MECHANISMS AND FUNCTION

OF THE HUMAN FOOT

An Introduction to a Hypothesis

DAVID STAINSBY

2

ROTATIONS AROUND FOOT AXES

VERTICAL AXIS (A)

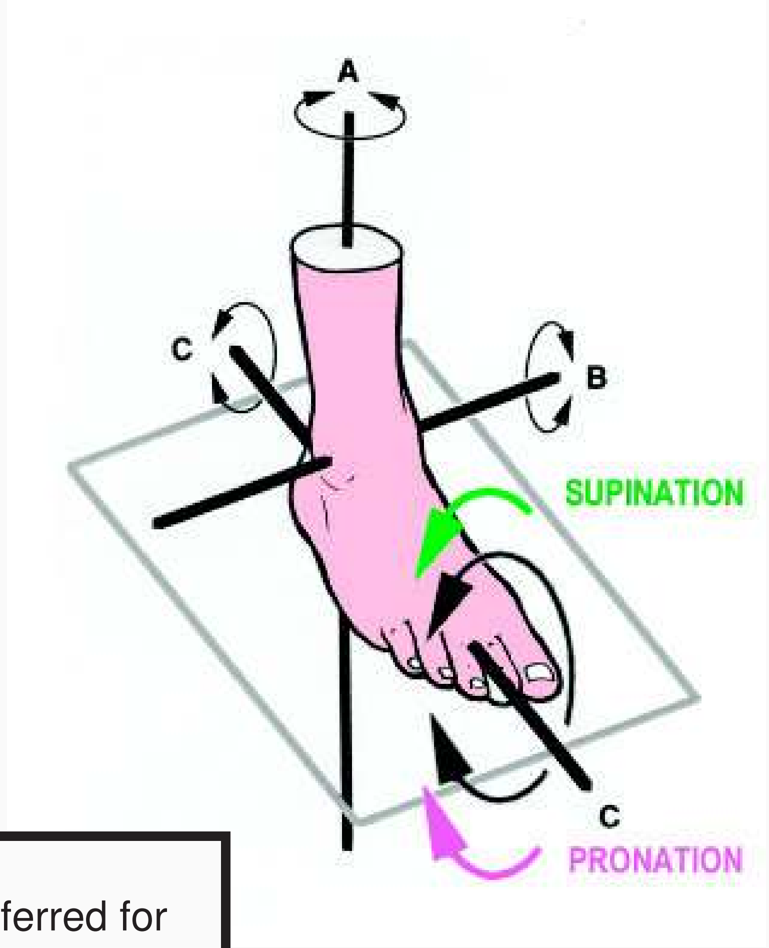
External / internal rotation

TRANSVERSE AXIS (B)

Dorsiflexion / plantar-flexion

LONGITUDINAL AXIS (C)

SUPINATION – GREEN
PRONATION – PINK



The terms **supination** and **pronation** are preferred for rotations around longitudinal axis – and are colour coded in diagrams

AIMS OF THIS INTRODUCTION

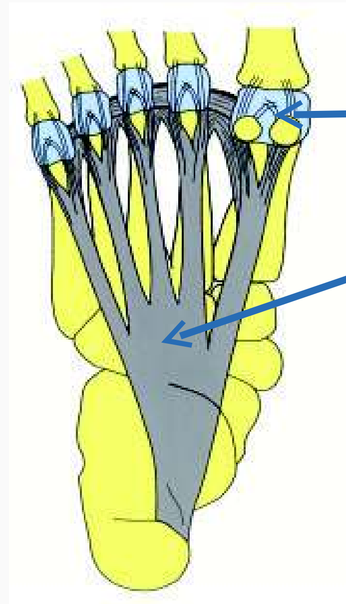
To draw attention to:

1. The multi-segmental tie-bar support system

   (a) The plantar aponeurosis

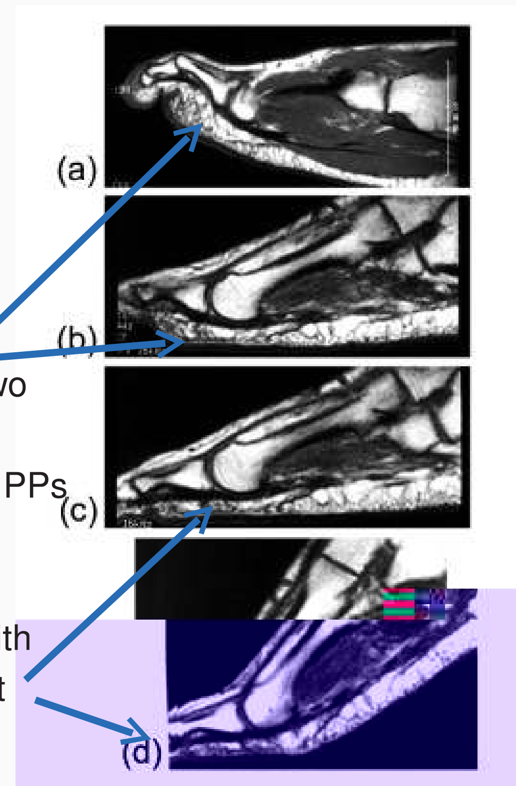
   (b) The transverse forefoot tie-bar

   (c) The plantar pad mechanism



Transverse tie bar (plantar plates and DTML's)

Plantar aponeurosis



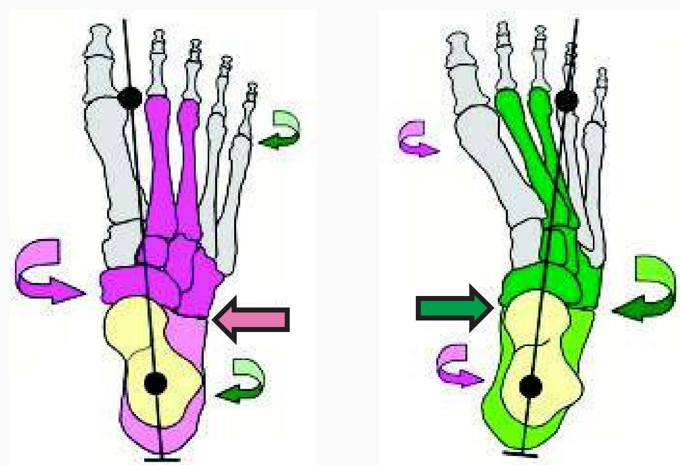
Plantar pad between the two layers of aponeurosis , beneath MT heads and PPs

Increasingly compressed with load transfer to forefoot

AIMS OF THIS INTRODUCTION

To draw attention to:

2. The concept of the foot being a 'balanced lever', with lateral swing movements at transverse tarsal joint level



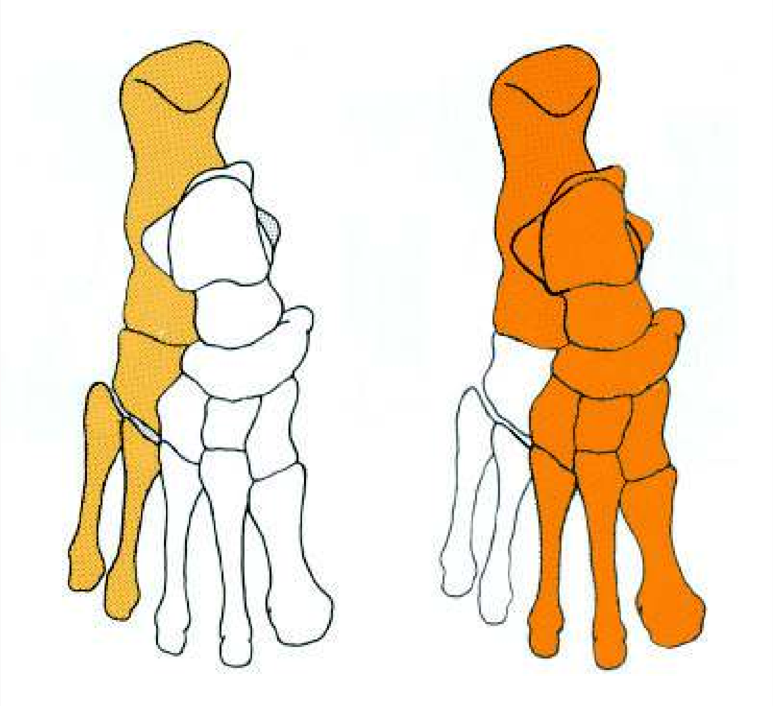
As posture alters with lateral swing movements at T-T joint level, foot can act as a balanced lever with TA attachment, body mass gravity line through talus, and centre of pressure beneath forefoot remaining in line

FOOT STRUCTURE AND FUNCTION

PREVIOUS CONCEPT

The foot has medial and lateral arches (or columns)

And a transverse 'arch' at the level of the MT heads



But an 'arch' structure requires foundations

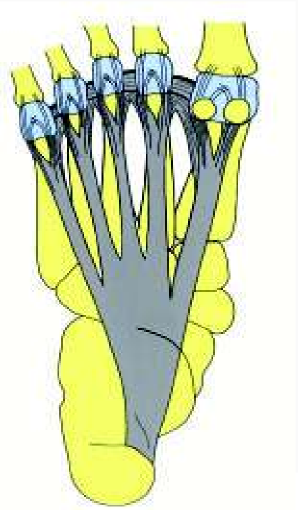
Now suggested basic design is that of a 'bow-string beam' construction – frequently used in the building of bridges

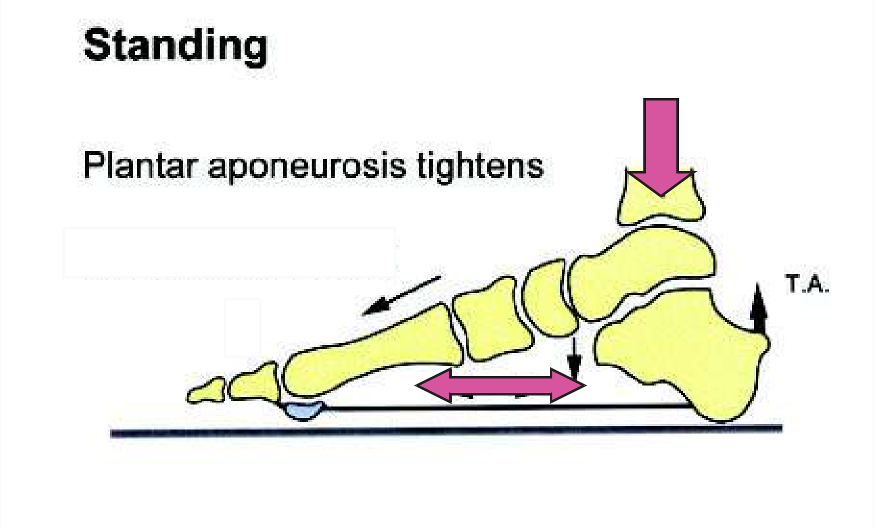
IMPORTANCE OF THE PLANTAR APONEUROSIS

HICKS 1954

Plantar aponeurosis acts as a longitudinal tie-bar extending from the calcaneal tuberosity to the plantar plates of the 5 MTPJs

Prevents ends of the curved structure moving apart when load-bearing (a ‘bow-string beam’ mechanism)

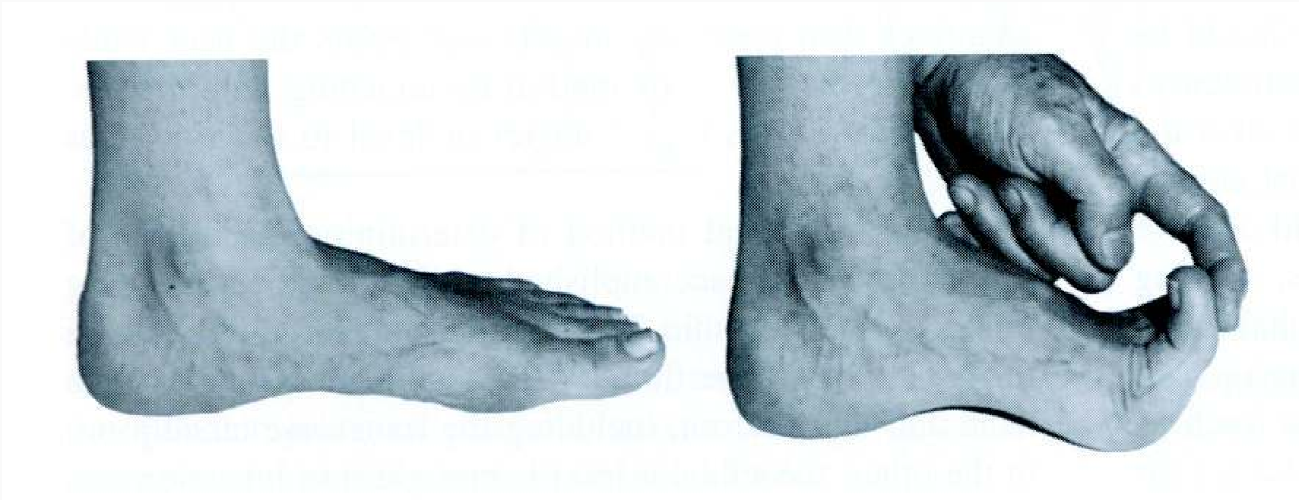




IMPORTANCE OF THE PLANTAR APONEUROSIS

HICKS 1954

Effects of passive extension of great toe at the M P joint :



‘Arch’ rises

Posterior part of foot assumes an inverted position (supinates)

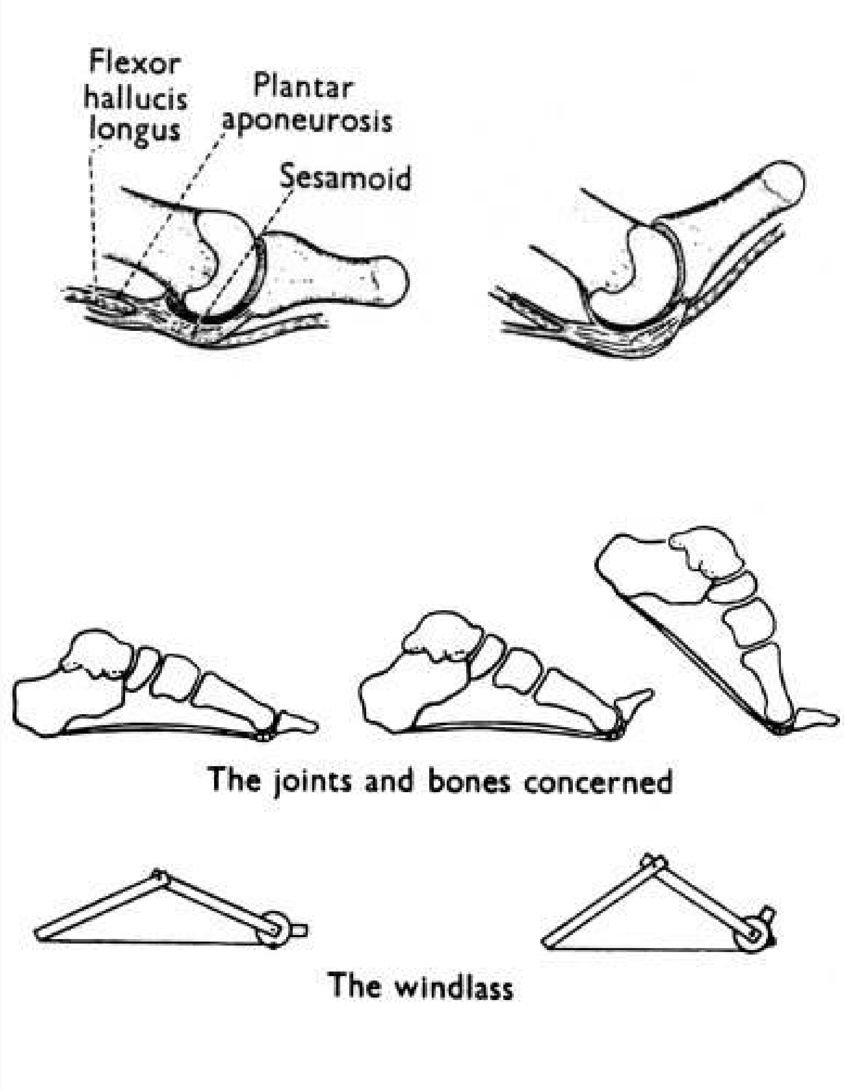
Leg rotates laterally (externally)

Tight band appears in the region of the plantar aponeurosis

IMPORTANCE OF THE PLANTAR APONEUROSIS

HICKS 1954

His diagrams show
plantar aponeurosis attached to plantar plate and demonstrate the windlass and reversed windlass mechanisms



IMPORTANCE OF THE PLANTAR APONEUROSIS

Windlass mechanism

Toes dorsiflexed

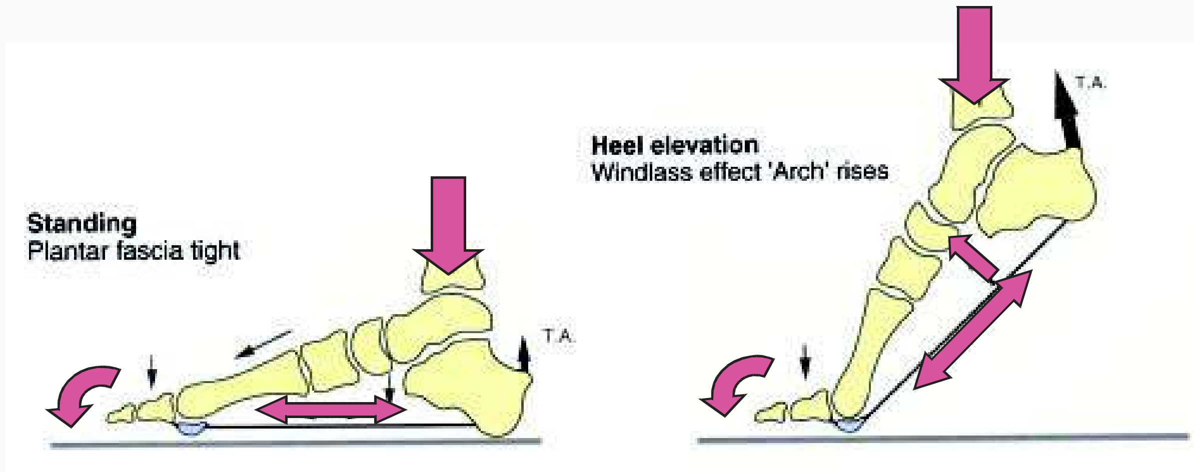
Plantar aponeurosis effectively shortens

Longitudinal 'arch' rises

- Greater effect from great toe – larger MT head pulley

IMPORTANCE OF THE PLANTAR APONEUROSIS

Windlass mechanism
in reverse



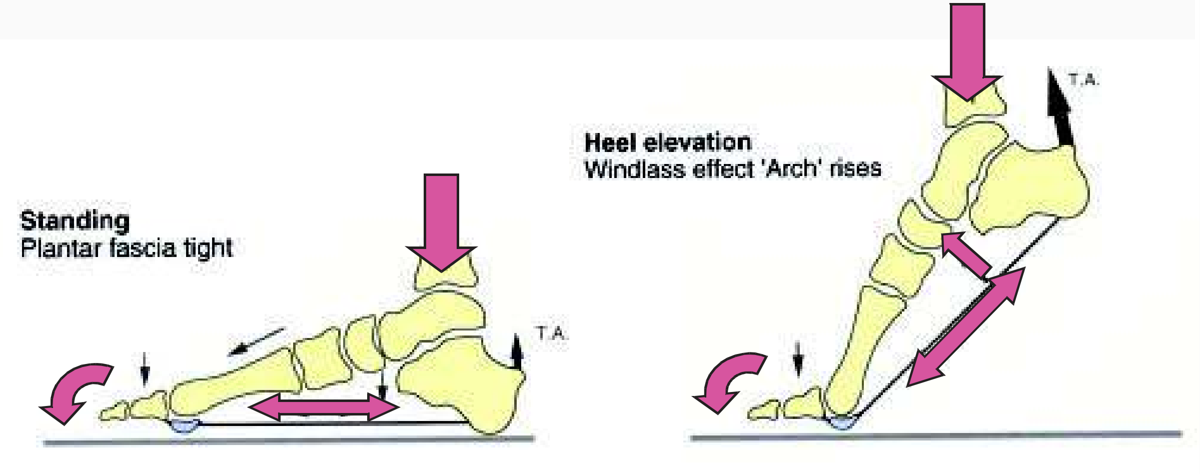
Load-bearing foot structure flattens/lengthens
Aponeurosis tightens
Toes plantar-flex against ground

Toes remain plantar-flexed with heel elevation

IMPORTANCE OF THE PLANTAR APONEUROSIS

Windlass mechanism

in reverse



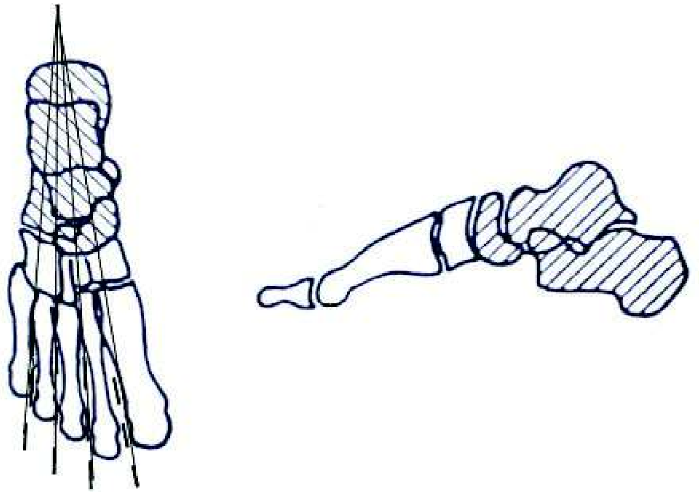
Load-bearing foot structure flattens/lengthens

Aponeurosis tightens

Toes plantar-flex against ground

Toes remain plantar-flexed with heel elevation

Each of the 5 MT rays form independent 'bow-string beam' structures

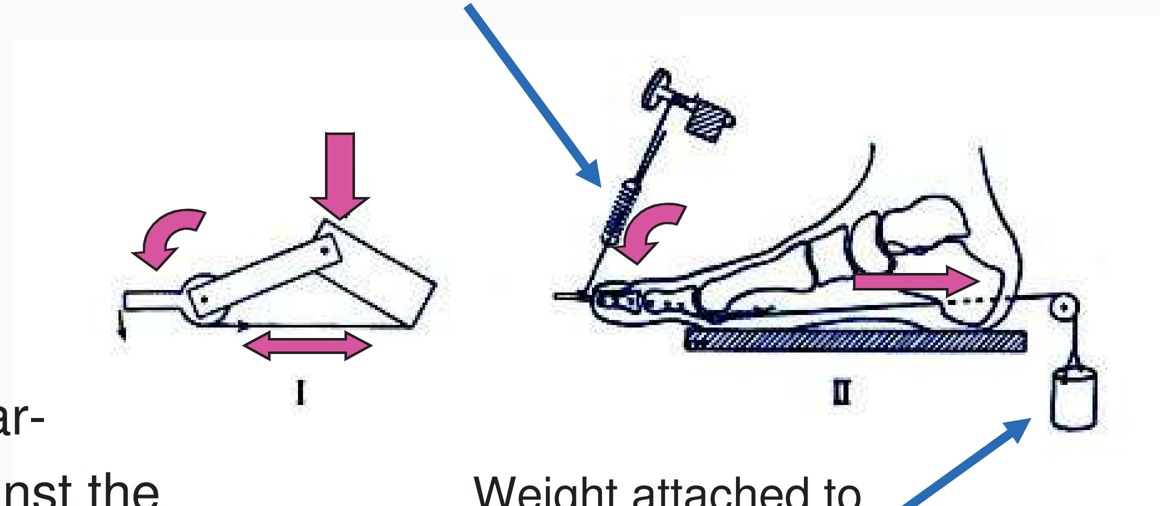


12

IMPORTANCE OF THE PLANTAR APONEUROSIS

Spring balance to measure downward force of the toe

Windlass mechanism in reverse



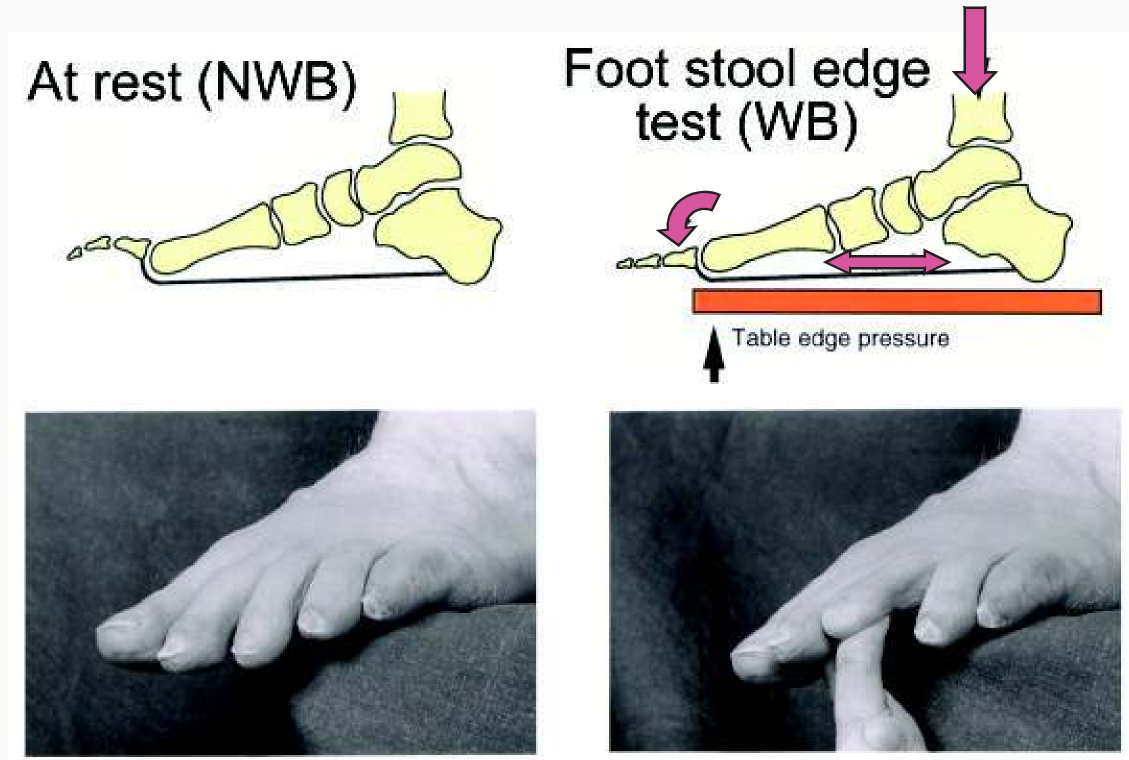
Weight attached to plantar aponeurosis

Hicks demonstrated that plantar-flexion force of each toe against the ground was proportional to the tension in its plantar aponeurosis process

13

IMPORTANCE OF THE PLANTAR APONEUROSIS

Reversed windlass mechanism can be tested (demonstrated) by 'foot-stool edge weight bearing test'



Toes mobile

Proximal phalanx resists passive dorsi-flexion

THE TRANSVERSE TIE-BAR
(PLANTAR PLATES AND INTERVENING DTMLs)

In 1992, at the Anatomy School,
Newcastle upon Tyne

A very strong continuous structure

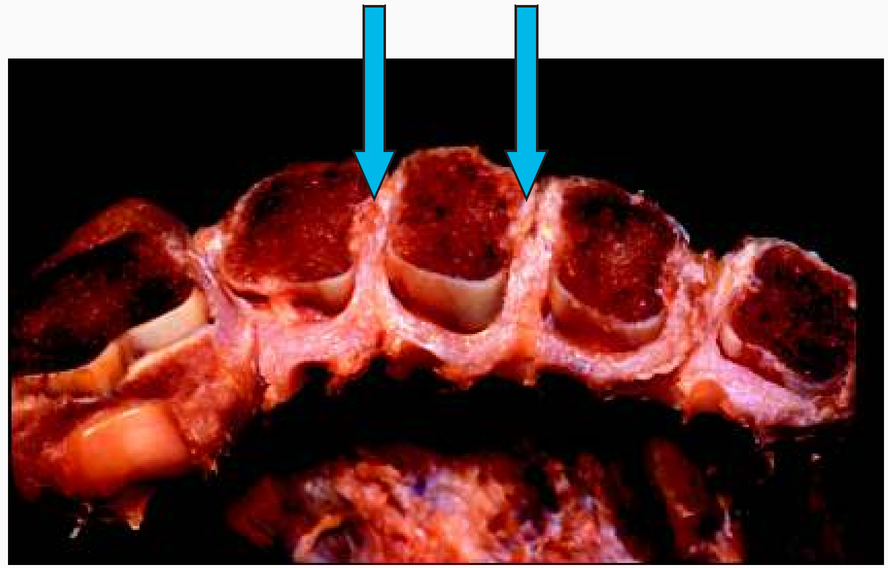
A dissection demonstrating
continuity of MTPJ plantar plates
and deep transverse MT ligaments

Capable of controlling splay of
metatarsal heads

THE TRANSVERSE TIE-BAR
(PLANTAR PLATES AND INTERVENING DTMLs)

In 1992, at the Anatomy School, Newcastle upon Tyne

A dissection demonstrating continuity of MTPJ plantar plates and deep transverse MT ligaments

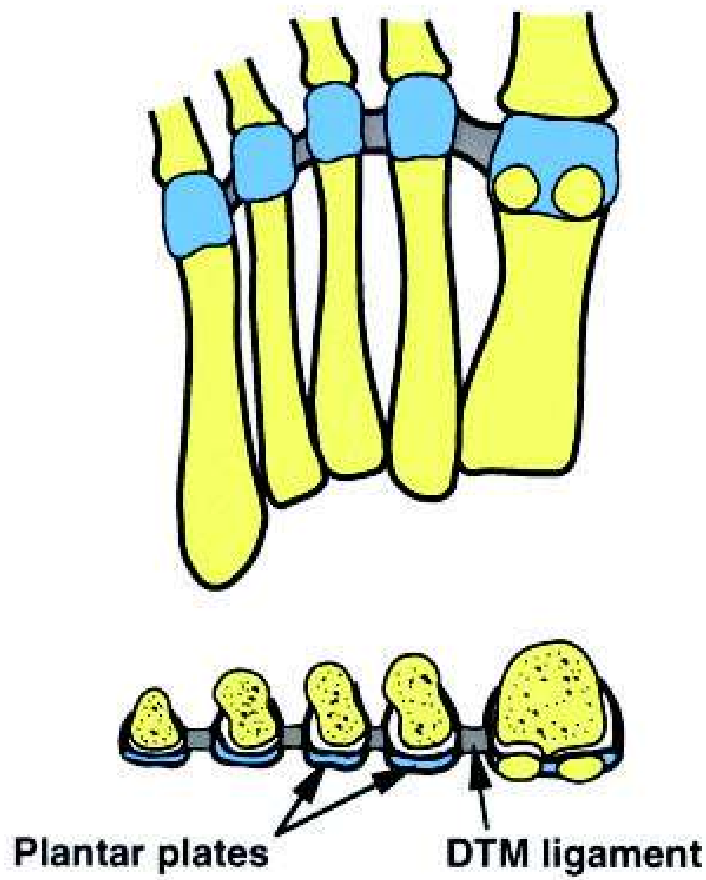


Plantar plates attached to MT heads by collateral ligaments

THE TRANSVERSE TIE-BAR
(PLANTAR PLATES AND INTERVENING DTMLs)

The plantar plates anchored to their MT heads by collateral ligaments

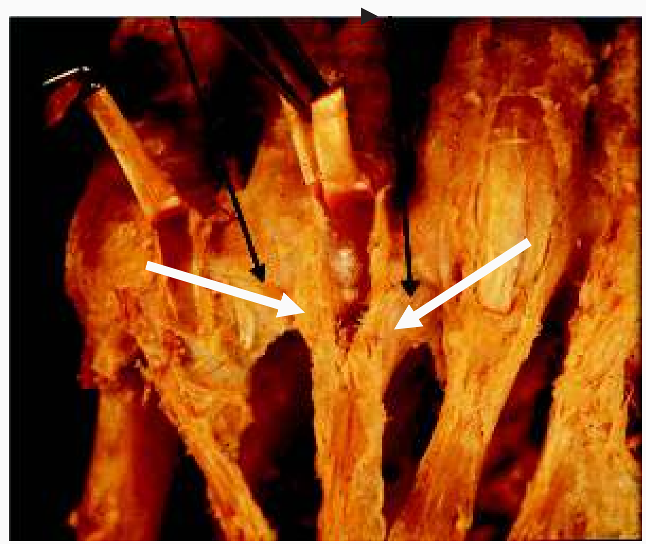
Transverse tie-bar is able to control splay between neighbouring MTs as well as across full width of forefoot



THE DEEPER LAYER
OF THE PLANTAR APONEUROSIS

Dissections of
the plantar aponeurosis
(deep layer)

Each digital process divides into two extensions which pass around flexor tendons to insert into the plantar plates
(white arrows)



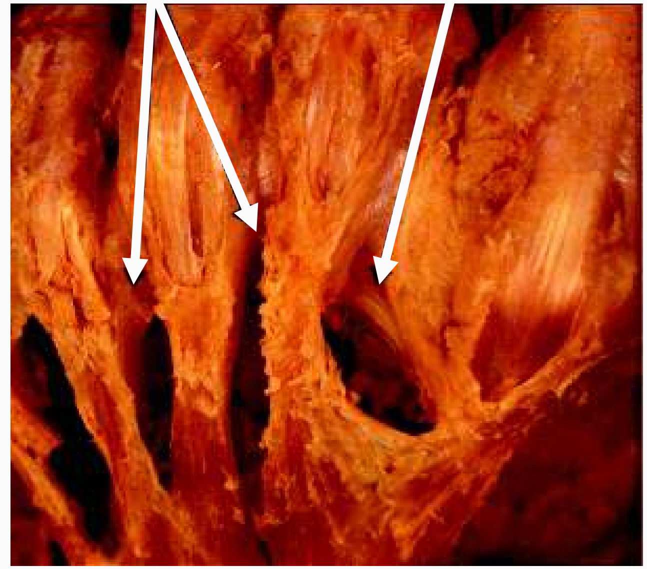
THE DEEPER LAYER OF THE PLANTAR APONEUROSIS

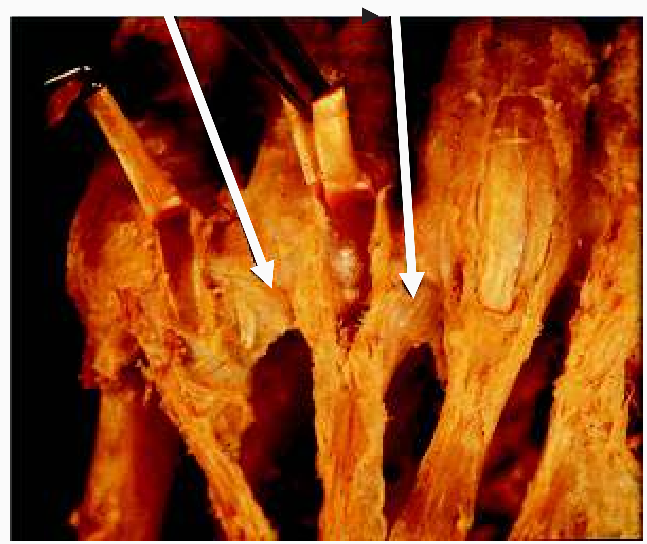
Dissections of
the plantar aponeurosis
(deep layer)

Each digital process divides into two extensions which pass around flexor tendons to insert into the plantar plates

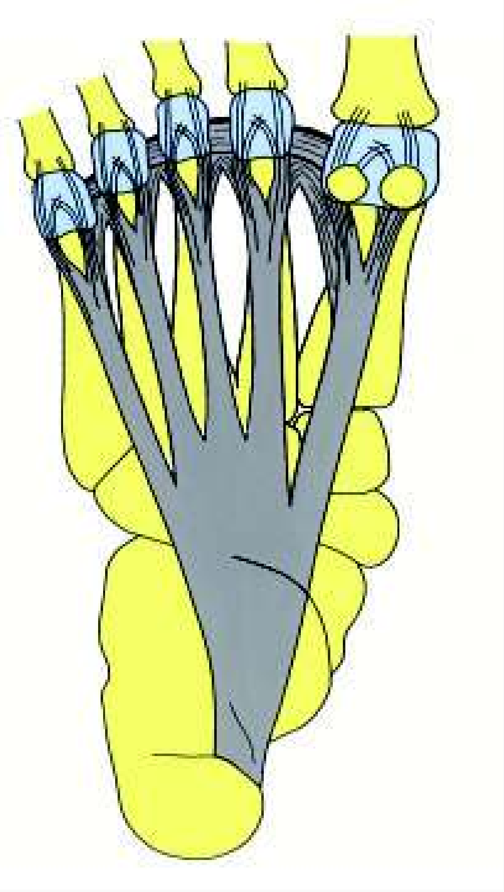
and

deep transverse metatarsal ligaments





THE DEEPER LAYER OF THE PLANTAR APONEUROSIS



Plantar aponeurosis forms

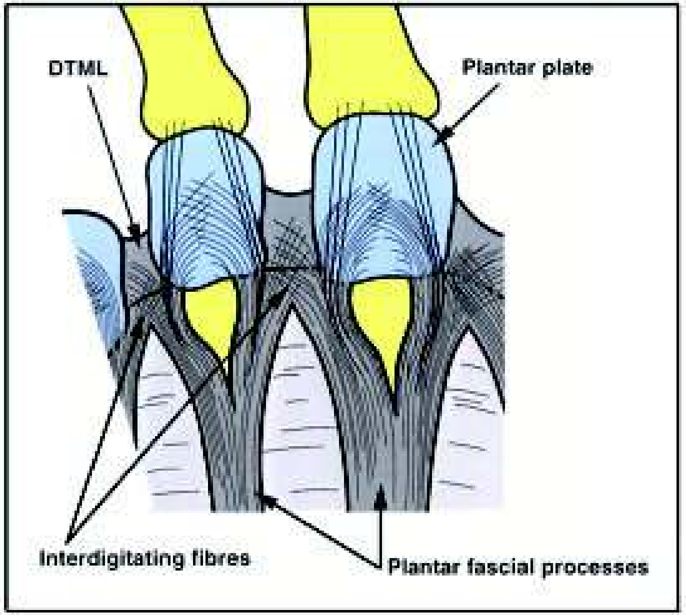
a longitudinal tie-bar

which is

inserted into

the full width of

the transverse tie-bar



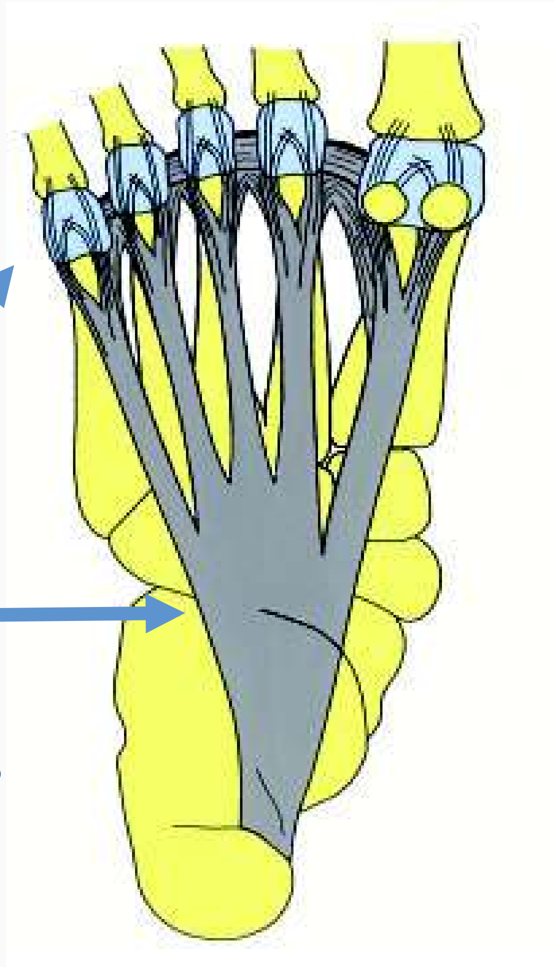
A MULTI-SEGMENTAL TIE-BAR SYSTEM

A Basic Foot Control Mechanism

The Multi-segmental Tie-bar System

(a) Transverse (plantar plates and DTMLs)

(b) Longitudinal (plantar aponeurosis)



A ligamentous/aponeurotic structure that supports foot skeleton, controls forefoot splay and toe plantar-flexion when its MT ray is load-bearing

PLANTAR APONEUROSIS AND PLANTAR PAD

Plantar plate beneath MT head

Plantar aponeurosis

Black arrow indicates plantar aponeurosis process separating from superficial layer proximal to MTPJ to insert into plantar plate

PLANTAR APONEUROSIS AND PLANTAR PAD

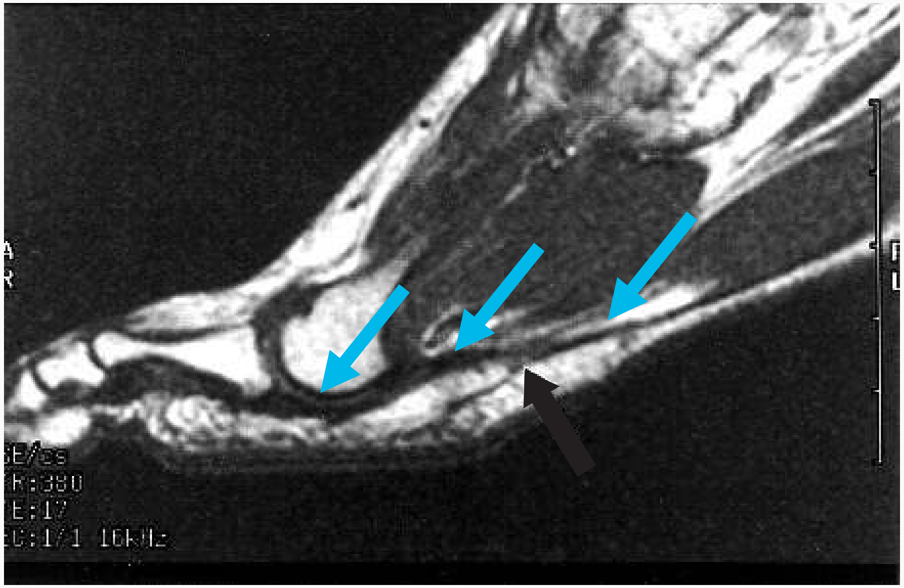
Plantar plate beneath MT head

Plantar aponeurosis

Black arrow indicates plantar aponeurosis process separating from superficial layer proximal to MTPJ to insert into plantar plate

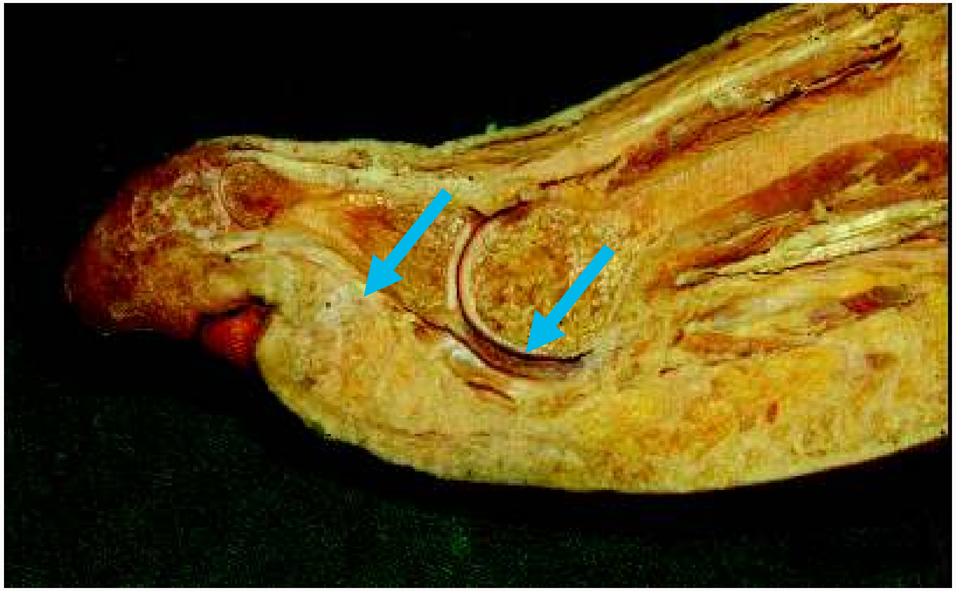
Plantar pad formed between the two layers of the aponeurosis beneath MT heads and the proximal phalanges

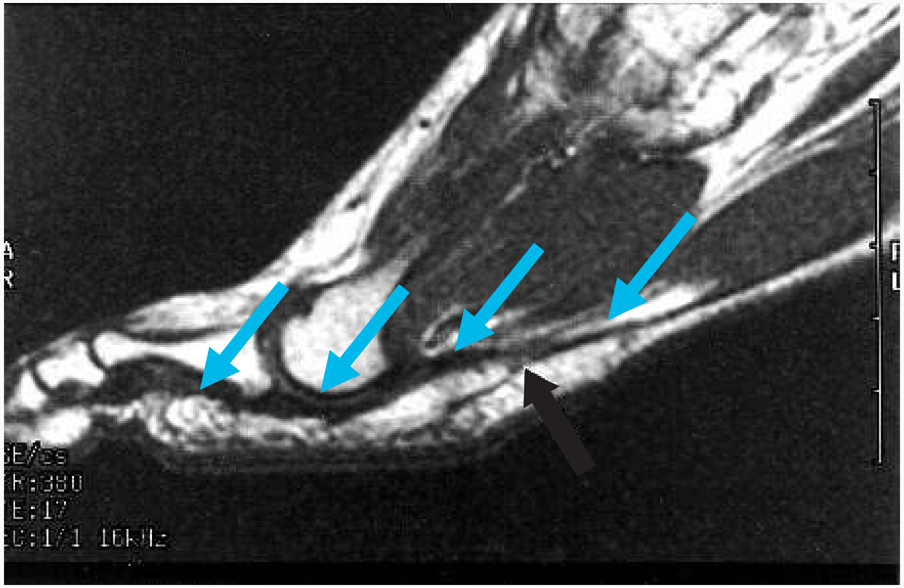
PLANTAR APONEUROSIS AND PLANTAR PAD



Plantar aponeurosis process continuous with MTPJ plantar plate

PLANTAR APONEUROSIS AND PLANTAR PAD

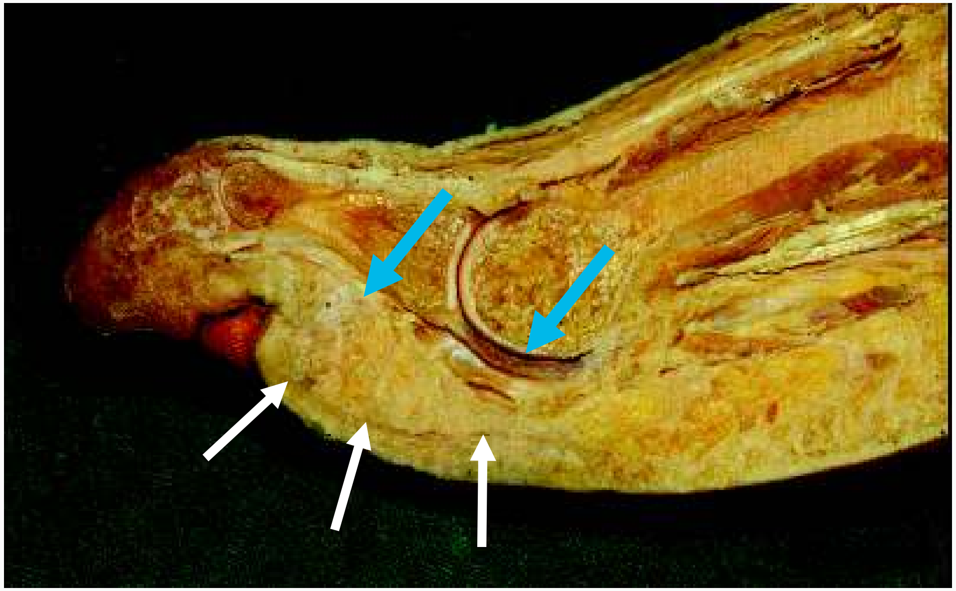


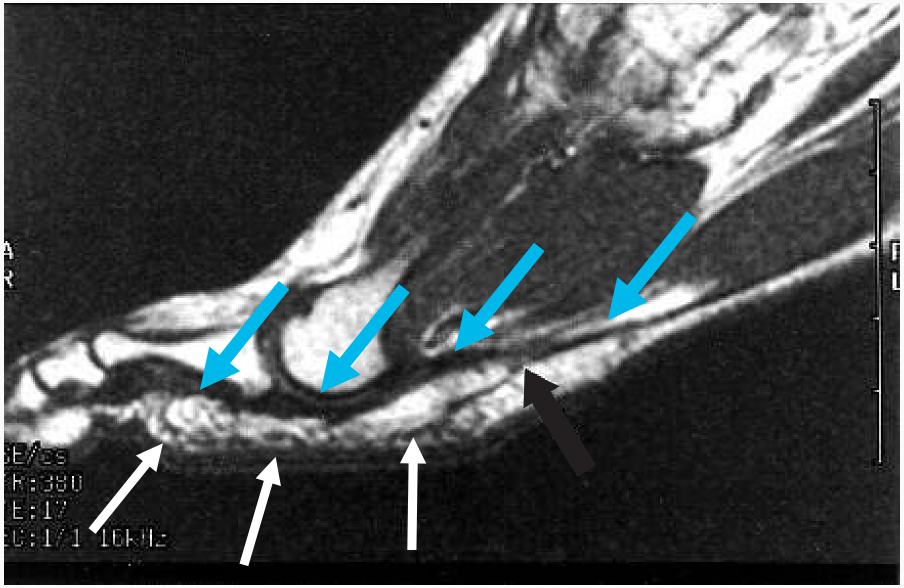


Plantar aponeurosis process continuous with MTPJ plantar plate

Plantar pad lies beneath deep layer of the plantar aponeurosis, plantar plate, and proximal phalanx (& flexor tendon sheath)

PLANTAR APONEUROSIS AND PLANTAR PAD



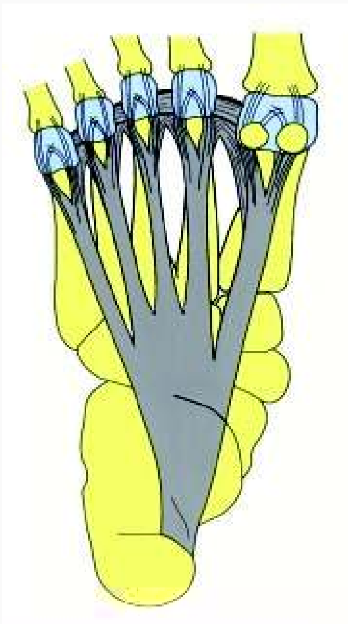


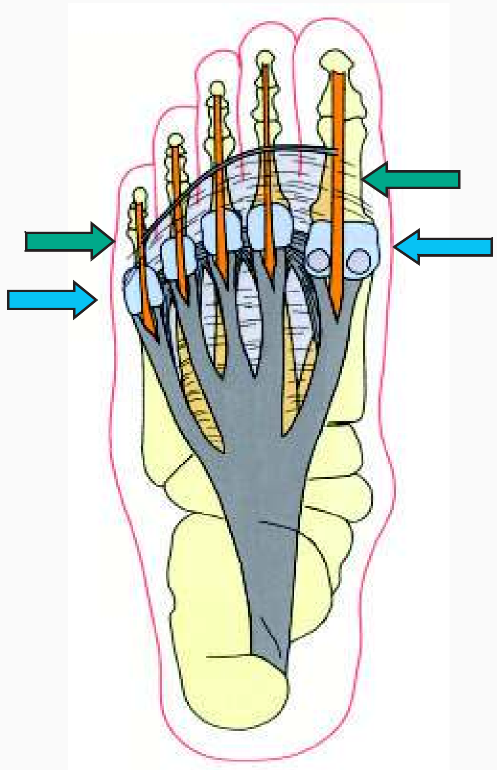
Plantar aponeurosis process continuous with MTPJ plantar plate

Plantar pad lies beneath deep layer of the plantar aponeurosis, plantar plate, and proximal phalanx (& flexor tendon sheath)

Superficial layer extends from level of MT neck to neck of proximal phalanx

PLANTAR APONEUROSIS AND PLANTAR PAD

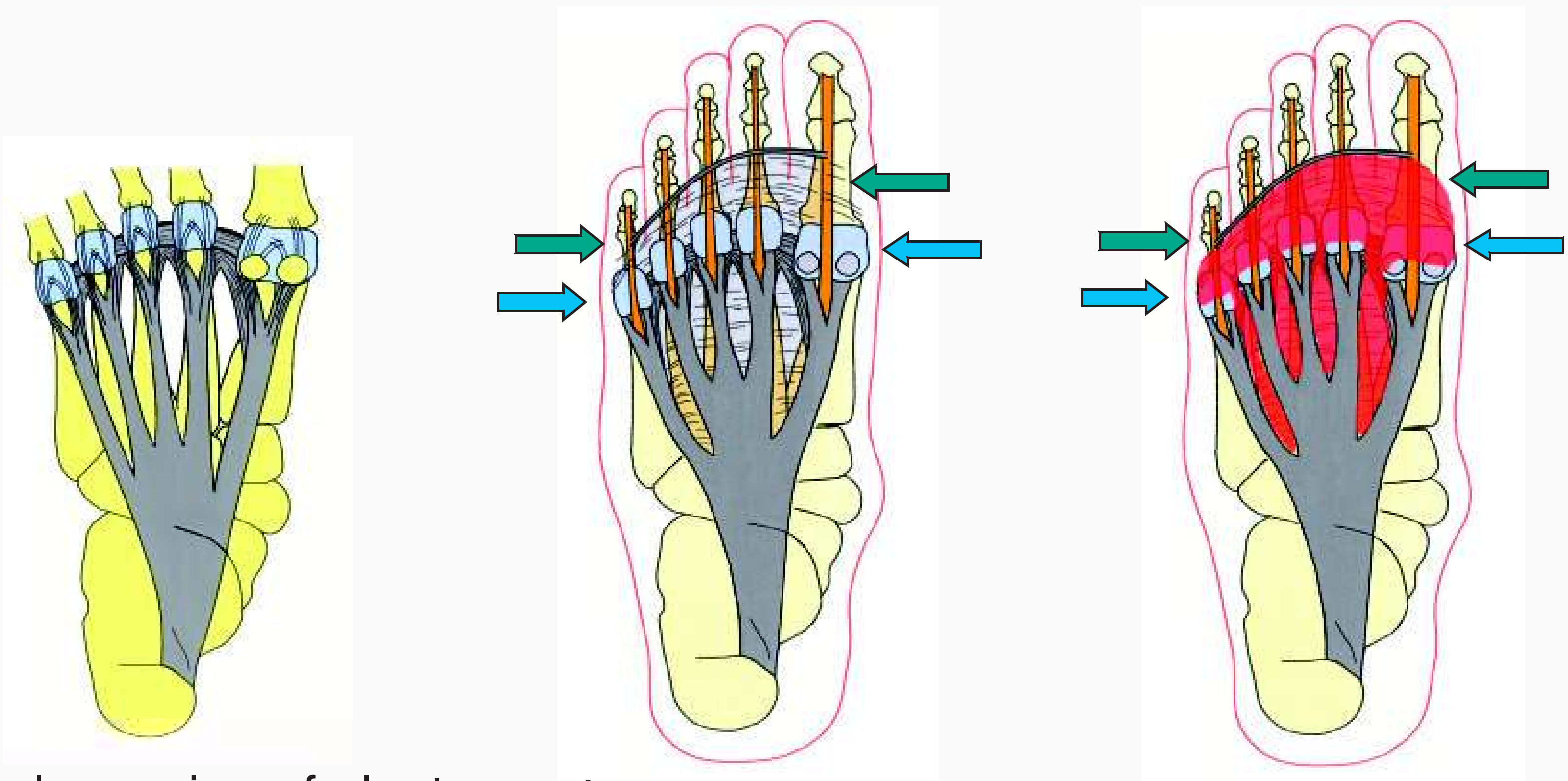




Dorsal covering of plantar pad:

- Flexor tendon sheaths of proximal phalanges and intervening mooring ligaments
- Plantar plates of MTP joints and deep transverse metatarsal ligaments

PLANTAR APONEUROSIS AND PLANTAR PAD



Dorsal covering of plantar pad:

Flexor tendon sheaths of proximal phalanges and intervening mooring ligaments

Plantar plates of MTP joints and deep transverse metatarsal ligaments

Areas of separation of the layers of aponeurosis

Forming plantar pad and ‘fat bodies’ – they are in continuity opposite toe clefts

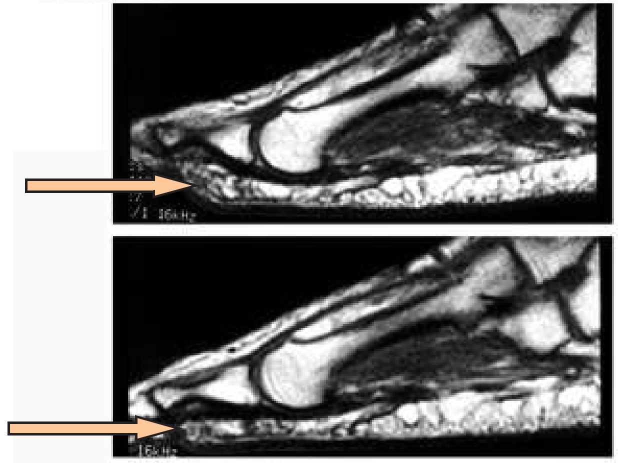
PLANTAR APONEUROSIS AND PLANTAR PAD

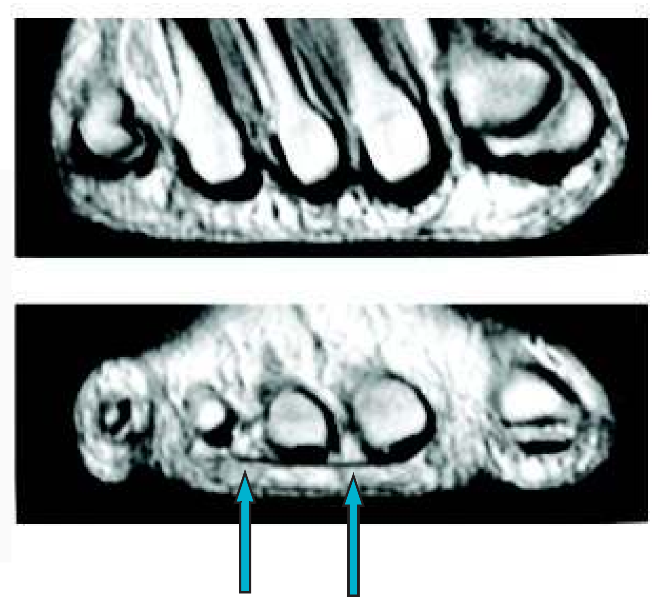
MRI scan studies have shown that the plantar pad lies between the deep and superficial layers of the plantar aponeurosis

Forms a continuous structure across forefoot beneath MTP joints and DTMLs,

and

Beneath proximal phalanges and mooring ligaments (only 2 shown)





PLANTAR PAD MECHANISM

MRI SCAN SERIES SIMULATING FOREFOOT LOAD-BEARING

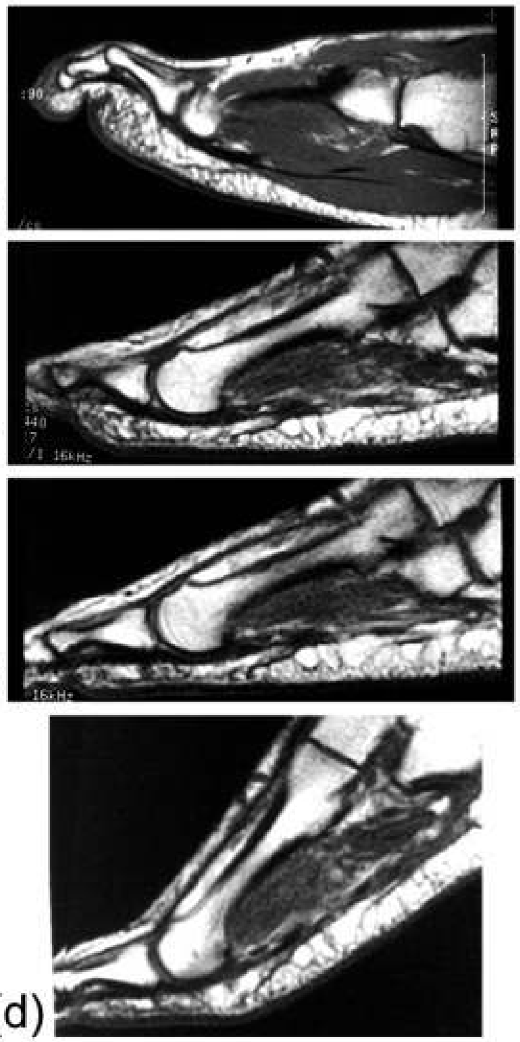
SAGITTAL

Heel strike

Foot flat

Early heel elevation

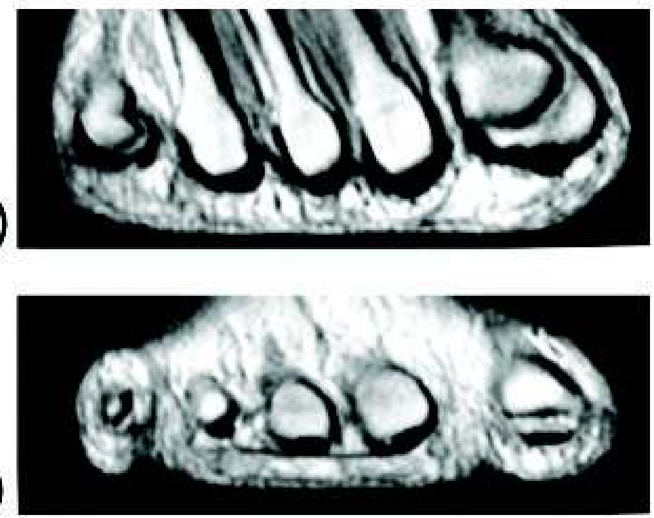
High heel elevation



(a)
(b)
(c)
(d)

CORONAL

Through central 3 MT heads

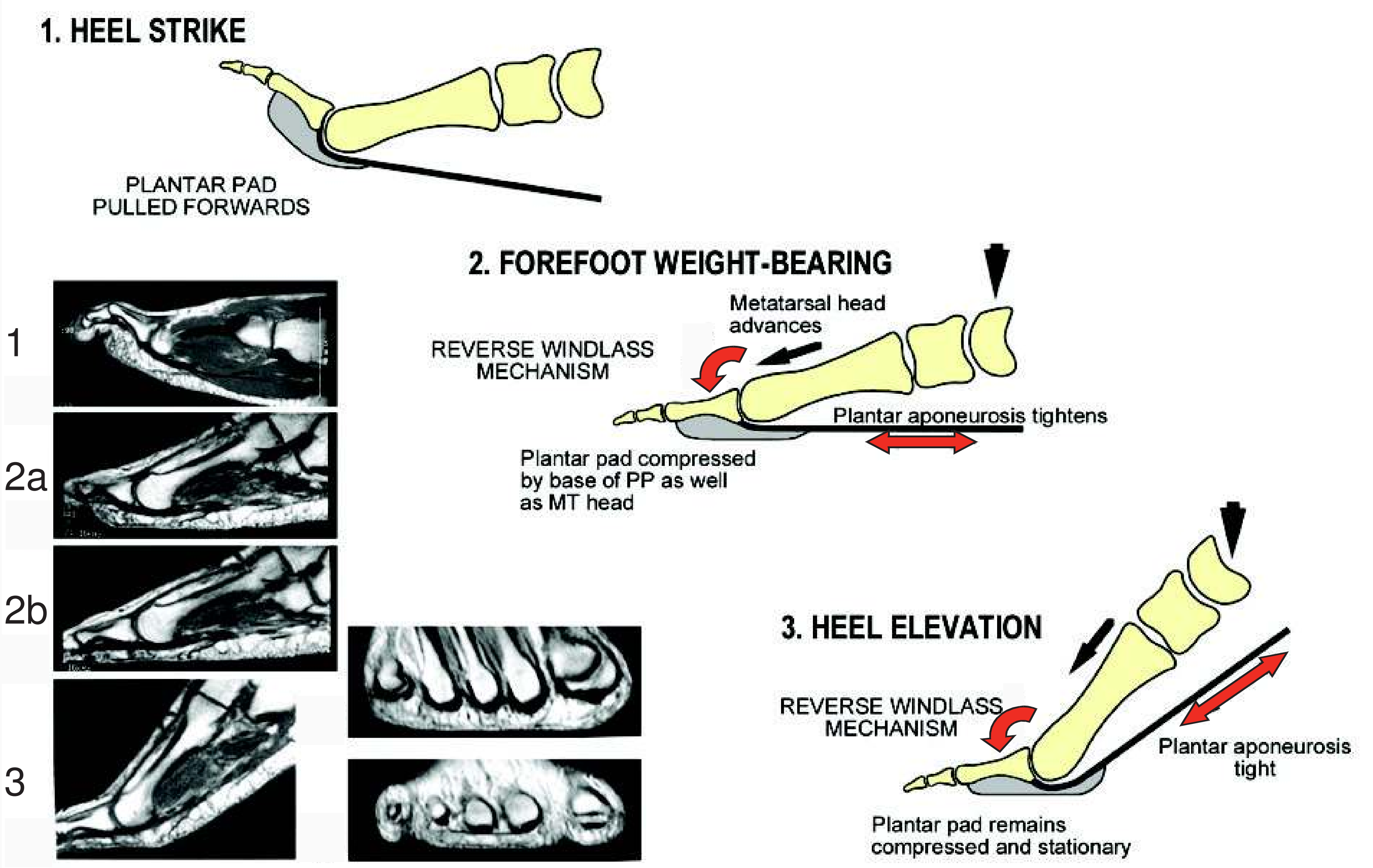


(e)
(f)

Through bases of proximal phalanges of central toes

PLANTAR PAD MECHANISM

MRI SCAN SERIES SIMULATING FOREFOOT LOAD-BEARING



PLANTAR PAD MECHANISM
CINE-RADIOGRAPHIC STUDY

Plantar pad and the toes of the weight-bearing MT rays remain stationary as heel elevation takes place

Note toes remain flexed against the ground with IP joints extended
Toe pulps and plantar pad provide a supporting 'platform' when heel elevated

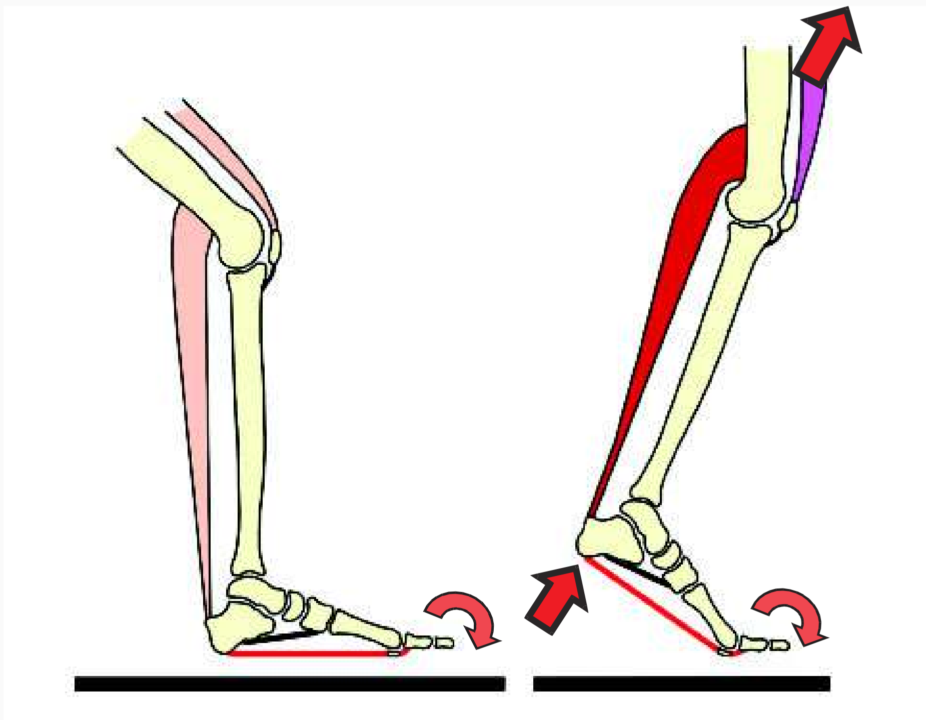
A TWO-PART PROPULSIVE MECHANISM

UNIQUE TO THE HUMAN FOOT

GASTROCNEMIUS (+ SOLEUS) AND THE

PLANTAR APONEUROSIS

A 'two-part sling-spring' mechanism

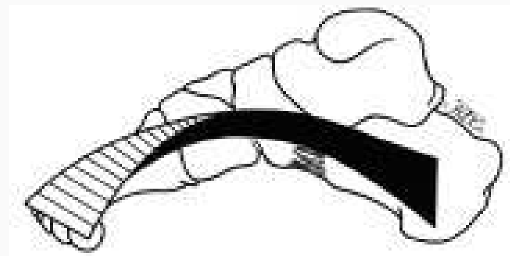


The reversed windlass mechanism

Plantar aponeurosis essential for normal toe function, structural support of the foot and propulsion

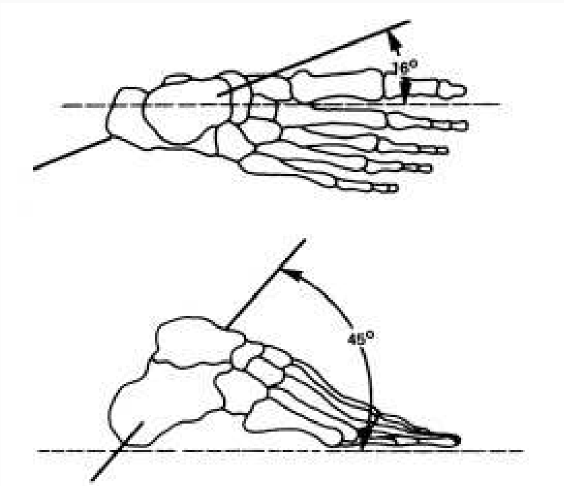
FOOT STABILITY, MOVEMENT AND CONTROL
PREVIOUS SUGGESTED MECHANISMS

(i) The foot has been regarded as a twisted plate (lamina pedis)

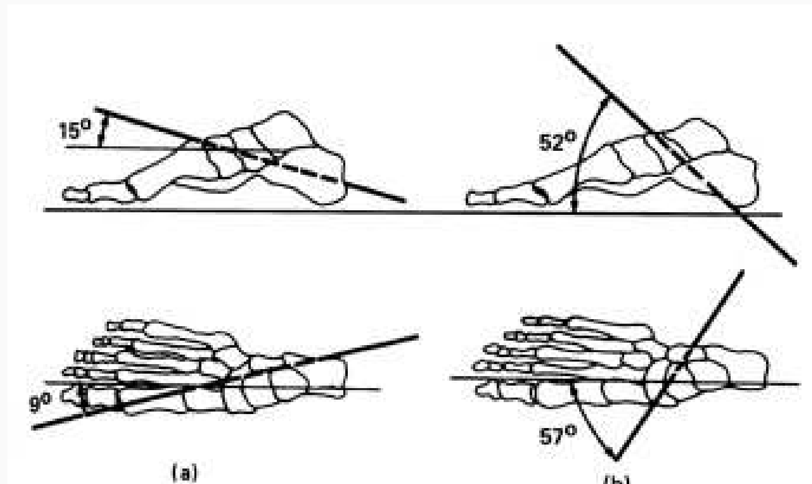


MacConaill (1945); MacConaill and Basmajian (1969)

(ii) As having discrete axes of motion



Manter (1941)



Manter (1941)

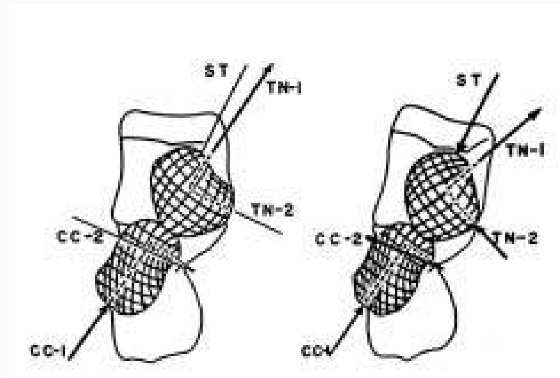
Sub-talar joint:

and longitudinal and transverse axes of transverse tarsal joints

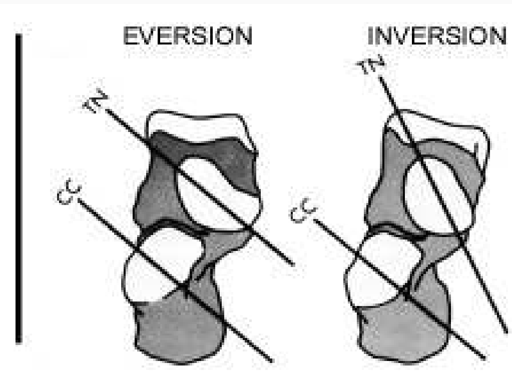
FOOT STABILITY, MOVEMENT AND CONTROL

PREVIOUS SUGGESTED MECHANISMS

(iii) The relative alignment of axes transverse tarsal joints thought to control mid-foot stability

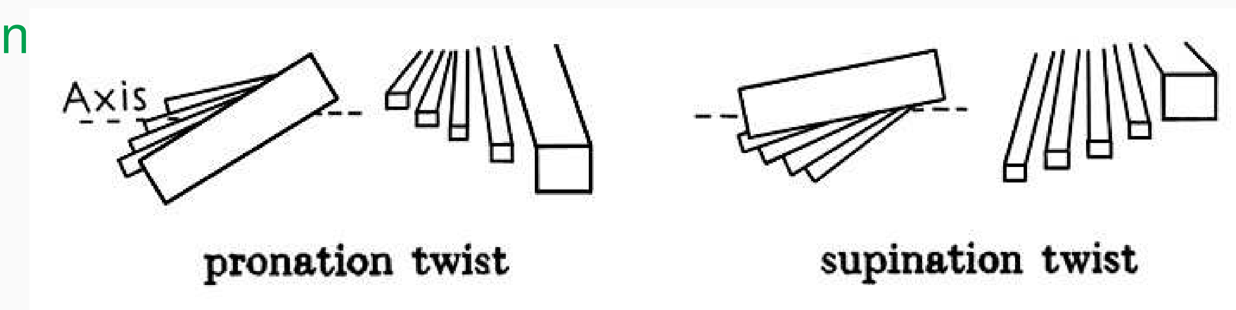


Elftman (1960)

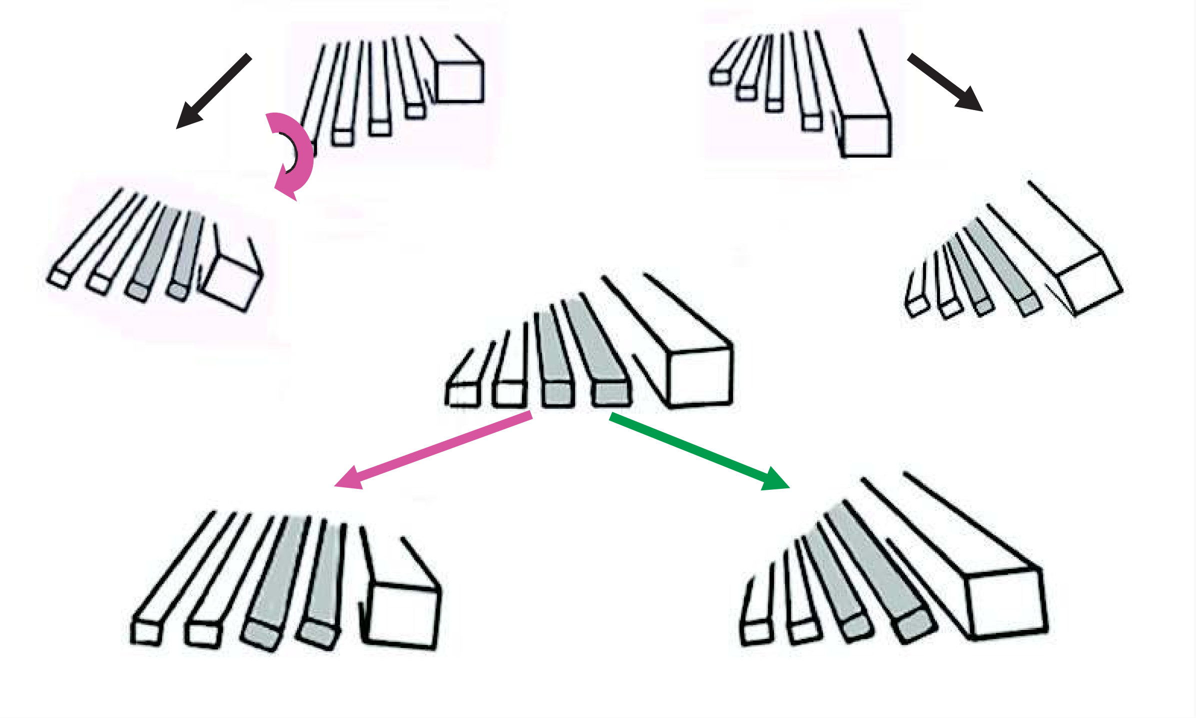


Mann (1993)

(iv) The ‘pronation/supination twist’ mechanism of the metatarsals



Hicks (1953)



FOOT STABILITY, MOVEMENT AND CONTROL

PREVIOUS SUGGESTED MECHANISMS

COORDINATED INTER-TARSAL MOVEMENTS

V: Huson stressed the difference between ‘open’ and ‘closed chain’ motion

‘Open chain’ movement

Foot free and inter-tarsal joint movements unrestricted as foot ‘everted’ and ‘inverted’

‘Closed chain’ movement

Inter-tarsal joint movements constrained
Talar dome & forefoot remain horizontal as mid-foot motion occurs

V: Huson stressed the difference between ‘open’ and ‘closed chain’ motion

‘Open chain’ movement

‘Closed chain’ movement

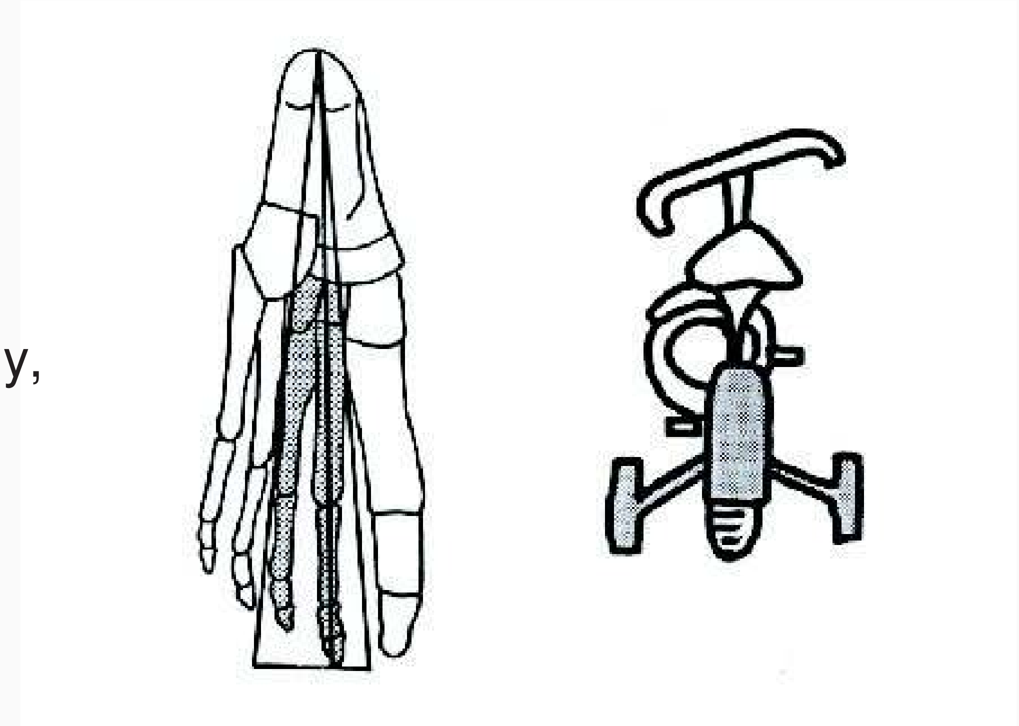
Huson also suggested that assessing coordinated tarsal joint movements be investigated in relation to joint structusis

FOOT STABILITY, MOVEMENT AND CONTROL

PREVIOUS SUGGESTED MECHANISMS

(VI) That 2nd and 3rd metatarsals form a central stable forefoot segment supported by medial and lateral 'pallettes' (the first MT ray medially, and the 4th and 5th laterally) –

Rather like child's bicycle fitted with stabilisers



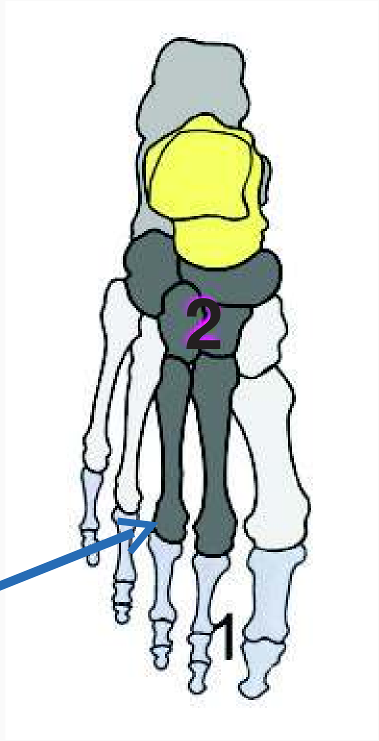
De Doncker and Kowalski (1970)

FOOT STABILITY, MOVEMENT AND CONTROL
PREVIOUS SUGGESTED MECHANISMS

Our studies showed there is very little lateral movement between the navicular, cuboid, lateral and middle cuneiforms, and 2nd & 3rd metatarsals

Then regarded as a larger

Central stable forefoot segment



FOOT STABILITY, MOVEMENT AND CONTROL

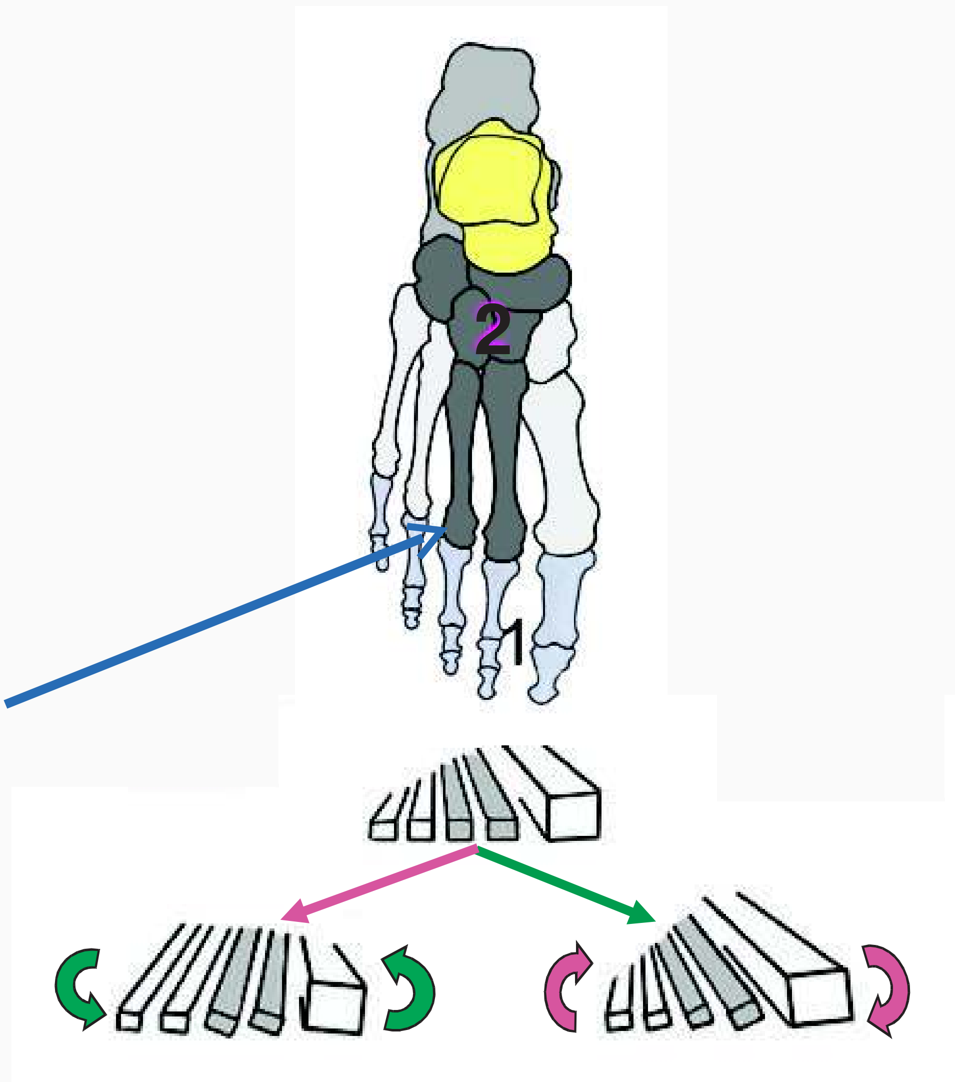
PREVIOUS SUGGESTED MECHANISMS

Our studies showed there is very little lateral movement between the navicular, cuboid, lateral and middle cuneiforms, and 2nd & 3rd metatarsals

Then regarded as a larger

Central stable forefoot segment

The 1st and 4th and 5th MTs able to perform Hicks' 'forefoot twist' around the central segment when mid-foot pronates and supinates



FOOT STABILITY, MOVEMENT AND CONTROL
THE NEW CONCEPT

Gradual realisation that talus, calcaneus and forefoot segment form strong longitudinal central beam structure

Anteriorly the 'central 3-part bow-string beam' has medial and lateral supporting metatarsals

THE FOUR PART FOOT

FOOT STABILITY, MOVEMENT AND CONTROL
THE NEW CONCEPT

Gradual realisation that talus, calcaneus and forefoot segment form strong longitudinal central beam structure

Anteriorly the 'central 3-part bow-string beam' has medial and lateral supporting metatarsals

Longitudinal beam supported by three layers of plantar ligaments:

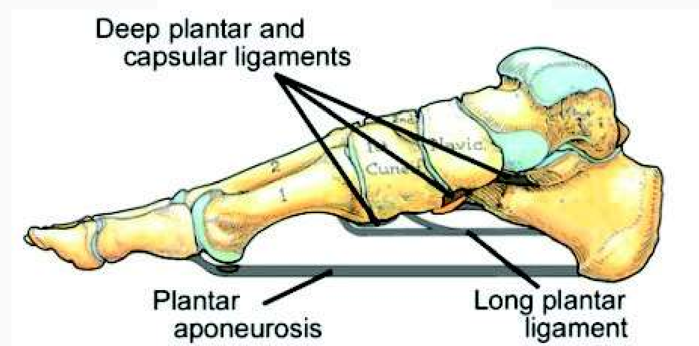
Deep plantar/capsular

Long plantar

Plantar aponeurosis

Toes with their windlass mechanisms provide the 4th part of foot

THE FOUR PART FOOT



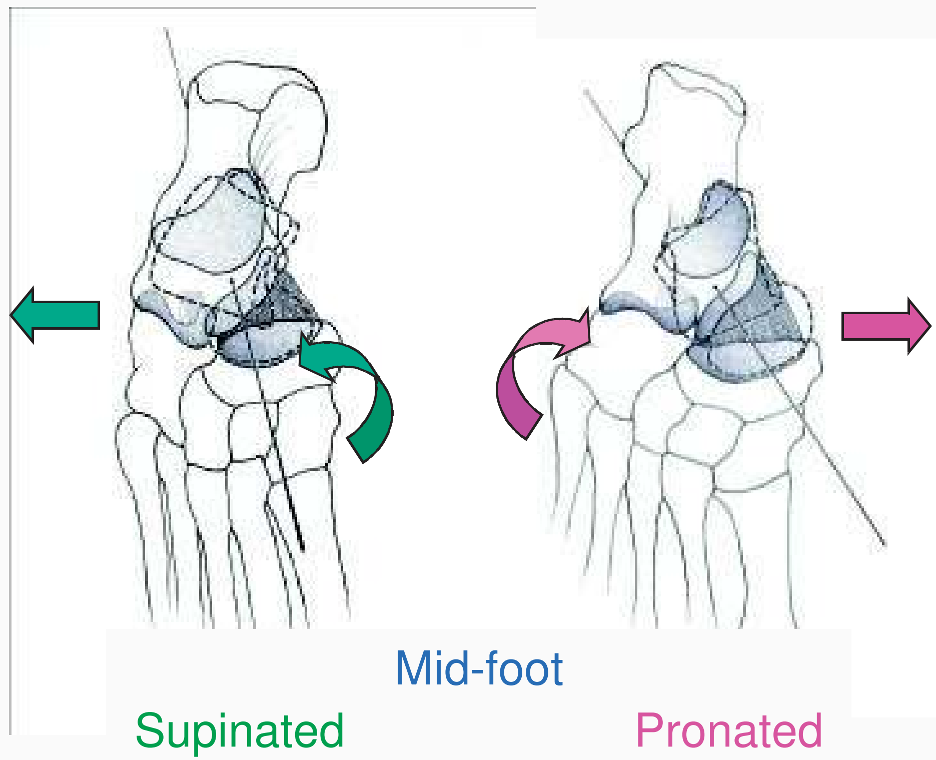
FOOT STABILITY, MOVEMENT AND CONTROL

LATERAL SWING MOTION AT TRANSVERSE TARSAL JOINT

VII: A more recent observation

Lewis (1989) stressed importance of lateral swing movement at transverse tarsal joints – a feature unique to the human foot

Instead of regarding 'arch' as rising now consider primary mid-foot movement to be 'inward' and 'outward' angulation



LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS

Demonstrated with
Great toe extension test

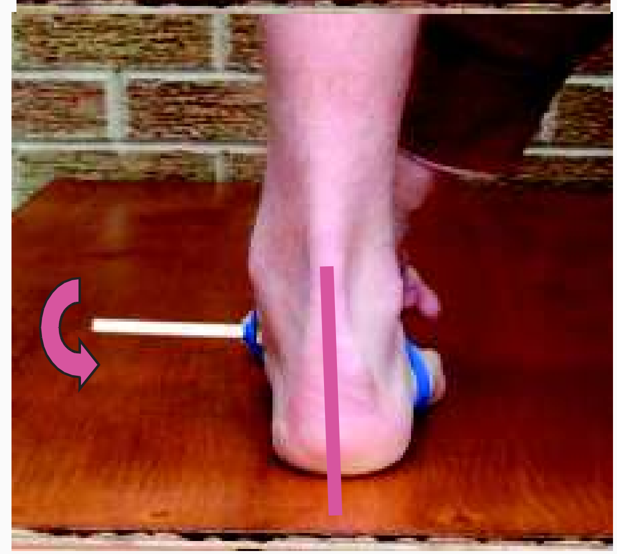
Sticks at mid-foot level
show
supination & pronation
of navicular and cuboid

LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS

Demonstrated with
Great toe extension test

Sticks at mid-foot level
show
supination & pronation
of navicular and cuboid

Posterior views show
outward and inward
swing movement at TT joint
with less
supination & pronation
of calcaneus



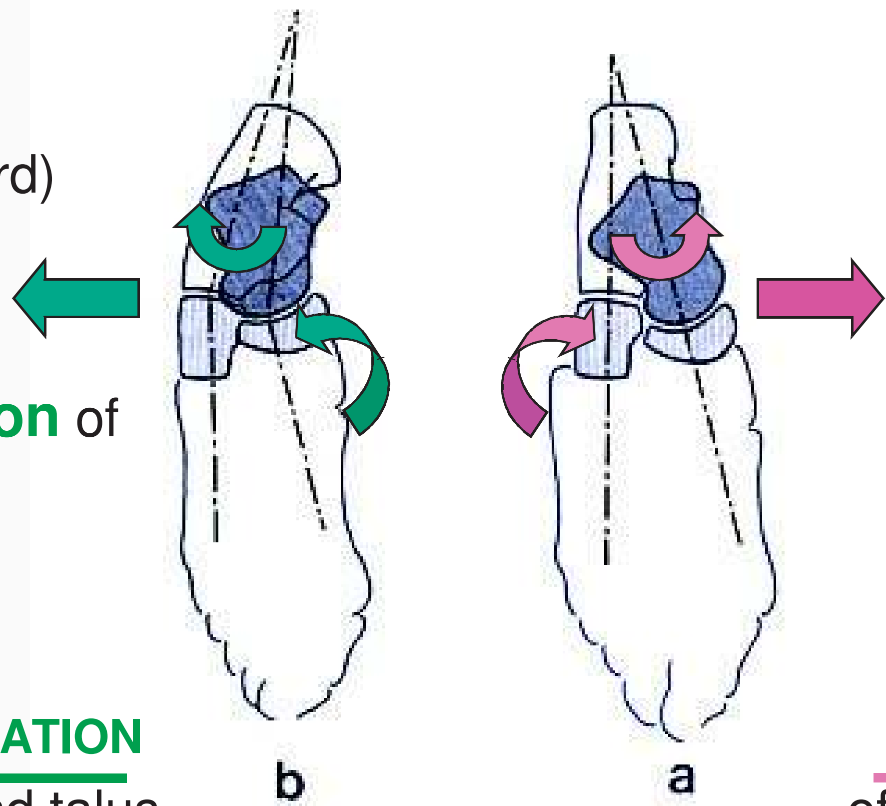
LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS

Lateral (outward) angulation

with **supination** of the mid-foot

+

EXTERNAL ROTATION
of calcaneus and talus



Medial (inward) angulation

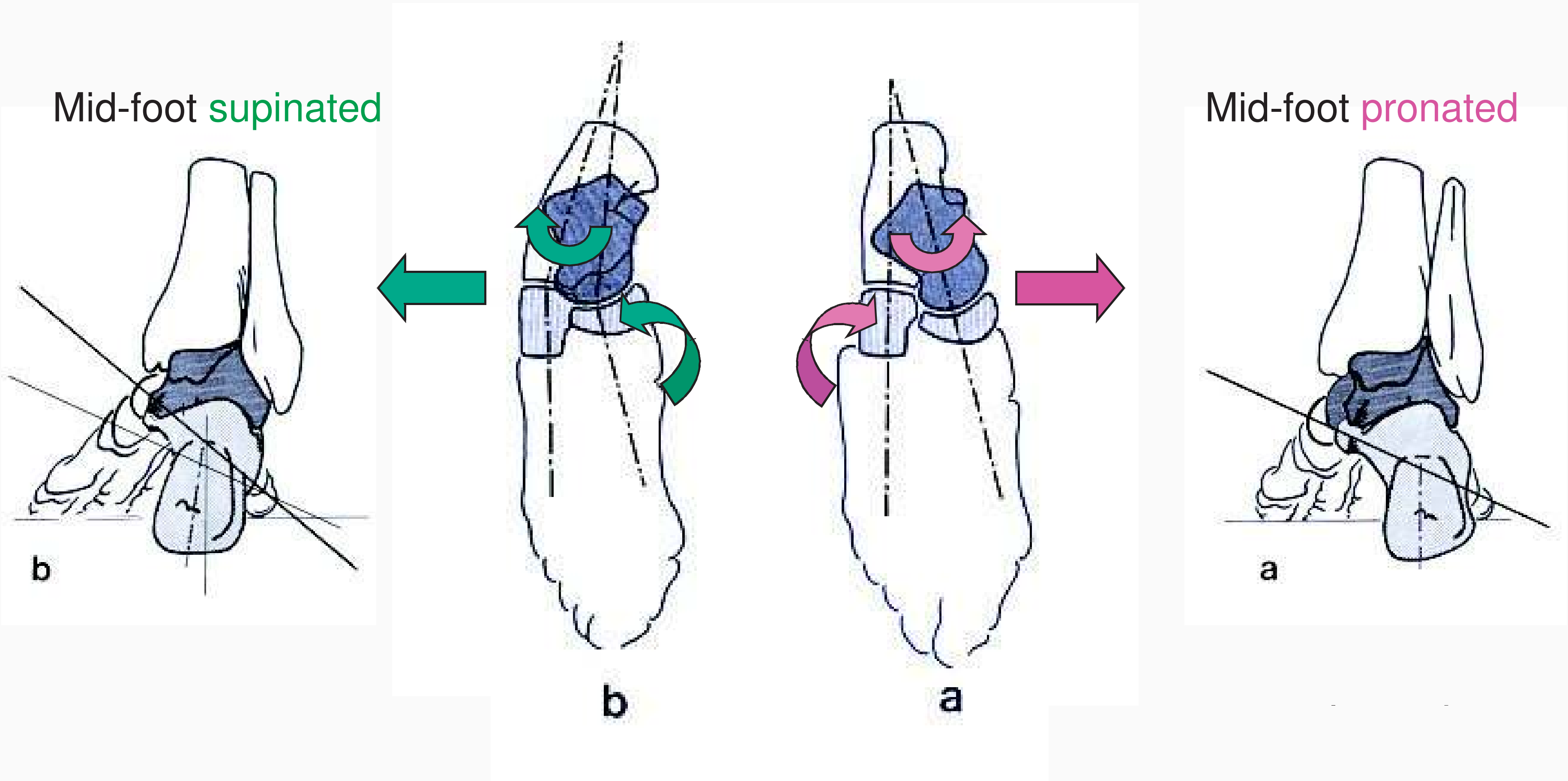
with **pronation** of the mid-foot

+

INTERNAL ROTATION
of calcaneus and talus

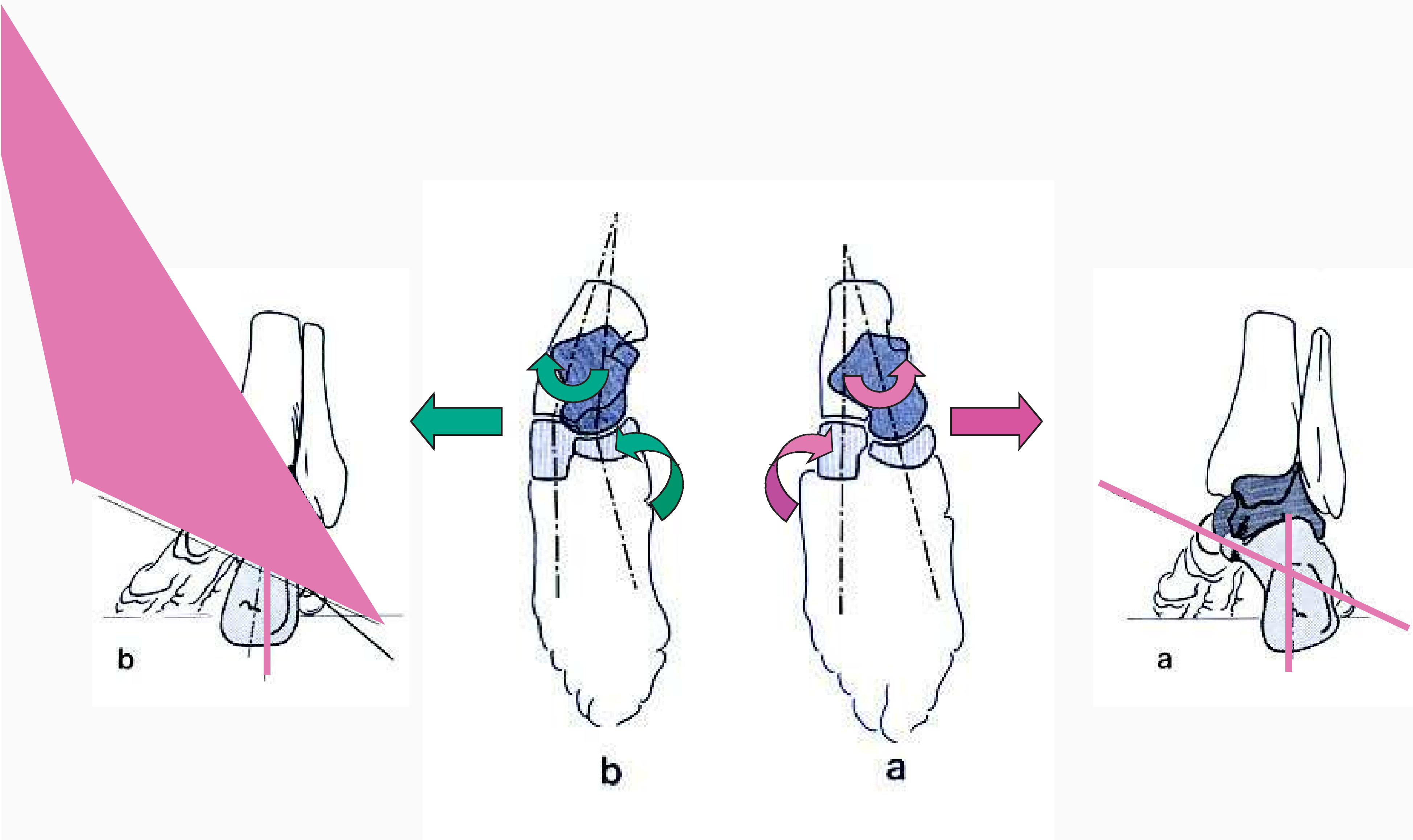
Lateral ‘swing’ movements at mid-foot level clearly demonstrated by Ambagtsheer in1978

LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS

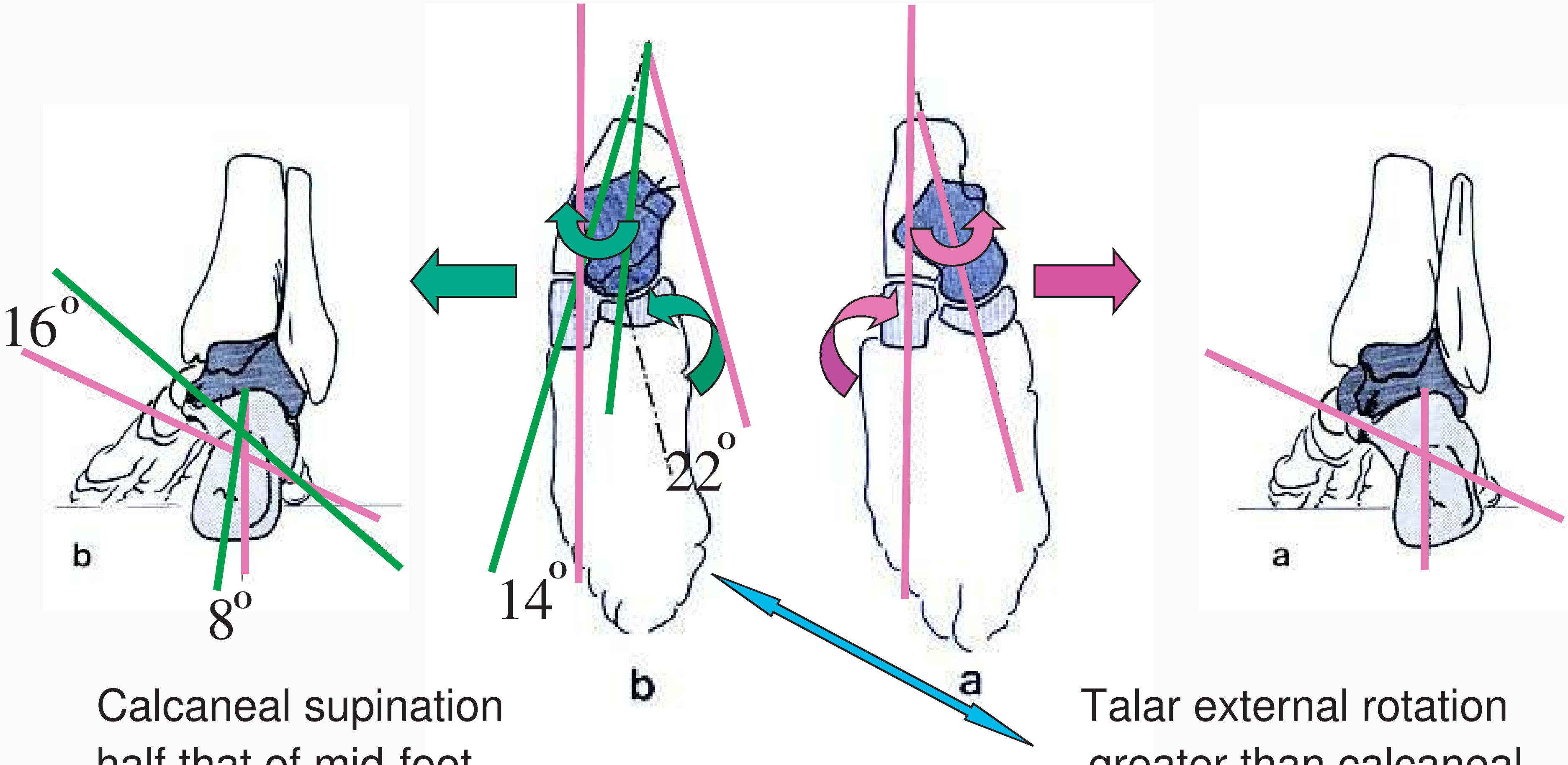


AMBAGTSHEER (1978)

Posterior views show mid-foot and calcaneal supination/pronation movements


b
b
a
a

LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS



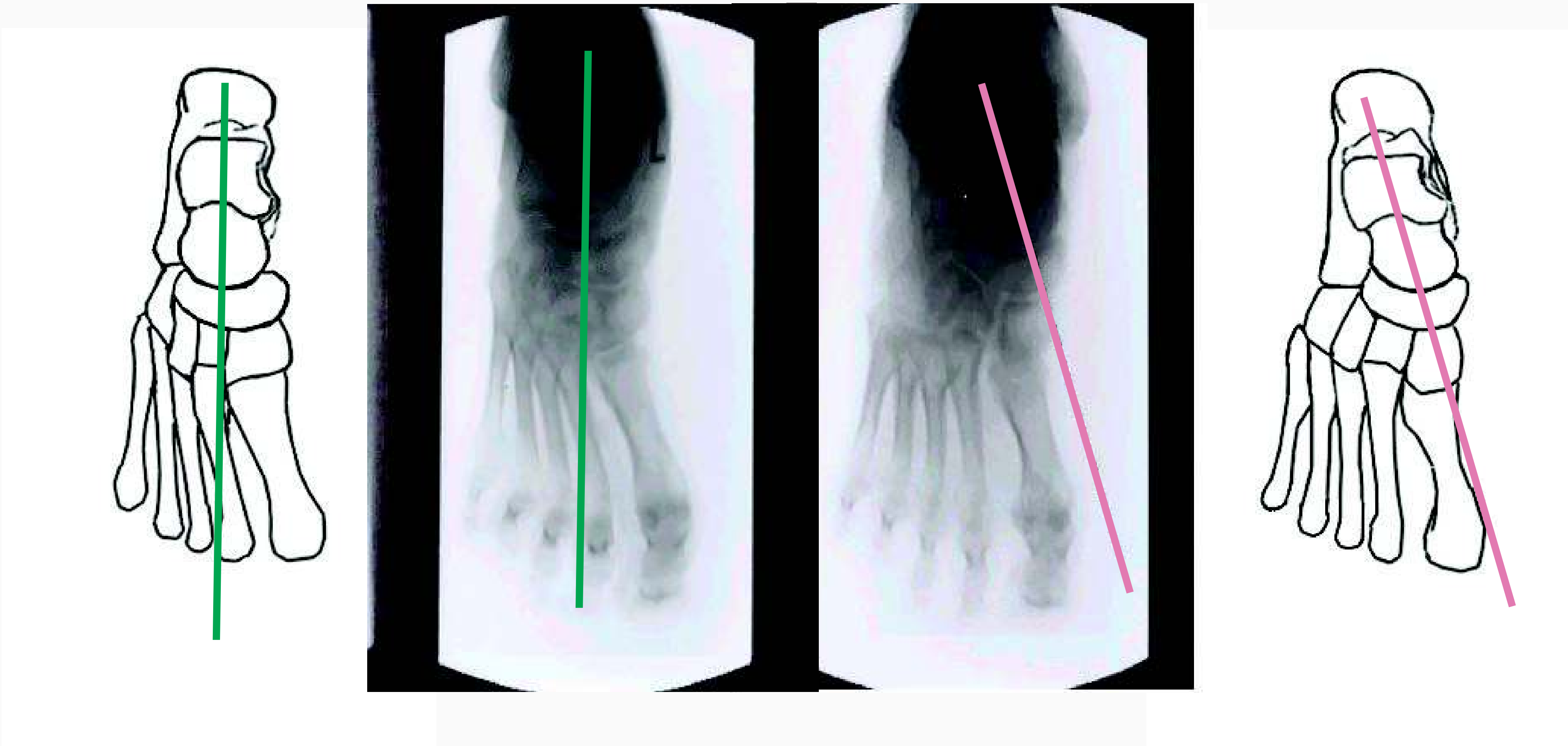
Calcaneal supination half that of mid-foot

Talar external rotation greater than calcaneal

AMBAGTSHEER (1978)

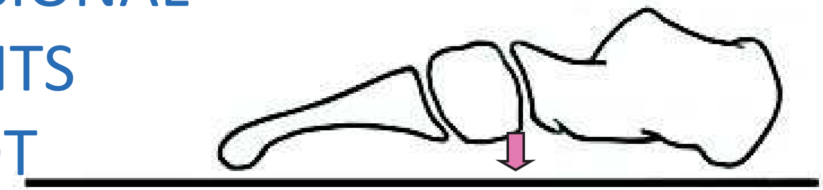
Posterior views show mid-foot and calcaneal supination/pronation movements

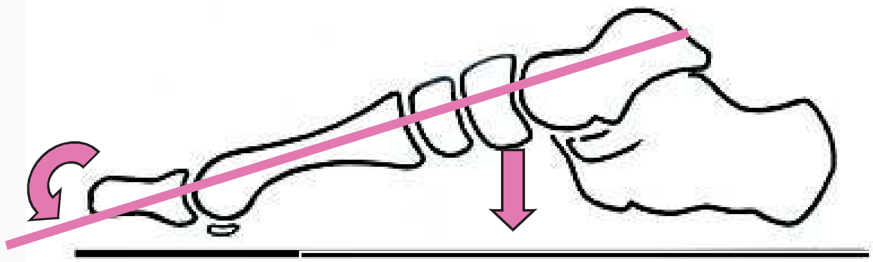
LATERAL SWING AT T-T JOINT
AND COORDINATED FOOT MOVEMENTS



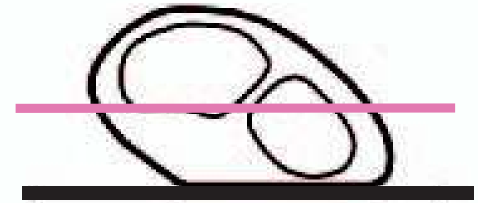
Pattern of movements at inter-tarsal joints investigated with cine-radiography and compared with clinical observations of Gt toe extension test

51 THREE DIMENSIONAL MOVEMENTS FOREFOOT

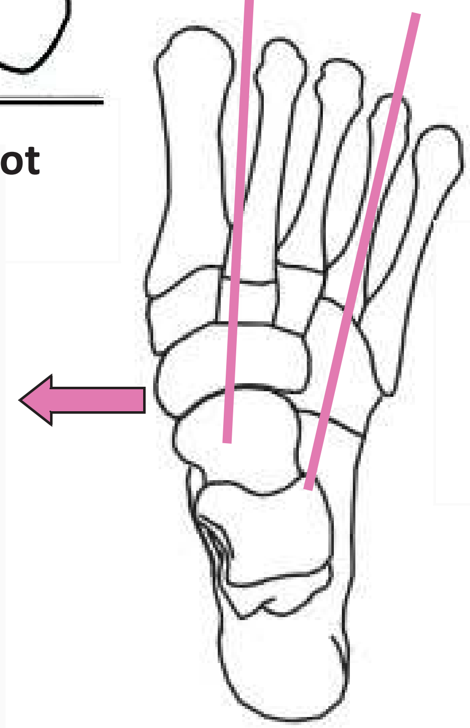




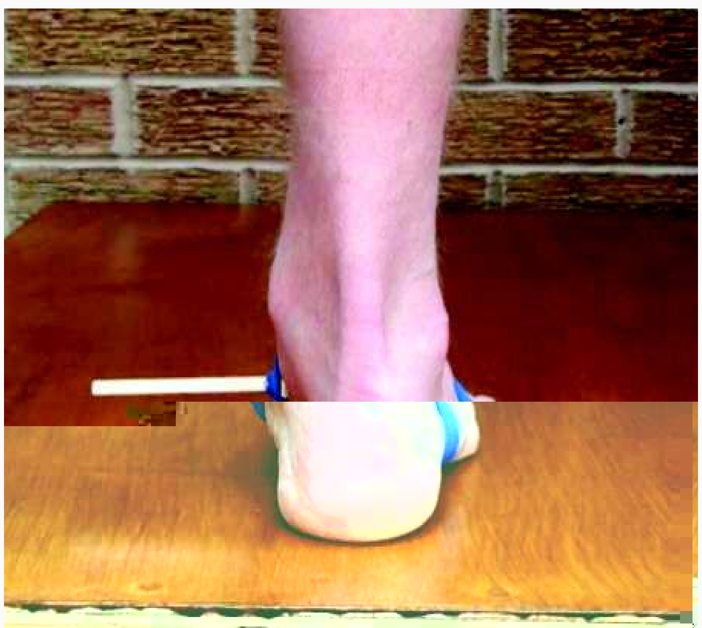
Flattening of mid-foot



Pronation of mid-foot
Navicular & cuboid

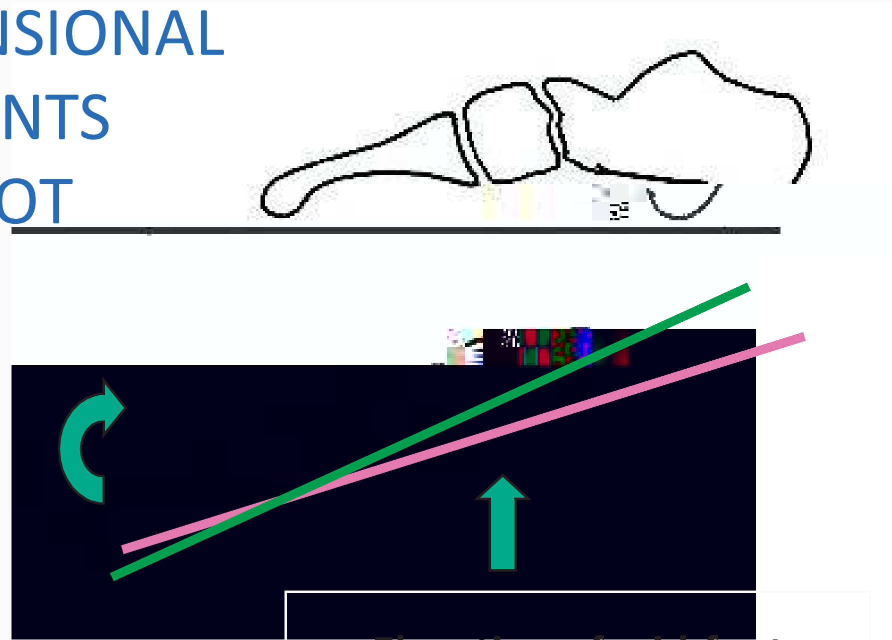


ER of forefoot navicular & cuboid

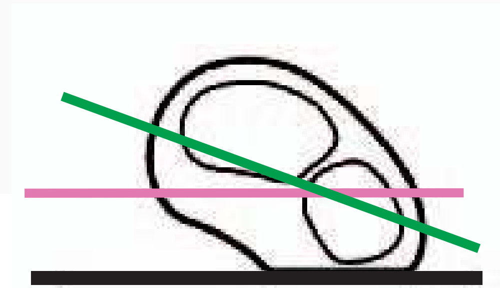


Inward angulation at mid-foot

THREE DIMENSIONAL MOVEMENTS FOREFOOT

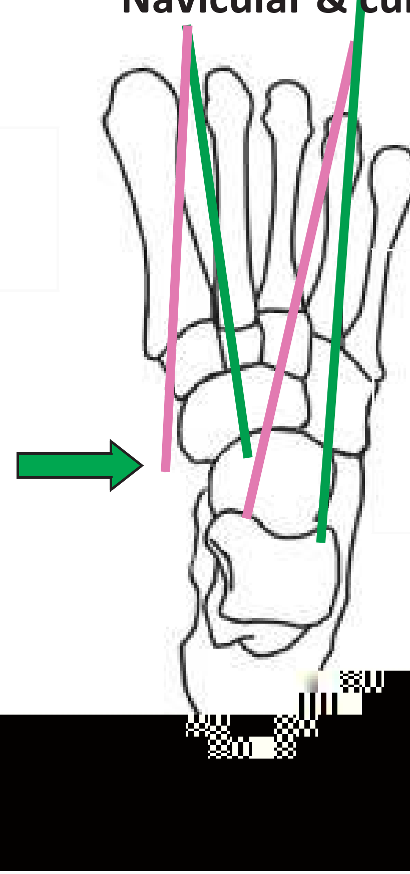


Elevation of mid-foot



Supination of mid-foot

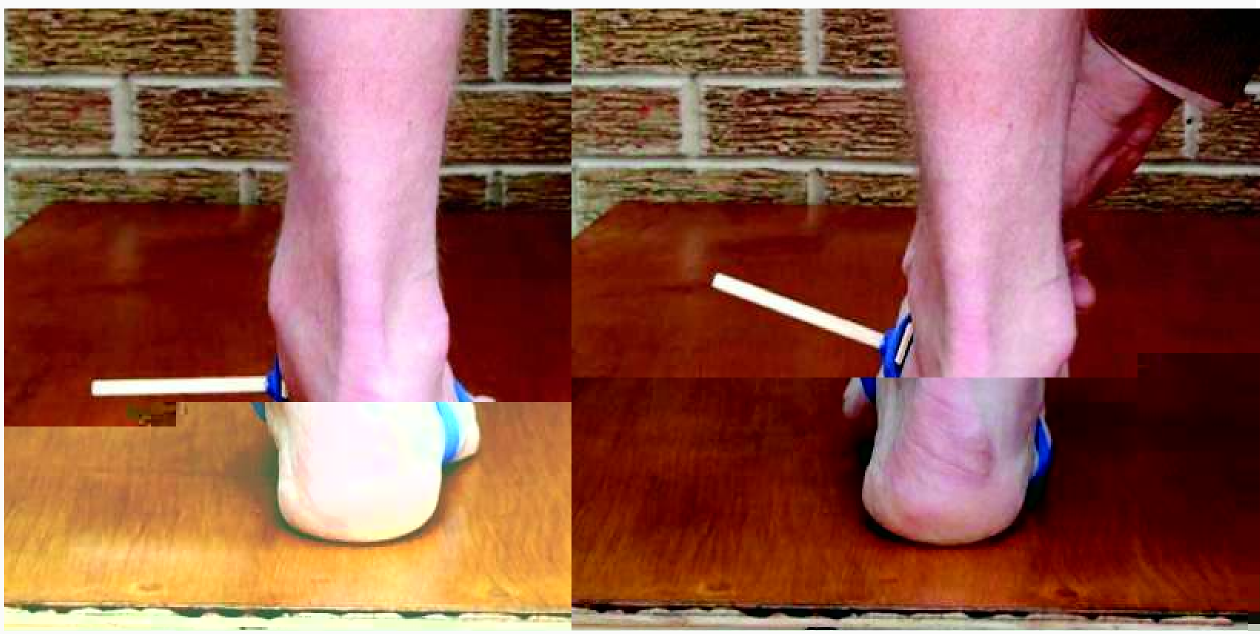
Navicular & cuboid



IR of forefoot

navicular

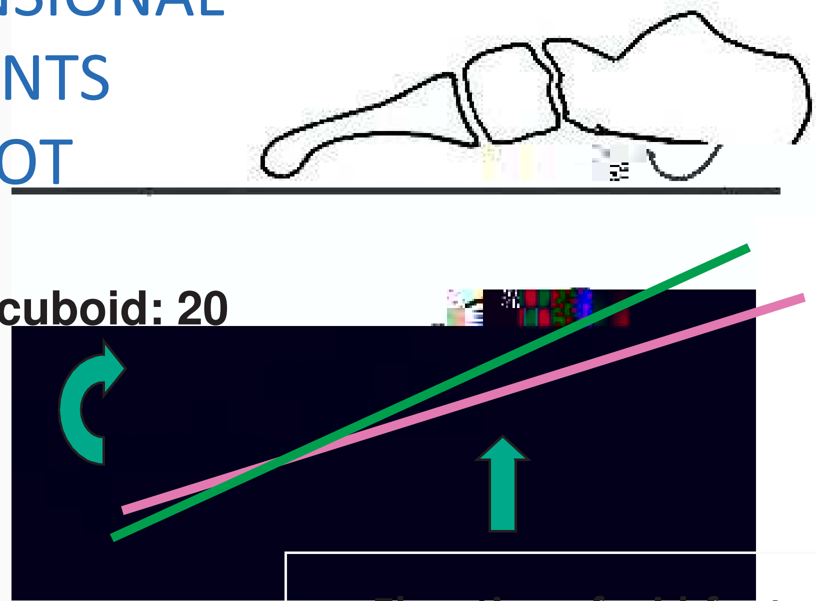
& cuboid



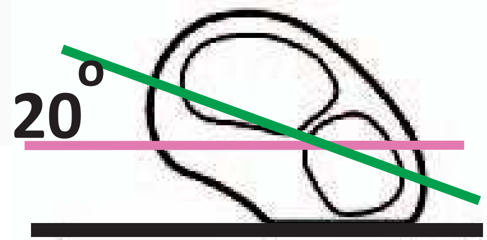
Outward angulation at mid-foot

53 THREE DIMENSIONAL MOVEMENTS FOREFOOT

Supination navicular/cuboid: 20

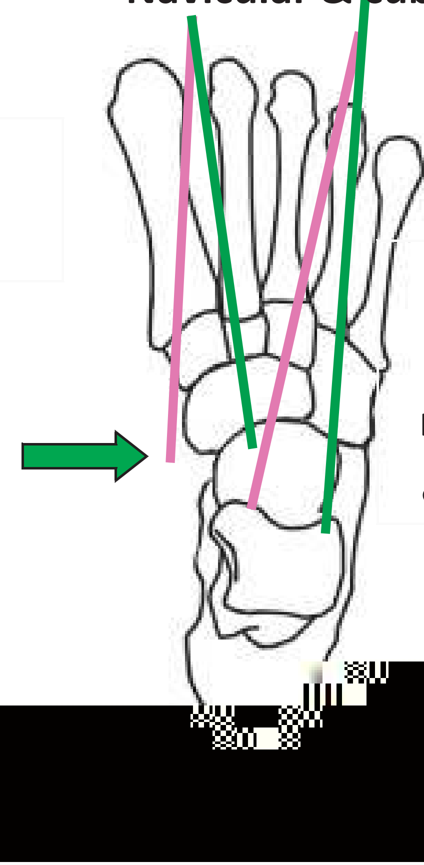


Elevation of mid-foot

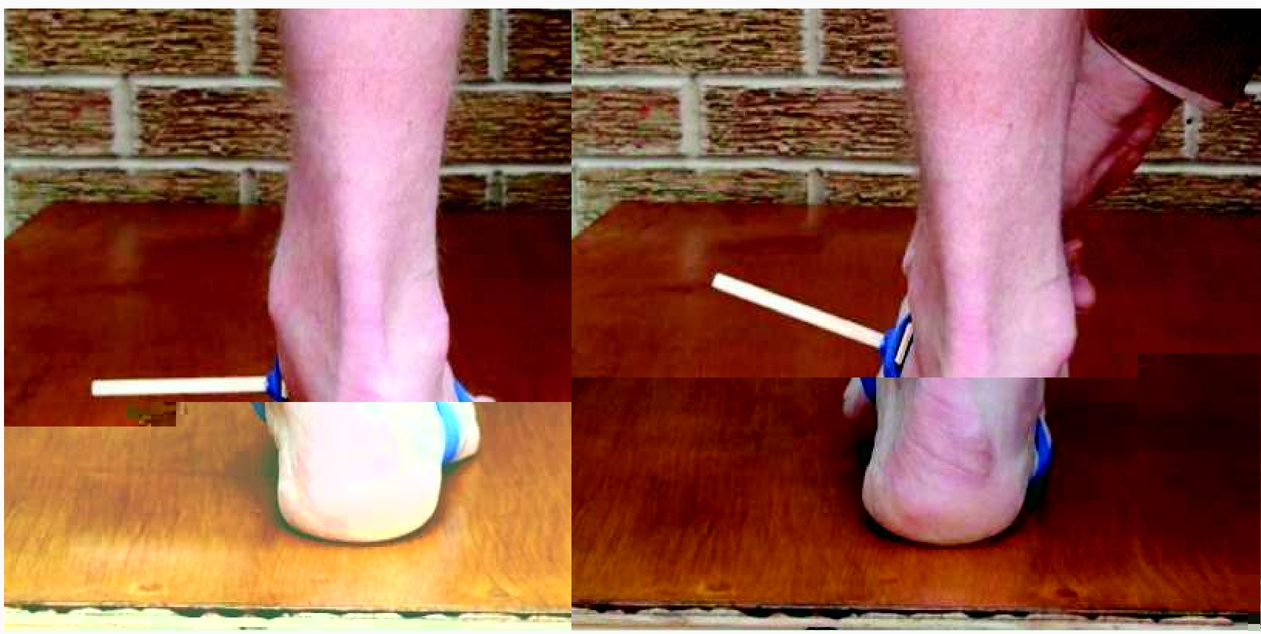


Supination of mid-foot

Navicular & cuboid



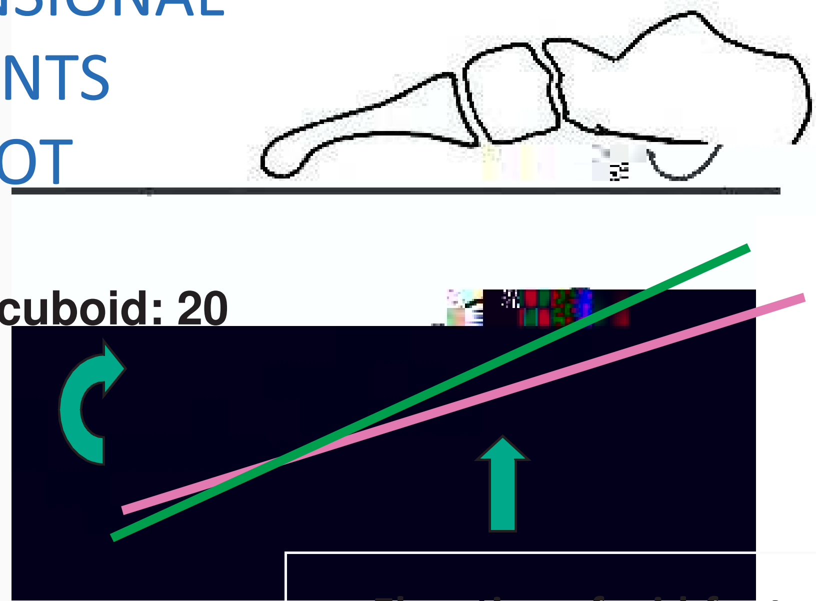
IR of forefoot navicular & cuboid



Outward angulation at mid-foot

54

THREE DIMENSIONAL MOVEMENTS FOREFOOT

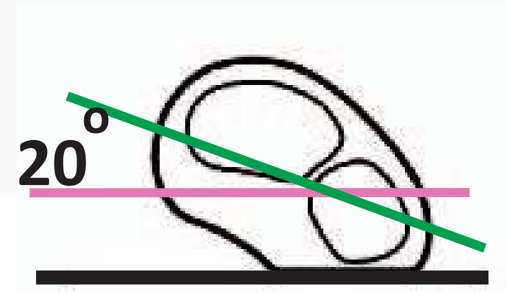


Supination navicular/cuboid: 20

IR navicular: 10

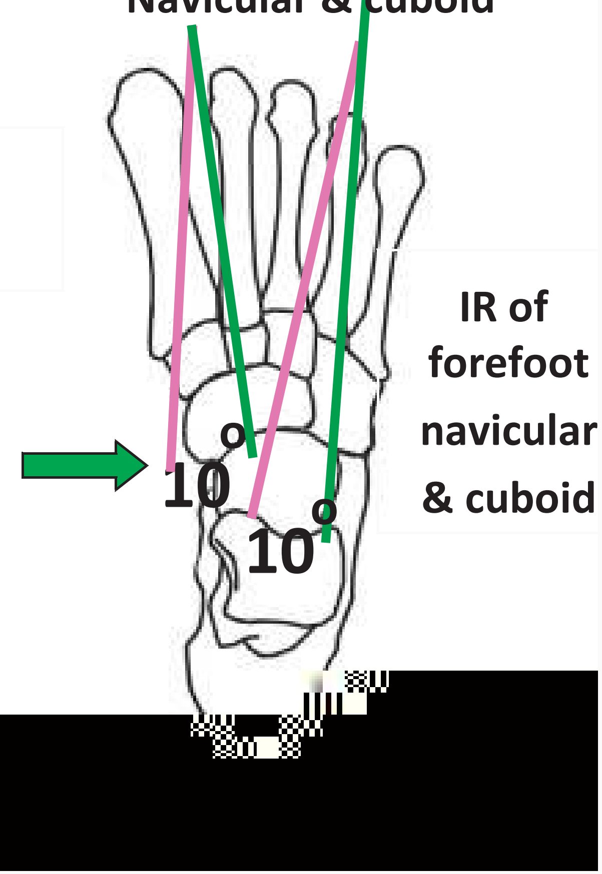
IR cuboid: 10

Elevation of mid-foot

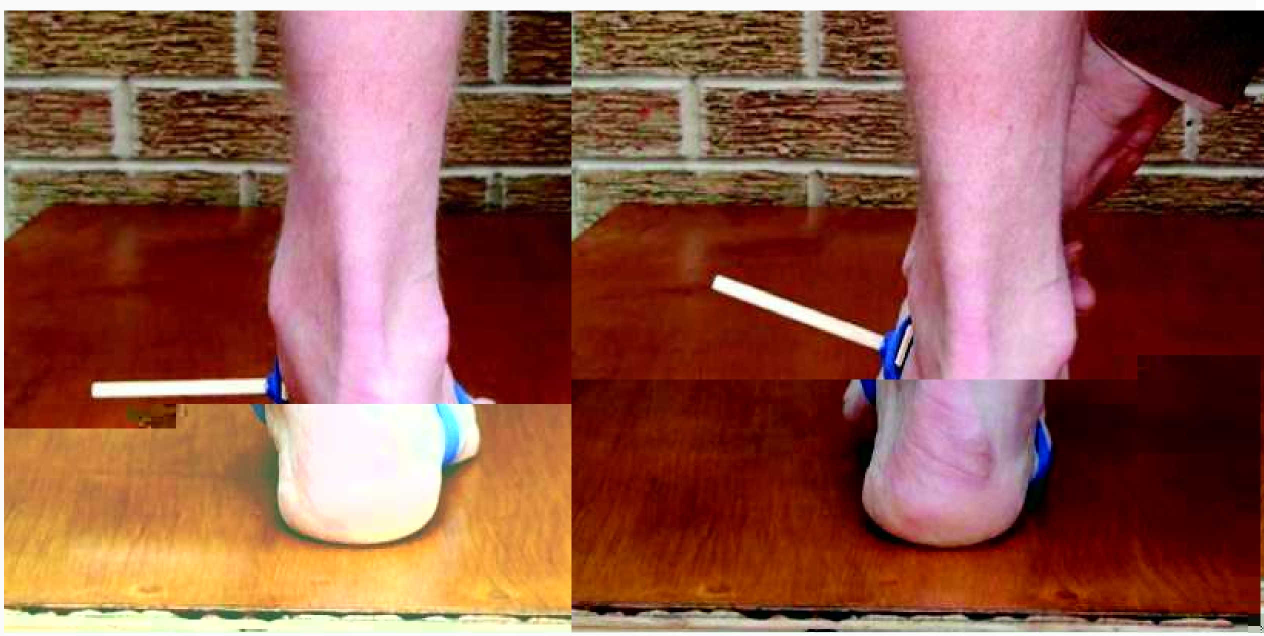


Supination of mid-foot

Navicular & cuboid



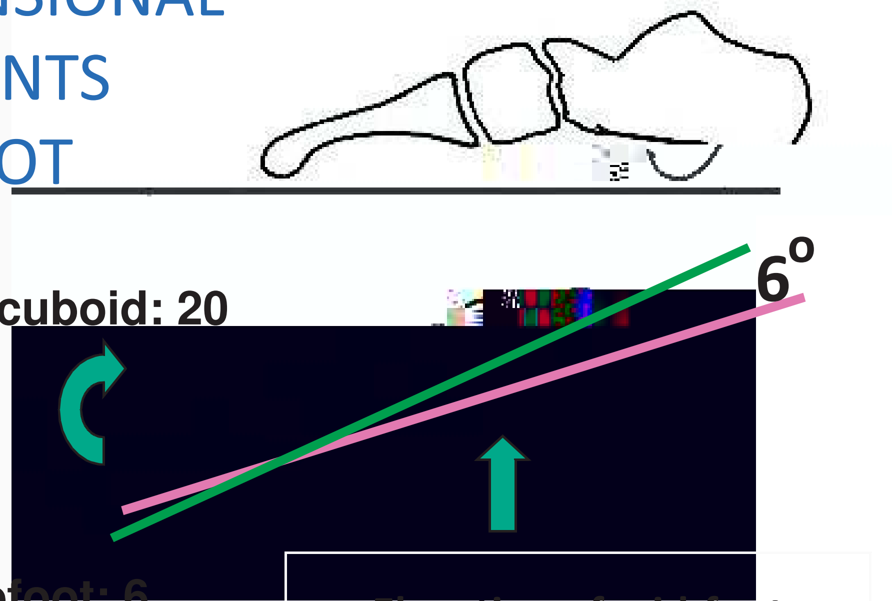
IR of forefoot navicular & cuboid



Outward angulation at mid-foot

55

THREE DIMENSIONAL MOVEMENTS FOREFOOT



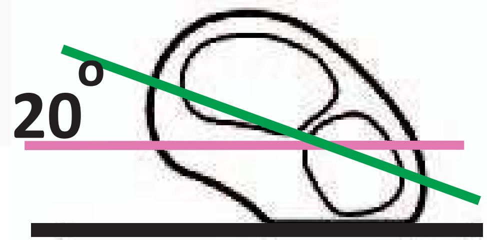
Supination navicular/cuboid: 20

IR navicular: 10

IR cuboid: 10

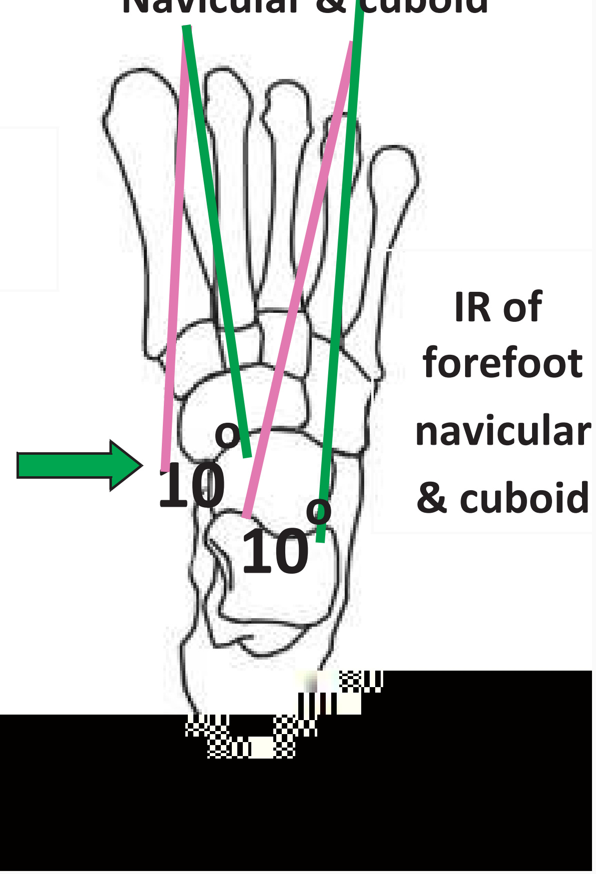
Plantar-flexion of forefoot: 6

Elevation of mid-foot

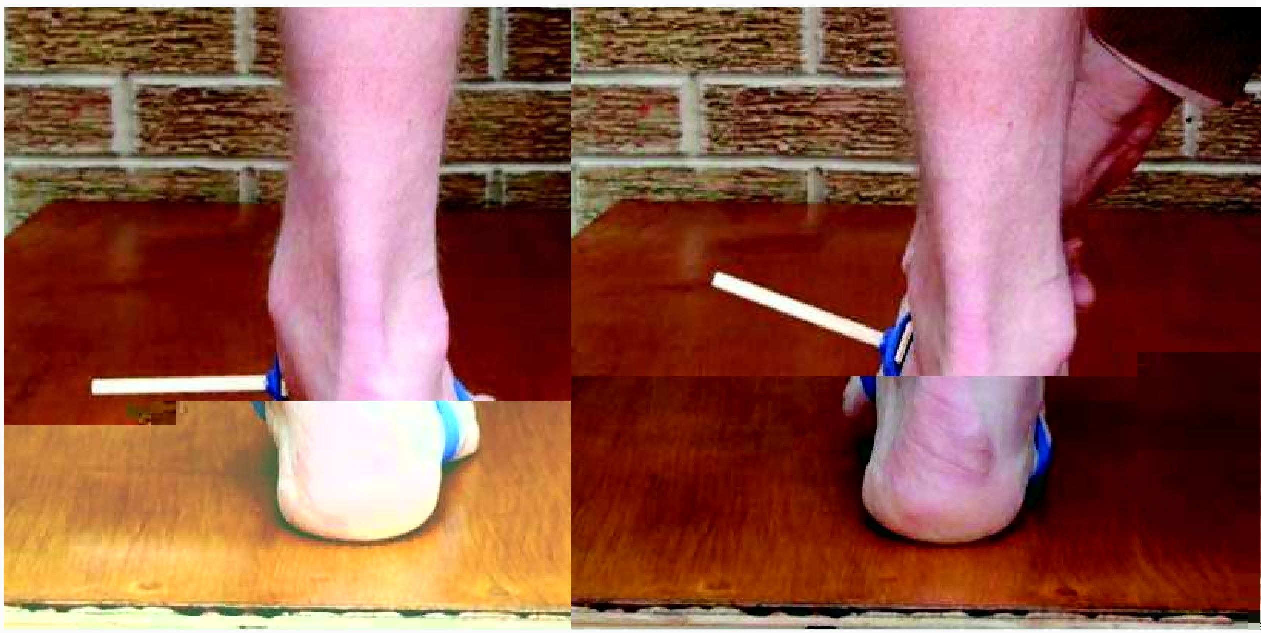


Supination of mid-foot

Navicular & cuboid



IR of forefoot navicular & cuboid



Outward angulation at mid-foot

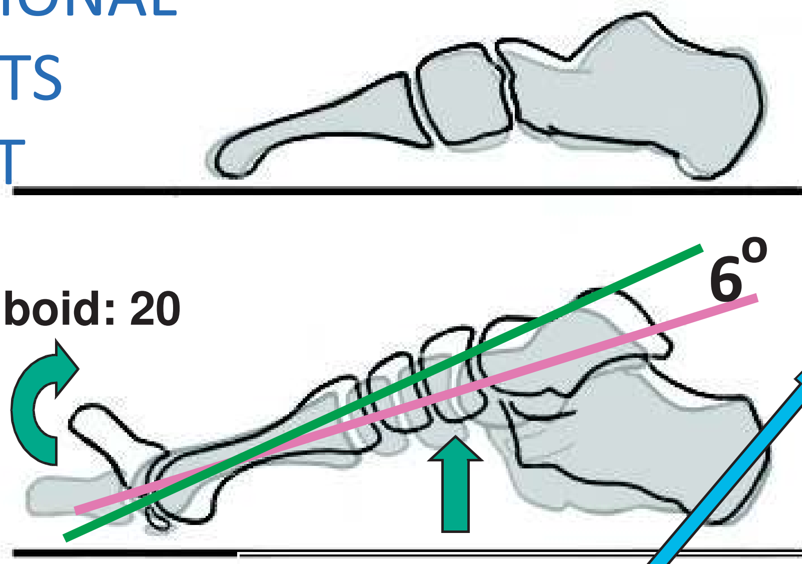
56 THREE DIMENSIONAL MOVEMENTS FOREFOOT

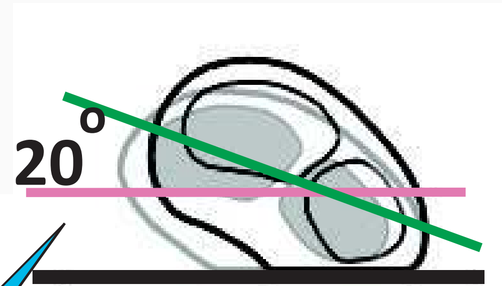
Supination navicular/cuboid: 20

IR navicular: 10

IR cuboid: 10

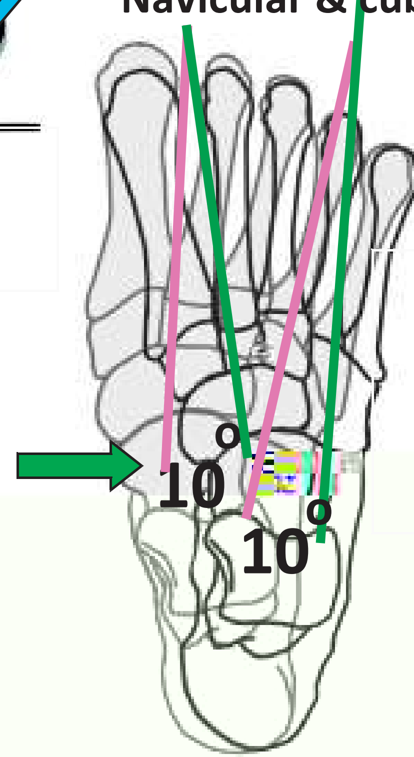
Plantar-flexion of forefoot: 6



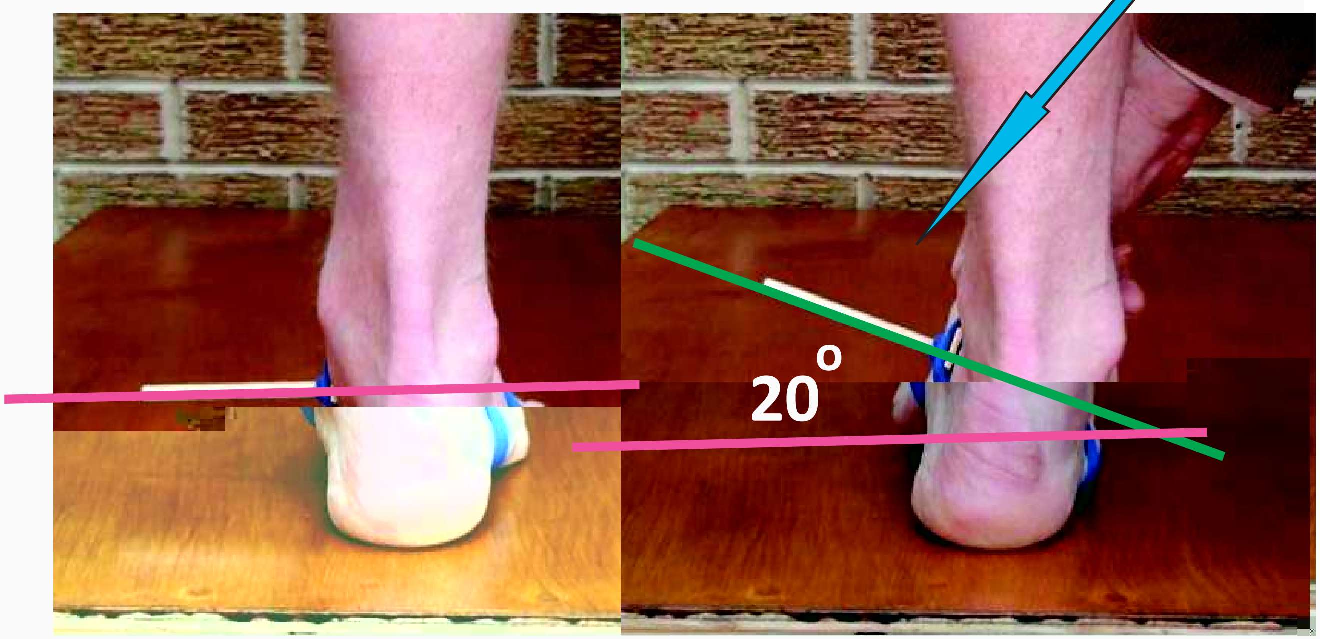


Supination of mid-foot

Navicular & cuboid

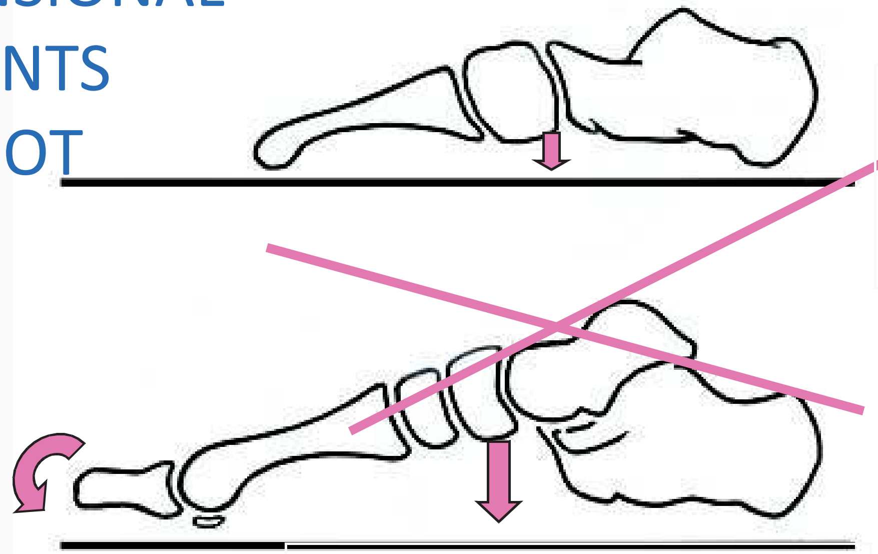


IR of forefoot navicular & cuboid



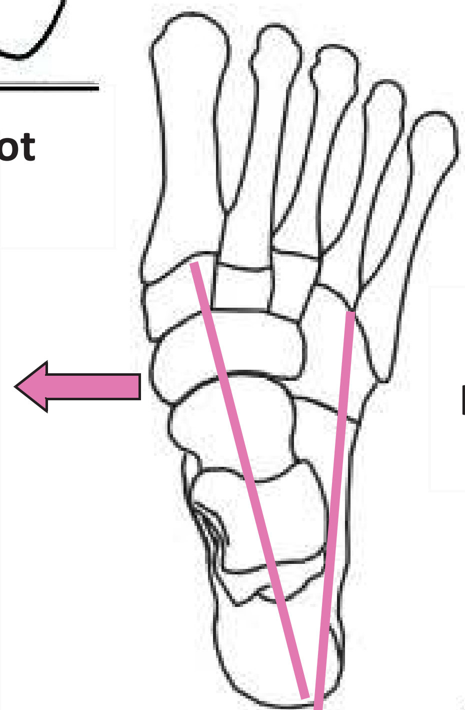
Outward angulation at mid-foot

57 THREE DIMENSIONAL MOVEMENTS HIND-FOOT

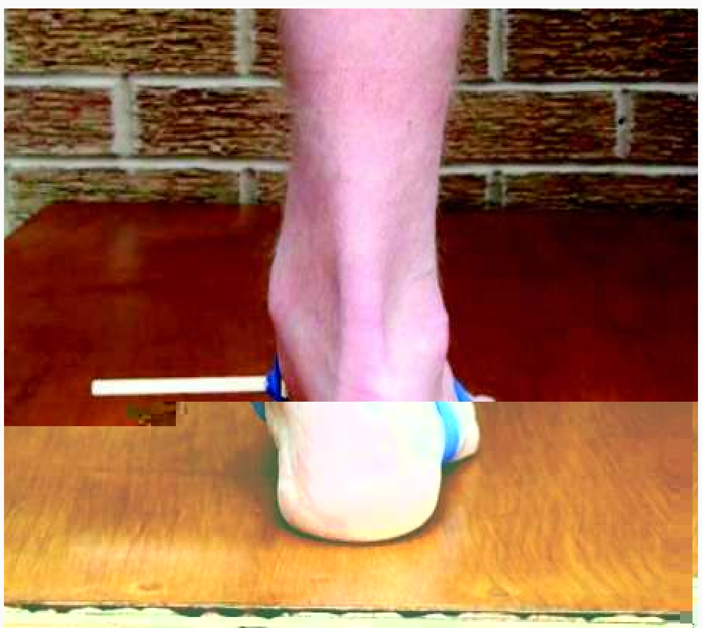


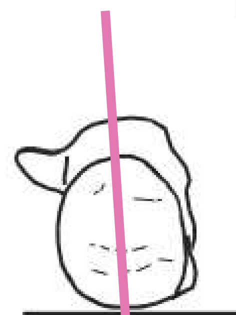
Plantar-flexion of talus & calcaneus

Flattening of mid-foot



IR of talus & calcaneus

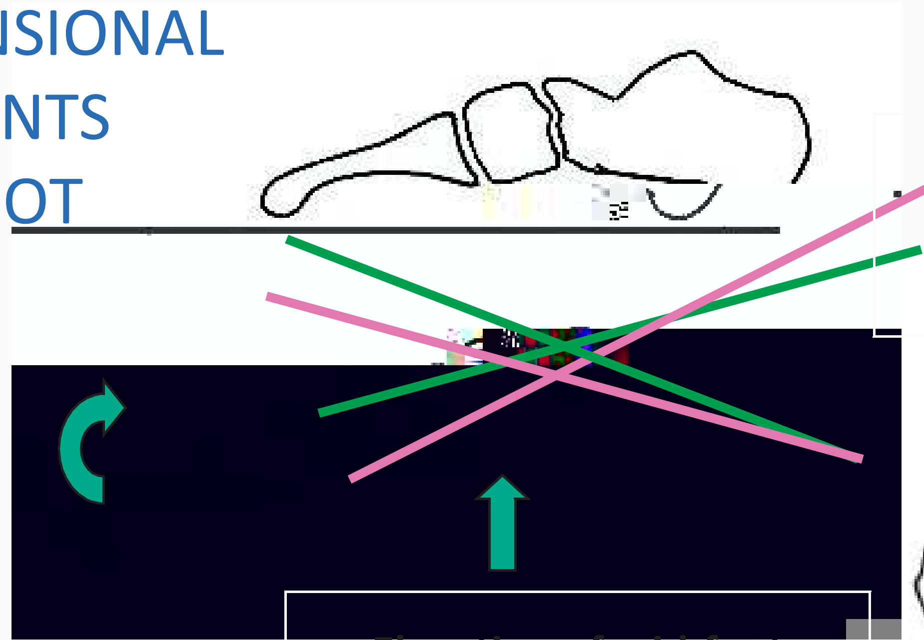




Inward angulation at mid-foot

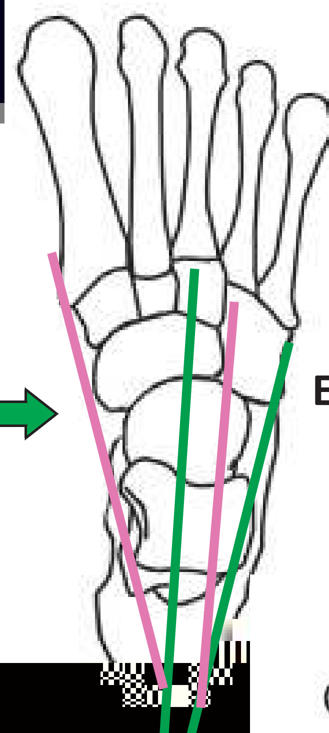
Pronation of calcaneus

THREE DIMENSIONAL MOVEMENTS HIND-FOOT

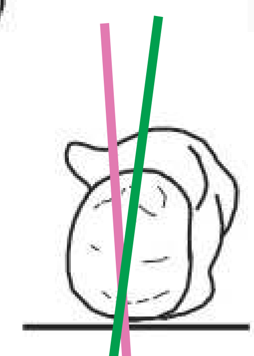


Dorsiflexion of talus & calcaneus

Elevation of mid-foot



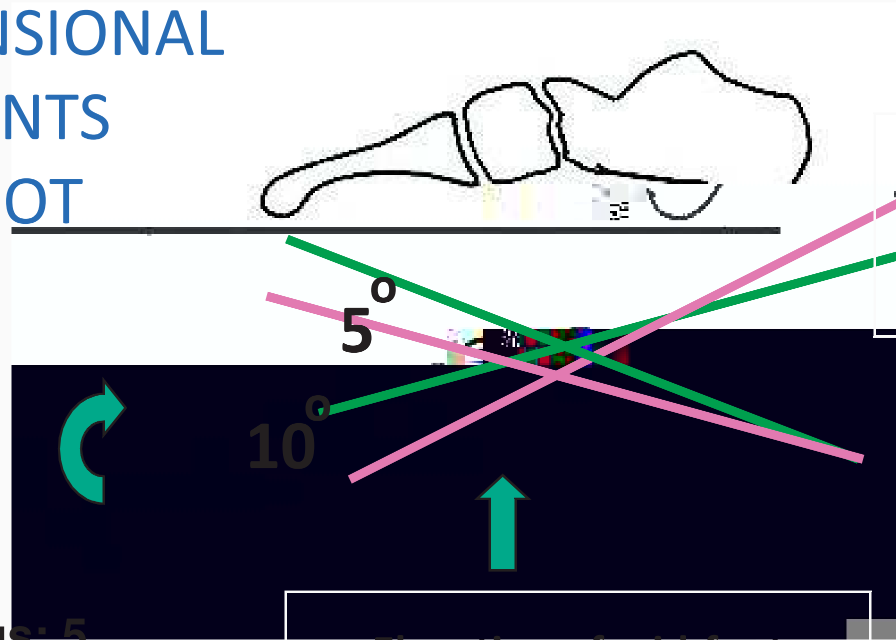
ER of talus & calcaneus



Supination of calcaneus

Outward angulation at mid-foot

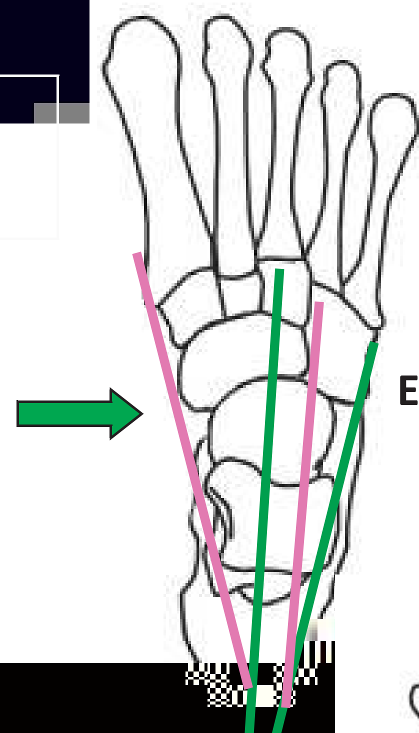
THREE DIMENSIONAL MOVEMENTS HIND-FOOT



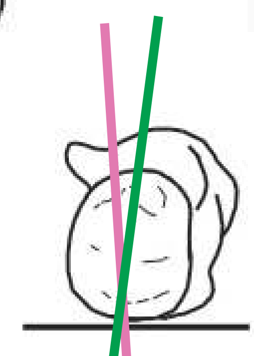
Dorsiflexion of talus & calcaneus

Dorsiflexion calcaneus: 5

Dorsiflexion talus: 10



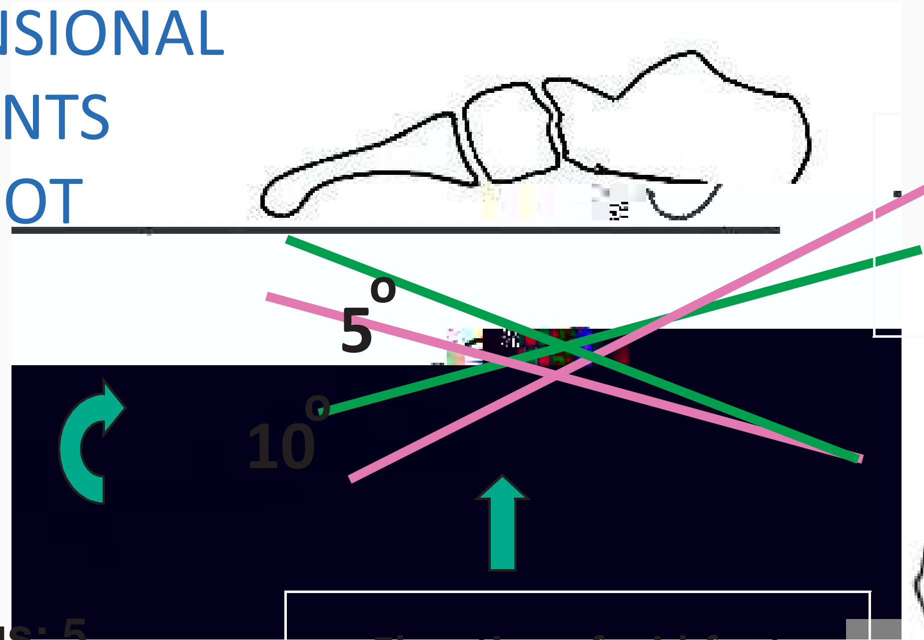
ER of talus & calcaneus



Outward angulation at mid-foot

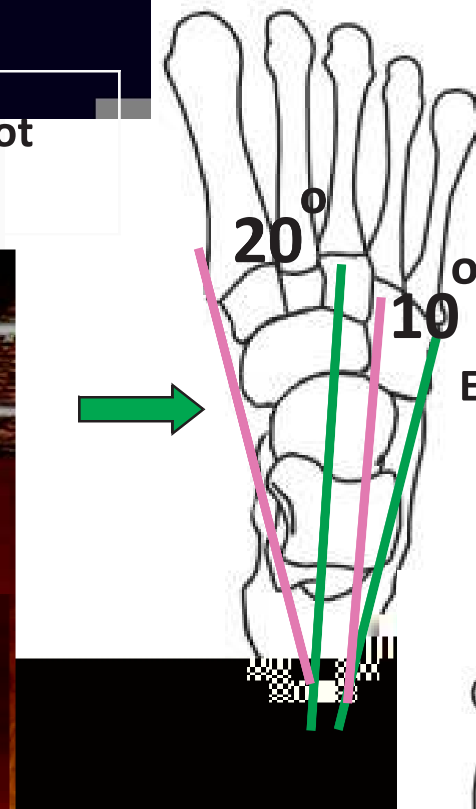
Supination of calcaneus

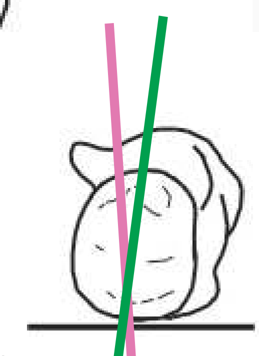
THREE DIMENSIONAL MOVEMENTS HIND-FOOT



ER calcaneus: 10
ER talus: 20

Dorsiflexion calcaneus: 5
Dorsiflexion talus: 10





Outward angulation at mid-foot

Supination of calcaneus

61

THREE DIMENSIONAL MOVEMENTS HIND-FOOT

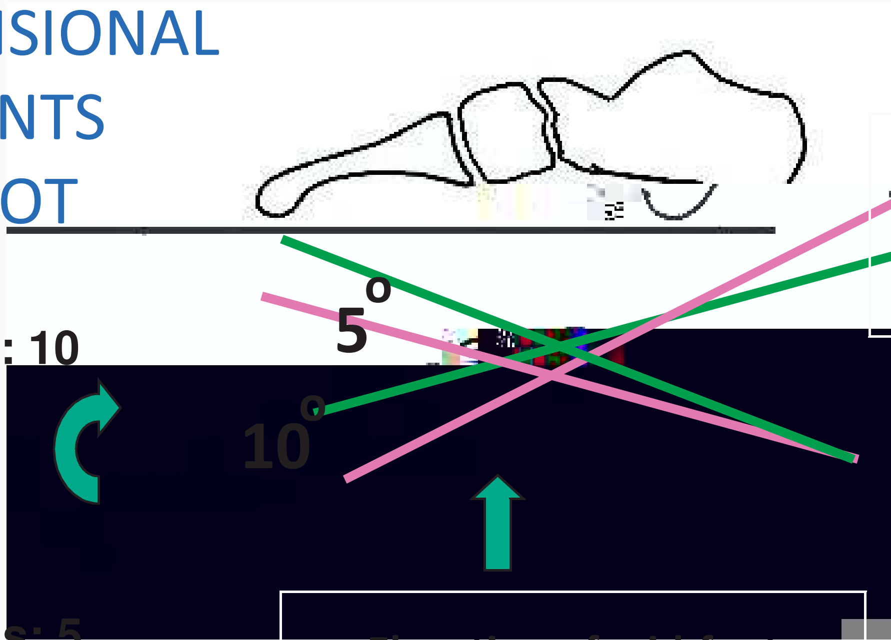
Supination calcaneus: 10

ER calcaneus: 10

ER talus: 20

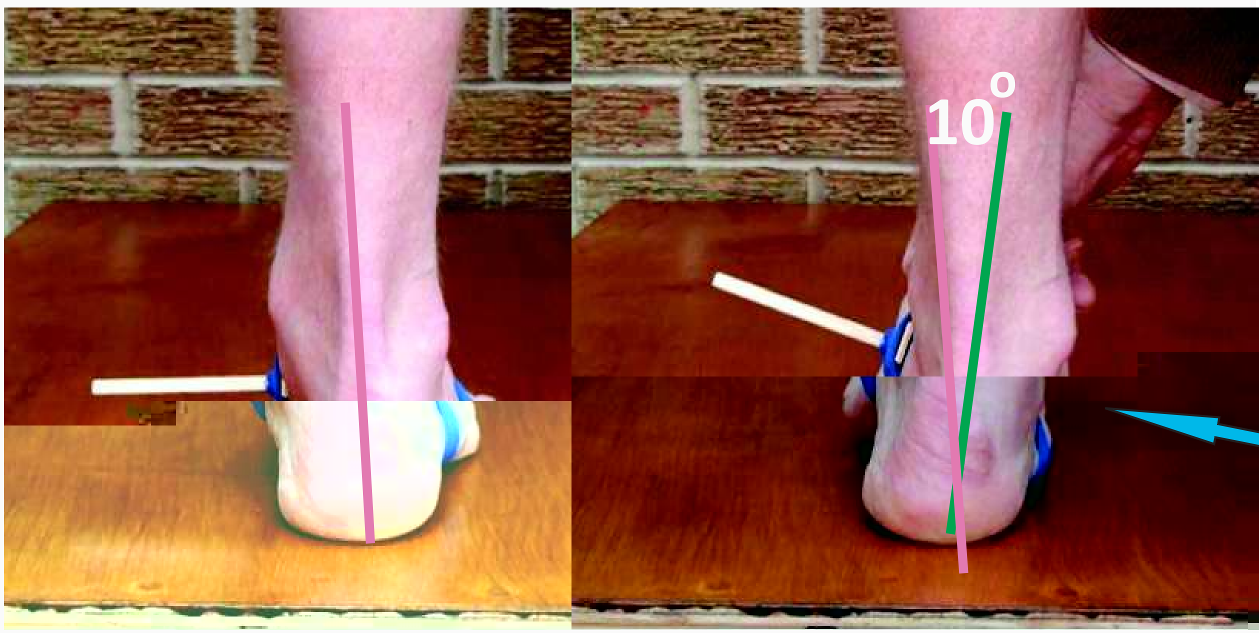
Dorsiflexion calcaneus: 5

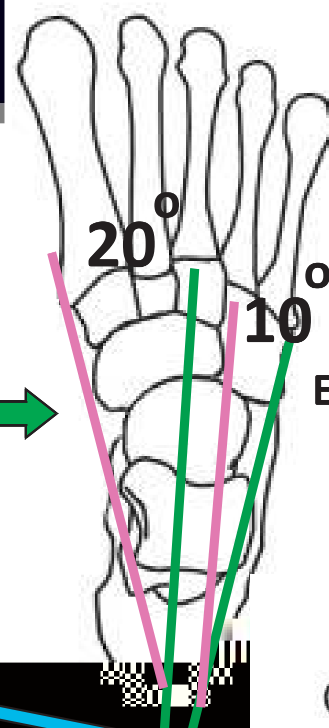
Dorsiflexion talus: 10



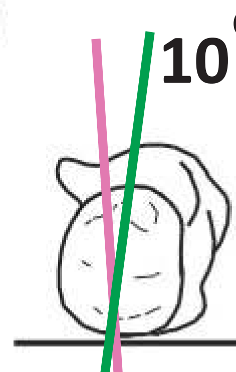
Elevation of mid-foot

Dorsiflexion of talus & calcaneus





ER of talus & calcaneus



Outward angulation at mid-foot

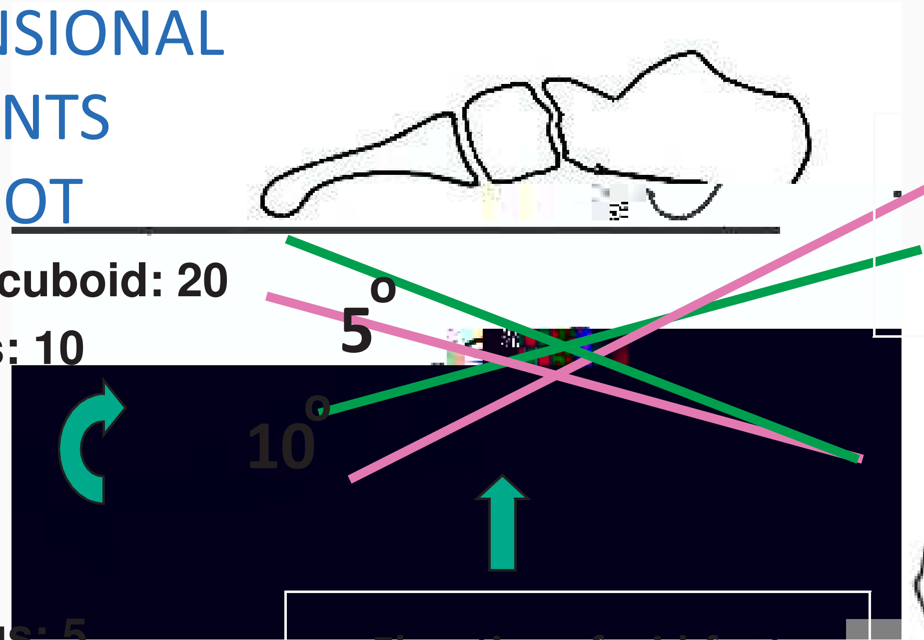
Supination of calcaneus

THREE DIMENSIONAL MOVEMENTS HIND-FOOT

Supination navicular/cuboid: 20
Supination calcaneus: 10

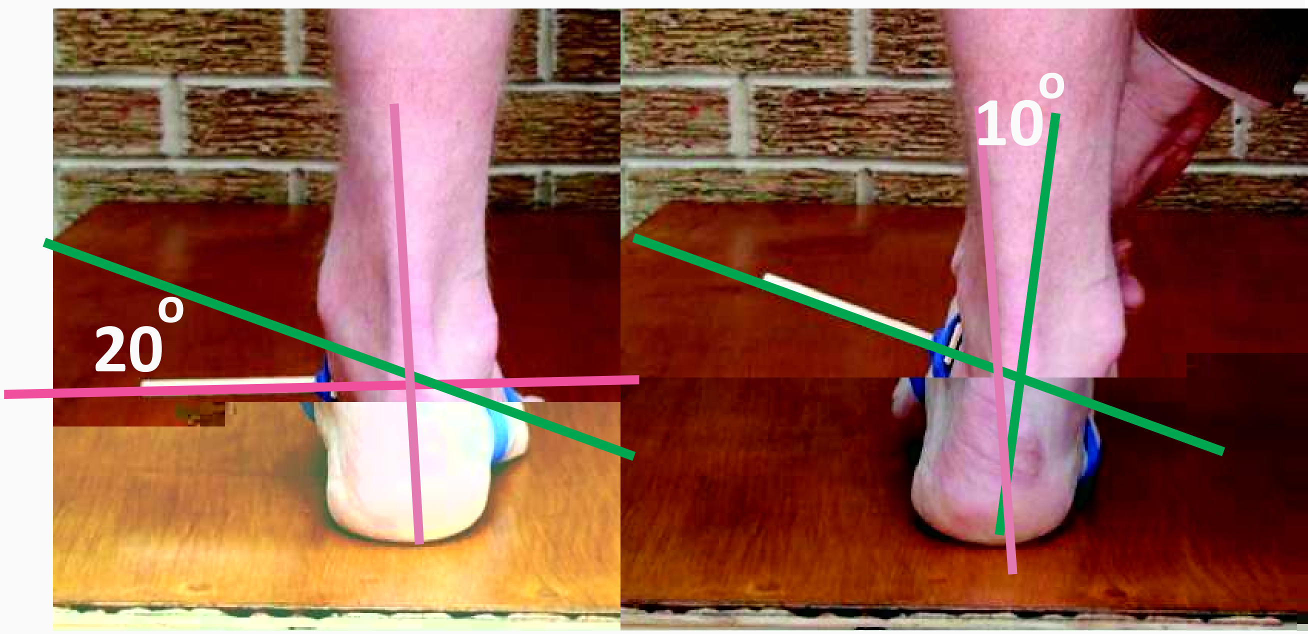
ER calcaneus: 10
ER talus: 20

Dorsiflexion calcaneus: 5
Dorsiflexion talus: 10

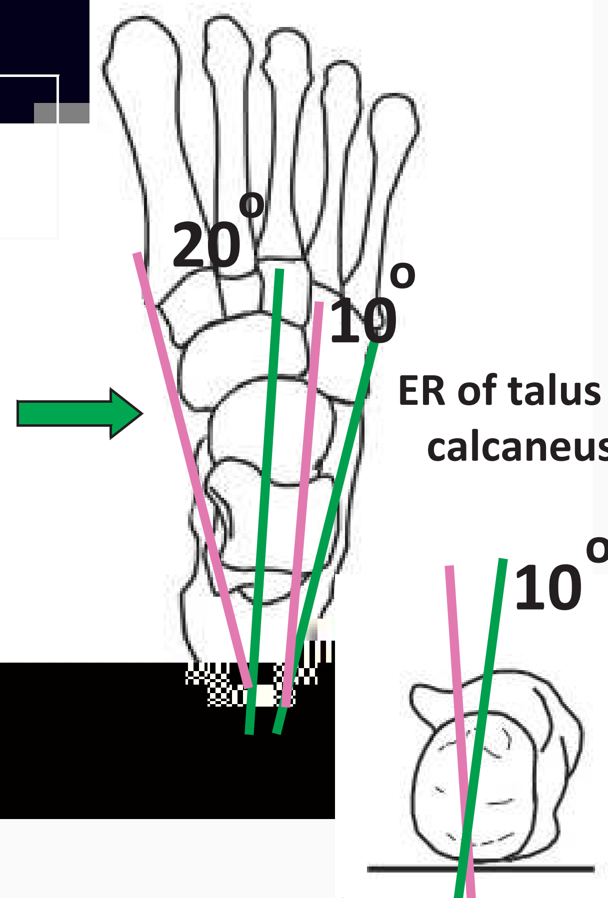


Dorsiflexion of talus & calcaneus

Elevation of mid-foot



Outward angulation at mid-foot



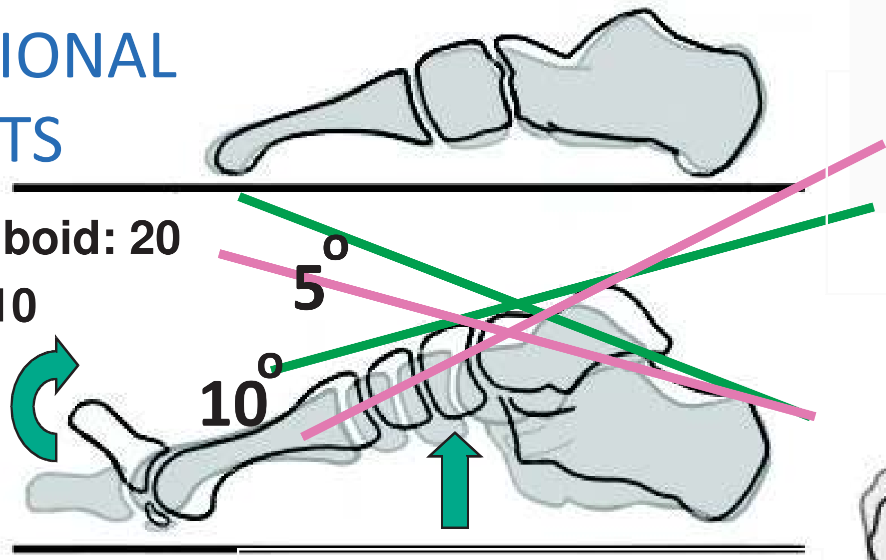
Supination of calcaneus

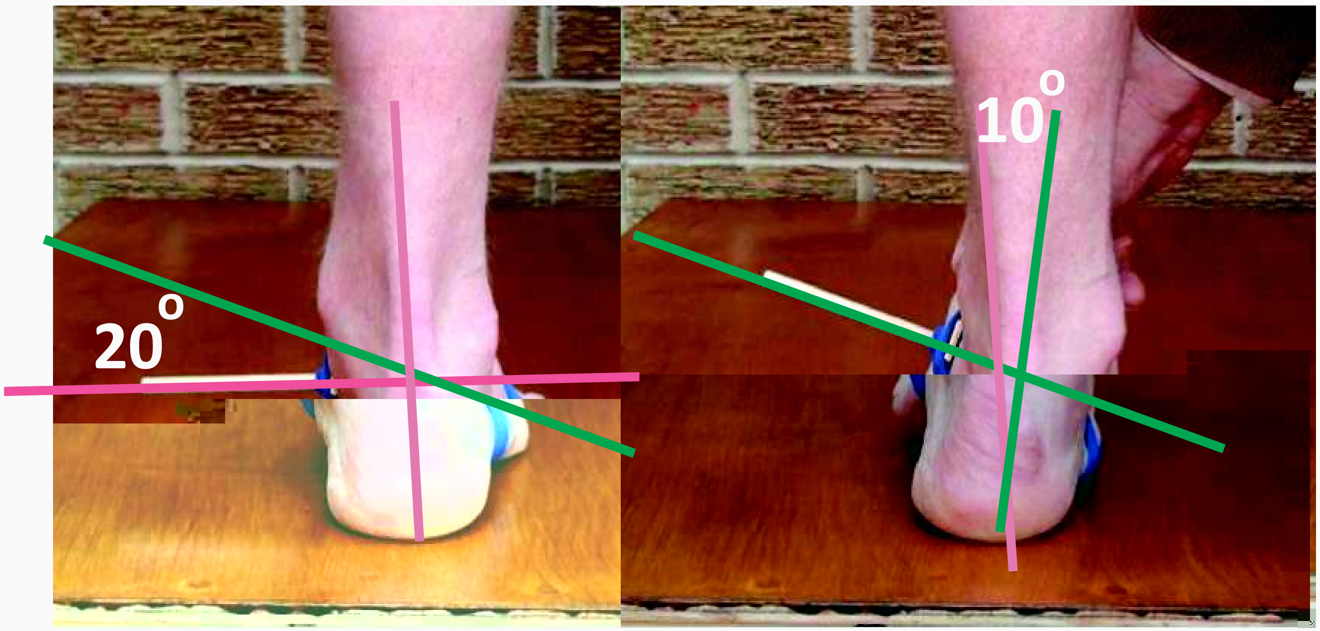
THREE DIMENSIONAL MOVEMENTS

Supination navicular/cuboid: 20
Supination calcaneus: 10

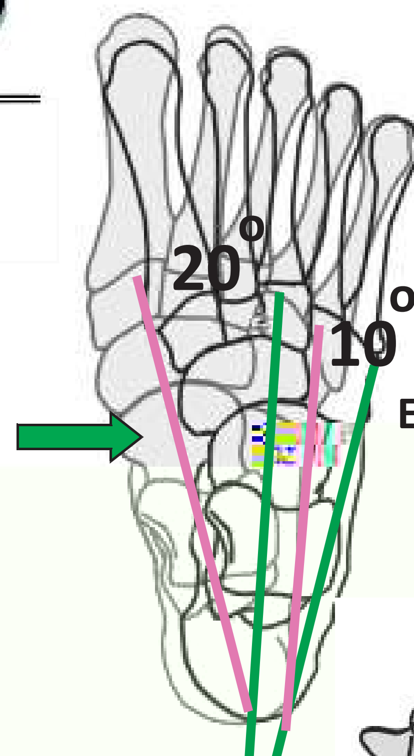
ER calcaneus: 10
ER talus: 20

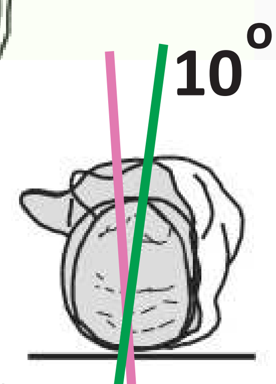
Dorsiflexion calcaneus: 5
Dorsiflexion talus: 10





Outward angulation at mid-foot





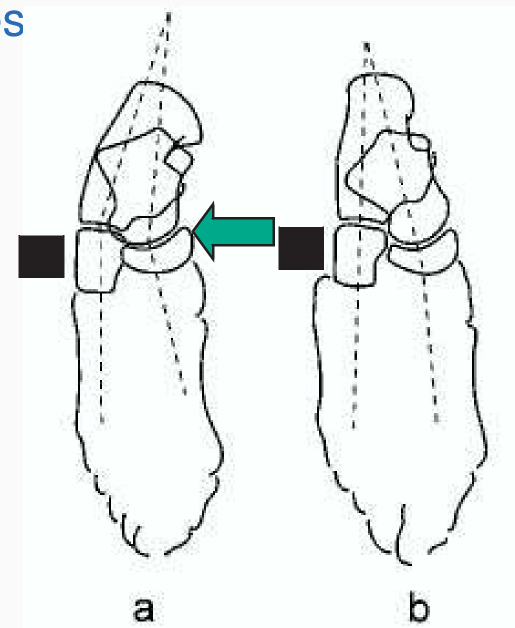
Supination of calcaneus

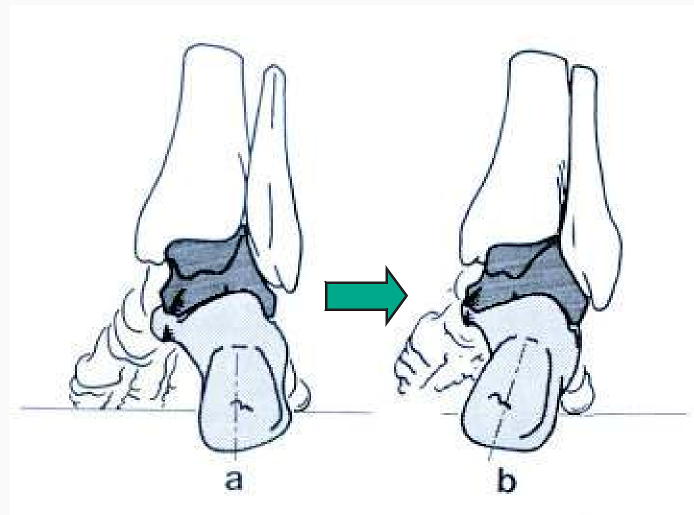
COMBINATION MOVEMENTS
(AMBAGTSHEER 1978)

The technique involved rotating the talus
A post was placed against the cuboid to prevent the whole foot rotating: cuboid was therefore ‘immobile’ in transverse plane

Rotations of individual bones

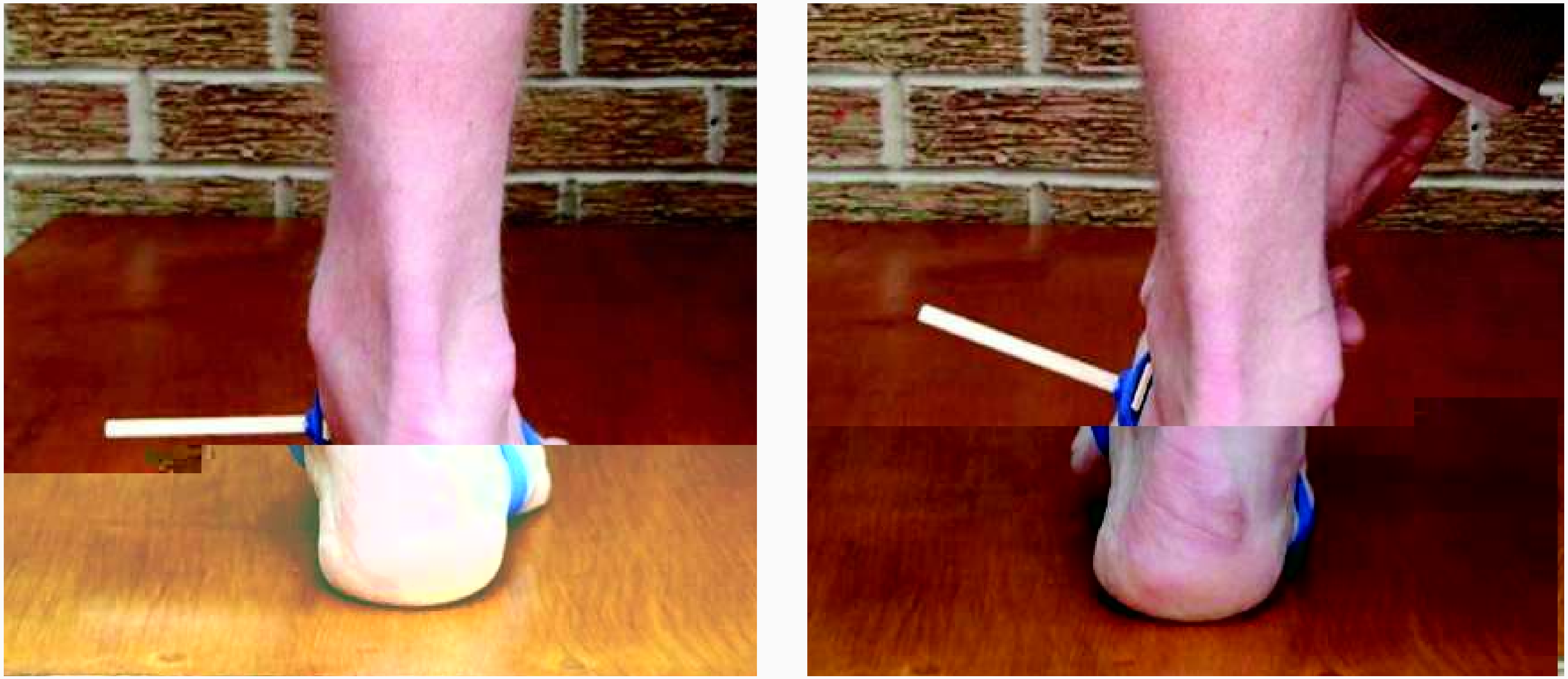
	ER	Sup	P-F
Talus	33	1	1
Calcaneus	16	12	4
Cuboid	0	23	6
Navicular	0	29	7





The rotations of the calcaneus being intermediate between those of talus and cuboid/navicular were shown by Ambagtsheer

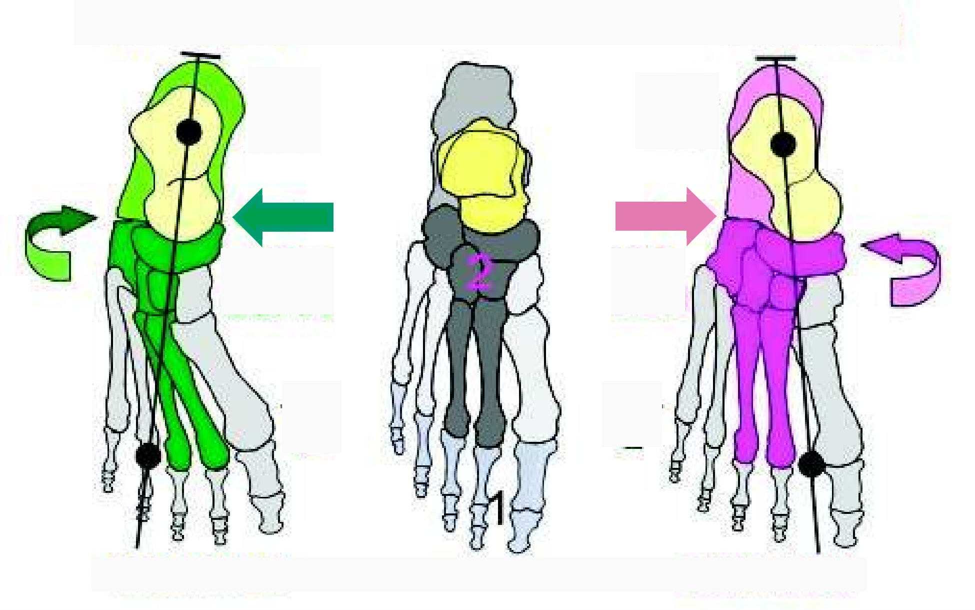
COMBINATION MOVEMENTS
AT INTER-TARSAL JOINTS



Evidence will be given supporting Professor Huson's suggestion
that the coordinated pattern of tri-planar movements at inter-tarsal joints
is dependent upon the contour of the articular surfaces
and the controlling ligaments

FOOT ROTATIONS
AROUND LONGITUDINAL AXIS

Mid-foot
Supination

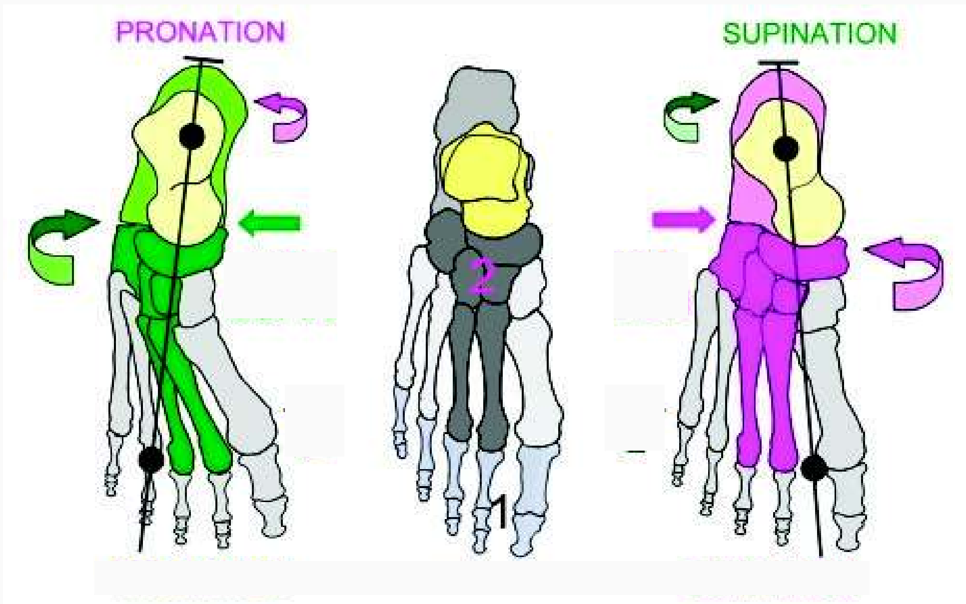


Mid-foot
Pronation

When mid-foot supinates or pronates
There is always lateral or medial swing movement at T-T joints

FOOT ROTATIONS AROUND LONGITUDINAL AXIS

Mid-foot Supination

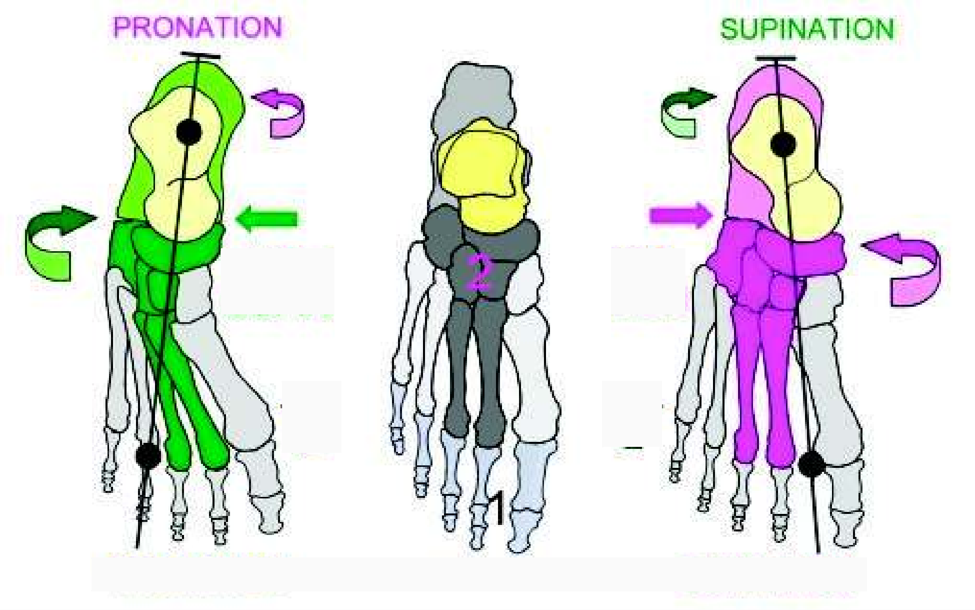


Mid-foot Pronation

When mid-foot supinates or pronates
If tibia is to remain vertical
calcaneus and talus are required to rotate in opposite direction

FOOT ROTATIONS
AROUND LONGITUDINAL AXIS

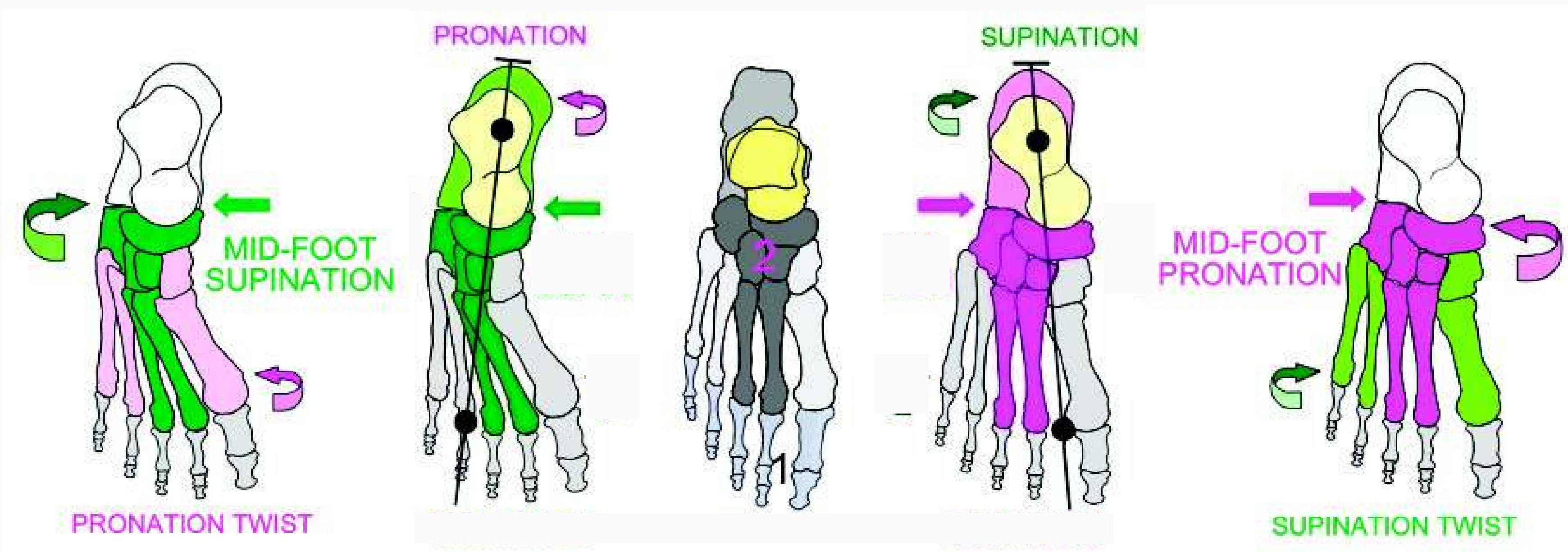
Mid-foot
Supination



Mid-foot
Pronation

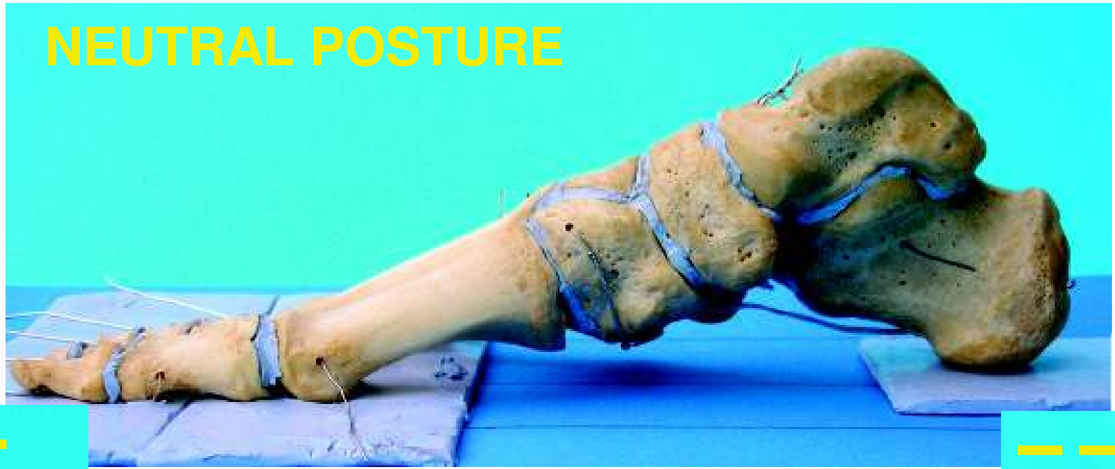
When mid-foot supinates or pronates
if tibia is to remain vertical
calcaneus and talus are required to rotate in opposite direction
Calcaneal pronation/supination always half that of navicular/cuboid

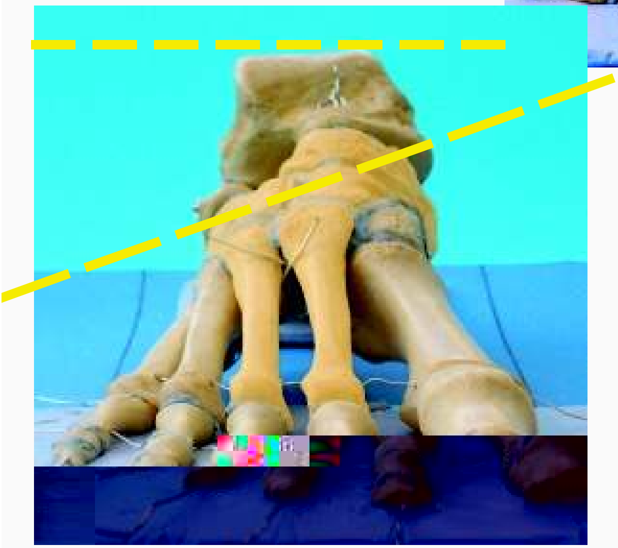
FOOT ROTATIONS AROUND LONGITUDINAL AXIS



Similarly, if forefoot is to remain plantigrade supporting metatarsals need to undergo compensatory rotation around central forefoot segment

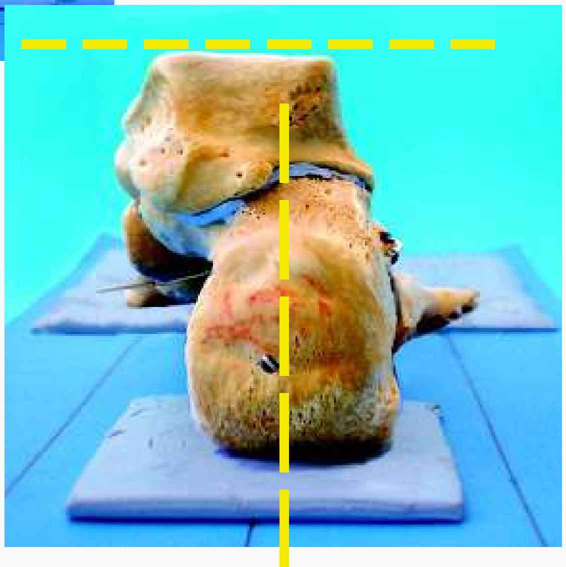
MID-FOOT ROTATION
AND COMPENSATORY FOREFOOT/HIND-FOOT MOVEMENTS IN CORONAL PLANE



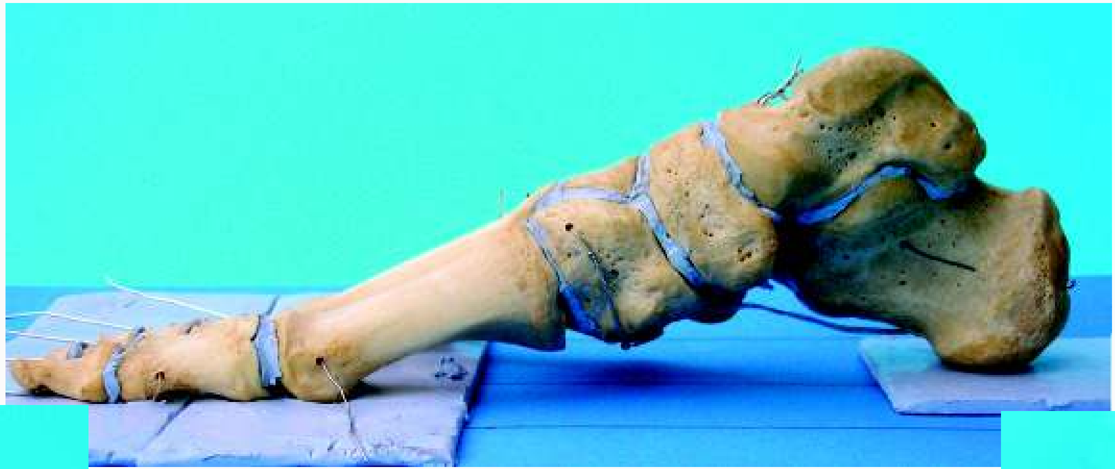


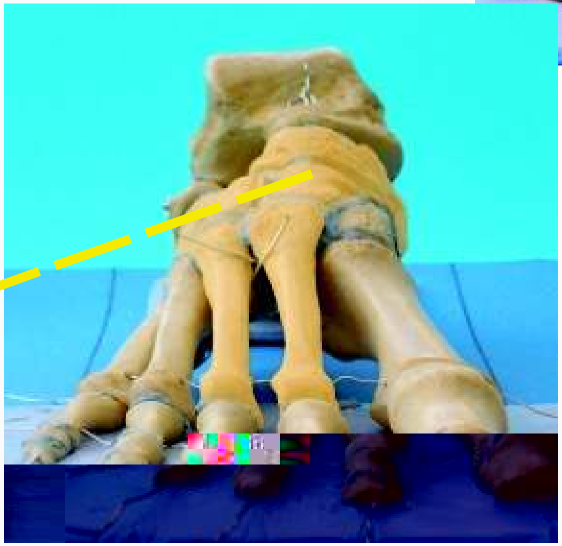
MID-FOOT ROTATIONS

This skeletal posture
represents foot
In a neutral position



MID-FOOT ROTATION
AND COMPENSATORY FOREFOOT/HIND-FOOT MOVEMENTS IN CORONAL PLANE





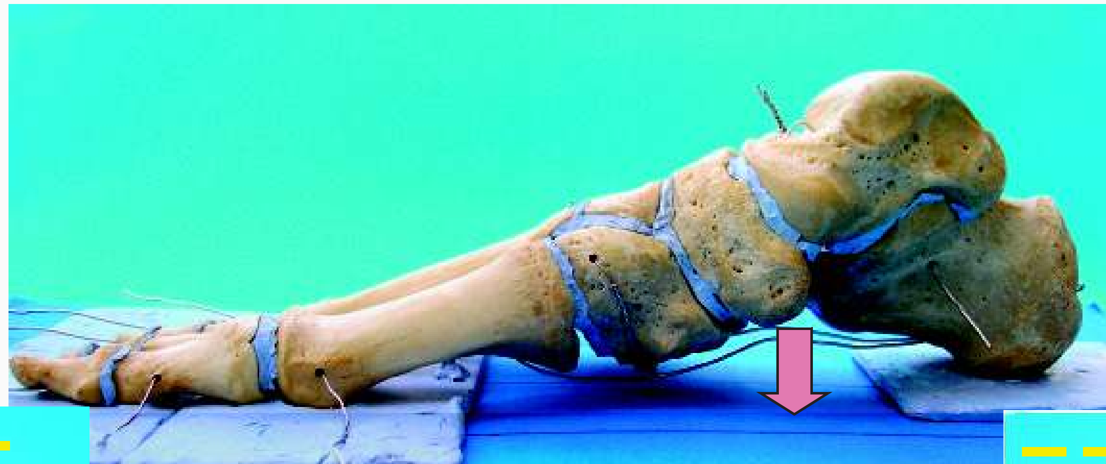
MID-FOOT ROTATIONS

As mid-foot swings medially & laterally and **pronates** and **supinates** Compensatory rotations required in forefoot and hindfoot to keep talus and forefoot horizontal

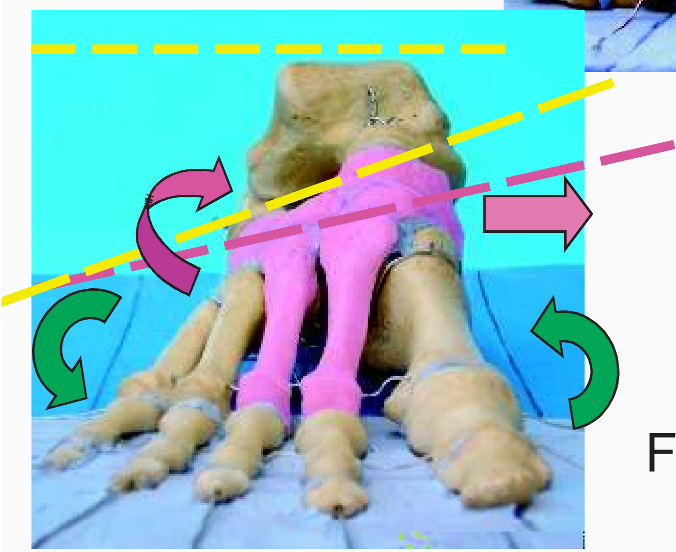
Note talus moves medially and laterally & talar dome remains horizontal

MID-FOOT ROTATION
AND COMPENSATORY FOREFOOT/HIND-FOOT MOVEMENTS IN CORONAL PLANE

Forefoot MT 'twist' (**supination**)

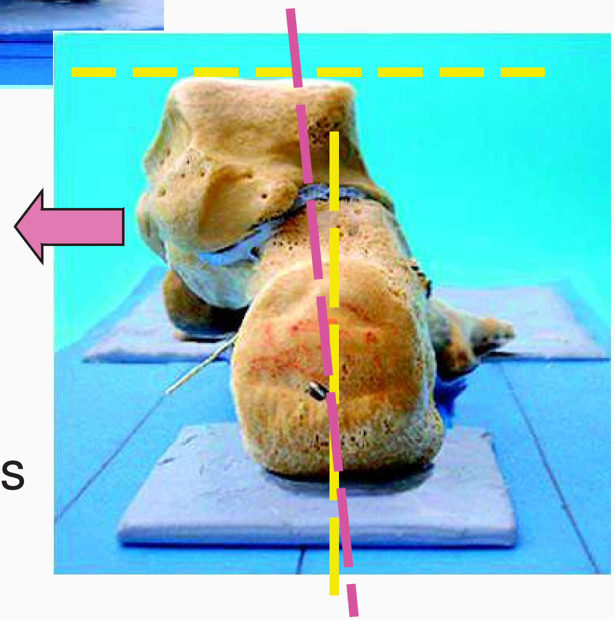


Calcaneus **pronates** only 'half' of the cuboid and navicular rotation movement



PRONATION

of mid-foot (navicular & cuboid)

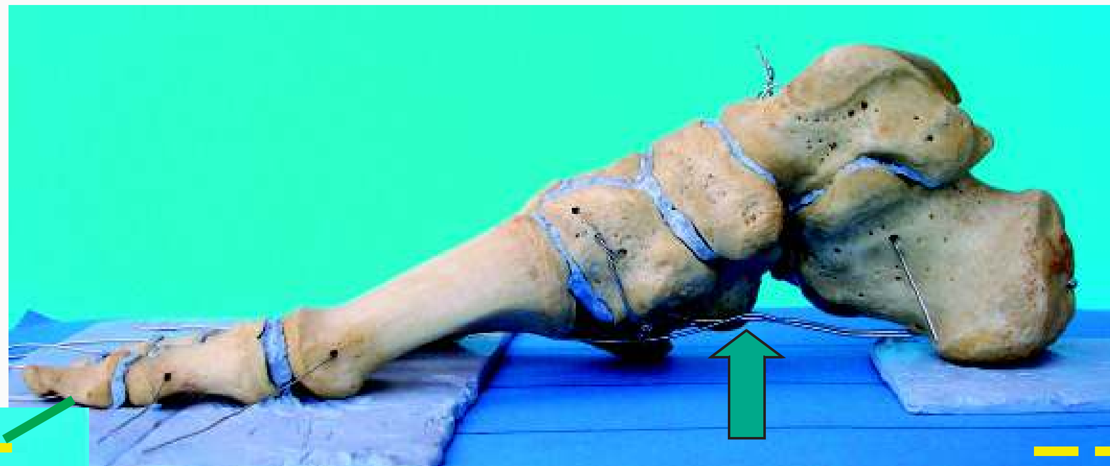


Foot 'flattens'

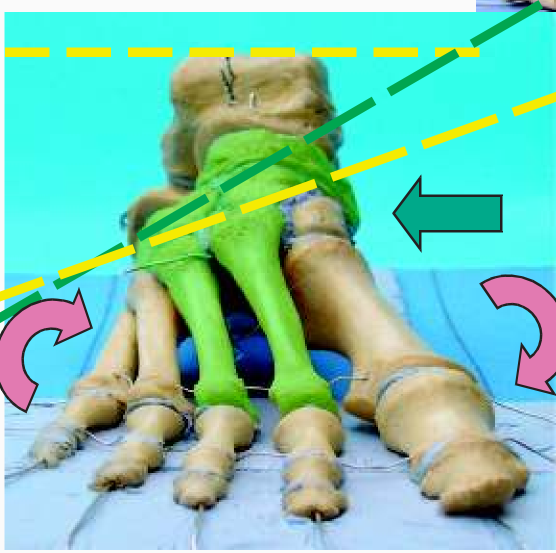
Forefoot segment externally rotates and becomes dorsiflexed

MID-FOOT ROTATION
AND COMPENSATORY FOREFOOT/HIND-FOOT MOVEMENTS IN CORONAL PLANE

Forefoot MT
'twist'
(**pronation**)

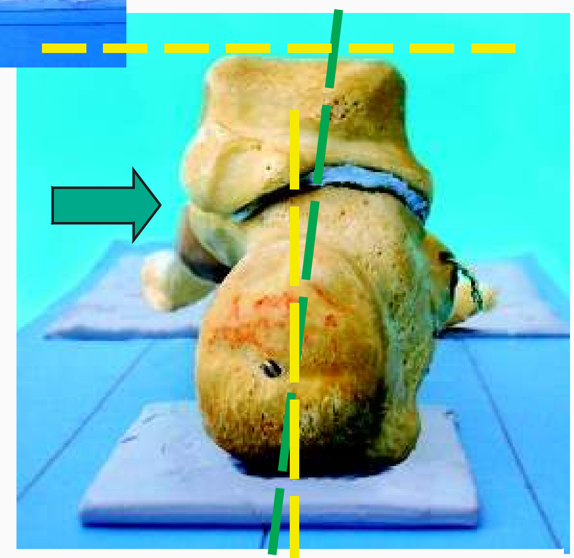


Calcaneus **supinates** only 'half' of the cuboid and navicular rotation movement



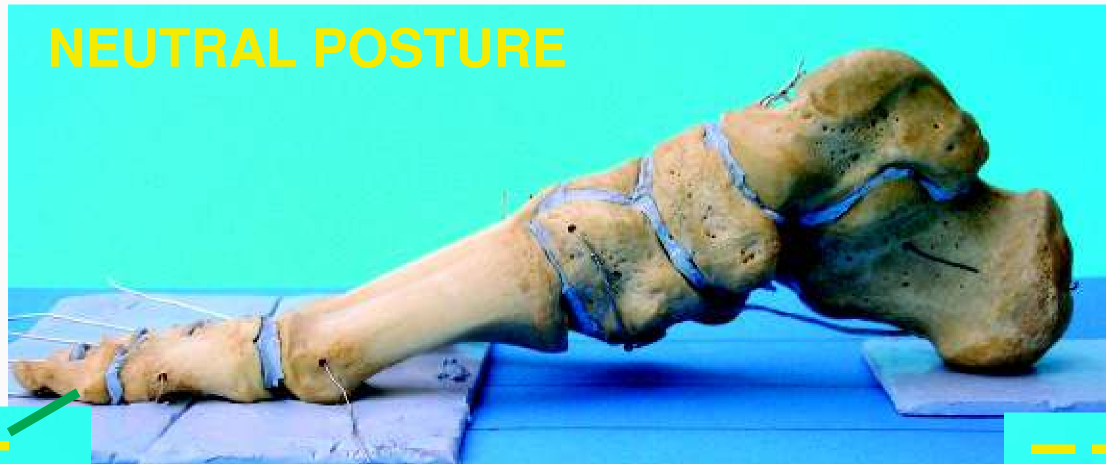
SUPINATION
of mid-foot

Mid-foot 'elevates'
Forefoot segment internally rotates and becomes plantar-flexed

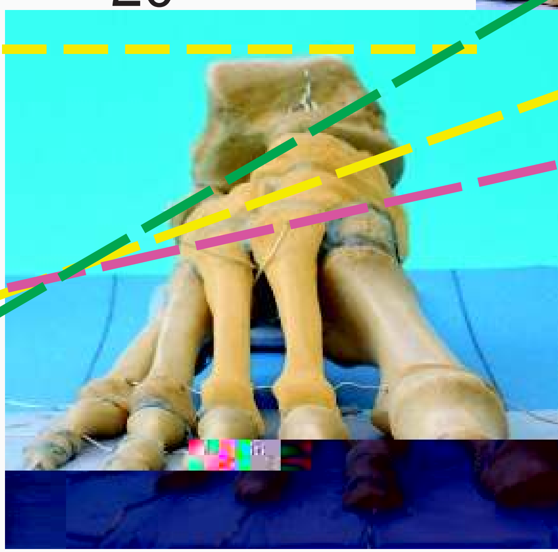


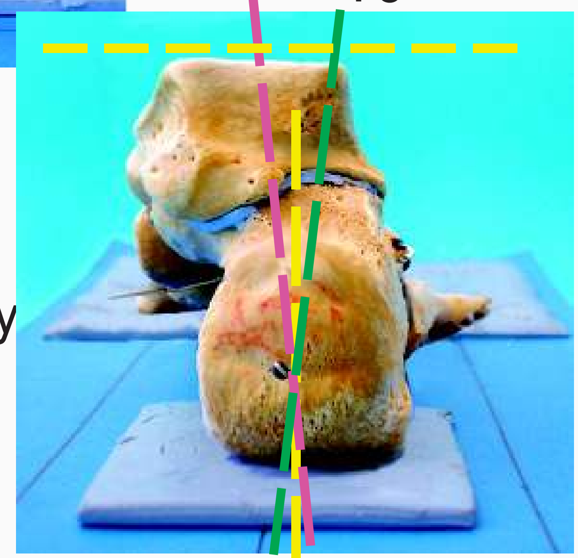
MID-FOOT ROTATION
AND COMPENSATORY FOREFOOT/HIND-FOOT MOVEMENTS IN CORONAL PLANE

Mid-foot
Pronation /
supination
20°



Calcaneal
pronation /
supination
10°

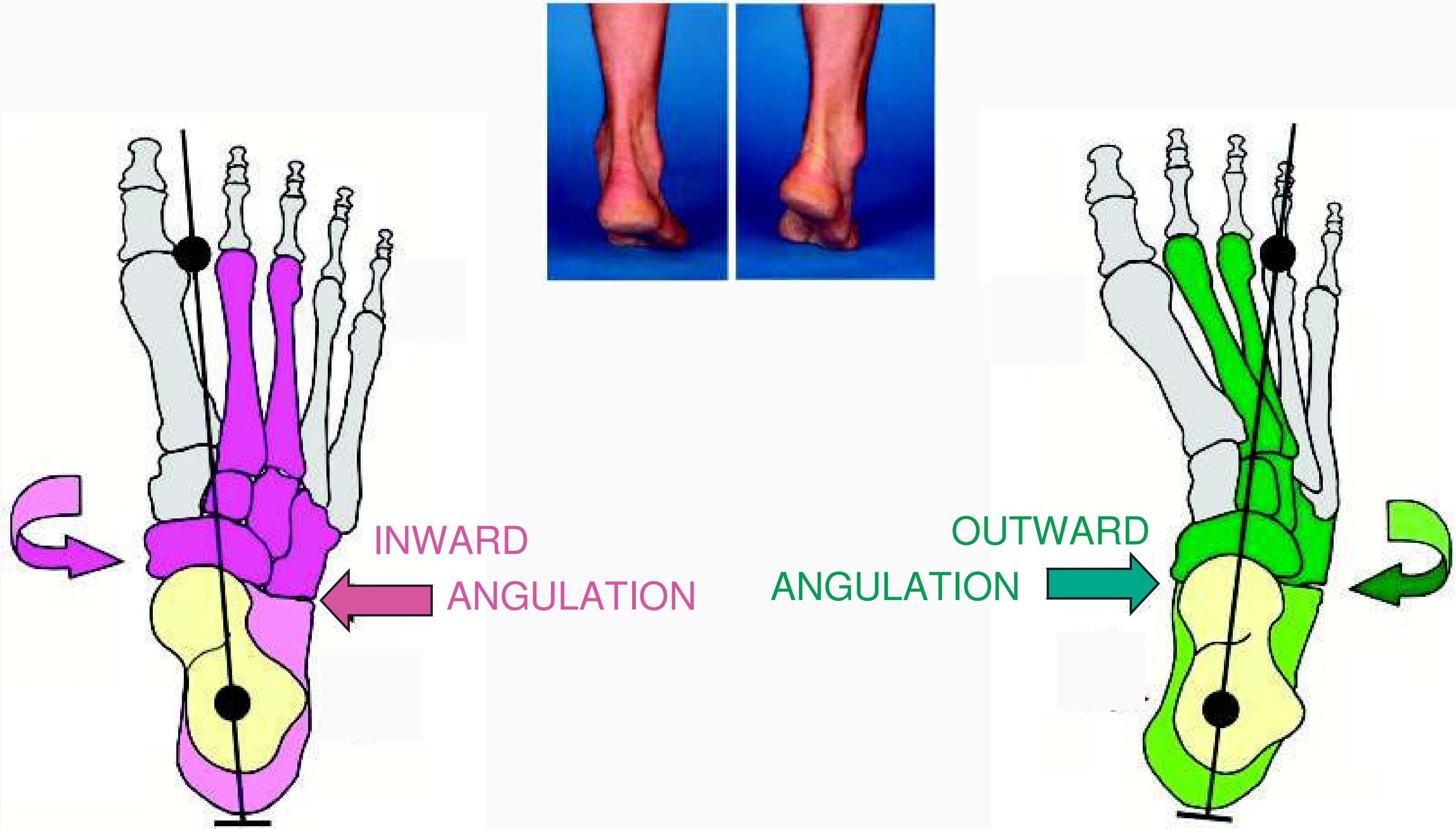




As mid-foot swings medially & laterally and **pronates** and **supinates**
Compensatory rotations required in forefoot and hindfoot to keep talus and forefoot horizontal

THE HYPOTHESIS

FOOT BEHAVES AS ‘BALANCED CANTILEVER’

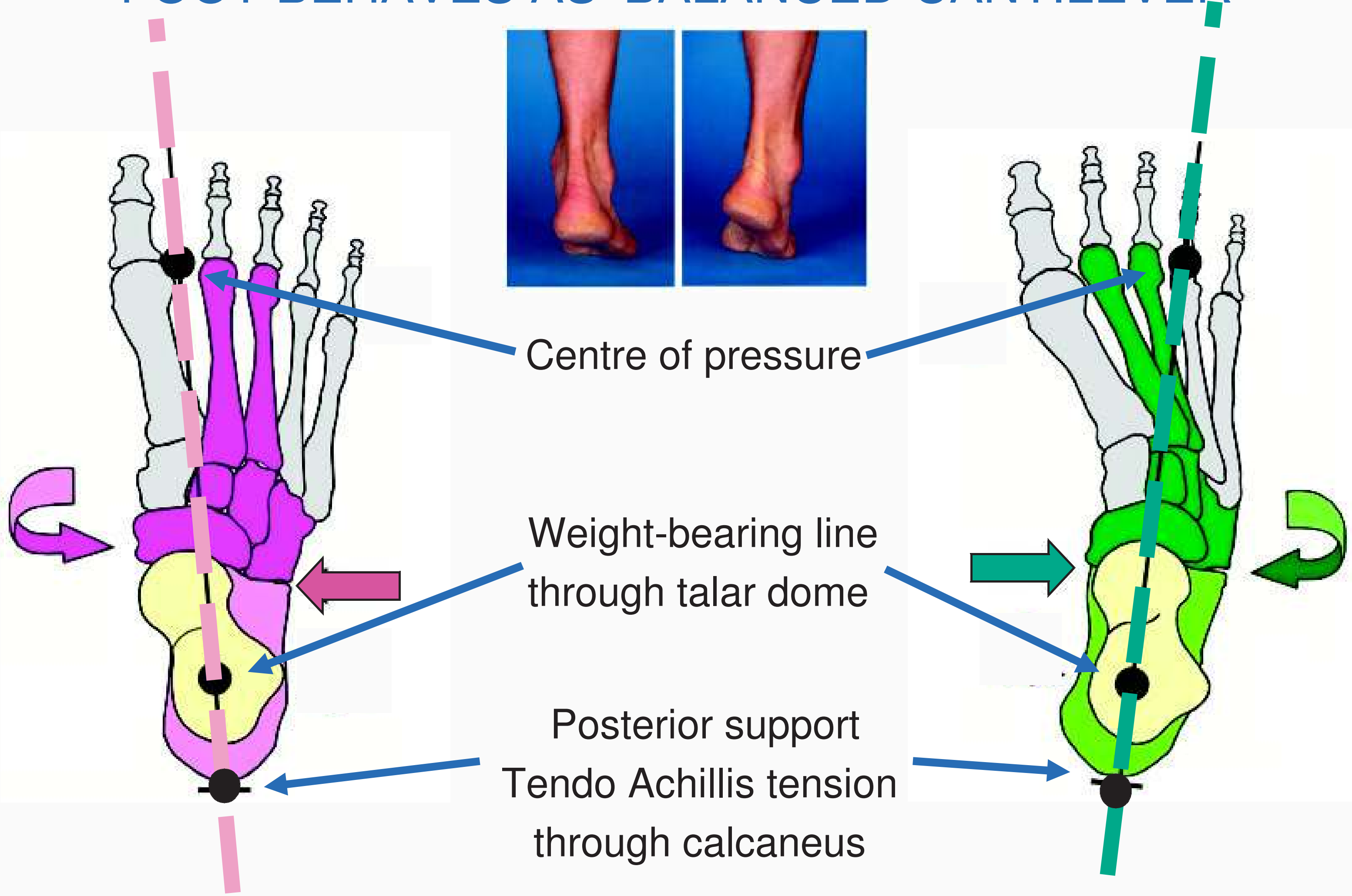


PRONATED **SUPINATED**

Full pronation and supination postures

THE HYPOTHESIS

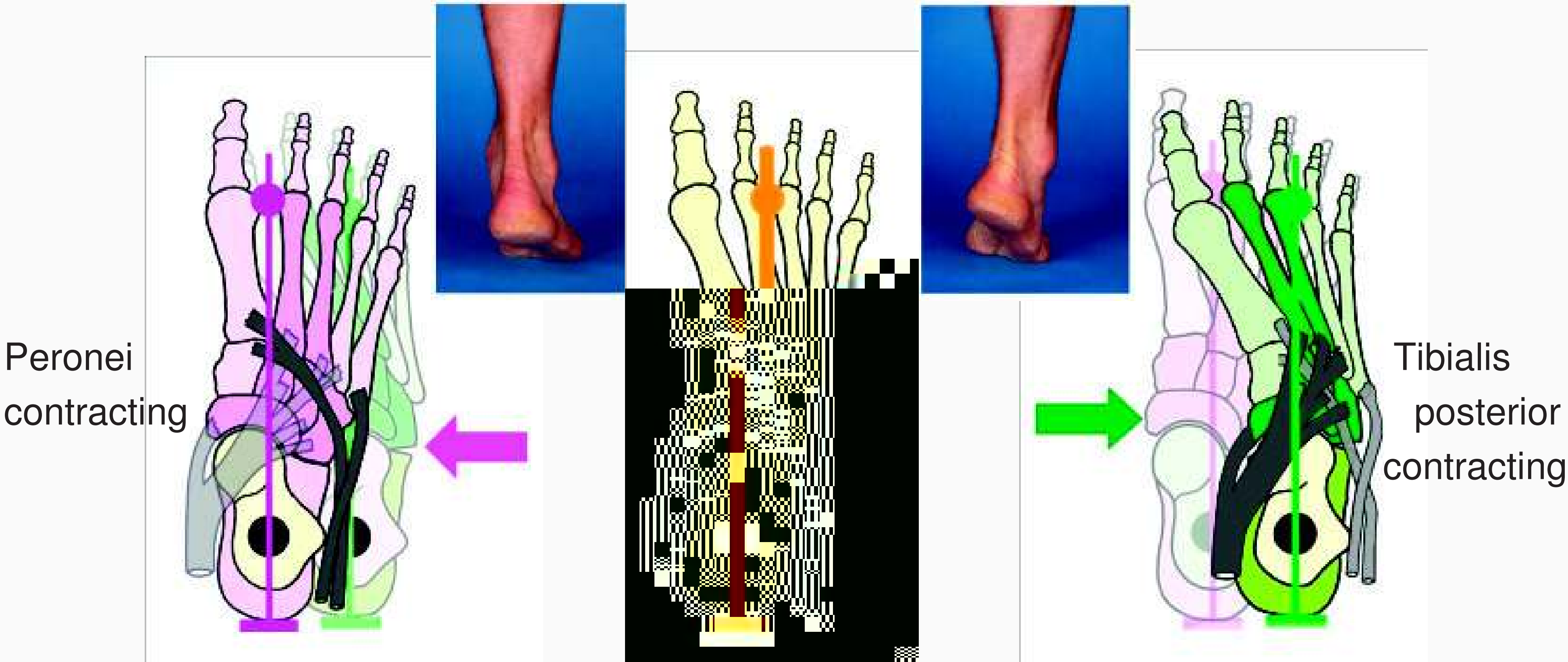
FOOT BEHAVES AS ‘BALANCED CANTILEVER’



THE FOOT WILL BE STABLE AND ‘BALANCED’ WHEN ALL 3 IN LINE

THE HYPOTHESIS

FOOT BEHAVES AS ‘BALANCED CANTILEVER’



The Peronei and Tibialis posterior control the lateral swing movements of the mid-foot

It is suggested:

This mechanism provides adjustments of foot posture for lateral balance

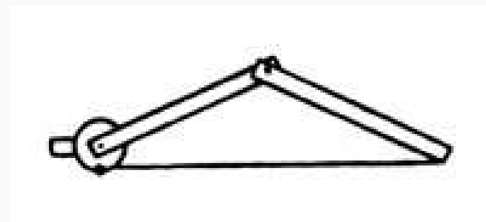
The coordinated inter-tarsal movements allow the foot to act as a ‘balanced lever’ within the full range of normal pronation/supination movement

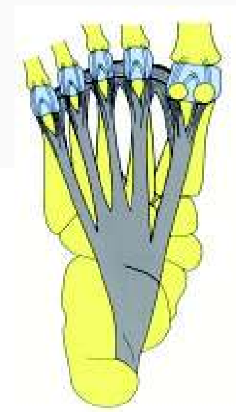
THE HYPOTHESIS

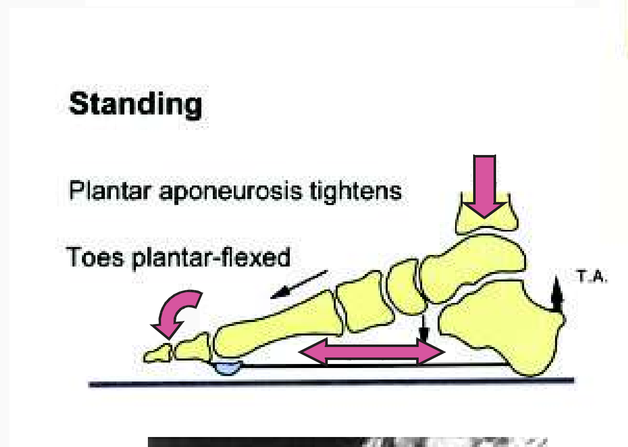
FOOT BEHAVES AS ‘BALANCED CANTILEVER’

It is suggested that:

1. Basic construction of the foot is that of a bow-string beam with longitudinal structures based upon the five metatarsals
2. Plantar aponeurosis, MTP joint plantar plates, and DTMLs form a supporting multi-segmental tie-bar system
3. Reversed windlass mechanism of aponeurosis plantar-flexes toe at MTPJ when related metatarsal is load-bearing
4. Forefoot weight-bearing is spread across the plantar pad area in contact with ground and the related toe pulps







THE HYPOTHESIS

FOOT BEHAVES AS 'BALANCED CANTILEVER'

It is suggested that:

5. Coordinated movements at inter-tarsal joints allow lateral swing angulation at mid-foot level (unique to the human foot in mammals)

6. These related movements in horizontal plane can allow the three forces acting on the single weight-bearing foot in sagittal plane to remain in line – foot can then behave as a 'balanced cantilever'

7. Controlled by peronei and tibialis posterior the accompanying medial and lateral displacements of ankle provide a mechanism for lateral balance