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1 Observation

Statics

Statics is the mainstay of the clinical examination of the foot and ankle. If the bony and articular alignment of the lower leg and foot doesn't follow a few simple rules of statics, function is probably jeopardized, and painful degeneration follows. Generally speaking, comparing the foot to the vertebral column, human bipedalism is stabilized by the musculature, and the ligaments are secondary.

The first static examination is performed while looking at the patient from behind while he or she is standing on an elevated ***platform of about 1 square meter*** (examination cube; 9).

9

For a comprehensive examination, the platform should be made of a thick glass plate that must support all usual body weights, and the space below should be occupied by an inclined mirror.

Pelvis and lower leg

The examiner stands behind the patient, with his or her eyes at about the level of the pelvic crests in such a way as to best evaluate any eventual ***pelvic inclination within the frontal plane***.

10

The level of the knees gives information about eventual length discrepancies of the lower legs.

The frontal angulation of the knees shows the mechanical axis between hip and heel. Quantitative assessments are made by ***measuring the intercondylar and intermalleolar spaces*** and considering their mutual relationship.

11

12

Genu valgum is often compensated for by a varus of the hindfoot but worsens the stability in cases of hindfoot valgus. The converse is true for genu varum in the presence of a neutral axis of the hindfoot or in varus. If the problem is one of instability, surgical angular correction may be indicated at the proximal aspect of the leg ***(O189)***.

The ***perimeter of each calf***

13

is measured because it is a very sensitive parameter for evaluating atrophy of the extrinsic foot musculature that is due to an occasional limp caused by unilateral pain.

The extrinsic musculature is essential to stabilize the foot and ankle during stance and gait. There are 10 extrinsic muscles that coordinate and motorize the foot. The triceps surae is the most powerful. In the normal foot, the torque measured around the upper ankle joint is four times greater for the flexors than for the extensors. Around the lower ankle joint ***(E85)***, the supinators have twice as much power in torque compared to the pronators (10). The relationship between the powers of the muscles is essential and very sensitive. The natural difference between the agonists and antagonistsin flexion/extension and pronation/supination allows for a constant bone and joint recoil to the ground and thus counteracts gravity and weight bearing. This natural and functional difference can be termed "functional muscle tonus." Balance between muscle power and gravity is critical. A slight imbalance of the muscles may cause structural deformities by bending bones and joints. In critical cases, especially myopathies and central neuropathies, selective electroneurography is indicated.

Hindfoot

Sitting down, still behind the standing patient, ***the examiner faces the lower leg and the hindfoot***.

14

The axis between the upper ankle joint and the heel (tuber calcanei) is carefully evaluated (hindfoot axis). A stable lower limb includes a ***discrete valgus of the hindfoot*** axis (about 5–7 degrees).

15

Symmetry of both heel cords is evaluated. ***Eventual irregularities***, which may be painful at palpation, may hide chronic tendinitis ***(R159)***.

16

Symmetry of the hindfeet is evaluated. The hindfoot may be in valgus that is more or less pronounced or clearly placed ***"ad latus"*** to the lower leg ***(E42)***

17

in the case of a chronic rupture of the posterior tibial tendon.

The hindfoot may, alternatively, ***show a varus***,

18

which should always be considered together with the angulation of the lower leg.

The hindfoot axis determines the weight-bearing pattern of the heel and the ***wear of the shoes***.

19

Exaggerated, symptomatic valgus and varus of the hindfoot may be linked to a deformity observed within both the horizontal and sagittal planes: eversion and inversion. The valgus and everted foot is called ***"flat foot,"***

20

21

while the varus and inverted foot is termed ***"cavus foot."***

22

23

The symptoms of an exaggerated eversion or inversion of the foot are the indications for treatment. Symptomatic eversion is mostly due to a painful abutment of the lateral process of the talus onto the anterior process of the calcaneus ***(O316)*** and eventual tendinopathy of the posterior tibial tendon ***(T812)***. Symptomatic inversion is mostly linked to functional instability during stance and walking and painful overload of the lateral column of the foot.

Considering the horizontal plane alone, the angulation between the lateral edge of the calcaneus and the lateral aspect of the fifth metatarsus is evaluated. In normal feet, the lateral wall of the calcaneus is aligned with the fifth metatarsus. Pes abductus presents a relevant lateral angle of the forefoot. This may partially compensate a varus of the hindfoot and improve functional stability. Pes adductus, on the other hand, in which the foot is angled medially at the tarsometatarsal joints ***(O330)***, tends to worsen the functional instability of a hindfoot varus.

Footprint

The weight-bearing pattern of the foot is then assessed by the reflected image of the loaded foot. The alignment of the calcaneus to the fifth metatarsus is verified. The "footprint" is divided between, roughly speaking, the heel (calcaneus) and the anterior heel (metatarsal heads). As both heel and anterior heel have contact with the floor, the ***most usual footprint***

24

includes a weight-bearing lateral edge of the foot, leaving part of the plantar aspect of the medial foot without contact with the solid, horizontal ground (medial longitudinal arch).

The anterior heel should have a homogeneous weight-bearing print across the whole width of the forefoot (4). If the ***anteromedial aspect of the footprint***


25

indicates reduced weight bearing, this might be a sign of an unstable first ray and an overloaded second metatarsus.

Occasional instability of the first ray ***(E115)*** disturbs the homogeneous load distribution of the anterior heel. By ***"escaping" in extension***


26

and eventually in ***adduction***,


27

the first metatarsus leaves the stiffest rays on the tarsometatarsal level, taking the resulting overload (12). This overload results in striking callosities beneath the corresponding central metatarsal heads. Plantar pain under the central metatarsals is the main sign of instability of the first ray (11).

Such imbalance ends in a degenerative lesion of the "plantar plate" situated beneath the central metatarsal heads and constituted by the confluent distal fibers of the plantar fascia and the intermetatarsal ligament, thus reinforcing the corresponding articular capsule. If such a plantar "tear" is big enough so that the toe is no longer able to be held to the ground, the toe undergoes ***dorsal subluxation***,


28

and the tip of the toe no longer touches the ground ***(O383)***.

Observing the ***dorsal aspect***

29

of the metatarsophalangeal joints allows assessment of an eventual subluxation or a true dislocation due to a "torn plantar plate"***(E117, R145)***.

The ***missing buttress of the second toe***

30

on the footprint is testimony to the imbalance of the anterior heel, and the radiograph shows the ***overlap of the second metatarsus***

31

with the basis of the first phalanx.

The midfoot demonstrates a more narrow contact surface to the floor, located at the lateral edge of the foot. The variability of the width of this contact "strip" located between the anterior and the posterior heel depends logically on both the height of the midfoot and the global orientation of the foot within the frontal plane (valgus).

The ***collapsed midfoot demonstrates a wide footprint***,

32

and the cavus foot shows a ***smaller footprint***.

33

However, the change of orientation within the frontal plane modifies considerably the weight-bearing pattern: An increased varus position ***enhances the buttress of the lateral column of the foot (E37, E38)***.

A stable morphological example of the pes cavus is the ***cavus valgus type***.

34

The lateral column does ***not demonstrate any plantar buttress***.

35

Tiptoe

The patient is then asked to ***rise onto the tips of the toes.***

36

A **normal foot demonstrates a varus** of the hindfoot, showing good functioning of the talocalcaneonavicular joint and the functional motors by means of the tibialis posterior muscle and the fibularis longus muscle. If the patient indicates apprehension while standing on tiptoe, the stability of the hindfoot must be investigated more closely by assessing the axis of the hindfoot, the ligaments, and the extrinsic musculature.

The cavus foot ***(E33)*** changes its weight-bearing pattern considerably with ***a different orientation within the frontal plane***.

37

With the patient standing on tiptoe, this weight-bearing pattern is noted by observing the ***plantar skin of the lateral column (right foot) (E33)***.

38

The mobile, flexible flat foot with a ***collapsed midfoot (E32)***

39

is not linked to a missing varus of the heel while on tiptoe but ***demonstrates strong inversion of the foot.***

40

This foot has a wide range of movement within the talocalcaneonavicular joint, demonstrating sufficient power of the posterior tibialis musculature.

Frequent pathology includes chronic rupture of the posterior tibial tendon ***(T812)***. The static examination demonstrates a ***pes "ad latus"***

41

and a ***missing varus of the heel in the digitigrade position (E36)***.

42

If the patient indicates pain in the anterior heel, the sagittal alignment of all metatarsal heads must be assessed (metatarsalgia) ***(E116)***.

Asking the patient to lift one foot demonstrates the ability to stabilize the body using a single lower limb.

The body weight is then concentrated on the anterior heel, and, again, the anterior weight-bearing print should be homogeneous to maximize the weight-bearing surface and reduce local pressure. As a rule of thumb, pressure on the plantar skin never exceeds 10 kg/cm^2 (10). ***Standing on tiptoe and on one leg may provoke a slight valgus of the heel***,

43

which is a sign of stabilization due to the missing contralateral foot. Occasionally, metatarsalgia increases when standing on one foot. ***Discrepancy of the metatarsal length***

44

can explain any ***pain experienced during push-off***.


45


46

The metatarsus turns vertical, and if the second (and third) metatarsus is longer than the first one, the patient may feel a painful corresponding overload beneath the second (and third) metatarsal head ***(O418)***.

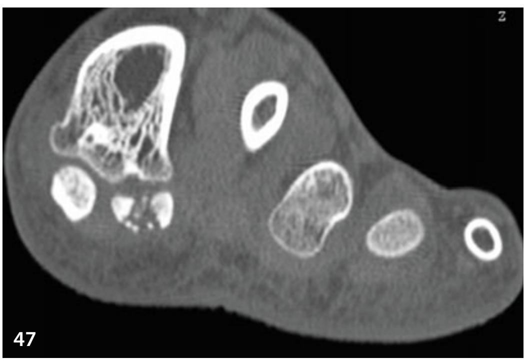
On the other hand, pain beneath the first ray may be evidence of a ***pathological overload of the sesamoid bones (R157)*** and reveal eventual fractures ***(T763)***.

The patient is then evaluated standing and from the side. All toe pulps should touch the floor, and the inclination of the tips of the toes to the bearing surface is critical because of the toes' push-off function. Despite the three articulated bones in the lesser toes, mutual retractile flexion (accordion) is avoided by the following:

- The "windlass mechanism" of the plantar fascia (12), which passively flexes the first phalanx
- The tensioning of the flexor digitorum brevis, which stabilizes the middle phalanx
- The tensioning of the long flexor of the toes, which presses the pulp of the toes onto the ground

Toe alignment

Asking the patient to ***stand at the edge of the examination cube*** with all toes free should demonstrate in the healthy foot the windlass mechanism of the plantar fascia: The plantar fascia is a strong mechanical link joining the heel and the basis of all phalanges. Steady weight bearing compresses the bony beams of the foot, tending to reduce the longitudinal arch and thus tighten the plantar fascia. ***Spontaneous flexion of all metatarsophalangeal joints*** ensues (8, 12).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48


49

The patient then turns 90 degrees to face the examiner. Rotation of the lower leg and hindfoot is considered by focusing the attention on the knee axis. ***With both patellae positioned within the frontal plane***,

50

the normal foot demonstrates an external rotation of about 15 degrees.

Excessive external rotation of the bimalleolar angle (ankle) is generally well supported and is often associated with a genu (crus) varus. ***External rotation of the feet***

51

may be augmented by excessive pronation of the lower ankle joint.

As the horizontal alignment of the toes has wide, individualized, symptomless variety, in a barefoot, walking subject, painful and generally disturbing misalignment may occur after surgical operations. ***Painful adductus of the big toe***

52

is one such misalignment.

This deformity is generally not tolerated due to pain and discomfort ***(O411, T841)***.

Rotational alignment is also critical. The big toe and the second and third toes are generally in a "neutral" position, as evidenced by the orientation of the toenail (horizontal). The ***fourth and the fifth toes may be turned slightly in supination***.

53

However, if the axial rotation of the toe ***exceeds 45 degrees***

54

of supination, there is a likelihood of a painful buttress of the outer edge of the nail, which may need correction ***(T849)***.

Heels standing

The integrity of the anterior tibial muscle is tested in a neutral position in the lower ankle joint by asking the patient to extend his or her foot dorsally. The lower ankle joint is inverted by the muscle action.

Rupture of the anterior tibial muscle tendon

55

causes eversion of the lower ankle joint due to the activity of the fibularis tertius muscle. Rupture rarely occurs, however, and mainly results from cortisone injections ***(E93)***.

Attention is given to the simultaneous activity of the tibialis anterior and the extensors of the toes. During active extension of the foot, all tendons around the dorsum of the foot are observed. Any slight weakness of the tibialis anterior muscle leads to recruitment of the long extensors of the toes. This is also evident in the case of shortening of the calf muscles ***(E74)***. It causes a strong pull on the toes, resulting in ***dorsal extension at the metatarsophalangeal*** and plantar flexion at the proximal interphalangeal joints ***(O389)***.

56

This position of the toes may become chronic and irreducible ***(E123)***; this condition is termed ***“hammer toes.”*** It should occasionally be investigated on the neurological level. Often, a pes cavus is associated.

2

Nonstatic observation

The patient is then asked to ***sit on the edge of the examination cube*** and face the seated examiner.

57

Unloaded alignment

This position corresponds to both the hip and knee being flexed. Any length discrepancy of the thighs is best seen in this position. The patient is asked to hold his or her feet horizontally, and the anatomic horizontal rotation angle between knee and foot axis is assessed (about 15 degrees). ***Rotation of the lower leg within the horizontal plane*** is assessed by considering the bicondylar knee and bimalleolar ankle axes

58

This assessment can also be performed in a standing position considering the plane of the patella (frontal plane) and the angle between the foot axis and the sagittal plane ***(E50)***.

The action of the anterior tibial muscle is seen in a neutral position of the lower ankle joint by asking the patient to extend his or her foot dorsally.

Extension power of the foot is augmented by the ***long extensors of the hallux and the toes (recruitment)***.

59

Sole of the foot

With the patient still seated as above and in front of the examiner, the plantar skin is visualized. The plantar skin reacts to chronic and repetitive pressure by thickening the epidermis of the skin and forming ***calluses***.

60

A reduced total weight-bearing surface (load concentration) and reduced subcutaneous plantar fat cause calluses. Pathological morphotypes such as pes cavus adductus may present painful calluses and eventual ***skin breakdown*** (ulcers).

61

The anterior heel corresponds to the horizontal alignment of all metatarsal heads. This is especially true in weight-bearing conditions ***(E24)***. In non-weight-bearing conditions, the horizontal view may demonstrate a ***convex contour of the plantar skin and hammering of the lesser toes.***

62

In those cases, there is often an unstable first ray and the corresponding absent anteromedial buttress of the foot. Calluses beneath the central (second and third) metatarsal heads demonstrate the secondary local overload. Those calluses are painful on palpation ***(E116, O340)***.

Diabetes mellitus causes a peripheral neuropathy in which deep sensibility is lost, probably along with the activity of the intrinsic musculature. Concentration of bearing load and callus formation in diabetic patients are considered the precursors to skin breakdown and the appearance of ***malum perforans***.

63

When the pulps of the toes do not make contact with the ground for a variety of reasons, calluses form beneath the metatarsal heads. This demonstrates the importance of the toes in load sharing during walking and running. Toes may present painful plantar calluses proximal to the distal phalanx, ***beneath the distal condyles of the proximal phalanx.***

64

This typically happens when the short flexors are insufficient (intrinsics) and the ***intermediate phalanx is dorsally extended*** (so-called swan-neck deformity).


65

It may also occur after the long flexor of the toe is transferred to the first phalanx for treatment of symptomatic hammer toes ***(O387)***. If the interphalangeal joints are hypermobile (hyperlaxity), the first and second interphalangeal joints hardly resist passive extension of the toe.

Interdigital calluses may form at the level of the interphalangeal joints. Rigid flexion of the distal interphalangeal joints may cause ***subungual calluses***.


66

This is due to shortening of the long flexor tendons and may have neurologic or traumatic (calcaneus fractures, including compartment syndrome of the foot) causes. Calluses around the toes are usually due to a mechanical dysfunction and are very painful ***(F454)***.

2 Palpation

Heel cord

The patient lies relaxed on his or her chest, placing the shins on a soft roll to passively flex the knees. This relaxes the gastrocnemius muscles. The examiner palpates the lateral and medial edges of the distal heel cord and examines the eventual peritendinous edema and/or irregularities of the tendon. Peritendinous edema might give the feeling of a crisp, dry sponge on palpation (tendinitis). Pain on palpation is the driving point ***(E16)***. The fulcrum of pain can be located at the insertion of the heel cord at the back of the tuber calcanei (enthesopathy).

If the knees are straight with the feet over the edge of the examination surface, both gastrocnemius muscles are in tension. Both feet should ***show a slight plantar flexion.***


67

If, however, one foot demonstrates a ***neutral position without flexion,***


68

a ruptured heel cord should be strongly suspected. By squeezing the calf muscles, the consequent muscle shortening provokes ***passive flexion of the foot*** in normal conditions.


69

If this maneuver doesn't occur, the ***heel cord is certainly ruptured*** (Thompson test) ***(T794)***.

70

Ruptures of the tendon at this location may be secondary to ***corticoid injections.***

71

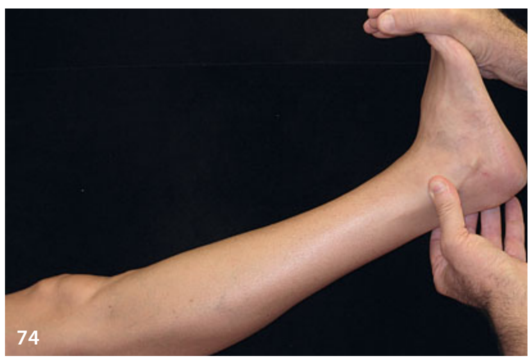
72

Turning onto his or her back, the patient keeps the knees relaxed, and the examiner holds the lower leg from behind (calf) with one hand and the foot with the other hand. The foot is held avoiding inversion/eversion (locking the talocalcaneonavicular joint). First positioning the lower leg to ***relax the knee in flexion***,

73

the foot is pushed in passive dorsal extension of the upper ankle joint.

Normal conditions allow the ankle to be moved 20–30 degrees in extension. Still holding the lower leg but with the ***knees straight***,



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the same passive dorsal extension is performed. If the extension angle of the foot does not exceed or is less than the right angle, we talk about a "functional pes equinus" by expression of a shortened gastrocnemius musculature (13) ***(T858, T793)***.

Functional pes equinus results naturally in chronic overload of the anterior heel and may induce metatarsalgia ***(E116)***.

2

In the standing patient, palpatory pain located at the anterior aspect of the last centimeter of the Achilles tendon may be related to an anterior bursitis, which in turn may have been triggered by an "aggressive" ***posterocaudal osteophyte of the calcaneus***

75

(Haglund) ***(O176)***.

To continue, the patient sits on the examination cube, relaxing the knees and ankles, and the ***examiner sits in front of the patient***.

76

Heel

The examiner holds the foot and deeply palpates the ***plantar, central aspect of the tuber***

77

calcanei. This pressure elicits pain in cases of calcaneodynia. Additionally, the proximal medial aspect of the plantar fascia will also be tender on palpation ***(T860)***.

Plantar fascia

Palpating from the plantar aspect of the tuber calcanei distally, the medial edge of the plantar fascia may be identified. The medial edge of the plantar fascia is demonstrated by pushing all toes in passive dorsal extension together with the whole foot: The fascia undergoes tension, and the ***medial edge is easily seen beneath the skin***.

78

If this palpation is painful, we are talking about a plantar fasciitis. If the medial edge of the plantar fascia presents irregularities such as painful firm nodules, there is a likelihood of facing plantar fibromatosis or morbus Ledderhose.

Upper ankle joint

The tibiofibulotalar joint is usually called the ankle joint. Mechanically this joint moves in flexion-extension following a slight conical path, with the center of the cone being medial. To emphasize the important and complex articular mobility of the hindfoot, we call this joint the "upper ankle joint." The laxity of the upper ankle joint is determined by the ligamentous structures with a fixed medial pillar, the medial malleolus, and a slightly mobile lateral pillar or "guide," the lateral malleolus.

Lateral ankle

Both tibia and fibula are connected by a strong three-part ligament, the tibiofibular syndesmosis. Traumatized, nonfractured ankles may result in painful insufficiencies of the syndesmosis. ***Forced external rotation of the foot in a neutral position*** may rupture the anterior syndesmosis, and the passive stress test in this direction is painful. This stress pushes the talus in external rotation and the fibula follows, while the tibia lags behind. Pain is thus located at the anterior aspect of the syndesmosis ***(O221)***.

Beneath the tibia, the fibula is connected to the talus by two rather lax lateral fibulotalar and calcaneal ligaments. Their function is to avoid joint subluxation before weight bearing.

The medial pillar is made up of the strong deltoid ligament, which links the tibia to the talus, calcaneus, and navicular bone.

Distal to the hip joint, the medial aspects of the joints are tight and less prone to giving way than the lateral aspect of the limb. The lateral condyle of the femur glides on the tibia, while the medial condyle rotates on the tibia. The upper ankle joint is also more lax on the lateral side than on the medial, and the subtalar joint is tightly fixed on the level of the sustentaculum tali with more mobility on its lateral aspect.

During weight bearing, the synergy between the ligaments that avoid joint subluxation and the musculature constitutes the essential stabilizing factor.

Following a sprain of the hindfoot, the lateral ligaments, especially the ***anterior fibulotalar ligament,***

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80

is usually first to sustain a tear ***(T771)***.

Palpating the origin of the ligament

81

and its insertion on the ***lateral aspect of the talar neck***

82

may remain painful for a longer period if the ligament is insufficient.

Forced supination of the foot stresses the anterior fibulotalar ligament, which may rupture and leave the talus while held firmly on its medial aspect, in an ***exaggerated anteroposterior drawer***.

83

84

Due to the wide range of normal and asymptomatic joint laxity, the asymmetry between the symptomatic and the asymptomatic foot is relevant in this test.

Acute ruptures and insufficient healing of those ligaments may cause functional incongruities of the upper ankle joint surfaces that are painful, leading to apprehension, "giving way," and posttraumatic joint degeneration ***(O210)***. The talus is no longer held by the lateral ligament and shifts anteriorly ***(R140)***. A chronic static shift of the talus anteriorly is due to the conical shape of the talar dome, which is wide anteriorly and narrow posteriorly.

Conversely, an overly strong ligamentous repair or a repair that does not allow for physiologic mobility of the upper ankle joint may lead to a (rare) posterior shift and joint destruction.

Medial ankle

If palpating the anterior aspect of the medial malleolus is painful, there is a high likelihood of a severe sprain that jeopardizes the stabilizing effect of the medial pillar of the joint.

The anterior fibers of the ligamentum deltoideum might be painful at palpation in the case of a severe sprain of the ankle in which the talus is rotated (internal rotation) excessively within the malleolar fork. Unlike a simple internal rotation around the medial malleolus (medial pillar) and a rupture of the lateral ligaments, a lesion at the ligamentum deltoideum signifies a severe sprain in which only the posterior fibulotalar ligament might have resisted. This lesion is, however, common in certain malleolar fractures. Together with the posterior dislocation of the distal fibula, the medial malleolar dislocation/dissociation brings the rotating talus to shear off the posterior tibiaI articular rim. Without fracture and in relation to a sagittal hyperlaxity of the upper ankle joint in internal rotation, a lesion of the anterior part of the deltoid ligament may be the result of a significant joint instability.

Lower ankle joint

Motion

The inversion of the subtalar joint stresses the fibulocalcaneal ligament, which yields under load. Subtalar hyperlaxity is tested specifically ***between the talar neck and the heel***

85

when evaluating the arc of the talocalcaneonavicular joint, which shares its exceptional mobility with the hip joint. To be precise, the path of motion of the calcaneus beneath the talus follows a helix situated on an inclined, flattened part of a cone, the center of which is located at the level of the sustentaculum tali. The axis of the cone is oblique from posterolateral to anteromedial. The cone is flattened on its superolateral aspect: Its curve has a smaller radius medially than superiorly and laterally. The underlying calcaneus (male part of the joint) thus rolls and slides beneath the talus. ***The calcaneus moves posteriorly during heel strike,***

86

which includes pronation, and ***moves toward the anterior during push-off,***

87

which includes supination of the coxa pedis.

In maximal pronation, the talus abuts the calcaneus laterally (angle of Gissane),

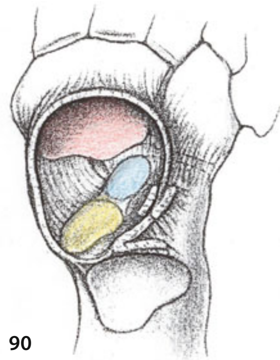
88

while ***in maximal supination the talus abuts the calcaneus medially*** (sustentaculum tali).

89

The path of motion of the navicular beneath the talus follows the calcaneus: During weight bearing (pronation), the navicular is pulled laterally, following the calcaneus, which moves posteriorly. During push-off, motored by the strong pull of the tibialis posterior muscle, the navicular moves medially, preceding the anterior move of the calcaneus (supination).

The articular play of the navicular and the sustentaculum tali (calcaneus) around the talar head very much resemble the abduction–adduction of the hip joint. The shape and configuration of the proximal navicular joint facet and the anterior/medial calcaneal joint facets are ***very similar to the coxal acetabulum***.



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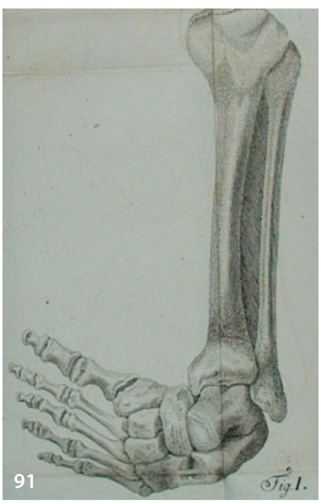
Antonio Scarpa (14) noted this morphologic and functional resemblance, especially in relation to pathology such as clubfoot, which demonstrates ***subluxation of the talocalcaneonavicular joint.***



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He named the talocalcaneonavicular joint the **"coxa pedis."** The mainstay of the acetabular arch is made up of the calcaneocuboid joint, which allows some motion between both the anterior (navicular) and posterior (sustentaculum tali) acetabular walls (8).

Again, to emphasize the important and complex articular mobility of the hindfoot, we call this joint, together with the posterior subtalar joint, the "lower ankle joint."

The anterior part of the lower ankle joint is made up of the navicular bone. The navicular bone is basically a transversal bone that directs the three medial rays of the foot. Shifting around the talar head, the whole foot is either inverted or everted. The main extensor of the foot is the anterior tibial muscle, which inserts distal to the coxa pedis and thus either inverts or everts the foot while pulling it strongly in dorsal extension.

The ***strength of the anterior tibial muscle and toe extensors***

92

is evaluated during active extension of the foot. The examiner opposes resistance to foot motion and evaluates the produced force.

2

Insertion of the tibialis anterior tendon occurs on both the first cuneiform and the first metatarsus. Painful enthesopathy of this tendon is quite frequent, and direct palpation of the insertion and restrained active extension of the foot cause the pain. ***Rupture of the tibialis anterior tendon***

93

is common after local cortisone injections, which can cause necrosis. The consequent functional disability is obvious ***(E55, T818)***.

Different locations on the lower ankle joint may demonstrate specific pathological conditions:

Lateral process of the talus

The lateral process of the talus forms the posterior aspect of the sinus tarsi, which includes a high concentration of mechanoreceptors, giving us information about the statics and stability of the lower limb. In the case of a hindfoot sprain that includes the lower ankle joint, the sinus tarsi may continue to cause pain ***(R155)***.

While Scarpa observed a "dislocation" of the talocalcaneonavicular joint or coxa pedis in the congenital clubfoot, we can talk about a "protrusio" of the same coxa pedis in the pronated foot ***(O255)***. In pronated feet ***(O246)***, pain may be the result of talocalcaneal impingement ***(E88)***. Along its spiral and pronating motion beneath the talus, the calcaneus stops its movement abutting the lateral process of the talus. Fortunately, normal feet have different soft tissue structures that slow down pronation. Contact of the processus lateralis tali with Gissane's angle of the calcaneus may be painful and is also a frequent cause of fracture: The strong pronation and internal rotation of the foot beneath the talus may ***fracture the lateral process of the talus***

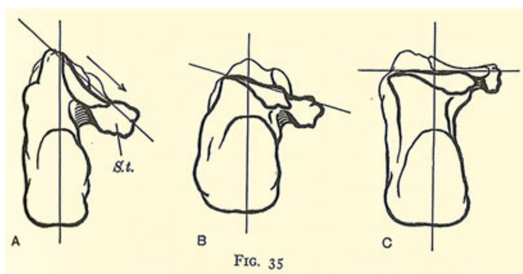
94

by impingement ("snowboarder's fracture").

Subtotal subtalar coalition (bar) ***(R158)*** may cause pain when the sinus tarsi is palpated due to micromotion.

Sustentaculum tali

The sustentaculum tali is a small and very strong bone that is part of the calcaneus and the ***mainstay of the medial longitudinal arch*** (4, with permission)

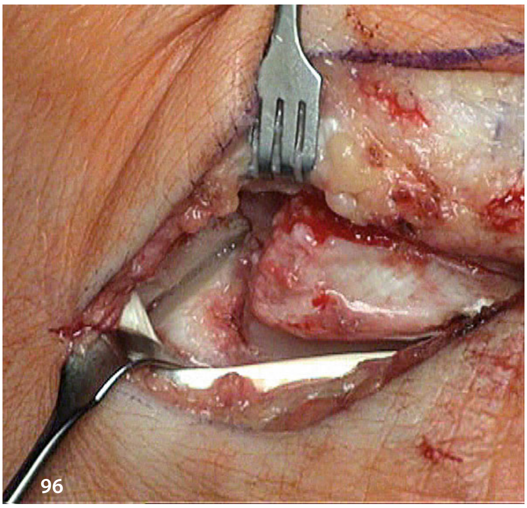


95 Calcanea of the Gorilla, Neanderthal and Modern Man

of the foot. This arch is actually specific to *Homo sapiens*, beginning with *Homo erectus* (15).

The sustentaculum tali lifts the talus phylogenetically, and with this move it is assisted functionally by the tibialis posterior muscle and tendon.

The sustentaculum tali is tightly fixed to the above-lying talus by a strong capsule and by ligaments. The flexor digitorum longus tendon runs above, while the flexor hallucis longus tendon runs below. The sustentaculum tali constitutes the posterior wall of the acetabulum pedis. Right behind the sustentaculum is the canalis tarsi, with an important neurovascular bundle passing close to the talus (roof). In supinated feet, the sustentaculum tali abuts the posteromedial tubercle of the talus, thus closing the canalis tarsi. Posttraumatic osteophytes (after subtalar subluxation or dislocation) at this location may induce invalidating pain by ***medial subtalar impingement***.



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Talonavicular joint

Pain on palpation can be due to arthritis and joint degeneration. Diagnostic articular anesthetic infiltration may confirm such a suspicion.

Posterior subtalar joint facet

The posterolateral border of the subtalar joint may be palpated behind the fibular tendons. It is at the base of the aforementioned cone that guides the helicoidal articular path of the calcaneus beneath the talus. This spot is especially painful in subtalar arthritis due to arthrosis that might be degenerative due to chronic overload (malorientation with hindfoot varus or valgus), chronic instability, or trauma (calcaneus or talus fracture). Pain more posteriorly and deep, painful palpation might be the expression of a posterior impingement with the upper ankle joint (tibia). Passive hyperflexion of the foot may be irritating and painful. Three bones are in close proximity to each other here, and the intermediately placed talus may suffer through a ***large posterolateral or posteromedial tubercle,***

97

which may fracture or present an impinging os trigonum. ***Diagnostic anesthetic infiltration*** indicates surgical treatment ***(O186, T581)***.

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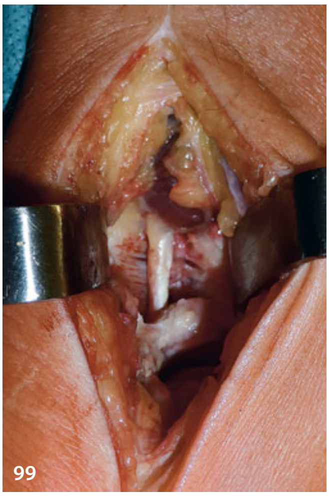
It may also be due to a soft tissue impingement involving the upper or lower ankle joint.

Exceptional cases involve congenital malformations such as additional muscle bellies (fibularis quartus or accessory soleus muscles). Some of those abnormal muscles and tendons may insert into the posterior aspect of the talus.

This condition might cause neurologic symptoms while compressing the tibial nerve.

On the medial side and on the same level, the impingement may involve the flexor hallucis longus tendon between both posterior talus tubercles, which present a ***restricted passage to the tendon.***



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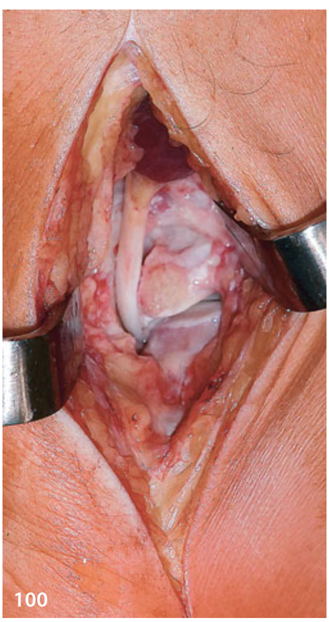
Operative revision and ***liberation of the passage*** may be helpful in rare cases.



100

Navicular bone

Passively mobilizing the lower ankle joint, the ***medial aspect of the navicular bone***

101

is palpated without difficulty.

The importance of its prominence is critical. Abnormal pain at this point may be a sign of a morphologic particularity such as an ***accessory navicular bone (O295).***

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The *posterior tibial* muscle is tested while the examiner holds the lower leg with one hand and asks the patient to ***flex and adduct the foot***

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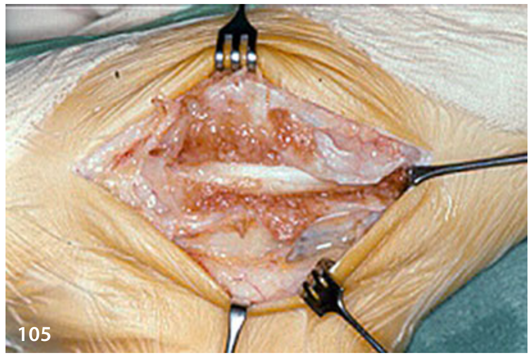
During this maneuver, the examiner opposes resistance to the motion of the foot and with one finger palpates the retromalleolar and inframalleolar space in which the tendon glides. This tendon is poorly vascularized and frequently undergoes chronic degeneration or rupture in elderly patients and in pathological inflammatory conditions such as rheumatoid arthritis. The degenerating tendon generally increases in volume, which may correspond to scarring tissue, including local irregularities due to partial ruptures and spontaneous repair in the past. In those cases, the tendon rupture is located in the retromalleolar region. Palpation may demonstrate no supination power and submalleolar and retromalleolar pain ***(E42)***.

Starting at the navicular, where pain may be linked to an enthesopathy, and running proximally, palpation of the ***posterior tibial tendon may reveal effusion and/or tendon and synovial irregularities***.



105

These pathologies are very painful on palpation and may be accompanied by the aforementioned crisp, dry sponge feeling.

Scarring of the tendon increases its diameter, which may ***rupture preferentially about the posterior aspect of the medial malleolus (R161, T812).***

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2

Anterior calcaneal process

At the top of the anterior calcaneus, the strong retinaculum or bifurcate ligament is inserted laterally, as is the main part of the musculus extensor brevis. This might be the location of ***traumatic avulsion***,

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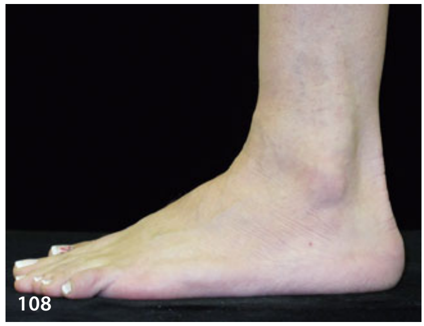
which may or may not involve bone, after sustaining a forced supination trauma.

Calcaneocuboid joint

The calcaneocuboid joint is the mainstay of the lower ankle joint or acetabulum pedis. As a saddle-shaped joint, it opens and closes the acetabulum pedis more or less horizontally. It also cushions the sudden pronation of the calcaneus at heel strike. The lateral aspect of the calcaneocuboid joint may be palpated easily. Palpation is best performed in slight passive flexion and abduction of the foot to avoid interference with the fibularis brevis tendon. Pain at palpation may be due to a past trauma such as an articular fracture.

Fibular muscles and tendons

Both fibular tendons are guided around the lateral malleolus in a smooth gutter, which might allow the ***fibular tendons***



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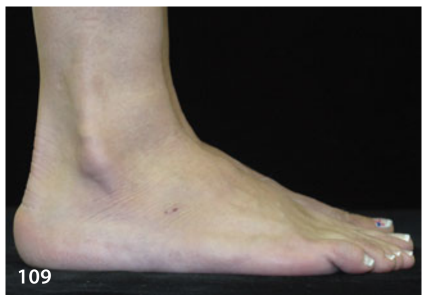
to pop out occasionally,



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although this is most often a benign particularity that causes no pain or discomfort.

Both tendons have essentially different functions: The musculus fibularis brevis is a pure pronator of the foot at the midtarsal joints and acts as an antagonist of the musculus tibialis posterior. The musculus fibularis longus is essential for holding the medial longitudinal arch of the foot by inserting into the plantar aspect of the first cuneiform and first metatarsus. It acts as an antagonist of the musculus tibialis anterior.

The *musculus fibularis brevis* is tested similarly to the musculus tibialis posterior by ***asking the patient to abduct the foot***


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while the examiner, opposing resistance with his or her hypothenar, palpates the course of the tendons about the lateral inframalleolar and retromalleolar space.

The *musculus fibularis longus* is tested similarly to the musculus tibialis anterior by ***asking the patient to strongly flex the first metatarsus*** toward the plantar plane


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without moving his or her foot at the talocalcaneonavicular joint.

The action of the fibularis longus tendon is palpated at the retromalleolar space.

The critical locations on the tendons that may be linked to pathology (longitudinal splits) ***(T809)*** are beneath the lateral malleolus and at the curve around the cuboid bone.

The fibular tendons may be tender on palpation on their path along the lateral wall of the calcaneus. A crisp feeling akin to the squeezing of a synthetic dry sponge may also be felt.

In some cases, the peroneal tubercle might have an abnormally large dimension and be very painful to palpation. Degenerative lesions of the tendons are due to overuse or overload. An overload such as this occurs in chronic malposition of the hindfoot such as hindfoot varus or cavus and should be evaluated in the static position ***(E18, O203)***.

This situation corresponds to a chronic inflammation of the tendons, which have the tendency ***to split along their axes***


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without increasing diameter.

Pain on palpation at the proximal tip (basis) of the fifth metatarsus may be linked to an enthesopathy of the fibularis brevis tendon. This is common with a varus adductus foot morphotype. A fracture of the tip of the fifth metatarsus may result from a loaded supination trauma, though it does not include the whole insertion of the fibularis brevis tendon and generally heals without medical intervention.

Naviculocuneiform joint

Pain on palpation can be due to arthritis and joint degeneration. Instability due to hyperlaxity may be assessed radiologically ***(R151)*** (plantar articular gap) or during surgery ***(T645)***.

2

Second and third tarsometatarsal joints

The central tarsometatarsal (TMT) joints are adaptive joints. Their medial part plays a role in smoothing the push-off during gait. The central TMT joints are the least mobile. The second ray became the central axis of the foot during evolution from its ancestor, the hand, and the symmetry of the interosseus musculature is testimony to this evolution ***(A5)*** (4). Painful palpation of the central Lisfranc joints may be linked to degeneration of those joints. In this case, it is common to palpate a preeminent osteophyte at this location. A majority of rheumatoid arthritis cases are linked to this kind of symptom. Posttraumatic conditions, including lesion of the cuneiform 1–metatarsus 2 ligament (Lisfranc's ligament), may cause clinically relevant subluxation that is difficult to assess radiologically ***(R143)***.

Fourth and fifth TMT joints

The lateral TMT joints are essential joints and are more mobile than the first TMT joint. As a prolongation of the calcaneus foot, only two joints link the metatarsal heads to the heel. Painful palpation and mobilization of the lateral TMT joints may occur after trauma. Such symptoms are frequently seen after reorientation of the axis of the foot (e.g., correction of pes planus). Changing the weight-bearing axis of those joints may provoke such irritation. Articular desensitization or interposition arthroplasty may considerably improve this condition ***(T680)***.

Metaphyseal fractures of the fifth metatarsus may be the result of supination trauma, but this also includes the fibularis brevis and fibularis tertius tendons. This results in a mechanically unstable situation that requires very stable fixation for successful healing (Jones fracture).

First TMT joint

Mobility of this joint was reduced considerably during evolution from the prehensile organ (hand) to a weight-bearing organ (foot). However, the missing ligamentous structure linking the first metatarsus to the central axis makes it a delicate structure, and instability of the first ray is a very common problem that causes imbalance of the forefoot and secondary disability. Due to the medial position of the first ray, the imbalance causes, in general, an angulation toward medial (adduction) and dorsal (extension). The triggering effect of proximal particularities and deformities (kinematic chain) such as general hyperlaxity, tight heel cord, genu valgum, and hindfoot valgus must be assessed during the clinical examination. Stability may also be jeopardized by intrinsic muscular imbalance that has undergone a local compartment syndrome (16) or simple trauma. As a physically unstable construction that is stabilized by balanced agonists and antagonists, the forefoot may then develop a rapid deformity at the first TMT joint ***(O345)*** due to the absence of strong ligamentous structures, missing because of phylogenetic reasons.

Painful ***palpation of the medial articular space of the first TMT joint***

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may accompany instability of the first TMT joint.

Passive mobility of this joint must be assessed precisely. The foot is held in a neutral position (right angle at the upper ankle joint and without pronation or supination) by the examiner ***with one hand at the metatarsals 2–5.***

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The other hand ***takes hold of the first metatarsus and moves it up and down***


115

starting at the plantar (horizontal) position within the sagittal plane.

The mobility path in dorsal extension is particularly interesting because it reflects the resistance to functional anteromedial buttressing of the foot during gait and push-off (17). Similarly to the sagittal "Lachmann" of the knee, it demonstrates the stability of this part of the foot. The fulcrum of rotation (or deflection) is most proximal to the TMT joint due to the type of joint (plane gliding joint or arthrodia) (11). Testing the activity of the fibularis longus muscle is part of the stability test of the first TMT joint ***(E111)***.

Second and third metatarsal heads

The second and third metatarsal heads, together with both sesamoid bones of the first ray, can be considered the bony, static, weight-bearing centrum of the forefoot ***(O350)***. In fact physiologic distribution of static load is shared between the tuber calcanei and the metatarsal row that we call the anterior heel ***(E24)***. Within the anterior heel, load is equally distributed on the six aforementioned bony prominences.

Painful ***plantar palpation of the second metatarsal head***


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(together with the third head) is very often linked to an unstable first ray. It may express a lesion of the corresponding plantar plate, which acts as a mechanical continuity of the plantar fascia. In progressed cases, the metatarsophalangeal joint becomes unstable due to the rupture of the plantar plate ***(O383)***. The ***dorsal aspect of the joint also becomes painful***


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on palpation, and the sagittal drawer test positive. The horizontal alignment of the first three metatarsal heads is relevant for a functional push-off. During push-off, the metatarsus becomes vertical; therefore, their relative length, especially in relation to the first metatarsus, is critical. Radiologic assessment in weight-bearing conditions is indispensable.

The joint and the dorsal aspect of the second (eventually third) metatarsal head may also become painful without subluxation. ***Swelling (left foot) and pain on palpation and with motion***


118

may be the clinical expression of a ***metatarsal head necrosis (morbus Freiberg) (T725)***.


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Fourth metatarsal head

The fourth metatarsus may become painful during walking and running and on precise palpation. This condition is not linked to the instability of the first ray and often requires exclusively localized surgery.

Lesser intermetatarsal space

At the level of the anterior heel, distal ramifications of the nervus plantaris lateralis are not protected by the digitations of the plantar fascia and are located within the plantar fat. They are located at the lower half of the metatarsal heads and so are submitted to high strain because of the intermetatarsal mobility at the spot where the nerve divides into the two plantar digital nerve ends. Continuous repetitive strain on nerves may cause fibrosis, which in turn destroys the axons. This process leads to the formation of pseudoneuroma (7), which may cause burning pain ***(T855)***. Squeezing all metatarsi within the sagittal plane may elicit the same pain. This pain is increased with additional ***intercapital digital pressure.***


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Tactile sensation between the toes may be reduced due to the autodestruction of the nerve ***(R164)***. It must be noted, however, that the presence of the pseudoneuroma on magnetic resonance imaging does not necessarily imply corresponding symptoms.

Metatarsophalangeal joints

First ray

Palpatory pain and dorsal pain during passive flexion of the first metatarsophalangeal joint together with an ***evident dorsal osteophyte (left foot)***

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of the first metatarsal head (***O371)*** are often the clinical manifestations of hallux rigidus. Mechanical prerequisites that combine to bring about an increase in functional overpressure within the first metatarsophalangeal joint are as follows: The first metatarsus is aligned with the first phalanx within the horizontal plane; the gastrocnemius muscles are tight; and the morphotype is often Egyptian with a positive index metatarsus ***(O367)***. Surgical correction in all stages is usually helpful ***(O370, O372, O375)***. The *long flexor of the hallux* is tested while opposing resistance to the flexion of the end phalanx.

Lesser rays

Stability within the sagittal plane is tested to verify the integrity of the plantar plate. In the case of a significant lesion of the plantar plate, palpation of the dorsal rim of the first phalanx is very painful ***(E117).***

The *long flexors of the toes* are tested easily as the patient is asked to flex his or her toes toward plantar. Attention should be given to the flexion of the distal interphalangeal joint. As a matter of synergy, this is generally easier when all flexors of the foot are innervated simultaneously. Dysfunctional intrinsic muscles, including the short flexor of the toes, may then appear due to a break in the flexion arc of the toes. Ankylosis of any origin can be detected with this exam. A lesion of the plantar plate due to chronic overload of the metatarsal head may cause progressive ***dorsal subluxation of the metatarsophalangeal joint***.

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Dysfunction of the stabilizing intrinsic muscles may appear as insufficient local metatarsophalangeal flexion.

Sesamoids of the first ray

Painful plantar palpation of the sesamoids may be due to an articular pathology of the metatarsosesamoid joint. Multifragmentary sesamoids are reputed to be more frequent in those who play football (18). Trauma may cause acute fractures of the sesamoid bones ***(T760)***. The patient often refers late to his or her doctor at the painful, nonunion stage.

Toes

Calluses can cause a lot of pain in the toes. The interphalangeal joints are not essential but should allow the pulp of the distal phalanx to make slightly oblique contact with the ground. An ankylosed flexion of the proximal interphalangeal joint might be compensated for by hyperextension of the distal interphalangeal joint, but this can cause some discomfort in footwear. Flexion contracture of both interphalangeal joints may be the expression of a past compartment syndrome of the foot or a neurologic disease. *Intrinsic muscles of the foot* are very sensitive to plantar hematoma or any cause of augmented pressure within the plantar muscular compartments. These compartments are separated by very tight fascia and have very little room to expand. Very frequently following foot trauma, including a simple, slightly displaced calcaneus or a metatarsal fracture that was not treated by immediate open reduction and internal fixation, hammer toe is likely to occur. The metatarsophalangeal joint rests in an exaggerated dorsally extended position, together with a progressively ***ankylosing flexion of the first interphalangeal joint,***

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while the distal interphalangeal joint may remain more or less normal.

In severe cases and/or compartment syndromes of the lower leg, however, the distal interphalangeal joint gets ***tethered in flexion***

125

by a strongly retracted flexor digitorum longus (claw toe).

Sensibility

The anatomic distribution of skin sensibility is divided across the dermatomes of the nervus fibularis superficialis, the fibularis profundus, the saphenous, the suralis, and both plantaris medialis and lateralis, together with the sensitive part of the nervus abductor digiti minimi. Symptoms due to nerve compression are rare and may be linked to tumors such as ***ganglia***

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or anatomic malformations such as ***abnormal, additional muscles (left medial ankle)***.


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3 Active joint mobility and functional exam

Active joint mobility

Upper ankle joint

The patient, still sitting on the edge of the examination cube, faces the seated examiner. After the motors of the foot are checked, the effectiveness of the musculature on the joints, especially the essential joints, must be verified. The patient flexes the knee at about 60 degrees and rests his or her heel on the knee of the examiner, thus relaxing all the extrinsic muscles.

Observing the foot from lateral, the patient pulls the foot in extension, avoiding pronation of the lower ankle joint. The true extension angle of the upper ankle joint is ***measured in between the tibial axis and the posterior lateral edge of the foot***,


129

which corresponds to the level of the calcaneus.

Then flexing the foot, the same landmarks are considered to ***quantify flexion***.


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Lower ankle joint

Quantifying active motion of the lower ankle joint is difficult. A good alternative for verifying relevant mobility of the lower ankle joint is to ask the patient to describe the largest circles he or she can draw in space with the big toe. To do this, the patient will mobilize both the upper and lower ankle joints at their maximum. A valuable alternative to this coordinating motion is to ask the ***patient to lie prone on the examination table***

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with both feet extended over the edge of the table by levering out the extended lower legs. This allows for contemporaneous dynamic visualization of both feet in pronation and supination.

With the patient sitting once again, the active mobility of the metatarsophalangeal and both interphalangeal joints are verified in flexion and extension.

Functional exam

Walking barefoot should always be observed with knees and lower legs visible. All compensation mechanisms appear when both knee joints and feet are observed together. A strong genu varum may be compensated for by a strong hindfoot valgus and/or pronounced external rotation of the feet ***(E51)***. This rotational component may be located within the lower leg, and the amount of rotation may be quantified statically ***(E50)***. Four exercises of progressive difficulty verify global foot and ankle balance:

Walking tiptoe

Performing the exercise standing, the patient is asked to walk on tiptoe. The tuber calcanei will be pulled medially by the synergic activity of the triceps surae and the musculus tibialis posterior. A prerequisite to this function is stable coordination of the extrinsic musculature. The agonist–antagonist coordination between the musculus tibialis posterior and fibularis brevis as well as that between the fibularis longus and tibialis anterior are verified. Absence of the varus of the heel while rising on the tips of the toes may be linked to several pathologies, such as a coalition ***(R158)*** between two or more of the four bones of the hindfoot or insufficient function of the musculus tibialis posterior ***(E42)***.

Walking on the heels

Normal anatomic conditions should allow anyone to raise the forefoot and walk, bearing all weight on the tuber calcanei. Inability to do this can be related to insufficiency of the extensor musculature ***(E55)*** due to either local traumatic pathology or neurologic problems such as a lumbar radicular compression of the motor fibers of L5. The metatarsophalangeal joints may be excessively extended due to ***"recruitment" of the long extensors of the toes.***

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This condition is common in some deformities such as cavus feet due to a proximal neurologic disorder. Generally, those feet progress to a generalized fixed hammer toe deformity.

Hopping on one leg

Hopping on one leg gives a good picture of the function of the gastrocnemius (jumper's muscle) because it works over two main joint groups, the knee joint and the upper and lower ankle joints. With this anatomy, extending the knee joint powered by the quadriceps puts tension on the gastrocnemius muscles, thus multiplying the action of the gastrocnemius alone in flexing the ankle joints.

Additionally, this exercise shows the ability to coordinate the extrinsic musculature and the potential to amortize the landing. Again, stiffness of the joints as well as a lack of coordination of the musculature of the hindfoot can be seen in the inability to use the elastic potential of normal foot anatomy. Lack of mobility at an essential joint such as a subtalar coalition is markedly demonstrated during this test.

Static tiptoe

The single-leg tiptoe stance test gives a good clinical image of the power of the soleus muscle (ballerina's muscle). Rising on the tips of the toes and balancing on one leg is the most difficult physical exam because it involves the proprioception and coordination of all 10 extrinsic muscles of the foot.