12

Biomechanical Assessment of the Foot

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INTRODUCTION

This chapter discusses the biomechanics of the foot and in particular its relevance in relation to the pathogenesis of foot ulceration and deformity. The integrity of the foot is discussed mainly as it relates to foot function during the stance phase of gait. This is followed by a section that discusses major features that need to be taken into account when examining the foot. Orthotic treatment of 'dys' functioning feet is discussed in Chapter 17.

MAINTAINING THE INTEGRITY OF THE FOOT

Stability in Stance

During the stance phase of gait the skeleton of the foot is constantly in motion developing an adaptable dynamic structure to suit the demands of deceleration, support, equilibrium and acceleration.

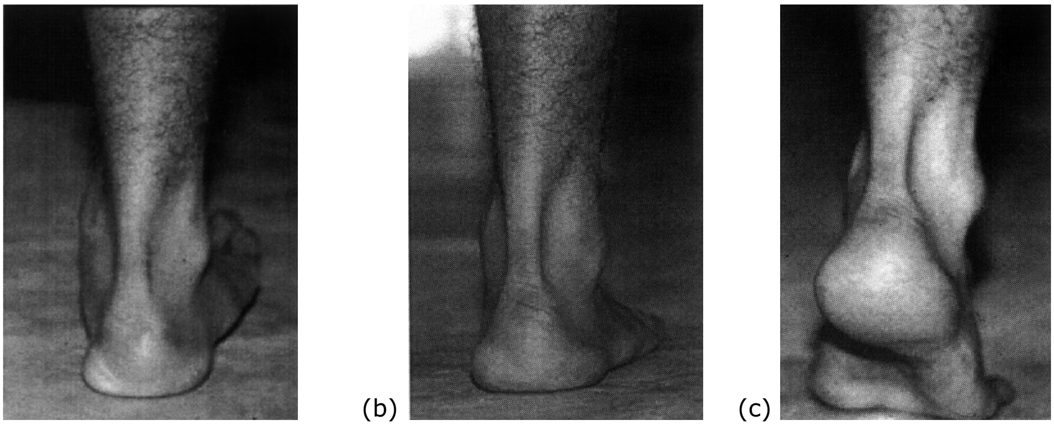
Static Stance

The subtalar joint (STJ) is immobilised by ground reaction forces during static stance. However, even during these apparently quiescent periods, a force applied by the gastrocnemius plantarflexes the foot, the only extrinsic muscle recorded to demonstrate activity during static stance, to effect tension forces at the other joints of the foot.[6] During this phase, passive ligamentous function maintains the integrity of the skeleton by resisting tension. In resistance to potential subluxation, the ligaments initially become taut but gradually stretch. Root et al. suggest that there is probably an elastic threshold at which proprioceptive innervation is activated.[6] Momentary muscle contractions are activated which reposition the bones and allow the ligaments to shorten, thereby continuously facilitating the passive protection of skeletal integrity.

It is during kinetic stance that the foot is particularly dynamic. The integrity of the foot is primarily dependent on safety information relating to current conditions of the substratum. The high density of Vater-Pacini corpuscles in the subcutaneous fat chambers provide an acute sense of deep pressure and vibration associated with high frequency shock and tissue displacement. Meisner's corpuscles register low frequency shock which also stimulates Ruffini endings, but at levels as deep as the capsules of diarthrodial joints.[1] It is, however, the mechanical integrity of the skeleton and efficiency of joint articulations during locomotion that is crucial if the effects of applied and reactional forces during locomotion are to be optimised and damage is to be avoided.

Joint Stability

The stability of any joint is dependent on the component of force affecting it. During contact with the supporting surface, ground reaction forces interact with the resultant force of body mass, muscle tension and acceleration to exert linear and rotational forces on bones and joints respectively. Whereas linear forces tend to stabilise joints by compression of opposing bones, rotational forces promote instability at articulating surfaces.[6] Throughout most of the stance phase of gait the ideal functional position for any joint in the foot is achieved when the joint



(a) **Heel Strike:** The foot assists in shock absorption. The foot and leg are required to be a loose chain structure.

(b) **Mid Stance:** The foot supports the entire body. A stable structure is required.

(c) **Propulsion:** The foot is required to adapt to the needs for propulsion. A rigid lever is required.

FIGURE 12-1 Normal foot function.

is able to function in a position which provides maximum potential for compressional forces with minimal influence of bending forces.*

Root et al. suggested that it is the aphasic instability of joints during kinetic stance that presents the primary cause of mechanical trauma to the foot.[5] They explained that as articulating bones are forced to respond to inadequately restricted rotational forces, joints respond by moving beyond their normal range of motion. They may alternatively move in planes of motion contrary to those dictated by their structure and position.[6] One effect is that the general deficiency of the foot will compromise the body by high energy demands to try to impose stability. A second effect is that if the demands exceed the functional capacity of soft tissue mechanisms, the dissipation of mechanical energy may demand the destruction of solid structures.

When soft tissues of the foot are compressed, energy is stored within elastic elements until it is unloaded with decompression. During rapid decompression the viscous elements of soft tissue permit shock absorbency converting mechanical energy into thermal energy. Local heating is controlled by the dissipation of energy through the vascular system.

If the strain imposed by excessive deformation of soft tissue becomes too great to be accommodated within the normal ranges of tissue mouldability and elasticity, tissue may experience fatigue failure and damage may ensue. Fatigue describes the resistance to normal or shear stress displayed by any structure subjected to stress. As a general principle, fatigue failure is avoided as the fatigue period of soft tissue is such that it allows sufficient

* Manter described a longitudinal loading axis from the centre of the trochlea to the second intermetatarsal space.[5] Where joints were angled away from a perpendicular relationship with the loading axis a decrease in compressional force was measured. He established that if a chain of bones was aligned so that all articulations were congruous and perpendicular to the direction of force, then the chain would be stabilised by compression. The skeleton of the foot is constantly shifting throughout stance and as it does so forces on the proximal bones will angle with reactive forces on distal bones. When the angle is small, compressional force will exceed rotational forces and the joint will be relatively stable. Assuming this ideal is achieved the most economical utilisation of energy will be accomplished.[2]

time for self-repair. Where strain has been excessive there is a degree of soft tissue relaxation on relief from load, but excessive demands may result in incomplete recovery. If the number of load cycles, or the magnitude of stress is such that demands for tissue recovery periods exceed the fatigue period, the tissue will experience fatigue failure and breakdown.

The Action of the Rearfoot in Determining Joint Alignment

It has been suggested that the motion of the ankle-subtalar joint complex is analogous with a universal joint mechanism.[4] Allowing for minor individual variations, the ankle joint axis runs through the inferior tips of the fibular and tibial malleoli. It has a slight lateral incline and is externally rotated in relation to the axis of the knee. The motion at the joint therefore is almost exclusively in the sagittal plane. Frontal plane and virtually all transverse plane motions are transmitted to the tarsus via the talus which, in concert with the calcaneus, cuboid and navicular, translates such forces into triplane motion. This mechanism has been the focus of much study. Current understanding of pedal mechanics, based predominantly on the theories of Manter and Elftman, indicates the pivotal role of the rear foot complex in determining the harmony between locomotion and the environment.[3,4]

Manter's hypothesis suggested that the mid tarsal joint (talar navicular and calcaneo cuboid complex) has two axes. The gross frontal plane motion of the forefoot rotates about a longitudinal axis, whilst an oblique axis allows a limited extent of sagittal motion. The extent and direction of motion available is dependent on tarsal midtarsal configuration.

NORMAL AND ABNORMAL FOOT FUNCTION

Normal Phasic Activity

Heel Strike

When the heel strikes the ground the STJ is in a supinated position. On contact, the STJ pronates to enhance shock absorption (Fig. 12-1a). Pronation of the subtalar joint causes a reduction in the congruency of other joints distal to it. An effect is that the skeleton of the foot becomes a more open chain structure. As an open chain structure it assists in the dissipation of force at heel strike.

The STJ further enhances shock absorption by:

- Encouraging the tibia to rotate faster than the femur thus enhancing knee flexion
- Facilitating the "unlocking" of the midtarsal joint** and all joints distal to it, thereby releasing tension in plantar soft tissues

Mid Stance

At mid-stance the foot is required to be a stable structure to support the body. During this phase the foot is also required to prepare for the demands of propulsion. Stability is facilitated if the STJ is in neutral position (neither pronated or supinated). In the neutral position the midtarsal joint is "locked" and the foot becomes a stable support (Fig. 12-1b).

If the STJ is in neutral position at mid-stance it should be able to rotate further into a supinated position for effective propulsion.

Propulsion

During the propulsive phase joint congruency is required to ensure that forces effect compression rather than rotation at joints.

** Motion around the mid tarsal joint.

Compressional forces will protect joints and soft tissue during the application of forces which peak beneath the forefoot during this phase (Fig. 12-1c). A rigid foot is effected if the STJ is supinated. When the STJ is supinated the forefoot cannot evert around the longitudinal axis of the midtarsal joint (eversion at the MTJ is only possible if the STJ is pronated).

A further effect of STJ supination is that the height of the medial arch is maintained. The effects of a well maintained arch are:

- Peroneus longus has an increased angle of approach and a strong mechanical advantage to stabilise the first ray.
- The plantar fascia becomes an effective 'windlass' to help stabilise the hallux.

Abnormal Phasic Activity

Aphasic STJ Pronation

A common problem is that the STJ compensates for other structural or functional abnormalities by pronating excessively at heel strike (Fig. 12-2). When this occurs the STJ is usually unable to "recover" to a neutral position at mid-stance and is often still in a pronated position during propulsion (Fig. 12-4b). The skeleton of the foot therefore remains as an "open chain" structure and responds to forces by allowing excessive rotation at joints. The most significant problems occur during the propulsive phase.

If the STJ is pronated during the propulsive phase, the foot will still be mobile. The arch will not have recovered by mid-stance and peroneus longus will not be able to effect stabilisation of the first ray. The plantar fascia will bow string causing further destabilisation of the hallux.

The effects for the foot are:

- The unstable 1st metatarsal will dorsiflex in response to ground reaction forces. It therefore becomes less competent leaving the 2nd or 3rd metatarsal to bear greater loads than they are designed for.
- In ideal gait, during propulsion, the hallux will dorsiflex around the 1st metatarsal head, but if the 1st metatarsal is incompetent this action cannot be facilitated. Instead of dorsiflexing around the 1st metatarsal head, the hallux impinges on the joint surface. If insufficient dorsiflexion for propulsion is not found at the MPJ dorsiflexion is forced at the hallux IPJ.

The most significant effects of propulsive forces when the subtalar joint is excessively pronated are:

- Tissue stress beneath the 2nd or 3rd metatarsal heads.
- Tissue stress beneath the IPJ of the hallux.
- Buckling of the toes.
- Hallux limitus (rigidus).
- Hallux abducto valgus.
- Plantar fasciitis.

Note: Other problems, notably in the knee, are also excited or exacerbated by aphasic STJ pronation.

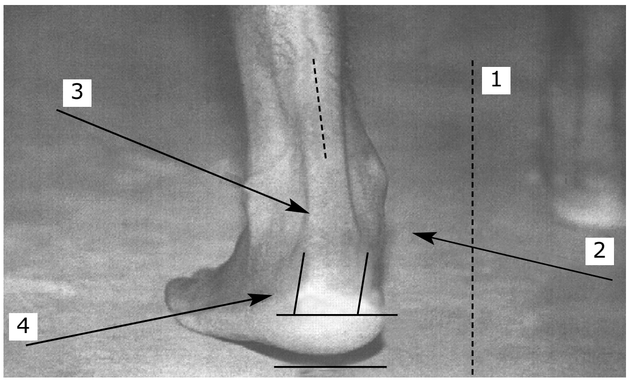


FIGURE 12-2 Abnormal Foot Function- Aphasic STJ Pronation: If the STJ is still pronated during propulsion the foot will be too mobile to become a rigid lever. The metatarsals will not be stable. The first metatarsal cannot be plantarflexed effectively.
1. Mid line of the body, 2. Medial bulging and flattened medial arch, 3. Curve in the Tendon Achilles, and 4. Everted heel.

Aphasic STJ Supination

Aphasic supination (Fig. 12-3, 14-4c) is a less common anomaly but when it does occur it is far more problematic. For the insensate foot the most serious problem is related to the early and sustained application of force beneath the fourth or fifth metatarsal heads. A further problem is that the first ray may become excessively plantarflexed (resulting in a cavus foot). In such circumstances the tissue beneath 1st metatarsal head is highly vulnerable. A hallux flexus deformity may also develop which exposes the distal aspect of the hallux to stress.

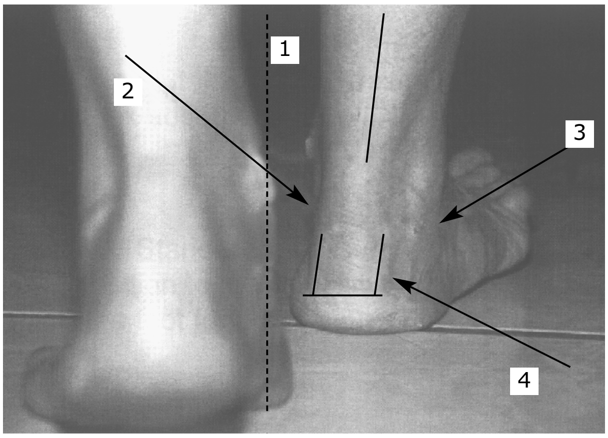


FIGURE 12-3: Abnormal Foot Function – Subtalar Joint Supination at Heel Strike: STJ supination at heel strike will result in poor shock absorption. It will also lead to Limited forefoot dorsiflexion and hence early loading of the forefoot. 1. Mid line of the body, 2. High medial arch, 3. Slight bulging beneath lateral malleolus, and 4. inverted heel.

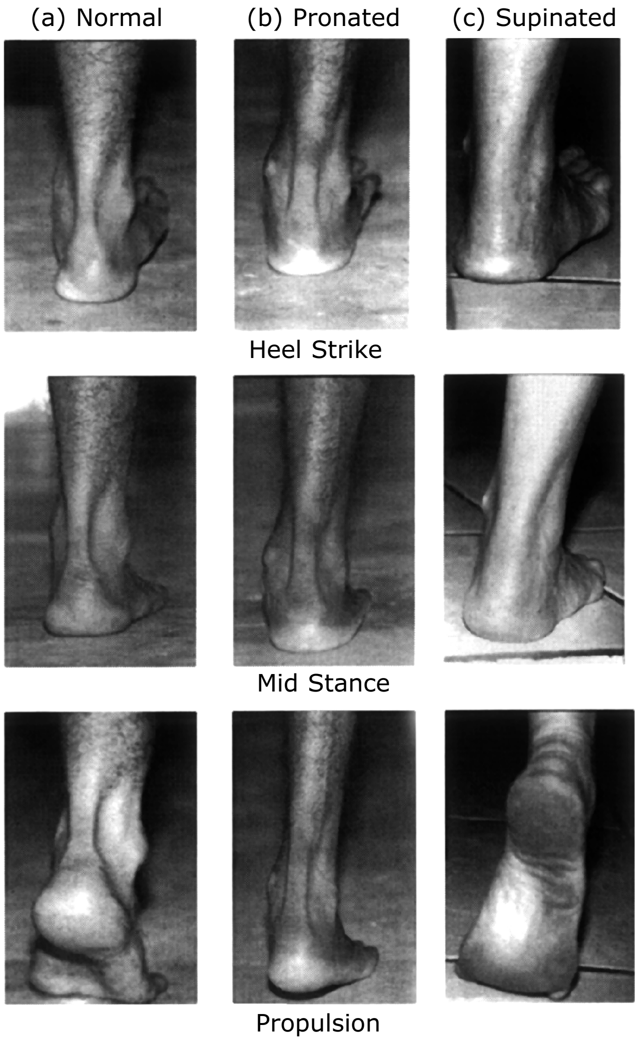


FIGURE 12-4: A comparison of normal foot function (a) with aphasic subtalar joint foot function (b and c)
(a) Normal Heel Strike: STJ pronates to allow shock absorption; Normal Mid Stance: STJ assumes neutral position to give stability and to prepare the foot for propulsion; Normal Propulsion: STJ supinates to allow sound propulsion.

Factors That Cause Pathomechanical Foot Function

Compensatory STJ Pronation is commonly a result of:

- Tibial Varum
- Internal Tibial or Femoral Torsion
- Inequality of Limb Length
- Forefoot Varus
- Plantarflexed 5th Metatarsal
- Ankle Equinus
- Tibial / Genu Valgum
- Obesity

Aphasic Supination may result if the following abnormalities are not compensated:

- Forefoot Valgus
- Rearfoot Varus
- Tibial Varum
- Internal Tibial or Femoral Torsion
- Forefoot adductus

Aphasic Supination may also result if the following abnormalities are compensated:

- Tibial / Genu Valgum

There are also abnormalities of a neuropathological origin that will result in aphasic supination of the STJ. Most notable is foot drop, a consequence of lateral popliteal dysfunction.

Essential Features of Concern to be Excluded Through a Biomechanical Assessment:

- Are there any structural abnormalities intrinsic or extrinsic to the foot that may affect foot function?
- Are there any restrictions or excesses in range of motion at significant joints?
- Is the timing of kinetic events during locomotion a reflection of the ideal model?

Analysis of the findings should give an understanding of the likely outcomes for a foot that does not meet ideal criteria. The insight thus gained provides the rationale for an appropriate orthotic intervention.

EXAMINE FOOT STRUCTURE

STJ Neutral Position – A Reference for Foot Examination

When a foot is not bearing weight, and is relaxed, it will rest in plantarflexion and slight inversion. This is not an appropriate reference position for examination because it is not a reflection of the position the foot assumes during weight bearing.

To be able to ascertain how the foot may interact with the supporting surface it is imperative to examine it from the ideal perspective: i.e. with the subtalar joint in neutral position. In an ideal foot that is not weight bearing, if the STJ is neutral it can be assumed that soft tissues will draw the sections of the foot into model alignment: i.e.

- The forefoot and the heel will be parallel in the frontal plane.
- The forefoot will be at 90° to the leg.

If the foot is passively held with the subtalar joint in its neutral position and it is found that the criteria given above are not as expected, it can be assumed that the foot is abnormal.

Having manipulated the foot into STJ neutral position:

Right Foot

1. With the patient seated and the leg supported, straighten the leg so that the patella is horizontal with the ground.
2. Check the areas just beneath the malleoli. (There will probably be a slight bulge just beneath the lateral malleolus and a dip beneath the medial malleolus).
3. Using the left hand place the thumb over the fourth and fifth metatarsal heads.
4. Using the thumb of the left hand to control the foot, gently but firmly dorsiflex the foot until resistance is registered.
5. Slowly abduct and adduct the foot a few times noticing how the curves beneath the malleoli change. With abduction, a bulge will develop beneath the medial malleolus. As you adduct the foot, a bulge will develop beneath the lateral malleolus.

6. Slowly adjust the position of the foot until the curves under the malleoli are even: i.e. no bulge beneath either of the malleoli.

Check

The leg is straight and the knee is neither internally or externally rotated.

The foot has been dorsiflexed to resistance.

There are no bulges beneath the malleoli.

If these criteria have been met, it is likely that the foot is in a position where the subtalar joint is neutral.

The same procedure should be carried out for the left leg, but using the right hand to manoeuvre the foot.

FOREFOOT ABNORMALITIES

With the thumb placed beneath the fifth and fourth metatarsal heads the foot can be held in subtalar neutral position.

a. The foot should be viewed from the forefoot to the heel (frontal plane) to ascertain whether the plane in which the forefoot lies is parallel with that of the heel.

1. If the forefoot and heel are parallel the indication is that the forefoot lies in the correct frontal plane position.
2. If the forefoot appears everted, relative to the plane of the heel the indications are either:
    - Forefoot valgus deformity (Fig. 12-5) (a fixed osseous deformity of the mid tarsal joint)
    - Plantarflexed first ray (gives the appearance of an everted forefoot)

An anaesthetic foot with an everted forefoot can be susceptible to the development of ulcers at:

- the first metatarsal head
- the toes

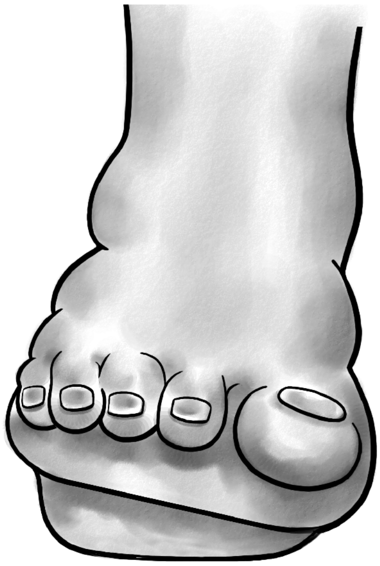


FIGURE 12-5 Forefoot Valgus: A frontal plane abnormality where the forefoot is everted relative to the heel.

3. If the forefoot appears inverted relative to the plane of the heel, the indications are either:

    Forefoot varus (Fig. 12-6) (a fixed osseous deformity of the mid tarsal joint).

    Plantarflexed fifth ray (gives the impression of an inverted forefoot.

    Supinatus (a soft tissue adaptation to stress imposed by aphasic STJ pronation.

An anaesthetic foot with an inverted forefoot can be susceptible to the development of ulcers at:

- The lateral aspect of the forefoot (with forefoot varus).
- The second or third metatarsal head (with supinatus).
- The IPJ of the hallux (with supinatus).
- The fifth metatarsal head (with plantarflexed fifth ray).
- The toes.

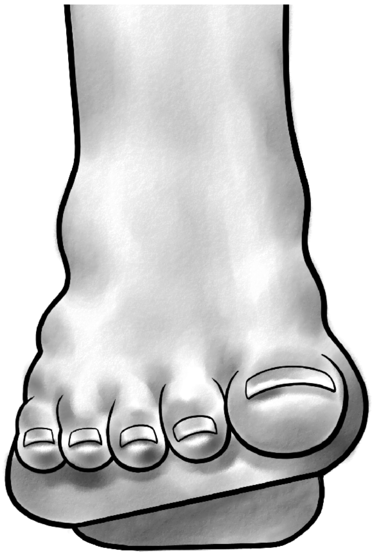


FIGURE 12-6 Forefoot Varus: A frontal plane abnormality where the forefoot is inverted relative to the heel.

b. With the foot in subtalar neutral position it should be viewed from lateral side to ascertain whether the forefoot is plantarflexed relative to the heel.

   1. If the forefoot and heel are positioned such that the forefoot is not plantarflexed (the fore foot should be at approximately 90° to the leg) the indication is that the foot is correctly aligned in the sagittal plane.

   2. If the forefoot is plantarflexed relative to the heel (greater than 90° from the leg) the indication is that the foot has a forefoot equinus deformity (on weight bearing the foot will present with a noticeable high medial arch and claw toes) (Fig. 12-7).

An anaesthetic foot with a forefoot equinus is very vulnerable and is susceptible to the development of ulcers across the entire forefoot.

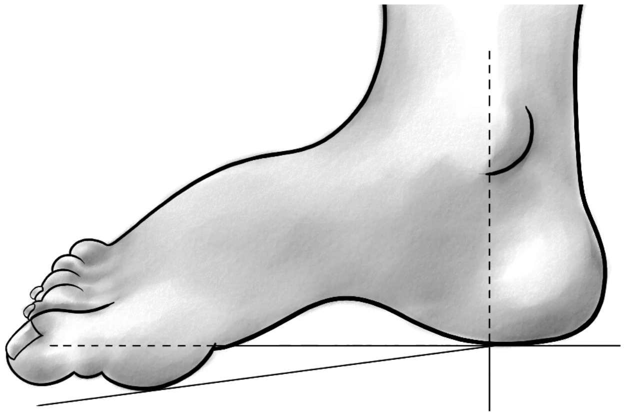


FIGURE 12-7 Forefoot Equinus: A sagittal plane abnormality where the forefoot is plantarflexed relative to the heel.

c. With the foot in subtalar neutral position view the foot from the plantar aspect.
   If the entire forefoot inclines towards the centre line of the body, the abnormality is a forefoot adductus.

An anaesthetic foot with a forefoot adductus is susceptible to developing ulcers at:

- The hallux
- The first metatarsal head
- The styloid process

JOINT EXAMINATION: GENERAL PRINCIPLES

- Localise the opposing bones that constitute the joint of interest.
- Firmly immobilise the proximal bone with one hand.
- With the other hand, manipulate the distal bone to establish the range and quality of movement.

  Note whether the joint allows:
  - Movement in the expected direction.
  - Too much or too little movement in the expected direction.
  - Smooth transition of the bones (no crepitus or obstruction).

The lesser Toes

The most important function of the lesser toes is to stablise the metatarsals during the propulsive phase of gait. If the toes are dorsiflexed and plantarflexion at the metatarsal phalangeal joints is not possible, the tissue around the metatarsal heads will be vulnerable to high pressure and shearing stress (if the toes are extended, the metatarsal heads will be forced into plantarflexion, the vulnerability will be exacerbated because the loss of toe function will leave the metatarsals unstable against reaction forces). If a toe is found to be hypermobile (due to dislocation or joint destruction) the metatarsal head that the toe articulates with will be vulnerable to the effects of shearing stress.

Method of examination

With one hand stabilising each metatarsal in turn, the opposing proximal phalanx of each toe is firmly held and passively dorsiflexed.

All toes should demonstrate 90° of uninterrupted passive dorsiflexion.

The Hallux

The function of the hallux affects the entire chain of kinematic events that determines human gait and posture. Its crucial role is reflected in the complexity of the anatomy that supports it. Although one of the major functions of the hallux is to stabilise the first metatarsal, it should never be considered to be merely a large toe. The function of the hallux is profoundly affected by the action of the STJ and the restricted movement that may be found on examination may suggest poor action at the STJ.

Method of examination

With one hand stabilising the first metatarsal, the proximal phalanx of the hallux is firmly held and passively dorsiflexed.

Sixty degrees of uninterrupted passive dorsiflexion at the 1st MPJ is required for effective locomotion. A finding less than 60°, but more than no dorsiflexion indicates hallux limitus. Absence of dorsiflexion indicates hallux rigidus. Either condition indicates the necessity to conduct a functional examination of subtalar joint action.

The subtalar joint examination

Because the STJ has an axis that extends through all three planes, the movement that the joint facilitates is triplanar (pronation and supination). The implication is that inversion and eversion of the foot (the most prominent components of STJ movement) must also be accompanied by movement in the other two planes simultaneously: i.e. if the foot is inverted it will also be slightly plantarflexed and adducted (STJ will be supinated) whilst eversion of the foot requires that the foot is also slightly dorsiflexed and abducted (STJ is pronated).

It has been established that 18° of motion around the STJ is required for efficient gait.[5] Studies have demonstrated that goniometric measurement of sub talar movement is not generally reliable because of poor repeatability. However, as a practical guide for joint examination, it should be noted that two thirds of the motion normally available at the STJ is in the direction of inversion with one third of the motion allowed for eversion (accepting that there will be movement in the other two planes simultaneously).

Method of examination

With the subject seated and the leg supported (in neutral position), stabilise the leg at the ankle joint with one hand and grasp the calcaneus with the other. Evert and invert the calcaneus around its articulation with the talus.

Note the quality of movement (no crepitus) and whether the ratio of movement is as expected (2:1 in favour of inversion).

Also note the extent of movement: i.e. if the joint allows excessive motion (palpably more than 18°) or limited motion (stiff joint allowing very little frontal plane motion)

A STJ that allows excessive motion indicates that the foot will be hypermoblie and may be unstable during gait. If the STJ allows limited motion the implication is that the foot will be rigid and may not be able to adapt adequately to challenging terrain or compensate for any distal structural abnormalities.

Generally, a rigid foot is vulnerable at sites where foci of high pressure cause tissue breakdown (usually on the lateral aspect of the foot). A hypermobile foot can be vulnerable to shearing stress and skeletal incompetence leading to a poor distribution of forces (see the Weight Bearing Foot).

The Ankle joint

With the axis of the ankle joint lying parallel to the transverse plane and almost parallel to the frontal plane, the only clinically important movement available at the joint is dorsiflexion and plantarflexion. The functional requirement of the ankle joint is that it should allow at least 10° of dorsiflexion to facilitate efficient gait.

Method of Examination

With the subject seated and the leg supported (in neutral position), stabilise the leg with one hand and position the ball of the hand under the forefoot. Move the foot through dorsiflexion and plantarflexion to check the quality of movement. Although it is possible to measure the range of motion at the joint with the limb non-weight bearing the method is not advised. The reasons are:

- The gastrocnemius may counter any force to dorsiflex the foot. It is a very powerful muscle and the examiner may not be able to over power it sufficiently to record the actual extent of dorsiflexion available.
- There is also some dorsiflexion available at the midtarsal joint which is made possible if the forefoot is inverted. It is difficult to avoid inverting the forefoot whilst dorsiflexing the foot at the ankle joint. There is a danger therefore of recording dorsiflexion that is greater than that actually available at the ankle joint in isolation.

Dorsiflexion is measured as a reduction in the angle between the leg and the foot and is therefore measured from a lateral perspective. A point is marked on the mid point of the head of the fibula and another on the mid point of the lateral malleolus, a line is drawn joining these two points.

The subject is then asked to stand approximately 2 feet from a wall with feet apart (approximately 12 inches between malleoli) and slightly adducted. With the knees, hips extended and the back straight, the subject is directed to rest against the wall, supported by extended arms. Then bending the arms, but keeping the knees and hips extended and the back straight, the subject is directed to lean toward the wall. The point where the heel starts to lift indicates maximum dorsiflexion of the ankle.

With the short arm of a tractograph on the floor, the other arm is aligned parallel to the fibula bisection. The angle measured at the position immediately before the heel lifts is noted as maximum dorsiflexion.

THE WEIGHT BEARING FOOT

It is not sufficient to limit an examination of the foot to a non-weight bearing examination because foot function can be compromised by extrinsic factors. Extrinsic factors can subtly affect the manner in which the foot interacts with the ground. Although such subtle affects do not usually make the foot vulnerable to acute damage they can have a profound effect on the distribution of forces. When the mechanics of the foot are compromised mild but unrelenting repetitive stress can lead to tissue fatigue and breakdown.

A principle objective is to gauge an impression of the typical alignment of the subtalar joint at mid stance. Ideally the subtalar joint should be neutral at mid stance, if it is pronated, or supinated, the indication is that the foot is not functioning as it ought.

If the STJ is very pronated the foot will be unstable (see Aphasic STJ Pronation) if the STJ is very supinated the foot will be compromised through rigidity (see Aphasic STJ Supination).

How Much Is "Very Pronated" Or "Very Supinated"?

As a general rule, if just by viewing the subtalar joint is obviously pronated then it is most likely that it is, in fact, very pronated. Likewise, if the foot looks as though the subtalar joint is obviously supinated, then it is most likely to be supinated further than it should be.

(See Figure 12–4: A Comparison of Normal Foot Function with Aphasic Subtalar Joint Foot Function).

Method of Examination

Establish the approximate alignment of the STJ at mid stance:

1 Direct the subject to walk on the spot.
2 After 10 seconds ask the subject to stop.
3 Suggest the subject should relax and look straight ahead with arms hanging loosely at his/her sides.
(The examiner should take care to ensure that curious subjects do not turn their heads to observe the examiner. Rotations of the trunk will cause one STJ to pronate whilst the other supinates).
4. The examiner takes a position behind the subject and examines the foot for indications of either pronation or supination.

The Pronated Subtadar Joint

Main Signs

1. The heel will be everted.
2. There will be a "bulge" under the medial malleolus.
3. There will be a "dip" under the lateral malleolus.
4. The Achilles tendon may be bowed.
5. The medial arch will be flattened.
6. The feet will probably be abducted.

(See Figure 12-2: Abnormal Foot Function – Aphasic STJ Pronation)

A subject with an obviously pronated STJ is vulnerable to ulceration beneath:

The second or third metatarsal head.
The IPJ of the hallux.
The lesser toes.

Calcaneal spurs and fasciitis are have also been attributed to aphasic STJ pronation an effect of which is strain on the plantar aponeurosis.

The Supinated Subtalar Joint

Main Signs

1. The heel will be inverted.
2. There will be a slight "bulge" under the lateral malleolus.
3. There will be a "dip" under the medial malleolus.
4. The medial arch will be high.
5. The feet may be adducted.

(See Figure 3: Abnormal Foot Function –

Aphasic STJ Supination)
A subject with an obviously supinated STJ is vulnerable to ulceration beneath:

The fourth or fifth metatarsal head.
The styloid process.
The apex of the hallux.

Subjects demonstrating STJ supination are also vulnerable to lateral ankle sprains.

FOOT FUNCTION AS A COMPONENT OF GAIT ANALYSIS

Although a reasonably good impression can be gained by a static examination of a weight-bearing subject, it is only really by observing gait that the extent and timing of phasic activity can be assessed. (The normal phasic activity of the STJ was described earlier - see Normal and Abnormal Foot Function).

Ankle Joint

The essential feature to note is the timing of plantarflexion. The weight-bearing foot should only start to plantarflex after the contralateral foot has swung passed the stance leg. Plantarflexion at any other phase will compromise the foot.

The two major conditions that will result in aphasic plantarflexion are:

- Foot drop (due to lack of anterior / lateral muscle activity the foot is unable to dorsiflex).
- Equinus (In normal gait the heel will only lift as the contralateral foot passes the stance foot. If the triceps surae is tight, or the tendo Achilles is contracted, stretch receptors in the TA will activate muscle contractions early in the stance phase of gait. The effect can be seen as an early heel lift as the foot responds to a plantarflexion force imposed by the triceps surae.)

The loading pattern of the "dropped foot" predisposes it primarily to damage on the lateral border of the foot.

The early heel lift caused by ankle equinus causes the foot to be vulnerable to excessive shearing stress across the forefoot. The damaging affects of early heel lift are often compounded by STJ pronation.

Subtalar Joint

The essential features to note are the positions of the STJ:

at heel strike (STJ should pronate on contact with the ground, not before)
at mid stance (STJ should not be pronated or supinated)
at propulsion (STJ should be supinated)

(See Figure 12-4: A Comparison of Normal Foot Function with Aphasic Subtalar Joint Foot Function).

CONCLUSION

- If the STJ is pronated at any time other than immediately after heel strike the foot will be compromised through instability.
- If the STJ is supinated at heel strike and does not pronate the foot will be compromised through rigidity and early forefoot loading.
- Primary abnormalities of foot structure may also compromise the integrity of the foot.
- A biomechanical examination of the structure and function of the foot may enhance treatment decisions.

Abduction: Moving the foot away from the mid-line of the body.

Adduction: Moving the foot toward the mid-line of the body.

Inversion: Tilting the foot so that the plantar surface faces toward the mid-line of the body.

Eversion: Tilting the foot so that the plantar surface of the foot faces away from the mid-line of the body.

Pronation: Movement including eversion, abduction and dorsiflexion of the foot. Results in the flattening of the arch and elongation of the foot.

Supination: Movement including inversion, adduction and plantar flexion.

Results in heightening of the arch and shortening of the foot.

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