bony, deformities of the foot. The STN was described by Root et al⁴ to mean the position of the STJ that was neither supinated nor pronated. This position has also been described as the position in which the talus and calcaneus are most congruent.¹³ The position is generally determined by palpation of the talus on the calcaneus. With the STJ thus positioned while the subject is nonweight-bearing, the structural alignment of the forefoot on the hindfoot can then be determined. The alignment of the hindfoot on the leg can also be assessed from this position.

Measurement of STN can be made by aligning the goniometer in the same manner as in measurement of STJ ROM. Elveru et al reported an ICC of .77 for intratester reliability of STN but an ICC of .25 for intertester reliability.¹⁷ They obtained an ICC of .35 when the intertester reliability of foot position classification (eg, hindfoot varus) was evaluated. It should be noted that this reliability study involved physical therapists with varying levels of experience and areas of expertise. Perhaps reliability can be improved with specific practice of this technique, which until recently was not a measurement made frequently by physical therapists. It is not clear how many schools incorporate assessment of STN in their entry-level education. Until reliability is improved, however, clinicians must be cautioned to be conservative in their use of STN measurements.

Because STN assessment is usually made with the client nonweight-bearing, the malalignments can generally be attributed to structural, usually bony, deformities. Thus, traditional terminology describing malalignments, such as "varus" and "valgus," is particularly useful. The positions that the foot assumes in weight-bearing, however, may be fixed postures but are often the resulting positions achieved by all of the joints of the foot as a compensation for a structural deformity. It is the terminology used to describe these weight-bearing postures that is most varied and confusing. The following paragraph reviews the terminology used to identify these positions and then proposes terminology to provide more consistency and to facilitate communication. Specific deformities and their associated biomechanical abnormalities are discussed by Gray.¹¹

The two most commonly described postural abnormalities of the foot are *pes planus* and *pes cavus*, or abnormally low- and high-arched feet, respectively. *Pes planus*, or flatfoot, is

generally characterized by a pronated STJ or transverse tarsal joint. Thus, the foot position is often described as pronated.^{4,18,19} This pronation results in a laterally positioned calcaneus, and thus the foot may also be said to have a valgus deformity.² The Table lists the various terms used to describe high- and low-arched feet. This multiplicity in terminology can be quite confusing, particularly because a structural deformity such as a varus hindfoot can lead to the compensatory positional abnormality of a pronated foot (see article by Tiberio in this issue).¹⁰ When assessing the posture of the foot in weight-bearing, it is only possible to determine the position of the joints of the foot. Only when the subject is nonweight-bearing can the clinician determine whether the postural abnormality is a fixed, osseous deformity or a compensation for another deformity. Thus, I suggest that the terminology used by Gray¹¹ be adopted, that is, that the terms varus and valgus be applied only to known, fixed deformities and that the terms pronation and supination be used to describe the position assumed by the foot during standing.

POSITION AND SUPPORT OF THE FOOT IN QUIET STANDING

The weight-bearing area of the foot has been assessed by several authors using many different methods.²⁰ The results of these studies have led to a general controversy over what areas of the foot actually bear weight during quiet standing. Cavanagh et al, however, recently reported data about weight-bearing in over 100 asymptomatic feet. These authors used an electronic mat with 256 sensors with a resolution of 1 × 1 cm to measure the pressure distribution under the foot. These authors reported that the largest pressure under the foot was located in the heel in 96 out of 107 feet tested and was greater than twice the mean pressure under the forefoot region. Assessment of mean weight distribution revealed that 60.5% of the weight was applied across the heel, 28.2% in the forefoot, and 7.8% in the toes, with the remaining 3.6% in the heads of the metatarsal bones bear weight during quiet standing. These authors also noted a very large individual variation in proportional loading of the foot. It should be noted, however, that these authors measured "asymptomatic" feet, making no attempt to describe or to assess the feet in terms of the arched foot. Thus, some subjects may have demonstrated hindfoot or forefoot deformities with corresponding postural abnormalities but had no clinically significant complaint related to these abnormalities. The variability reported by these authors, therefore, may be the result of a more heterogeneous population than suggested by the lack of symptoms reported by the subjects. Descriptive studies to determine the prevalence of asymptomatic structural abnormalities in the feet within a "normal" population will help expand our basic understanding of foot pathology.

TABLE
Common Terms Used in the Literature to Identify Abnormally High- and Low-Arched Feet

High-arched Foot	Low-arched Foot
Pes cavus	Pes planus
Varus	Valgus
Supinated	Pronated
	Flatfoot

The role of muscles in supporting the foot during quiet standing has been reported by several authors. Basmajian investigated the role of the extrinsic muscular support of the foot and ankle.²² He reported a wide individual variability in subjects studied but noted generally more activity in the posterior calf muscles than in the tibialis anterior muscle. He also noted a reciprocal activation of plantar and dorsiflexor muscles, which appeared to balance a teetering weight (the body) over a relatively small base of support (the feet).

Mann and Inman investigated the role of the intrinsic muscles of the foot during quiet standing and during ambulation.²³ In their study of 12 subjects free from gross abnormalities of the feet and legs, they found no significant, consistent activity in the intrinsic muscles of the foot during quiet standing. This finding suggests that intrinsic muscle activity is not required to support the foot during quiet standing. These authors suggested that support from inert structures such as the plantar fascia and the ligaments of the foot are responsible for supporting the foot during quiet standing. They, however, also noted the large individual variability in responses among the subjects.

SUMMARY

Although anatomically quite complex, the foot and ankle function using simple hinge joint motions. The axes of motion in the foot and ankle, however, are aligned obliquely to the cardinal planes of the body, resulting in uniaxial, triplanar motions. These joints must move during weight-bearing with the foot fixed on the ground, causing triplanar motions in the proximal segments as well. The abnormalities of the foot seen when standing may be either fixed deformities or compensatory reactions to other fixed deformities. Terminology describing the fixed deformities, therefore, should differ from the terminology describing the postural abnormalities. For clinicians to complete a reliable and valid assessment of the foot and then to communicate those results, they must understand the motions and postures available in the foot and must use a logical and consistent system of terminology to transmit those findings. The reliability of standard clinical tests is in question, at least for the ankle joint and the STJ where it has been studied carefully. Clinicians, therefore, are urged to use the results of such tests cautiously.

Individual variability is prevalent in weight-bearing patterns as well as in muscle activity. This variability must also be considered when making clinical decisions.

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