Assessment of the Foot in Relation to Gait Dysfunction and Injury Day 1

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Plan Day 1

Section	Theory	Practical
1) Introduction		
2) Functional Anatomy and foot morphology		
3) Normal Foot Function in Standing		
4) Abnormal Foot Function in Standing		
5) Terminology / Basics Of Gait		
6) Normal Foot Function in Gait		
7) Abnormal Foot function in gait		
8) Assessing for Abnormal function: i) Static Non-weightbearing ii) Static Weightbearing iii) Dynamic Weightbearing iv) Crossover		

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Section 1

Introduction

1) Introduction

Very briefly:

Who you are
What you do
Where you work

Course Introduction and Historical Perspective

For years, we've called it Podiatric Biomechanics

- However, there is NO professional ownership in this area (unlike for example, dentistry) with many professions having equal and valid input to the foot and ankle

- But, the definition does have worth in focussing the specific approach the foot and ankle needs as the contact medium of the leg to the floor

For years, we've called it Podiatric Biomechanics

- What is Podiatry?
- What is Biomechanics?
- What is Podiatric Biomechanics?

Podiatry

- Podiatry is the examination, diagnosis, treatment and prevention of diseases and malfunctions of the foot and its related structures.
- *Ref: The BMA's complete family health encyclopedia. Dorlans Kindersley, 1st Ed, 1993.*

Biomechanics

- The application of mechanical laws to living structures, specifically to the Locomotor system.
- *Ref: Dorlan's Illustrated Medical Dictionary, 25th Ed.*

Podiatric biomechanics?

‘The application of mechanical laws to the foot and its related structures’

1. Is there just one theory?
2. ‘Rootian biomechanics’ no longer demonstrates a reliable or valid paradigm
3. This weekend will be aimed at increasing practical knowledge of foot related gait dysfunction and their application to musculoskeletal injury

Gait Dysfunction Theory

With the development of podiatric biomechanics and orthotic management, diverse theories of its application have evolved. This can lead to perplexity in both clinical and educational settings as to the most efficacious method of patient assessment and treatment.

Harradine,Bevan and Carter 2003

The existence of various approaches impels the practitioner who uses biomechanical principles and techniques in the clinical setting to maintain an open, critical, and questioning mind.

Lee, 2001

Compliment or Conflict? The *team* approach?

- Harradine P, Bevan L, Carter N. Podiatric Biomechanics Part 1: Foot based models. **British Journal of Podiatry**. 11(1), 2003
- Carter N. Harradine P, Bevan L. Podiatric Biomechanics Part 2: The Role of core stability in Podiatric Biomechanics. **British Journal of Podiatry**. 11(2), 2003
- Harradine P, Bevan L, Carter N, An overview of podiatric biomechanics theory and its relation to selected gait dysfunction. **Physiotherapy**. 92(2): 122-127. 2006

The Interdisciplinary approach

- Drawing from physiology, biomechanics and psychology perspectives a realistic picture of foot function and gait dysfunction can be established

The Interdisciplinary approach

- Realistically this means podiatry, sports therapy, physiotherapy, orthotists, physiologists, biomechanists, Orthopaedic surgeons, Rheumatologists, chiropractors, osteopaths etc recognising and reading / sharing / critiquing each others theories and research.

Historical Context

- Past theories are not ‘wrong’
- New technologies have allowed us to ‘complete’ these theories.
- Paradigms have evolved from a more holistic perspective of lower quadrant symptomology.
- These theories must be able to explain the benefits obtained by ‘old’ standpoints

Historical Context – Unifying the Theory

- The next 2 days will present a unification of what has gone before, with current research amalgamating to form a logical and coherent step in our combined professions knowledge of foot function

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Section 2

Functional Anatomy and foot morphology

2) Functional Anatomy and foot morphology

Before understanding <u>abnormal</u>, we must understand <u>normal</u>

In describing normal, we initially need a recognised terminology everybody involved can understand.

- **Biomechanics….or biomagic?**

Terminology mixed a bit with anatomy

- **<u>VARUS</u> - A position of inversion**
- **<u>VALGUS</u> - A position of eversion**
- **<u>PRONATION</u> - A single motion comprising of Abduction, Eversion and Dorsiflexion**
- **<u>SUPINATION</u> - A single motion comprising of Adduction, Inversion and Plantarflexion**
- **<u>FOREFOOT</u> – Structures distal to the Midtarsal joint**

General Terminology

- **VARUS - A position of inversion**

- **VALGUS - A position of eversion**

Anatomy Revision
Functional and Clinical

- ✓ **Ankle Joint**
- ✓ **Subtalar Joint**
- ✓ **Midtarsal Joint**
- ✓ **1st Ray**
- ✓ **1st MTPJ**

Ankle Joint (Talocrural Joint)

- Clinically, we model this as sagittal plane “hinge” type joint
- This is a ‘clinical fiction’!

The Subtalar Joint –
a 'true' triplanar joint

	Frontal plane	Transverse Plane	Sagittal Plane
Pronation (arch lowering)	Eversion	Abduction	Dorsiflexion
Supination (arch raising)	Inversion	Adduction	Plantarflexion

Subtalar Joint

- Measured in the frontal plane, average ROM of 30 degrees with a 2:1 ration of inversion to eversion

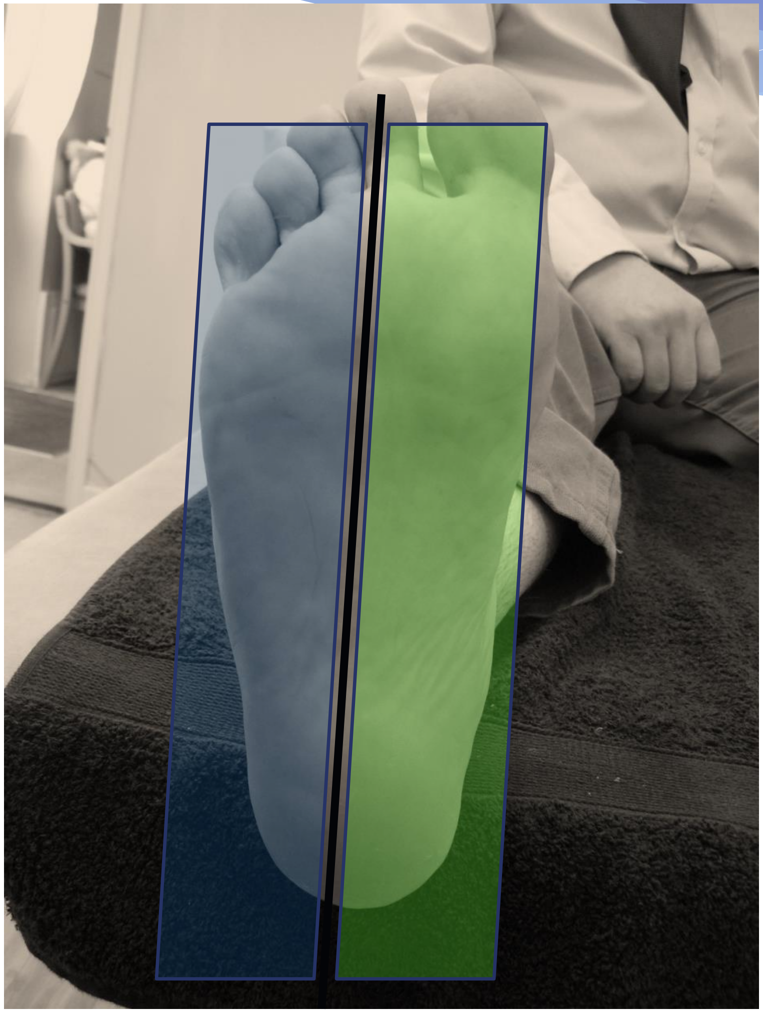
Eversion

(ROM average 10 degrees)

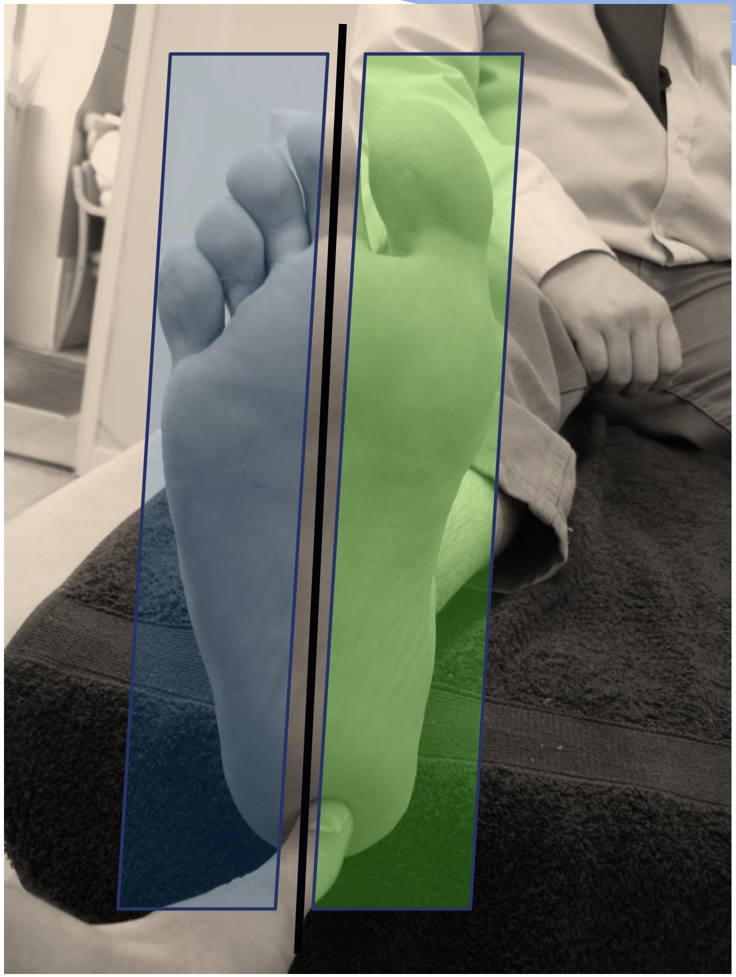
Inversion

(ROM average 20 degrees)

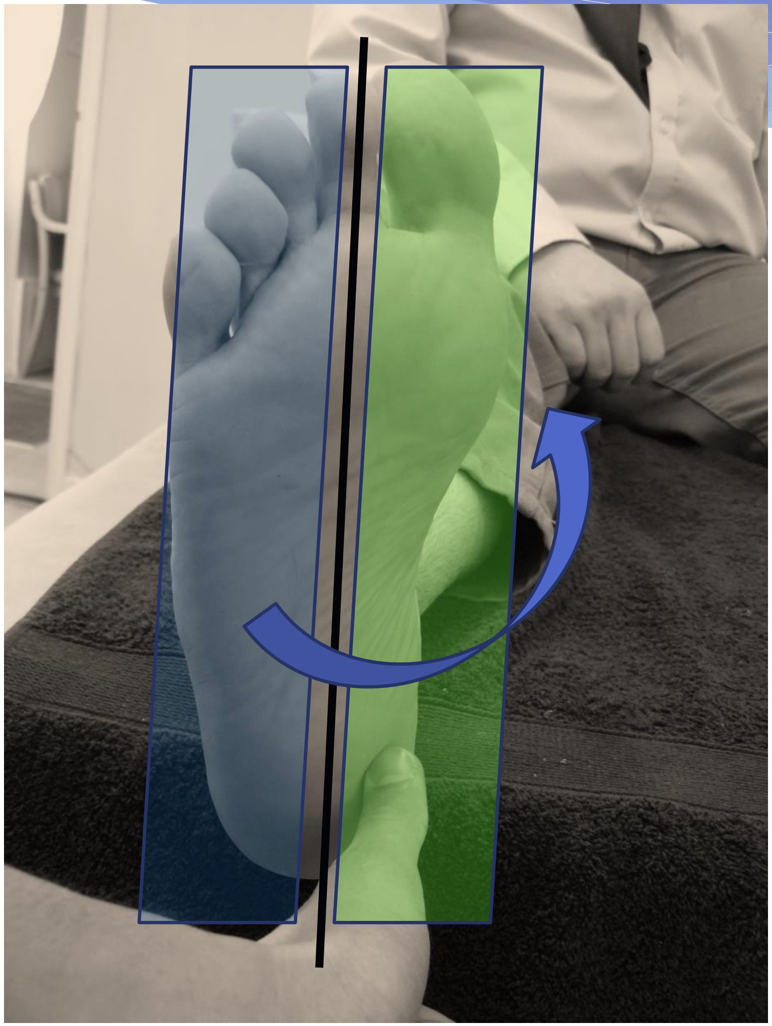
Normal STJ and Foot Function



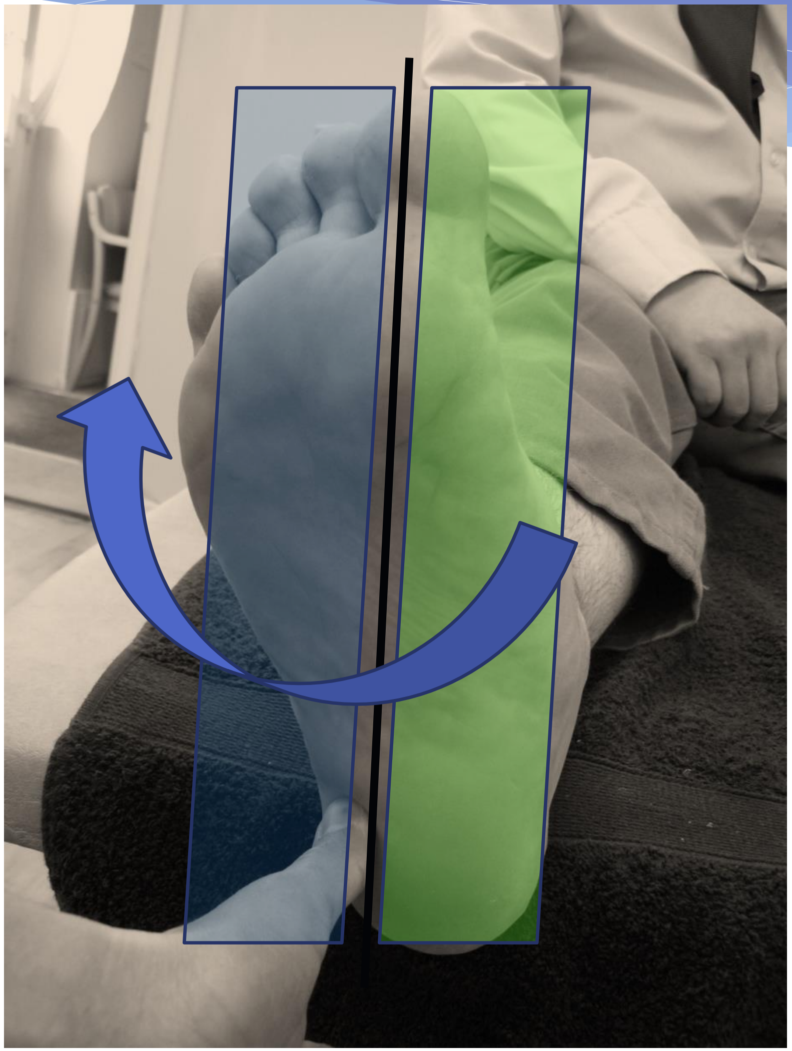
Normal STJ and Foot Function



Normal STJ and Foot Function

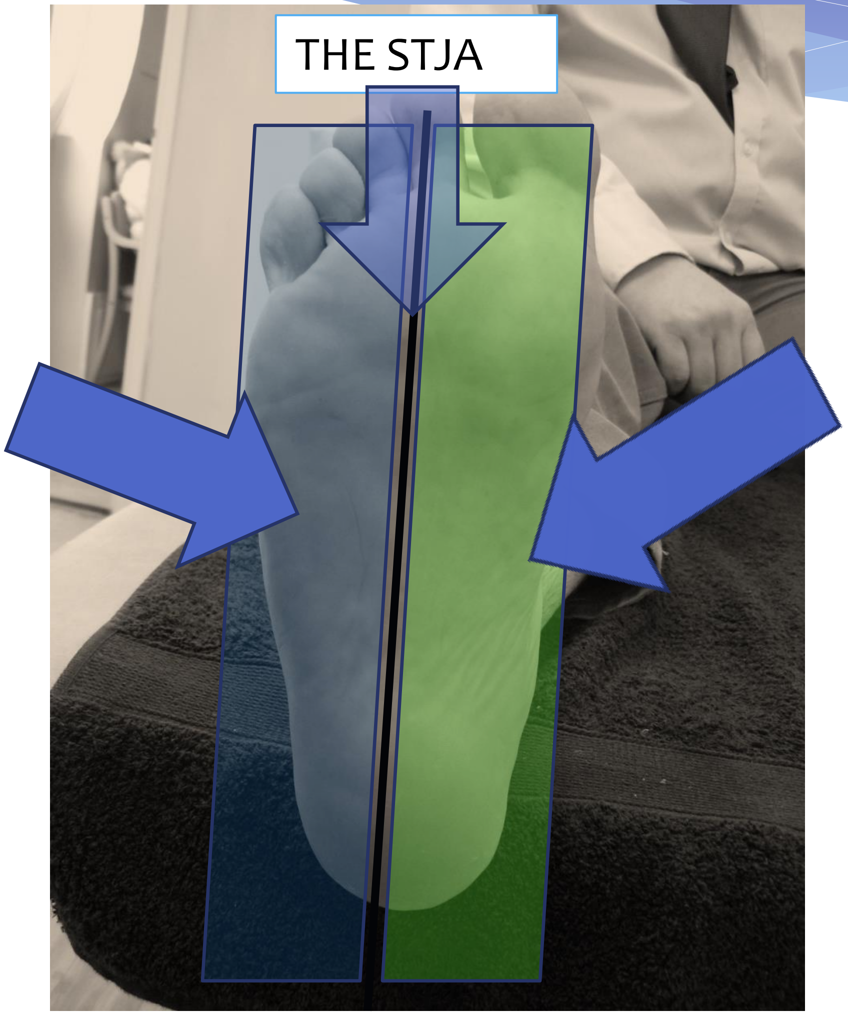


Normal STJ and Foot Function



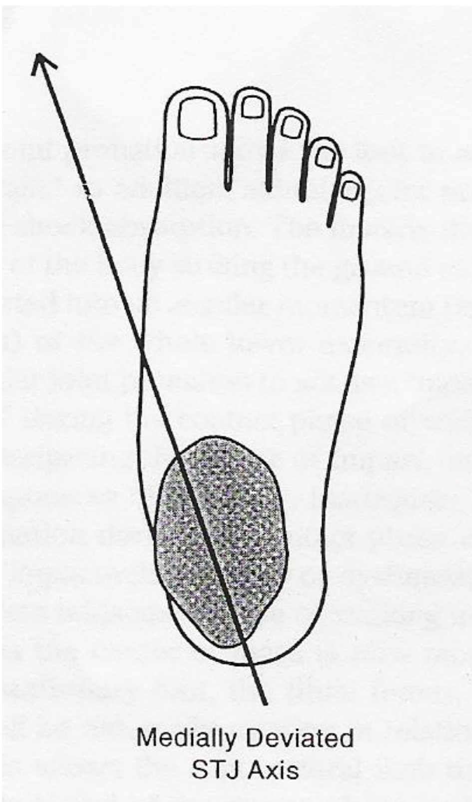
Normal STJ and Foot Function

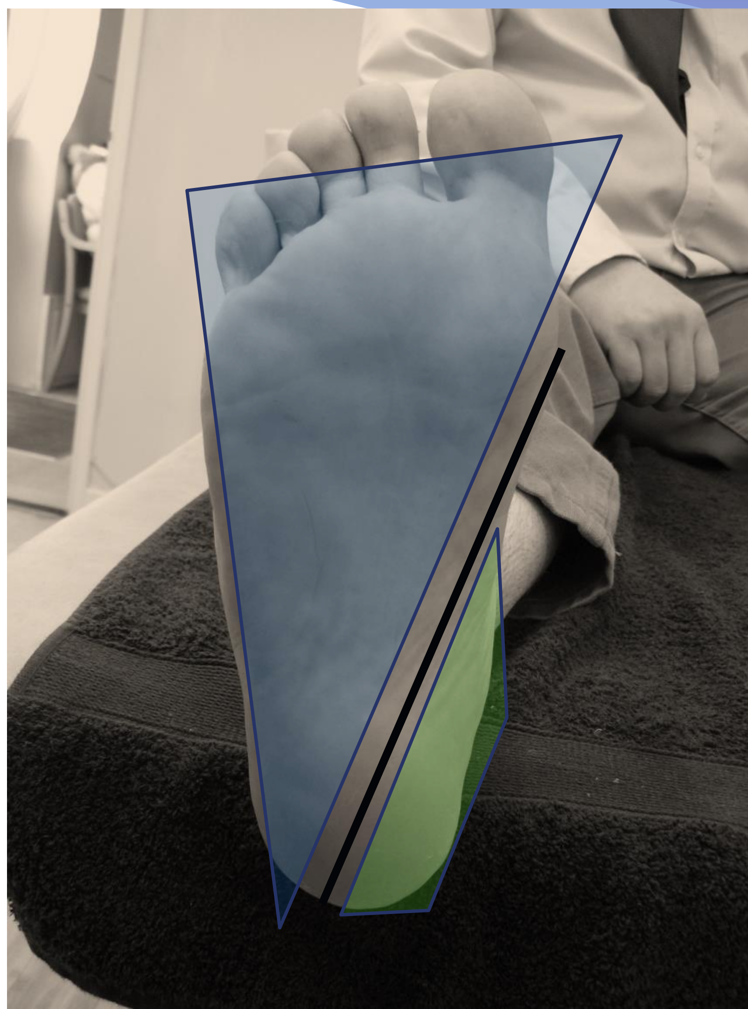
Lateral to the STJA



Medial to the STJA

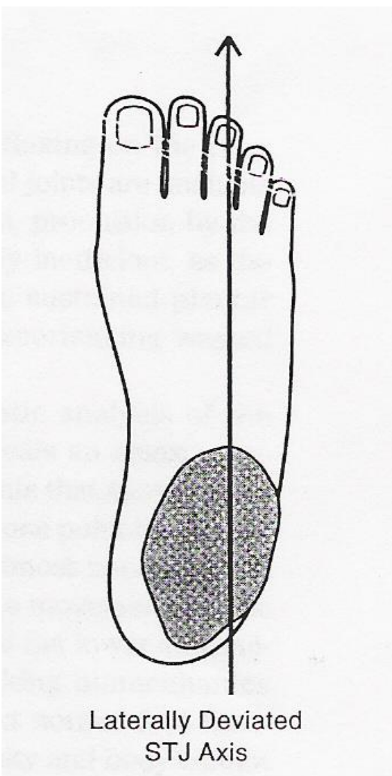
But what if the axis was NOT in the ‘middle’.....

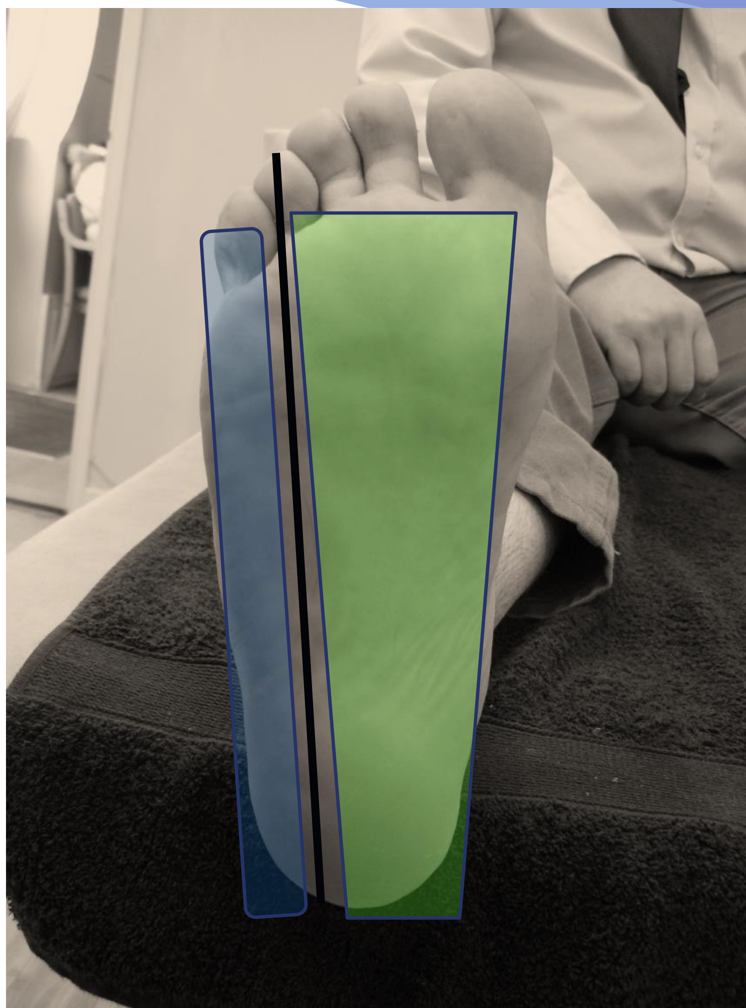




- But had instead moved medially......

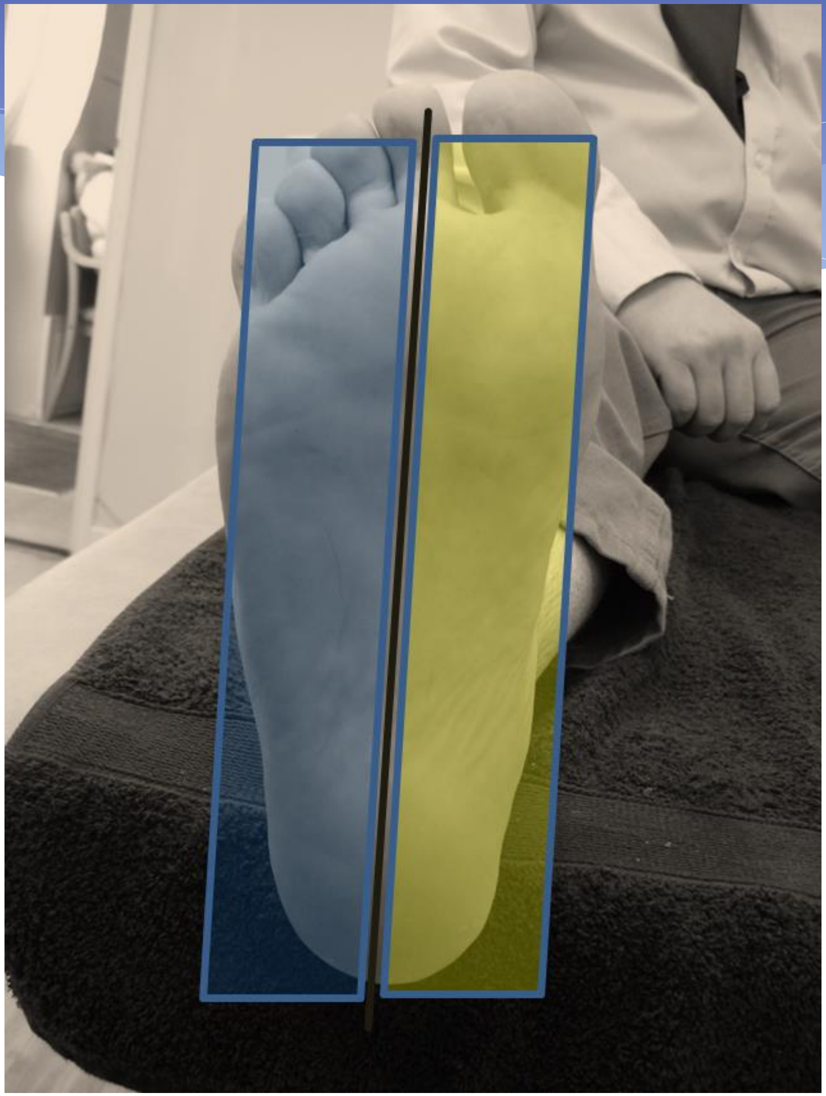
But what if the axis was NOT in the 'middle'.....





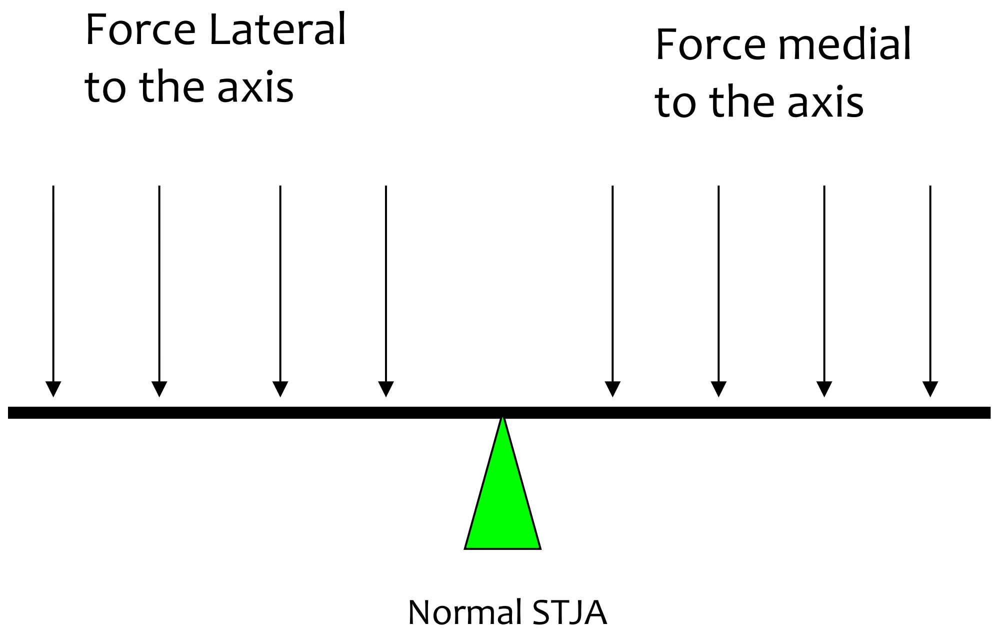
- But had instead moved or laterally......

Motion around the STJ is a type 1 lever



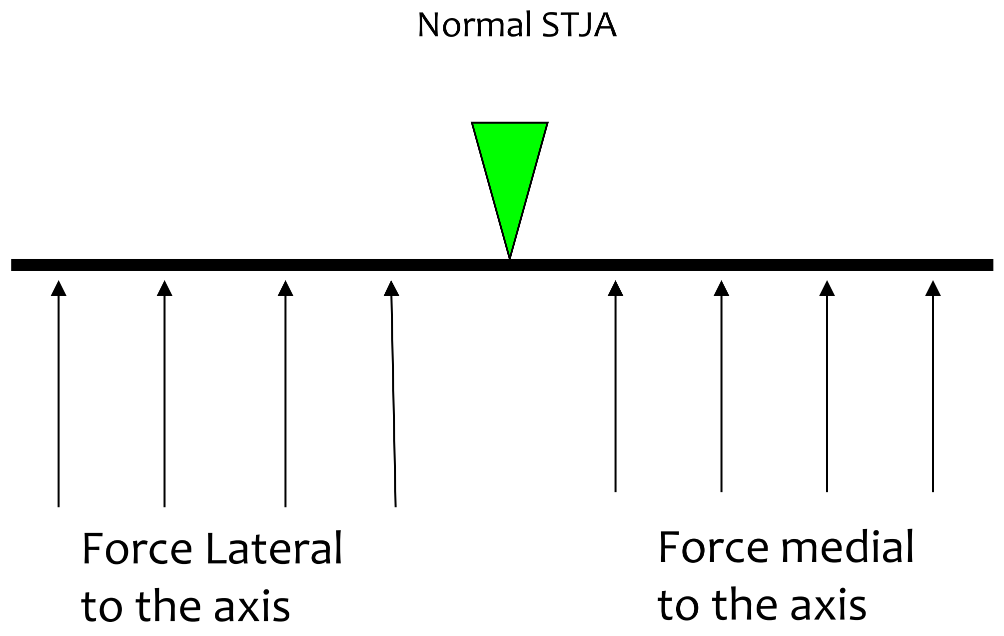
Moments and Movements at the STJ

The see-saw STJ axis analogy

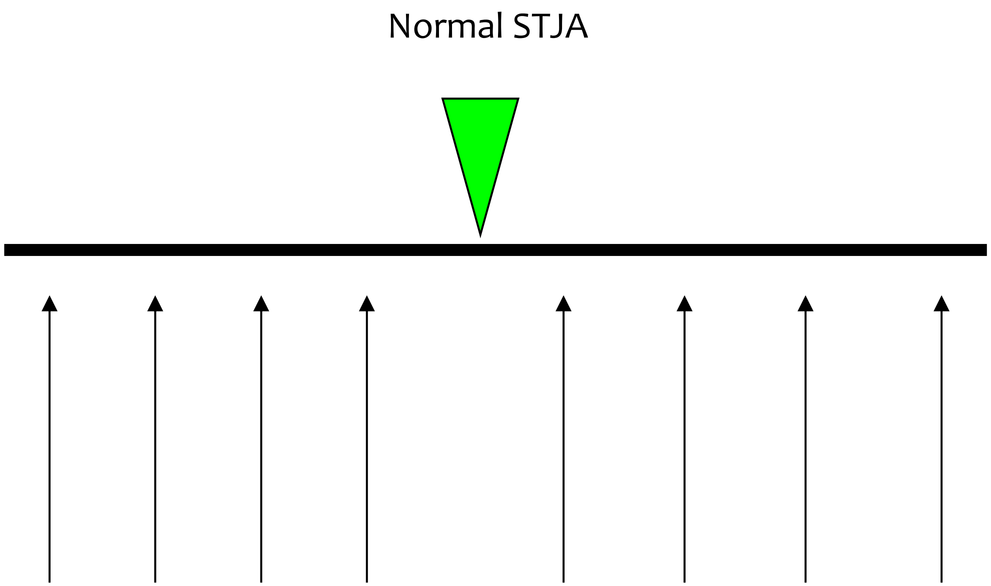


Moments and Movements at the STJ

The INVERTED see-saw STJ axis analogy

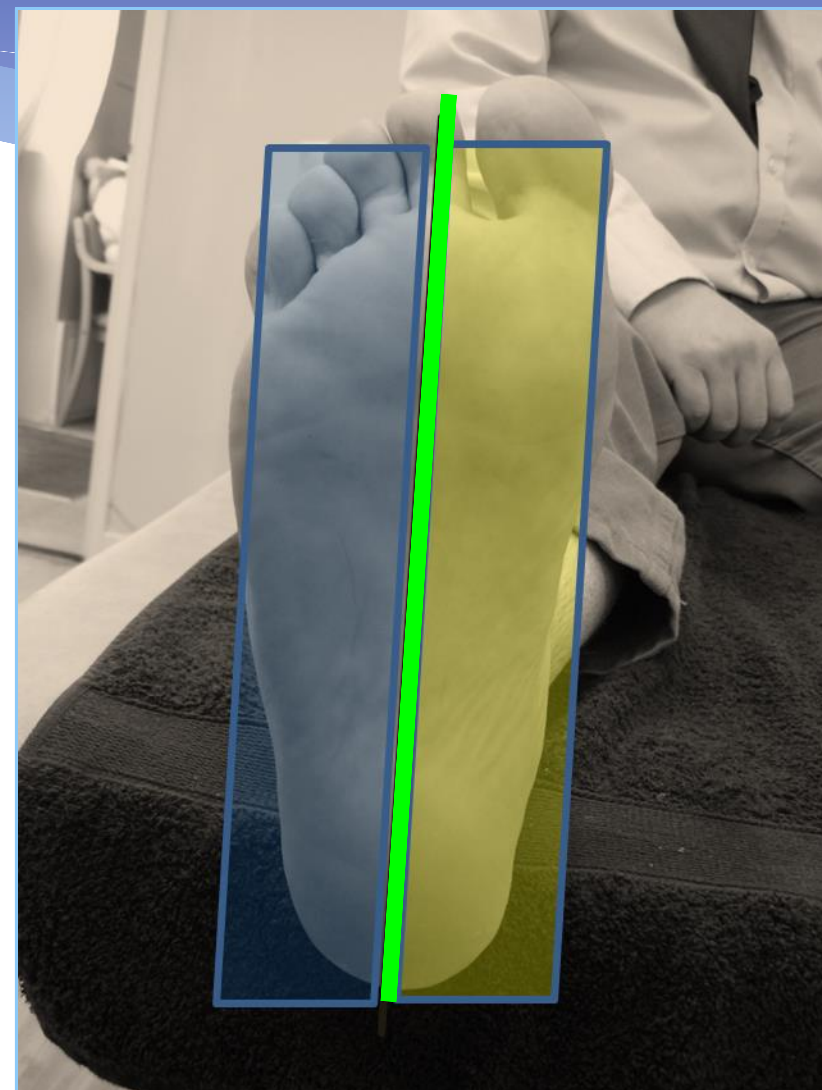


The more Valid inverted see-saw STJ axis analogy

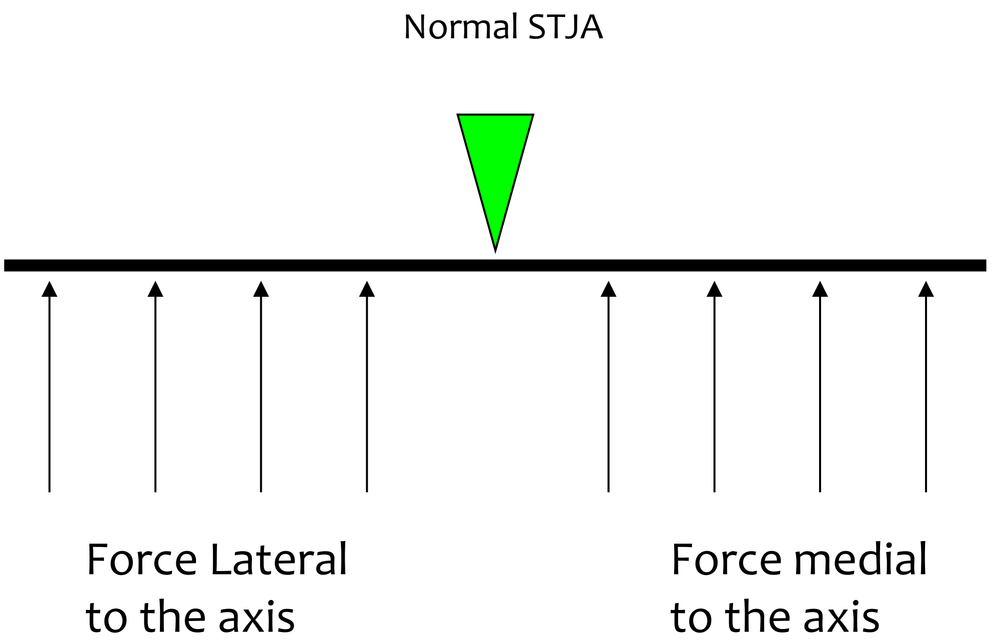


Force Lateral to the axis

Force medial to the axis



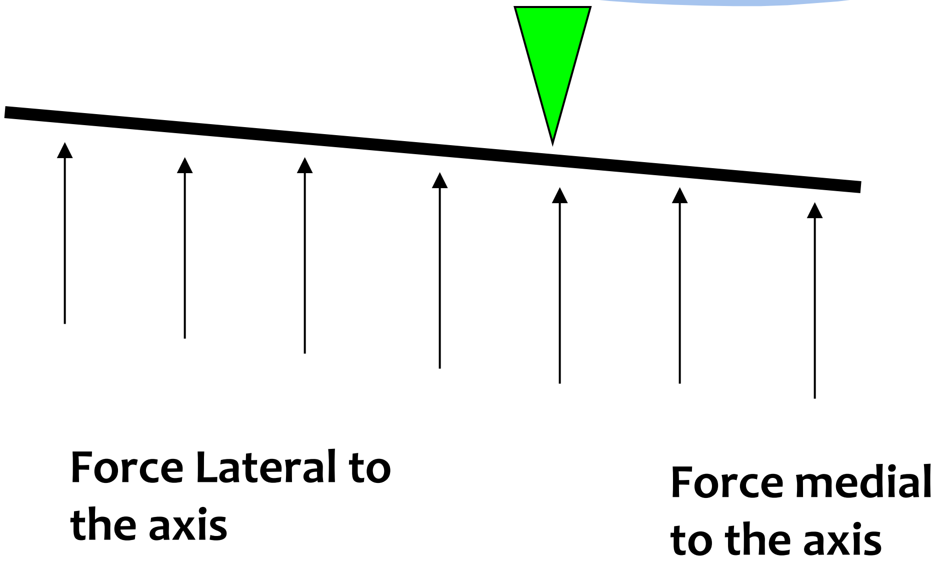
Moments across the STJ axis



lateral

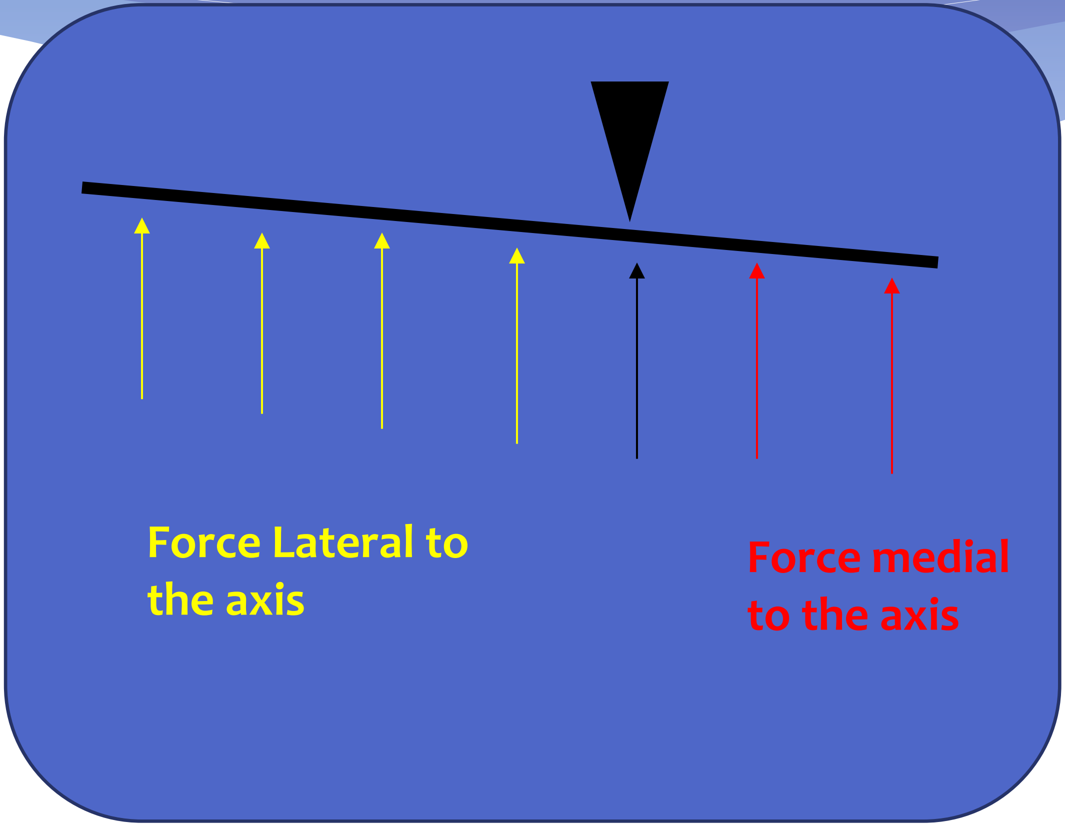
If the fulcrum, in this case a normal STJA, is in the middle of the see-saw and forces applied to the see-saw are equal and equidistant, **no motion will result**

Moments across the STJ axis



If the axis moves closer to one end of the lever, the lever will be longer on one aspect on the axis and the applied force increased. In this example, **a motion occurs around the axis (in this example, pronation).**

Moments across the STJ axis



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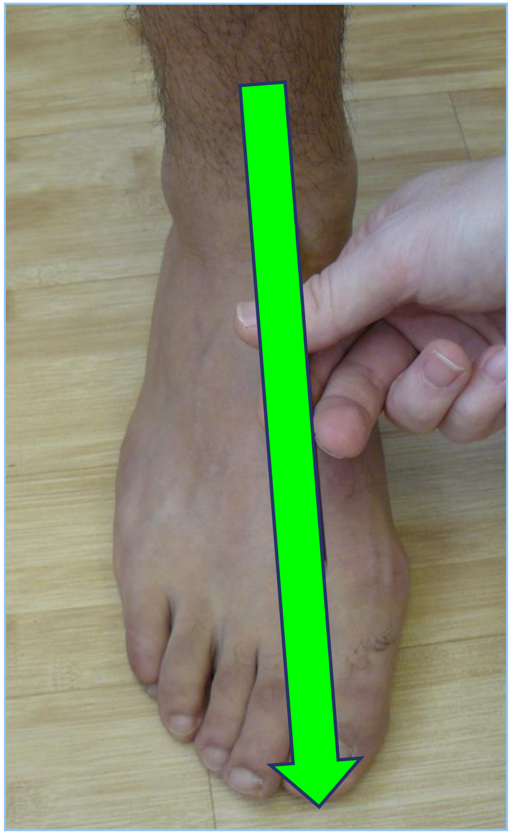
Dorsal estimation of STJ Axis

Dorsal estimation of STJ Axis



Subtalar Joint – Force coupling and the STJA

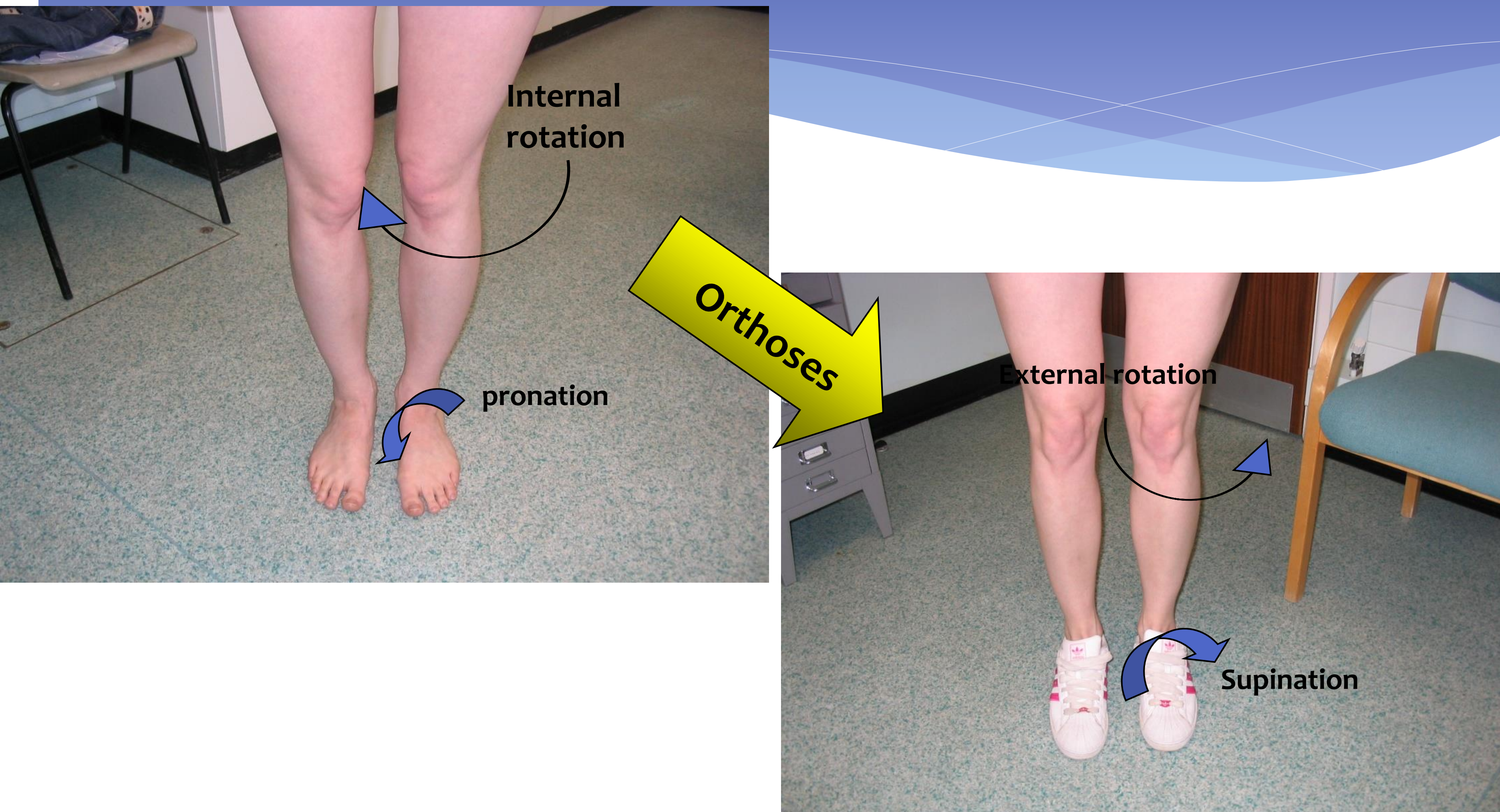
- STJ PRONATION causes the leg to internally rotate.

- STJ SUPINATION causes the leg to externally rotate.

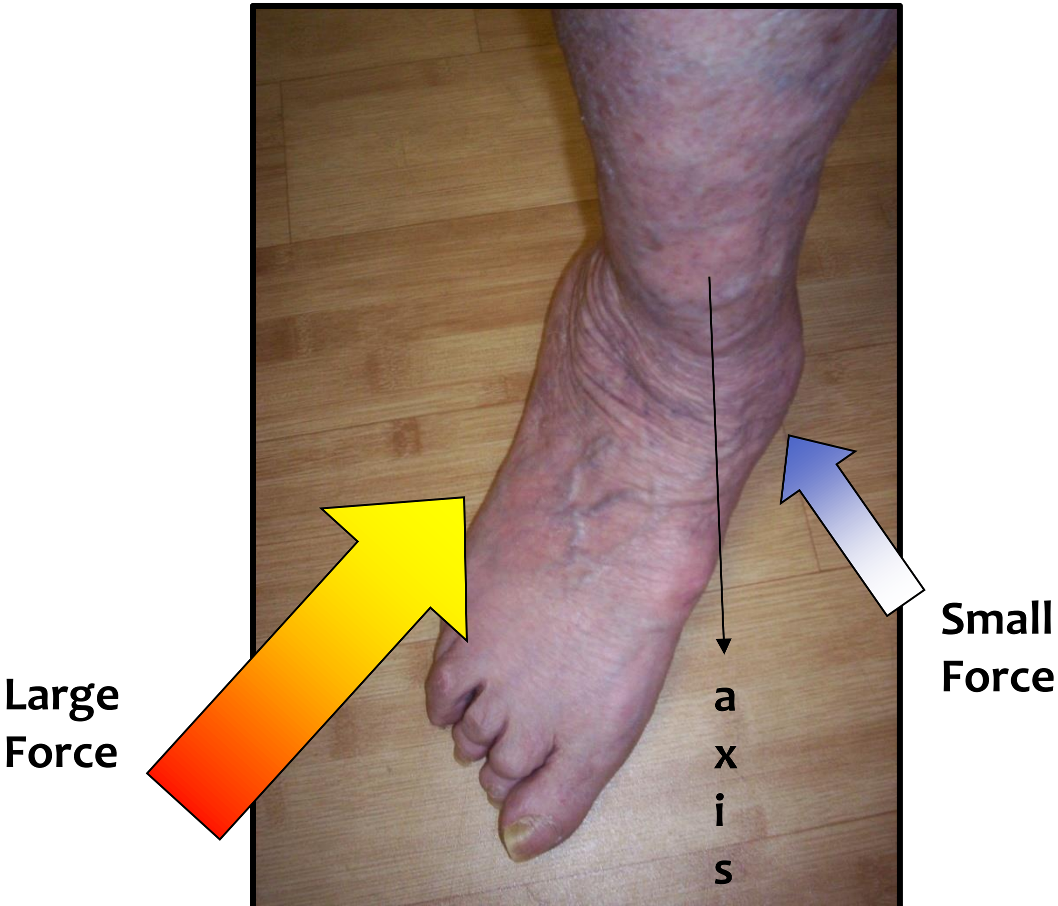
➢ The ratio of this force coupling is variable

Souza TR, Pinto RZ, Trede RG, Kirkwood RN, Fonseca ST. Temporal couplings between rearfoot-shank complex and hip joint during walking. Clin Biomech (Bristol, Avon). 2010 Aug;25(7):745-8. Epub 2010 Jun 8.

STJ and Force Coupling



Example of a medial STJA and application of GRF



Midtarsal Joint

- Made up of the talo-navicular and calcaneo-cuboid joints
- Has an envelope of motion
- Is Mono-Axial

Nester CJ, et al. Scientific approach to the axis of rotation at the midtarsal joint. JAPMA. 2001 Feb;91(2):68-73.

First Ray

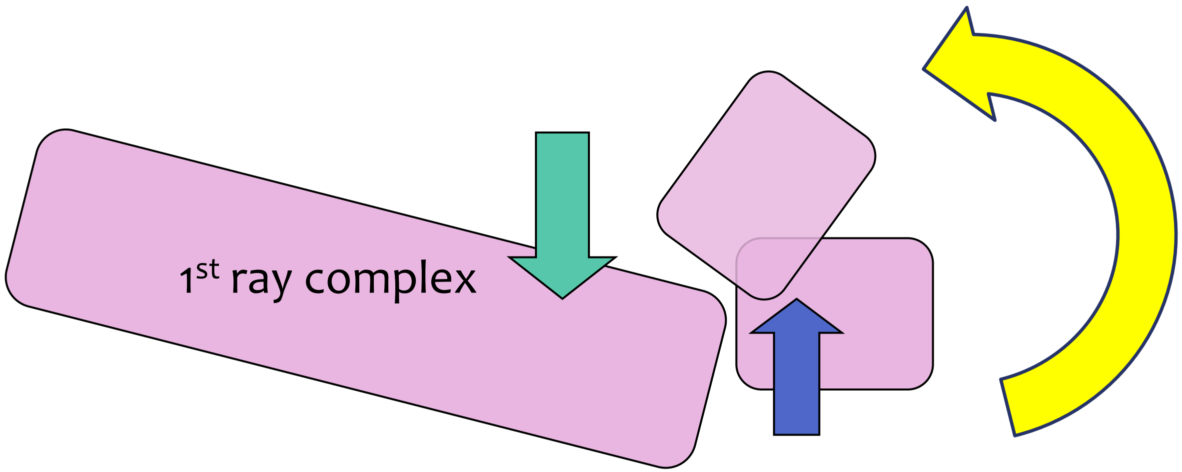
- The medial column of the foot, distal to the MTJ
- Made up of the 1^{st} metatarsal, medial cuneiform and navicular
- Triplanar, but majority of ‘relevant’ motion is in the sagittal plane

Dorsiflexion at the 1st Metatarsophalangeal Joint (MTPJ)

- **The Range of dorsiflexion at the 1st MTPJ is dependant on the position of the first ray**
- **Large group practical**

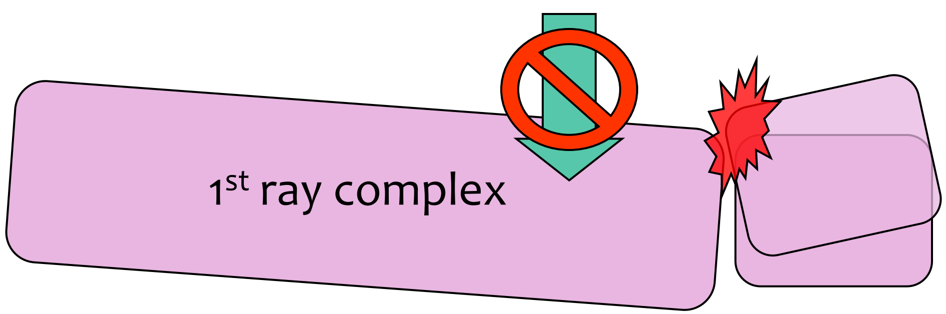
1st MTPJ

Medial view



Normal Hallux dorsiflexion with first ray plantarflexion

The Range of motion at the 1st MTPJ is dependant on the position of the first ray



Functional Limitation of Hallux dorsiflexion with lack of first ray plantarflexion

Introducing Foot Morphology and the STJ, MTJ and First Ray

Left

Right

Left

Right

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Section 3

Normal Foot Function in Standing

Normal Foot Function in Standing

- Many people spend more time standing than walking.
- Often a day is combined between both, with prolonged episodes of standing

Normal Foot Function in Standing

- In standing, the foot needs to provide a stable base for which relaxed bipedal stance can occur
- While in this position, ideally the foot should rest in equilibrium

Normal Foot Function in Standing

- Structures which oppose supination or pronation moments should not be placed under excessive stress which may result in injury
- Pressure should not be raised to a point where skin lesions or plantar joint irritation can occur
- Joint compression should not be increased to cause injury

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Section 4

Abnormal Foot Function in Standing

Abnormal Foot Function in Standing

- Structures which oppose supination or pronation moments should not be placed under stress which may result in injury

Abnormal Foot Function in Standing

- In Stance, this may be prolonged resulting in Creep past the point of Tissue Elasticity

Abnormal Foot Function in Standing

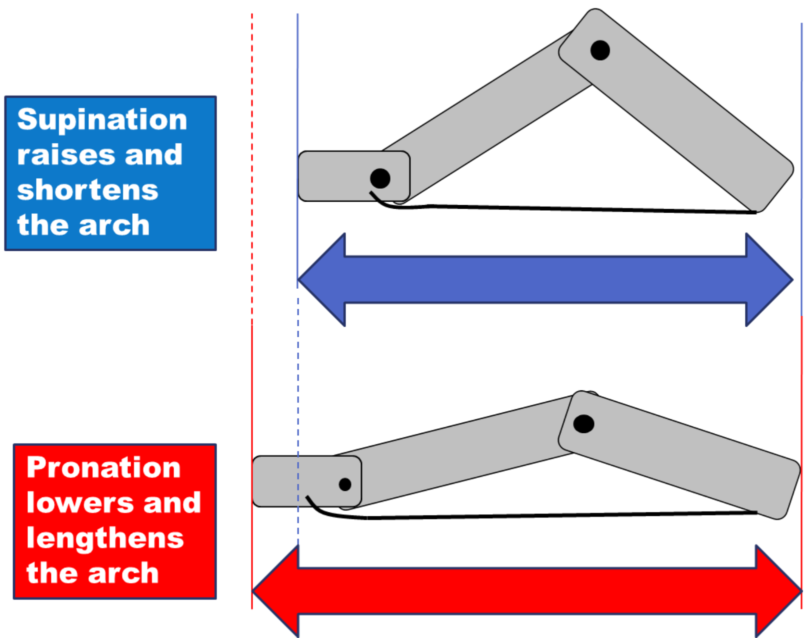
- Foot and ankle structures which may reduce pronation moments include, and therefore may become symptomatic in standing with increased pronation include:

- 1) Plantar fascia
- 2) Plantar foot ligaments which cross the midtarsus
- 3) Posterior Tibial Muscle and Tendon

Abnormal Foot Function in Standing

- Foot and ankle structures which may reduce pronation moments, and therefore may become symptomatic in standing with increased pronation, include:

- 1) Plantar fascia
- 2) Plantar foot ligaments which cross the midtarsus



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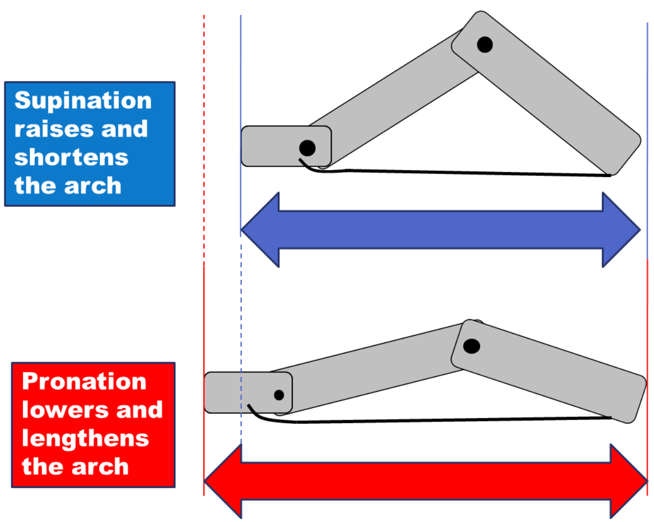

Abnormal Foot Function in Standing

- Foot and ankle structures which may reduce pronation moments, and therefore may become symptomatic in standing with increased pronation, include:

- 3) Posterior Tibial Muscle and Tendon

Abnormal Foot Function in Standing

- Foot and ankle structures which may reduce supination moments include:

- 1) Lateral ankle ligaments
- 2) Peroneal muscle Group

Abnormal Foot Function in Standing

Pressure should not be raised to a point where skin lesions or plantar joint irritation can occur

Abnormal Foot Function in Standing

Joint compression should not be increased to cause symptoms. Increased pronation increases dorsal midfoot interosseous compression forces

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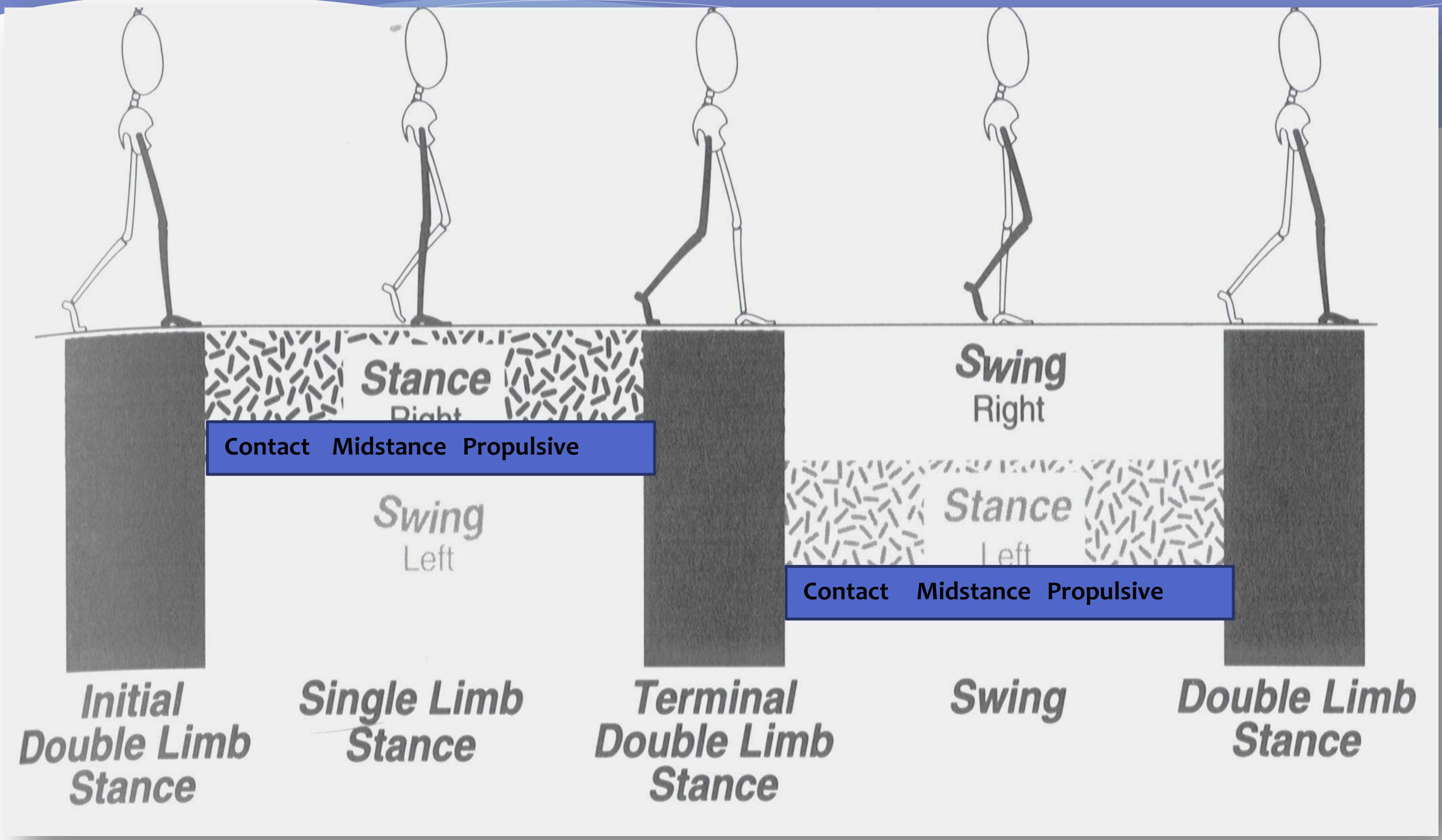
Section 5

Terminology / Basics of normal gait

5) Terminology / Basics of Normal Gait

Basics of Normal Foot function - The Gait Cycle



Diagrams adapted from Perry J: Gait analysis. Normal and Pathological Function. 1992

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Section 6

Normal Foot Function in Gait

6) Normal Foot Function in Gait

" People do not limp because they hurt, rather they hurt because the limp"

Dananberg 1993

Current theories on normal foot function in gait

With the development of podiatric biomechanics and orthotic management, diverse theories of its application have evolved. This can lead to perplexity in both clinical and educational settings as to the most efficacious method of patient assessment and treatment

Harradine et al 2003

Current theories on normal foot function in gait

Theoretical Perspective	Foot Morphology Theory	Sagittal Plane Facilitation Theory	Tissue Stress Theory
Criteria for Normalcy	The STJ passes through neutral at key stages of the gait cycle	The foot functions as a pivot allowing adequate hip extension and correct posture	The foot functions in a way that does not result in abnormal tissue stress and injury
Casting Methodology	The foot is cast in STJN, unless large deformity contraindicates this.	Casting methods are not documented, although recent non-custom orthoses from this theory may mean casting is not required	The positive cast is modified when taken to supply the shell shape required to apply the correct forces to the foot
Orthoses aim	To prevent abnormal joint compensation and place the foot into its normal position for key stages of the gait cycle	To allow the foot to work successfully as a pivot and facilitate Sagittal plane motion	To reduce abnormal stress upon symptomatic structures

Harradine and Bevan, JAPMA, 2009.

But, rather than spend the day focussing on the way theories disagree and be incredibly negative (again)….

Can we unify what has gone before?

The importance of bringing together what can be agreed on… to unify the theory.

I am convinced that this is the only means of advancing science, of clearing the mind from a confused heap of contradictory observations, that do but perplex and puzzle the Student, when he compares them, or misguide him if he gives himself up to their authority; but bringing them under one general head, can alone give rest and satisfaction to an inquisitive mind.

Sir Joshua Reynolds

How do we walk?

Before understanding ABNORMAL, we must have an understanding of NORMAL

Normal lower limb function in walking gait

1. **The 1st (Heel) Rocker**
2. **Internal hip rotation with foot pronation**
3. **The reverse windlass**
4. **The 2nd (Ankle) Rocker**
5. **External hip rotation with foot supination**
6. **The 3rd (Digits) Rocker**
7. **The Windlass mechanism with medial column propulsion**
8. **Adequate hip and knee extension for normal posture and swing phase**

Normal lower limb function in gait

1. The 1st (Heel) Rocker

- Shock absorption
- Weight-bearing stability
- Preservation of progression

Diagrams adapted from Perry J: Gait analysis. Normal and Pathological Function. 1992

Normal lower limb function in gait

2. Internal hip rotation and foot pronation

- The medial longitudinal arch (MLA) lowers and lengthens initially during stance phase of walking gait. The rearfoot everts (pronates) and then inverts (supinates) through a normal stance phase. Eversion occurs for the first 50-60% of the stance phase, followed by inversion (Leardini et al, 2007).

- The hip internally rotates during contact and mid stance and externally rotates throughout the terminal stance phase (Kadaba et al, 1990).

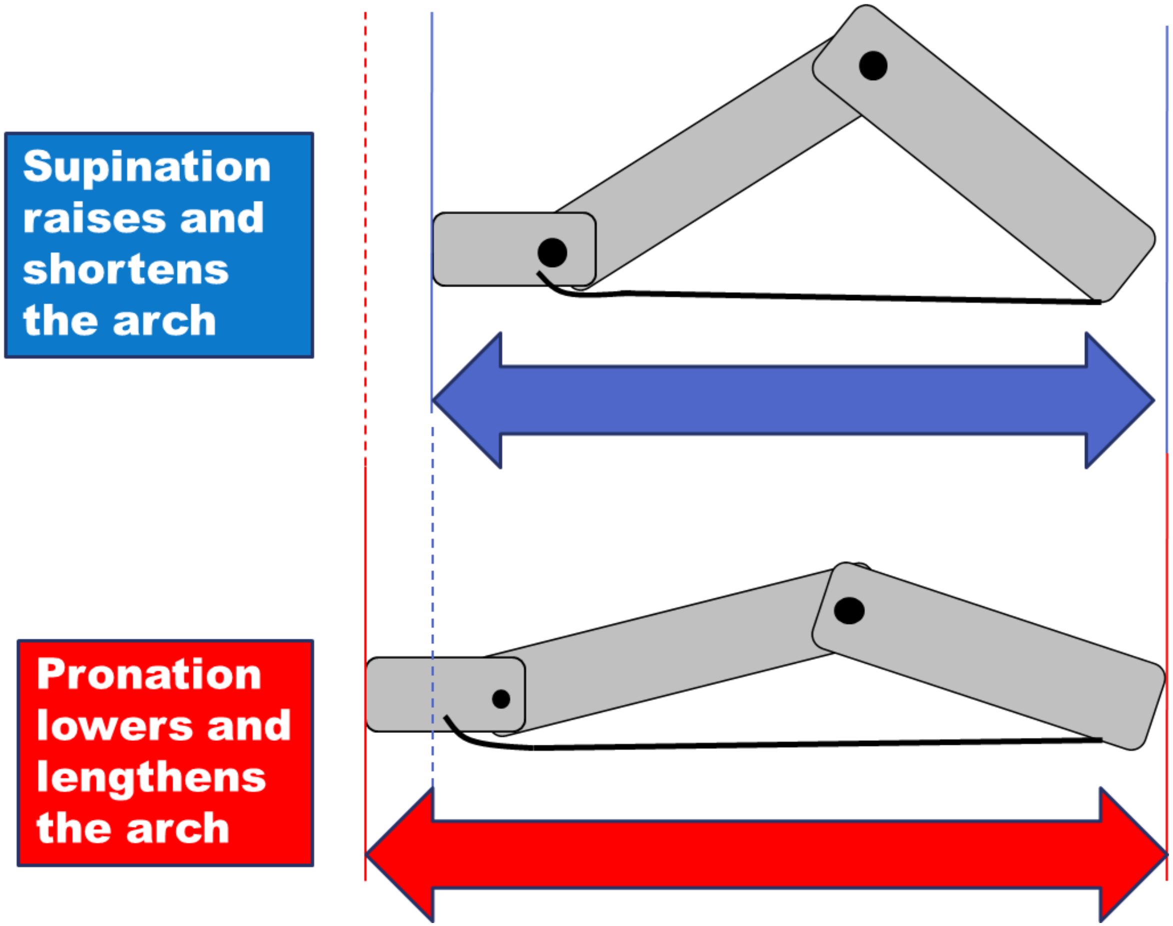
Normal lower limb function in gait

2. Internal hip rotation and foot pronation

- This motion has been proposed to couple with rearfoot complex pronation and supination, with pronation linked to internal rotation of the lower limb and supination with external rotation (Souza et al, 2010).

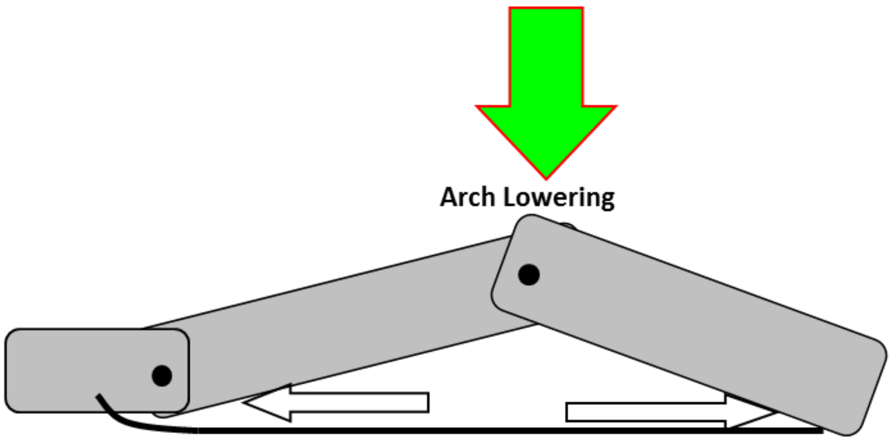
Normal lower limb function in gait

3.The reverse windlass



Normal lower limb function in gait

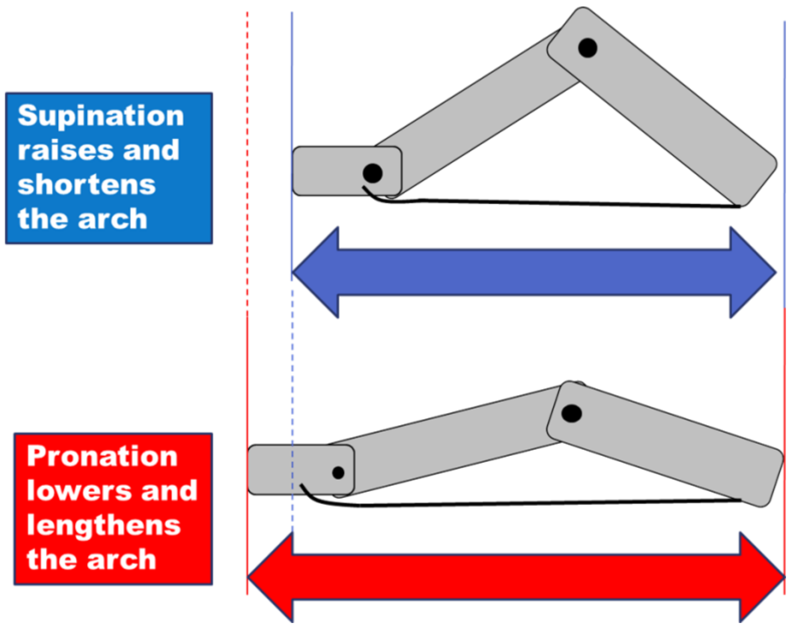
3.The reverse windlass



- **As the arch lowers it becomes longer and the plantar structures (in this example the plantar fascia) become more taut. This in turn applies a compressive force longitudinally**

Normal lower limb function in gait

3.The reverse windlass



We don't really want this to happen….

Midtarsal Joint Dorsiflexion

4. The 2nd (Ankle) Rocker

Normal lower limb function in gait

4. The 2nd (Ankle) Rocker

- The ankle is the 2nd rocker, used as the body progresses over the weightbearing limb
- Motion of the ankle in gait is predominantly in the sagittal plane, consisting initially of plantarflexion, then dorsiflexion (the ‘second rocker’), and then plantar flexion again.
- In swing phase, the ankle dosiflexes to ensure ground clearance of the swing limb

Normal lower limb function in gait

5. External hip rotation and foot supination

- The medial longitudinal arch (MLA) lowers and lengthens initially during stance phase of walking gait. The rearfoot everts (pronates) **and then inverts** (supinates) through a normal stance phase. Eversion occurs for the first 50-60% of the stance phase, **followed by inversion** (Leardini et al, 2007).

- The hip internally rotates during contact and mid stance **and externally rotates throughout the terminal stance phase** (Kadaba et al, 1990).

- This motion has been proposed to couple with rearfoot complex pronation and supination, with pronation linked to internal rotation of the lower limb and **supination with external rotation** (Souza et al, 2010).

6. The 3rd (Digits) Rocker

- Dorsiflexion of the digits provides this third rocker, allowing the foot to pivot correctly and the lower limb to obtain normal hip and knee extension.

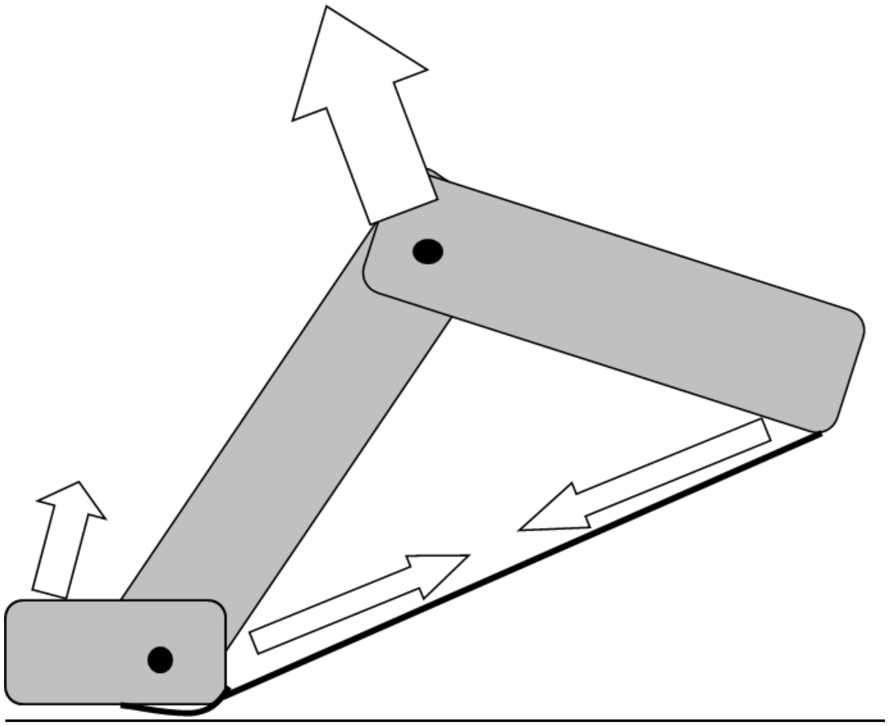
7. The Windlass mechanism with medial column propulsion

- Enough weight needs to pass medially through the foot to dorsiflex the hallux, and wind the windlass at heel lift. This increased tension in the medial and central bands of the plantar fascia maintains midfoot stability through the propulsive phase of gait (Harradine and Bevan, 2009)

Normal lower limb function in gait

7. The Windlass mechanism with medial column propulsion

- Enough weight needs to pass medially through the foot to dorsiflex the hallux, and wind the windlass at heel lift. This increased tension in the medial and central bands of the plantar fascia maintains midfoot stability through the propulsive phase of gait (Harradine and Bevan, 2009)



Normal lower limb function in gait

8. Adequate knee extension for normal posture and swing phase

- The knee is extended at heel strike, flexed during loading response and reaches the first flexion peak during early midstance.

- Thereafter, the knee begun extends until about 40% of stance phase and remains slightly hyperextended (average 3.5°) throughout the remaining midstance.

- Approximately halfway through the terminal stance the knee flexes again and the flexion continued throughout the pre-swing and peaked at toeoff when the stance phase ended. (Kozanek et al, 2009. Lafortune et al, 1992)

Normal lower limb function in gait

8. Adequate hip extension for normal posture and swing phase

- The total range of motion is around 20 -30 degrees, with contact phase flexion being approximately 10-15 degrees and maximum extension approximately 10-15 degrees also.
- This is measured from vertical to the floor, with half of this motion being stated to come from the hip itself, the other from a combination of pelvic rotation and anterior pelvic tilt (Bergmann et al, 2001. Foucher et al, 2012)

Normal 'lower limb' function in gait

8. AND the Lower back and Pelvis

- There is a large range of reported normal motion occurring in the back and pelvis in the asymptomatic population. There appears to be a general consensus on inclination of the trunk in the sagittal plane, a lateroflexion on each side per cycle in the frontal plane and a phase opposition between higher and lower trunk rotations in the horizontal plane. (Callaghan et al, 1999; Feipel et al, 2001; Lamoth et al, 2002; Ceccato et al, 2009)

Normal Lower limb function in gait

Normal 'lower limb' function in gait

8. AND the Upper Limb!

- The arm at the shoulder flexes and extends during each stride. Maximum extension is reached during ipsilateral heel contact, and peak flexion occurs with contralateral initial contact (Murray et al, 1967).

- Although considerable variation occurs amongst individuals, Perry and Burnfield (2010) quote Murray et als (1967) previous work that during moderate walking speed the average arc of motion is 32 degrees. A normal amount of extension to be 24 degrees and flexion to be 8 degrees. Faster walking increases the total arc of motion (Murray et al, 1967)

Normal 'lower limb' function in gait

8. AND the Upper Limb!

- Meynes et al (2013) concluded in a thorough literature review that arm swing should be seen as an integral part of human bipedal gait, and that arm swinging during normal bipedal gait most likely serves to reduce energy expenditure.

Normal lower limb function in gait - Recap

1. **The 1st (Heel) Rocker**
2. **Internal hip rotation with foot pronation**
3. **The reverse windlass**
4. **The 2nd (Ankle) Rocker**
5. **External hip rotation with foot supination**
6. **The 3rd (Digits) Rocker**
7. **The Windlass mechanism with medial column propulsion**
8. **Adequate hip and knee extension for normal posture and swing phase**

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Section 7

Abnormal Foot Function and Gait

Abnormal Foot Function in Gait

" People do not limp because they hurt, rather they hurt because the limp"

Dananberg 1993

So what goes wrong?

The hip

- **Essentially, any structural or functional abnormality which may reduce the ability of the hip to extend. eg OA hip, tight iliopsoas, tight rectus femoris etc.**

Other Postural Adaptations

But what about The Foot too

- **Any structural or functional abnormality that will decrease the foots ability to act as a stable pivot during terminal single limb phase and so permit hip extension**

But what about The Foot too

Any structural or functional abnormality that will decrease the foots ability to act as a stable pivot during terminal single limb phase and so permit hip extension

- Un-Round undersurface of the calcaneus / heel
- Ankle equinus
- Structural hallux limitus
- Functional hallux limitus… to be looked at now in more detail.

Functional Hallux Limitus

It is the ability of the first MTPJ to react to the pull of the body over it which ultimately dictates the ability to advance the body over the weight bearing foot (Dananberg & Guiliano 1999)

- The foot and first MTPJ may look functionally and structurally normal both in non-weightbearing and stance examinations.
- During function no hallux dorsiflexion occurs, preventing windlass, calcaneo-cuboid close packing and hip/knee extension from occurring … and/or causing compensatory mechanisms to present

Functional Hallux limitus - What causes it?

- **The first ray must plantarflex to allow for hallux dorsiflexion. (Root 1977)**
- **Hallux dorsiflexory moments must be greater than Hallux plantarflexory moments at the 1st MTPJ**

Functional Hallux limitus - What causes it?

- **What would increase ground reaction forces under the first ray?**

- **What would cause increased plantarflexory moments of the hallux at the 1st MTPJ?**

Causes of FnHL…..

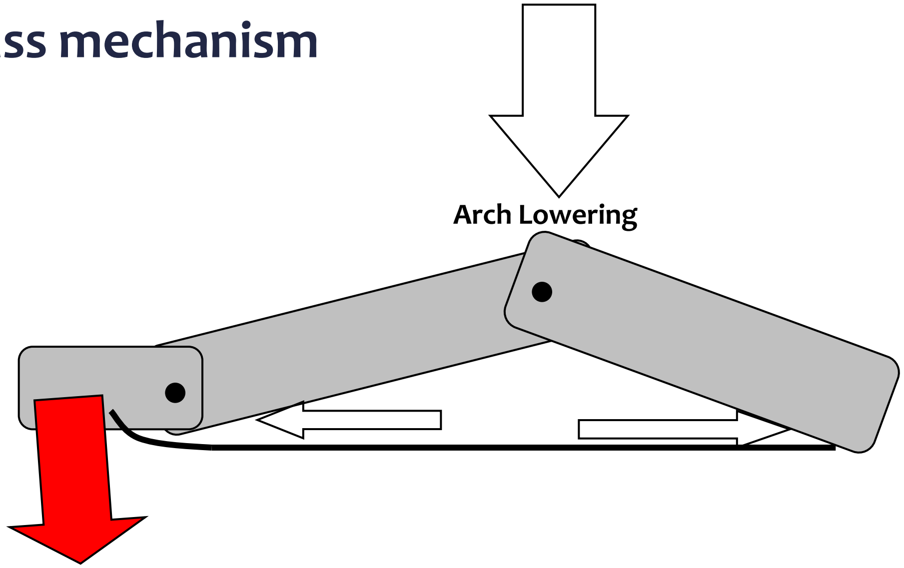
The most common are…..

- Plantarflexed first rays (Roukis et al, 1996)
- Prolonged reverse windlass (Aquino & Payne, 2000)

✓ Therefore, increased pronation will increase the presentation of FnHL (Harradine and Bevan, 2000)

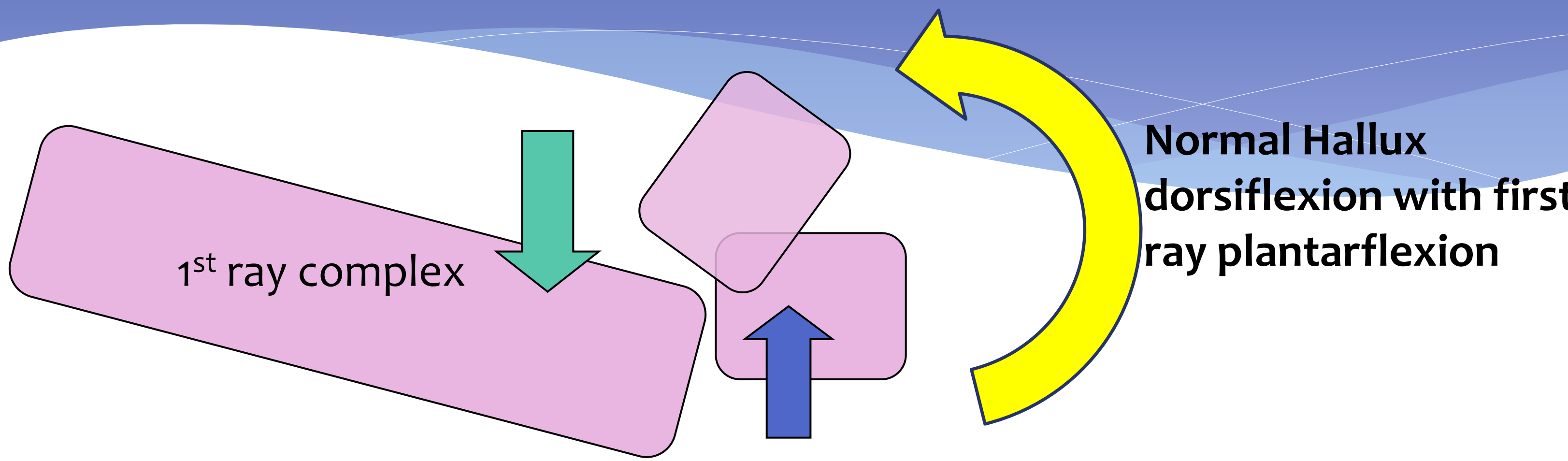
Increasing pronation limits hallux dorsiflexion via the pathological reverse windlass

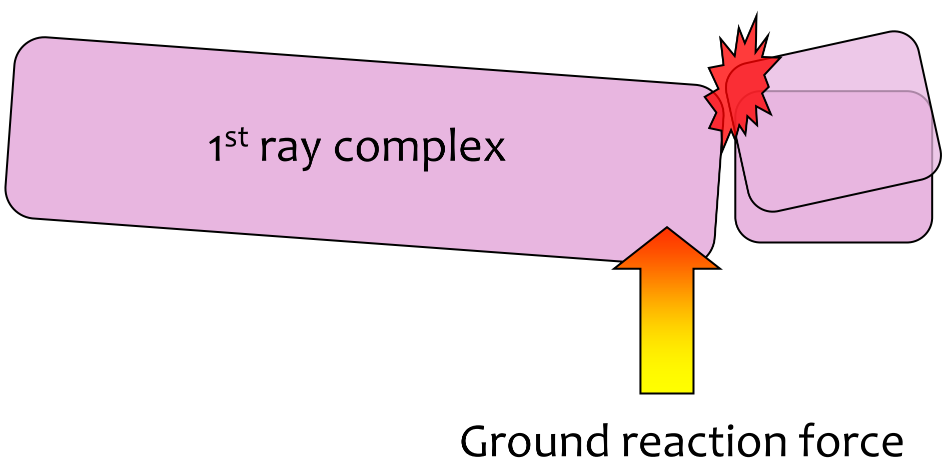
Simple model demonstrating the reverse windlass mechanism



- **As the arch lowers it becomes longer and the plantar structures (in this example the plantar fascia) become more taut pulling the digits DOWN (increasing plantarflexion moments of the hallux at the 1st MTPJ)**

Increasing pronation limits hallux dorsiflexion via the reverse windlass and……… **dorsiflexing the first ray**





Functional limitation of hallux dorsiflexion due to limited first ray plantarflexion with pronation

Causes of FnHL…..

* Dorsiflexion of the first ray
* Due to a plantarflexed first ray morphology

Causes of FnHL…..

* Dorsiflexion of the first ray
* Due to a Forefoot Valgus

Causes of FnHL…..

* Prolonged reverse windlass
* Due to excessive pronation…
* Due to Ankle Equinus

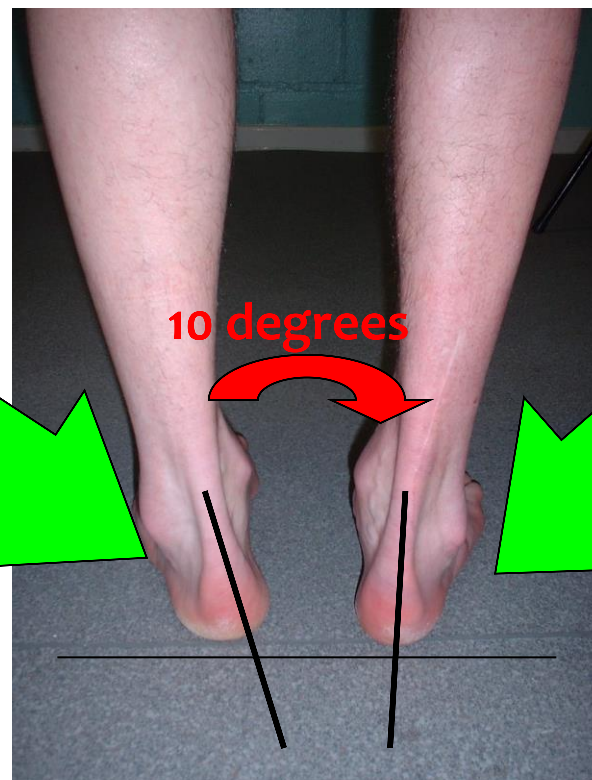
Causes of FnHL…..

* Prolonged reverse windlass
* Due to increased pronation….
* Due to Forefoot varus

Causes of FnHL

- Prolonged reverse windlass
- Due to increased pronation….
- Due to Rearfoot varus

Standing in ‘neutral’



Standing relaxed, But maximally pronated!

If there Is a Functional hallux limitus… how does that effect our gait?

Foot based theory for gait dysfunction examples

- **excessive pelvic rotation**
- **flattened lordosis**
- **lack of hip extension**
- **vertical heel lift**
- **Abductory twist**
- **MTJ Dorsiflexion**
- **1st IPJ Dorsiflexion**
- **lateral column propulsion** (Bevan and Harradine 2004)
- **side sway**

Foot based theory for gait dysfunction examples

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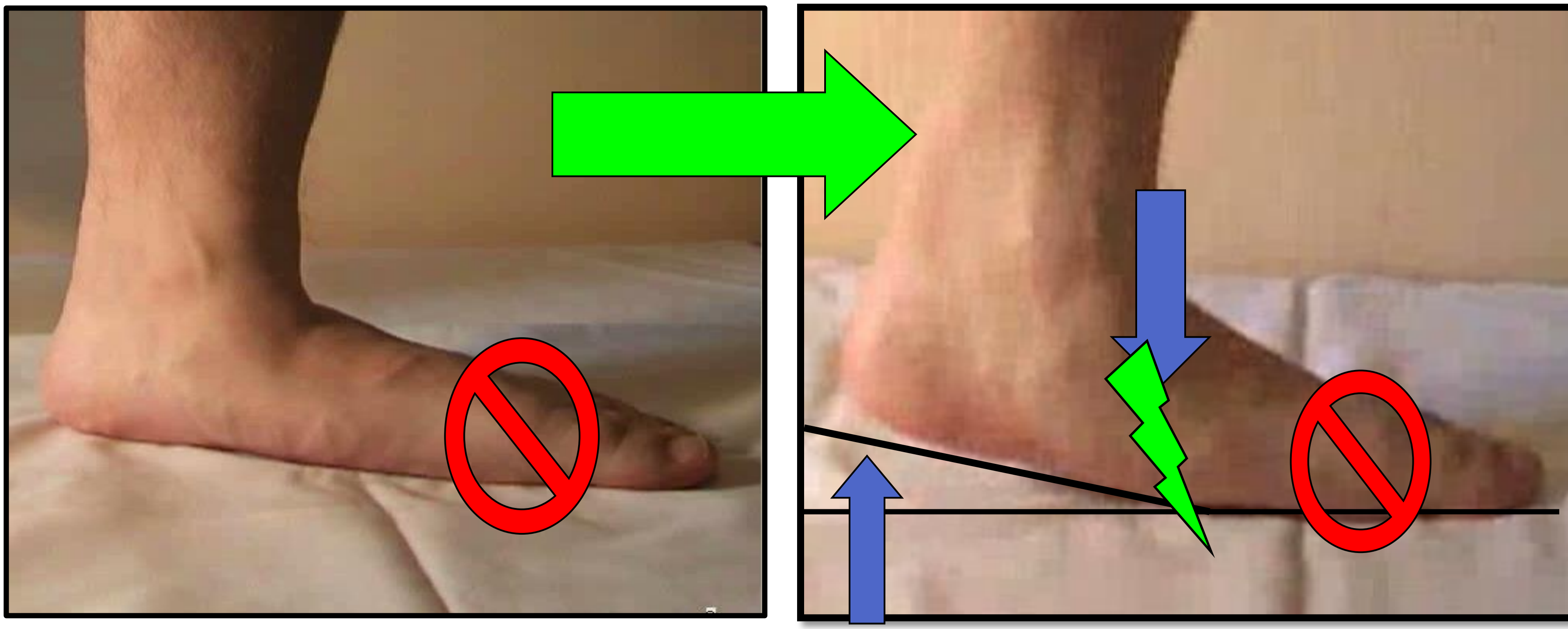
- **side sway**

FnHL and MTJ Dorsiflexion



Foot based theory for gait dysfunction examples

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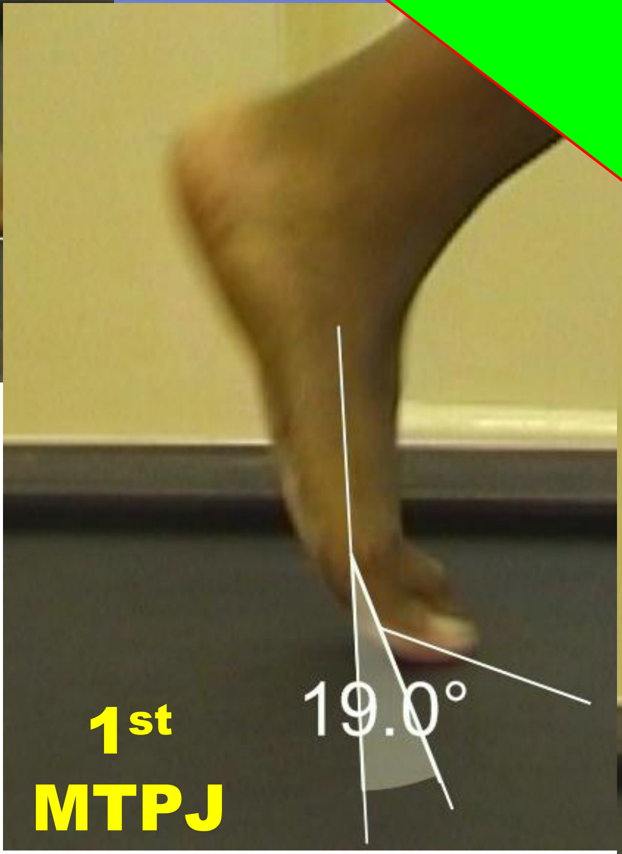

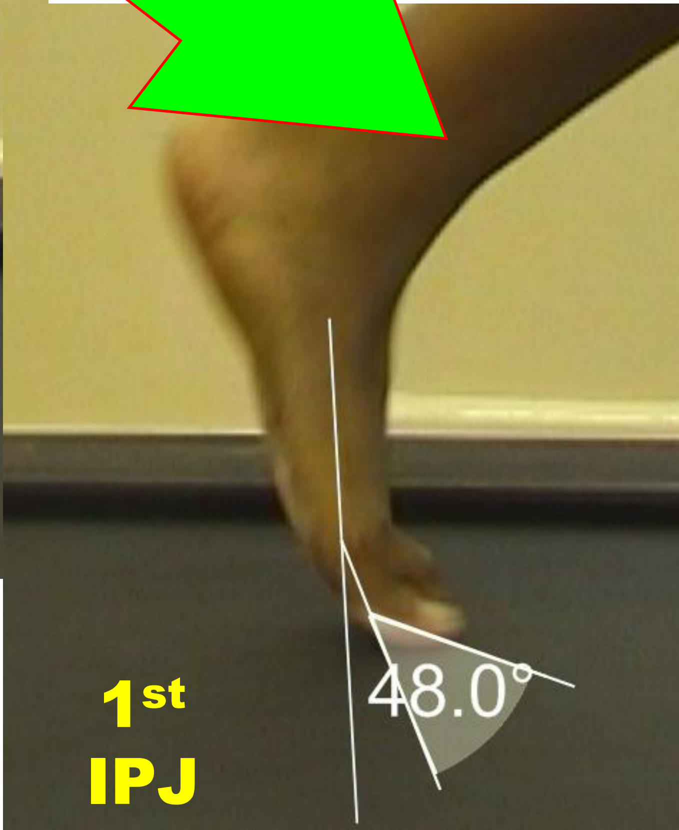

Munuera et al. Hallux interphalangeal joint range of motion in feet with and without limited first metatarsophalangeal joint dorsiflexion. J Am Podiatr Med Assoc. 2012 Jan-Feb;102(1):47-53.

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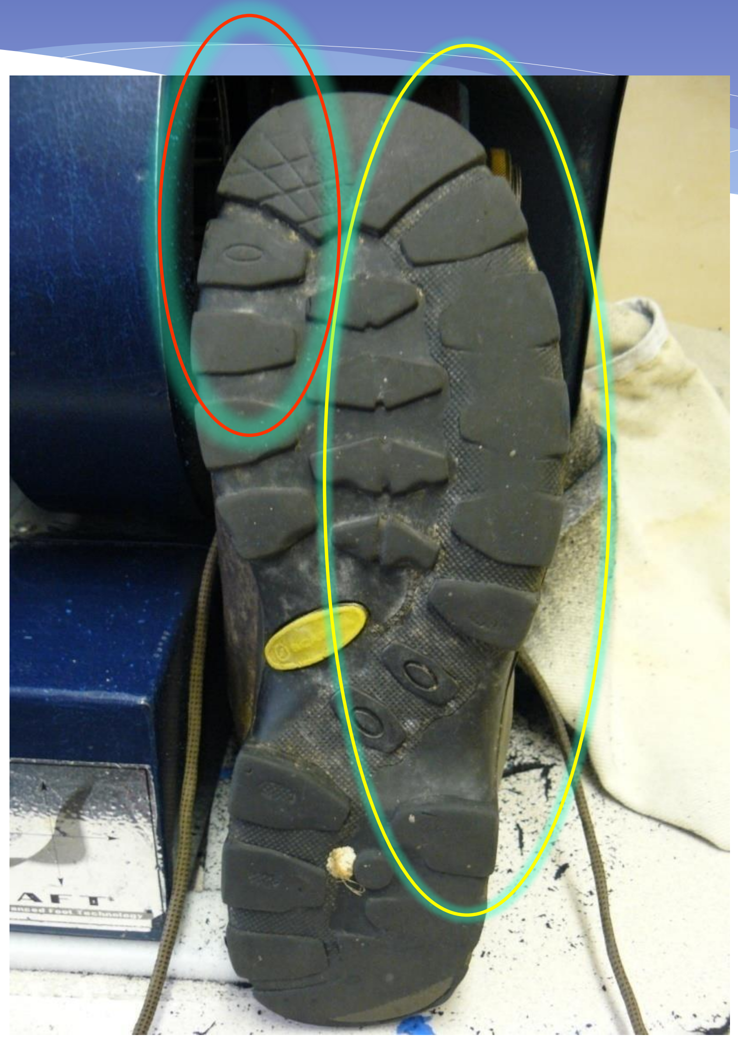
Foot based theory for gait dysfunction examples

- **excessive pelvic rotation**
- **flattened lordosis**
- **lack of hip extension**
- **vertical heel lift**
- **Abductory twist**
- **MTJ Dorsiflexion**
- **1st IPJ Dorsiflexion**
- **lateral column propulsion (Bevan and Harradine 2004)**
- **side sway**

Often seen as lateral shoe wear



Lateral Overloading……..

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Section 8

Assessing for abnormal foot function

8) Assessing for Abnormal Foot Function

- This can be divided into 4 sections, allowing for overlap:

1. Non weight bearing Assessment
2. Weight bearing Static Assessment
3. Weight bearing Dynamic Assessment
4. Crossover / Overlap of all 3 – e.g. Leg Length Difference

To these routine assessments we can then add symptoms specific assessment

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Section 8i

Static Non Weight Bearing

8i) Non weightbearing assessment

- Foot Morphology
- Ankle Dorsiflexion
- Hallux dorsiflexion

Classic Foot Morphology

Rearfoot Varus

Forefoot Varus

Forefoot Valgus

1st Ray Position

Classic Foot Morphology

Rearfoot Varus
Forefoot Varus
Forefoot Valgus
1st Ray Position

We are no longer trying to categorise "normal" or "abnormal" to foot morphology, but more the effect the present foot morphology may have on stance, gait and symptoms.

By recognising foot morphology (including asymmetry) we can be SENSIBLE in beginning to understand the role of the foot in the patients symptoms

Non weight bearing assessment (inc. Foot Morphology)

↓

Static weight bearing assessment

↓

Dynamic assessment

↓

(Activity Specific Assessment)

Classic Foot Morphology

- BUT lets be sensible… there are major issues in reliability, repeatability and validity with ALL these foot morphology 'measurements'

- A 4 degree forefoot varus does NOT equate to exactly 4 degrees of pronation in stance and then gait..

- … who taught us / teaches us this?!

> It is hard to imagine a more stupid or more dangerous way of making decisions than by putting those decisions in the hands of people who pay no price for being wrong.
>
> Thomas Sowell

Classic Foot Morphology

Rearfoot Varus
Forefoot Varus
Forefoot Valgus
1st Ray Position

We are no longer trying to categorise "normal" or "abnormal" to foot morphology, but more the REALISTIC effect the present foot morphology may have on stance, gait and symptoms.

Foot Morphology and uniformity of assessment

The foot should be examined with:

- **The knee joint fully extended**
- **The foot at 90 degrees to the leg**
- **The STJ in ‘neutral’**
- **The MTJ fully pronated**

Why 'STJ Neutral' Foot Morphology for uniformity of assessment?

Critical Points….

- **It has moderate repeatability**
- **The 'normal' foot never passes through this position in gait**
- **Its not the actual STJ neutral, its talonavicular congruency**
- **But… it's all we have.**

Why a ‘fully pronated MTJ’ for Foot Morphology uniformity of assessment?

The foot should be examined with:

- **The knee joint fully extended**
- **The foot at 90 degrees to the leg**
- **The STJ in ‘neutral’**
- **The MTJ fully pronated**

Reference point for Foot Morphology (or our version of 0 in maths)

- **In STJN the rearfoot is parallel to the lower 1/3 of the leg**
- **The forefoot is perpendicular to the rearfoot.**

Classic Foot Morphology

Rearfoot Varus

Forefoot Varus

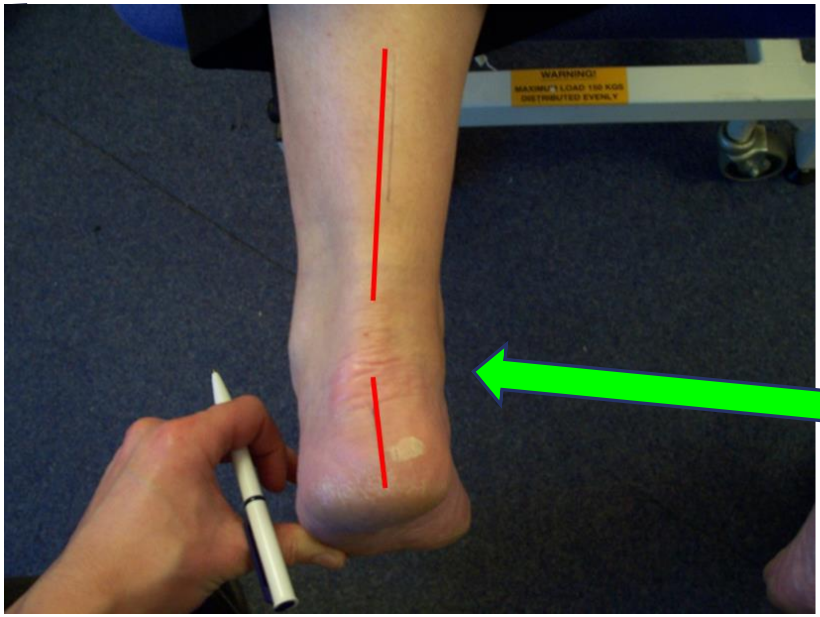
Forefoot Valgus

1st Ray Position



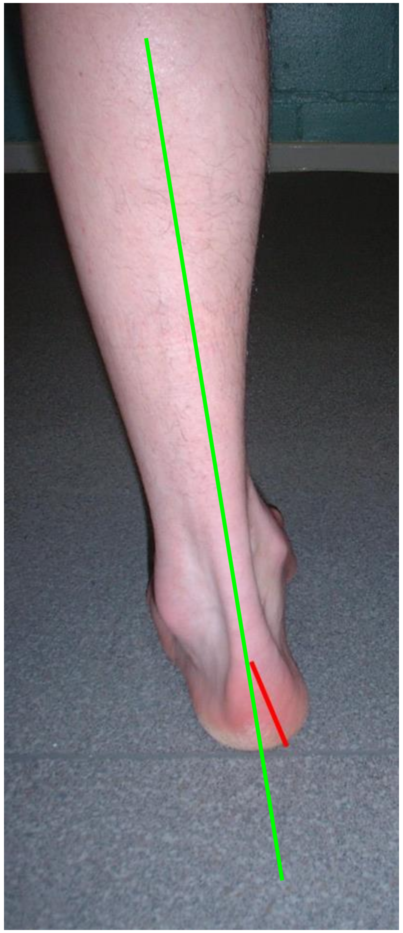

Rearfoot Varus

- **Where the rearfoot is inverted in relation to the lower 1/3 of the**



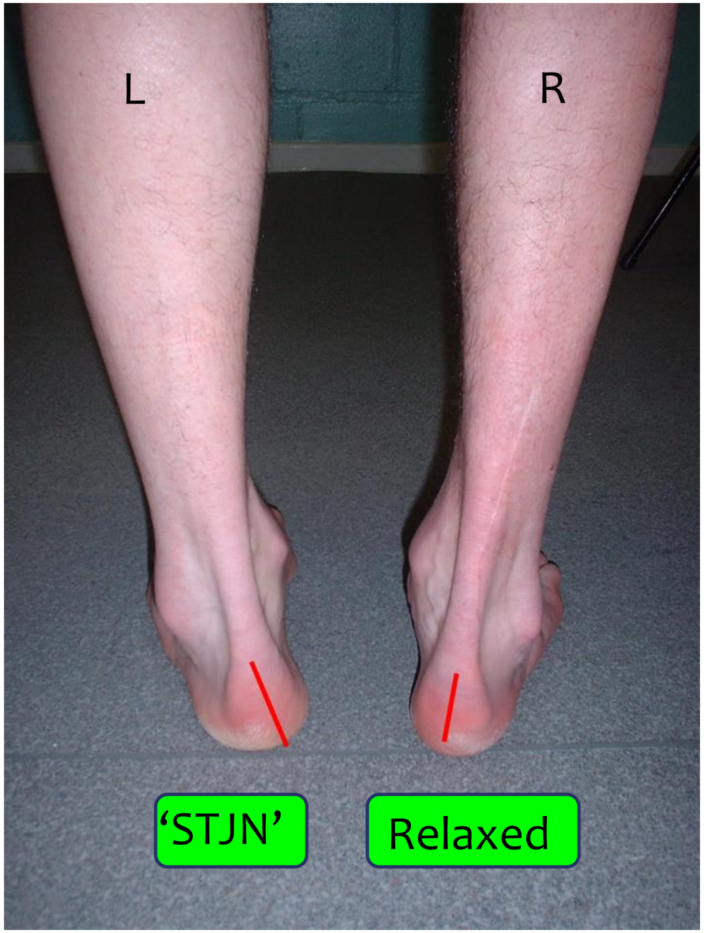
A Subtalar Varum

Rearfoot Varus



Tibial varum
+
Subtalar Varum
=
Rearfoot frontal plane calcaneal position in stance

Large Rearfoot Varus and understanding the STJ – A clinical point



Symmetrical lower limb morphology

The right side remains approximately 10 degrees INVERTED to the floor yet is maximally pronated

If the rearfoot is 20 degrees inverted in 'STJN', with 10 degrees eversion available…it will still be 10 degrees INVERTED in stance often with a "nice arch"

When relaxed the foot looks supinated, but is in fact MAXIMALLY PRONATED

Effect of a rearfoot varus on stance and gait

- A trend for increased pronation moments and magnitude from the contact phase

Forefoot Varus

- **Where the forefoot is inverted in relation to the rearfoot**

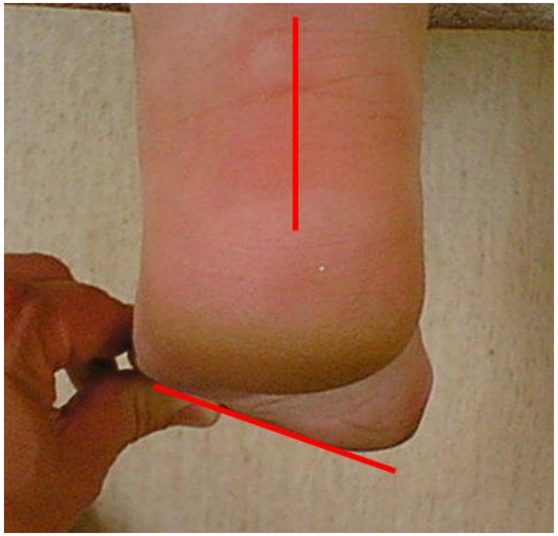
Forefoot Varus

Effect of a Forefoot varus on stance and gait

- A trend for increased pronation moments and magnitude from midstance (forefoot loading)

Forefoot Valgus

- **Where the forefoot is everted in relation to the rearfoot**



Left

Forefoot Valgus

- But, there are two foot shapes which will every the forefoot in relation to the rearfoot

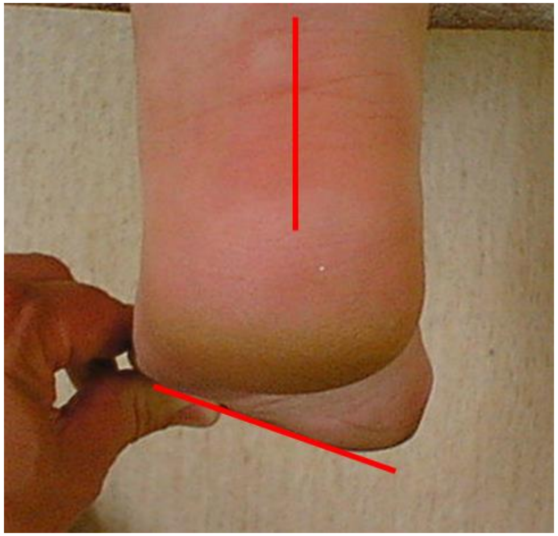
1) A Total forefoot valgus

2) A plantarflexed first ray

Forefoot Valgus

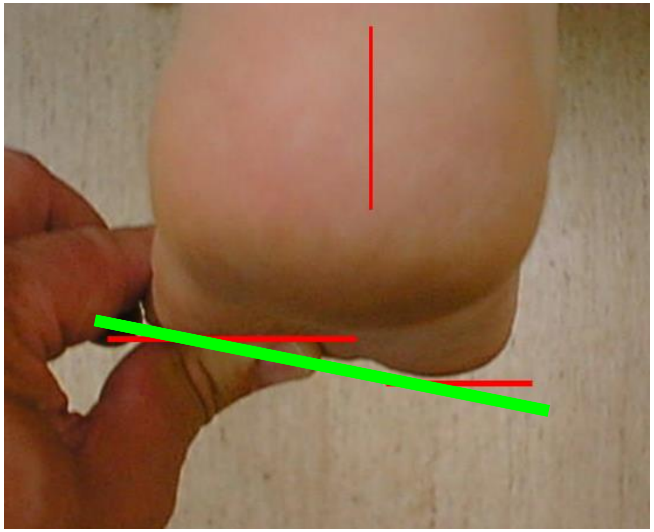
- **Where the forefoot is everted in relation to the rearfoot**

1) A total forefoot valgus



Left

2) A Plantarflexed 1st Ray



Left

Effect of a Forefoot valgus and / or plantarflexed first ray on stance and gait

A trend for increased Dorsiflexion moments on the 1st ray

↓

If large enough, increased supination moments across the MTJ

↓

If large enough, increased supination moments across the STJ

Ankle Dorsiflexion

- Weight-bearing and non weight-bearing methods of measurement
- Lunge with knee extended most valid to ROM in gait (Kang and oh, 2017)
- Significant difference between weight-bearing and non weight-bearing methods (Rabin and Kozol, 2012)

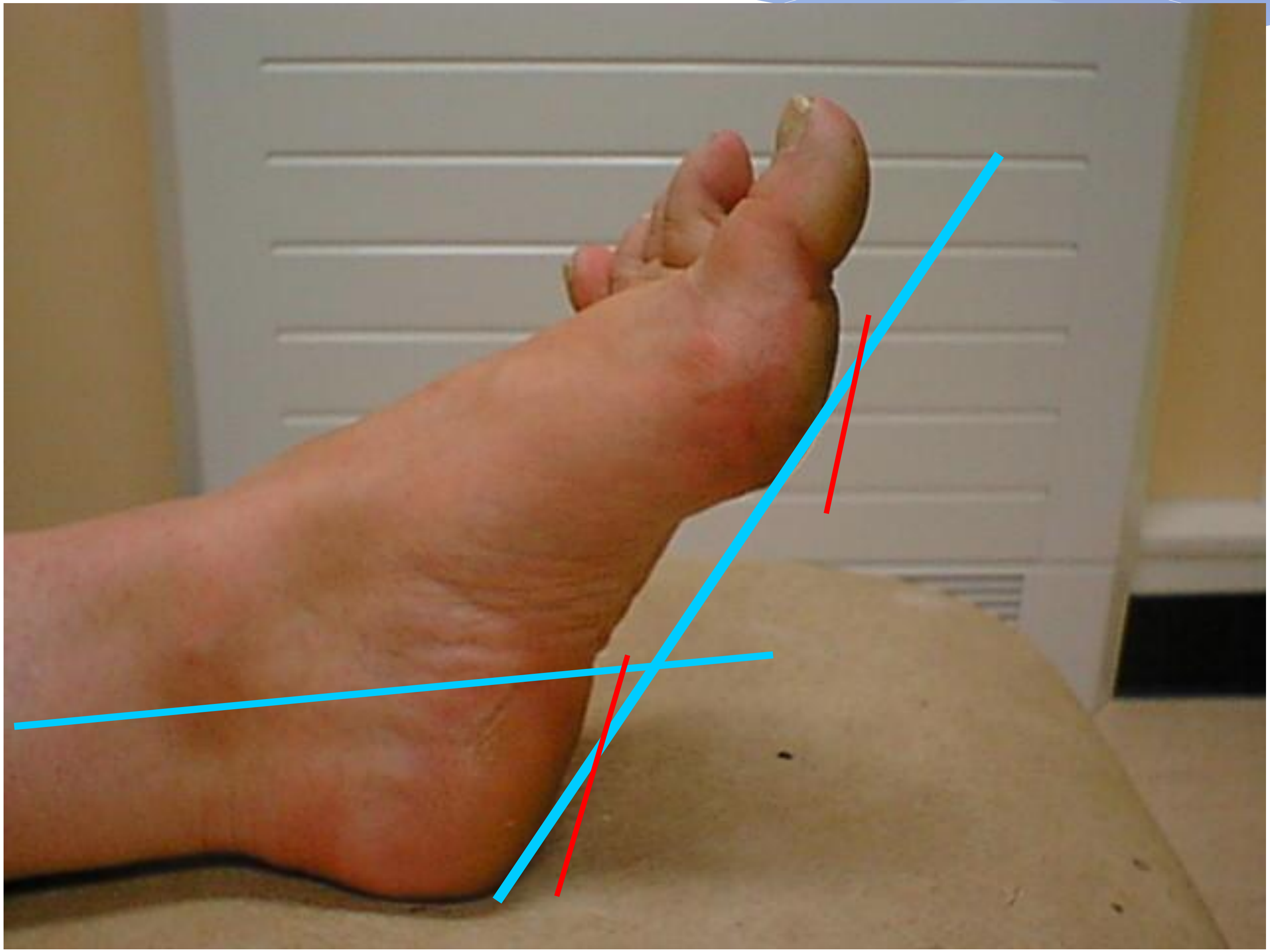
Ankle Equinus

- **Where there is less than 10 degrees of dorsiflexion available at the ankle joint with the foot in STJN**

Ankle Equinus

- **Where there is less than 10 degrees of dorsiflexion available at the ankle joint with the foot in STJN**

Ankle Equinus



Ankle Equinus - aetiology

- Soft tissue - Gastrocnemius / Soleus tightness
- Osseous - Osteophytic lipping of the Anterior aspect of the Tibia (an anterior tibial spur, or "footballers ankle")
- Osseous - Arthritis

Effect of an ankle equinus on stance and gait

- A trend for increased Pronation moments from midstance

- Rules of compensation:

1. Joint closest
2. Motion in the required direct
3. Subject to the same directional forces
4. Supplied enough ROM (to fully compensate)

Structural Hallux Limitus

- Required range of motion for walking gait varies in literature between 55 and 65 degrees

Practical on static non-weight bearing assessment

1. **Rearfoot varus**
2. **Forefoot varus**
3. **Forefoot valgus**
4. **Plantarflexed first rays**
5. **Ankle Dorsiflexion (NWB)**
6. **Hallux Dorsiflexion**

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Section 8ii

static Weightbearing Assessment

Routine static weight-bearing assessment

- International Musculoskeletal Foot and Ankle Assessment (IMFAA) and 5 additional tests .
- IMFAA is a core set of MSK foot and ankle assessment derived via expert agreement (Gates et al, 2015)
- It includes observation for Ankle Joint Dorsiflexion, 1st MTPJ Dorsiflexion and the Foot Posture Index
- Five additional tests often used are the Supination Resistance Test, the Maximum Pronation Test, Navicular Drop Test, Hubscher Test and Observation of Position of Subtalar Joint Axis (STJA)

Routine static weight-bearing assessment

- Ankle Joint Dorsiflexion
- FPI-6
- Supination Resistance Test
- Maximum Pronation Test
- Navicular Drop Test
- Hubscher Test
- Observation of Position of Subtalar Joint Axis (STJA)

Ankle Dorsiflexion

- Weight-bearing and non weight-bearing methods of measurement
- Lunge with knee extended most valid to ROM in gait (Kang and oh, 2017)
- Significant difference between weight-bearing and non weight-bearing methods (Rabin and Kozol, 2012)

The Foot Posture 6 Index (FPI-6)

	FACTOR	PLANE	SCORE 1 Date______ Comment______		SCORE 2 Date______ Comment______		SCORE 3 Date______ Comment______	
			Left (-2 to +2)	**Right** (-2 to +2)	**Left** (-2 to +2)	**Right** (-2 to +2)	**Left** (-2 to +2)	**Right** (-2 to +2)
Rearfoot	Talar head palpation	*Transverse*						
	Curves above and below lateral malleoli.	*Frontal/ trans*						
	Inversion/eversion of the calcaneus	*Frontal*						
Forefoot	Bulge in the region of the TNJ	*Transverse*						
	Congruence of the medial longitudinal arch	*Sagittal*						
	Abd/adduction of forefoot on rearfoot (too-many-toes).	*Transverse*						
	TOTAL							

Reference values
Normal = 0 to +5
Pronated = +6 to +9, Highly pronated 10+
Supinated = -1 to –4, Highly supinated –5 to -12

https://www.leeds.ac.uk/medicine/FASTER/z/pdf/FPI-manual-formatted-August-2005v2.pdf

The Foot Posture 6 Index (FPI-6)

	FACTOR	PLANE	SCORE 1 Date____ Comment____		SCORE 2 Date____ Comment____		SCORE 3 Date____ Comment____	
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Rearfoot	Talar head palpation	Transverse						
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	TOTAL							

Reference values
Normal = 0 to +5
Pronated = +6 to +9, Highly pronated 10+
Supinated = -1 to –4, Highly supinated –5 to -12

- Good inter and intra tester reliability noted (Evans et al 2003, Cornwall et al, 2008)
- Gives a standing static foot posture score allowing comparison to previous notes:

➢ 0-5 Normal
➢ +5 to +12 Pronated (the greater the positive number, the greater the pronation)
➢ -1 to -12 Supinated (the greater the negative number, the greater the supination)

The Supination Resistance Test

Used to assess the amount of force required to resupinate the STJ

With the patient in relaxed bipedal stance two or three fingers are placed under the navicular area and the examiner exerts a steady force to try to supinate the STJ

The Supination Resistance Test

Grade	Finding	Foot function clinical 'assumption' / possible cause
Easy	With moderate effort, the foot is easily supinated onto its lateral border	Abnormally small pronatory forces
Moderate	With moderate effort, the foot is supinated slightly	Normal
Hard	With moderate effort, the foot cannot be supinated	Abnormally large pronatory forces

The Supination Resistance Test

Reliability

- Noakes H, Payne C.J Am Podiatr Med Assoc. 2003 May-Jun;93(3):185-9.**The reliability of the manual supination resistance test.**

* The test had good reliability overall, with an intertester intraclass correlation coefficient of 0.89. For the two more experienced clinicians, the intratester intraclass correlation coefficients were good (0.82 and 0.78), but for the two inexperienced clinicians they were poor (0.56 and 0.62). The supination resistance test **may** be clinically useful in the prescription of foot orthoses, but more work is needed to determine its validity and its relationship to gait.

The Supination Resistance Test

Validity

- Griffiths IB, McEwan IM.. **Reliability of a new supination resistance measurement device and validation of the manual supination resistance test.** J Am Podiatr Med Assoc 2012 Jul-Aug;102(4):278-89.
- In this study, the force required to supinate a foot was independent of its posture, and approximately 12% of it was explained by body weight. Further work is required with a much larger sample size to build regression models that sufficiently predict supination resistance force and that will be of clinical use

The Maximum Pronation Test

Used to assess reserve of pronation, and therefore if the patient is maximally pronated irrespective of arch height

With the patient in relaxed bipedal stance, ask the patient to "roll down their arches" while assessing for calcaneal eversion. The knees should be prevented from flexing

The Maximum Pronation Test

Grade	Finding	Foot function clinical 'assumption' / possible cause
Maximally Pronated	Less than 2 degrees rearfoot eversion	No reserve of pronation, therefore abnormally pronated
Not maximally pronated	Greater than 2 degrees rearfoot eversion	Reserve of pronation, therefore not maximally pronated

The Maximum Pronation Test

Reliability and Validity

No papers forthcoming on either reliability or validity

<u>BUT:</u>

Javier Pascual Huerta, Juan Manuel Ropa Moreno, and Kevin A. Kirby Static Response of Maximally Pronated and Nonmaximally Pronated Feet to Frontal Plane Wedging of Foot Orthoses. J Am Podiatr Med Assoc 2009. 99: 13-19.

1. This paper did not test for reliability of the maximum pronation test

2. This paper found that a 10 degree valgus wedge with a maximally pronated foot caused a mean further calcaneal eversion of 3.9 degrees….**<u>validity????</u>**

The Navicular Drop Test

Indicates the amount of pronation relevant to the STJ, not the arch height

With the patient standing, record the height of the navicular tubecle in talo-navicular congruency and then relaxed

The Navicular Drop Test

Reliability and validity

Used in research to link to certain injury (e.g. ACL) (Jenkins, 2008)

Slight discrepancy on the definition of normal and abnormal, because some authors have used seated talo-navicular congrueny to standing relaxed.

General consensus at present is a ND of over 10mm (to 15mm) is classed as ‘abnormal pronation’

Foot size issues

The Navicular Drop Test

Reliability

McPoil TG et al. Reliability and normative values for the foot mobility magnitude: a composite measure of vertical and medial-lateral mobility of the midfoot. J Foot Ankle Res. 2009 Mar 6;2:6

Navicular drop has high levels of intra-rater reliability, poor to moderate levels of inter-rater reliability and a lack of normative data from a large cohort of healthy individuals

The Hubscher Test

Used to assess the available dorsiflexion of the hallux in closed kinetic chain

With the patient in relaxed bipedal stance, passively attempt to dorsiflex the hallux via the distal phalanx

The Hubscher Test

Grade	Hallux dorsiflexion	Effect on proximal structures	Foot function clinical 'assumption' / possible cause
0	Nil	Nil	Marked FnHL
1	Slight	Nil	FnHL
2	Yes, with resistance	Slight arch raising with limited external leg rotation	Normal
3	Yes, with limited resistance	Complete arch raising with obvious external leg rotation	Possible supinator

The Hubscher Test

No Reliability testing on the current grading system

For validity:

Halstead J, Redmond AC.Weight-bearing passive dorsiflexion of the hallux in standing is not related to hallux dorsiflexion during walking. J Orthop Sports Phys Ther. 2006 Aug;36(8):550-6

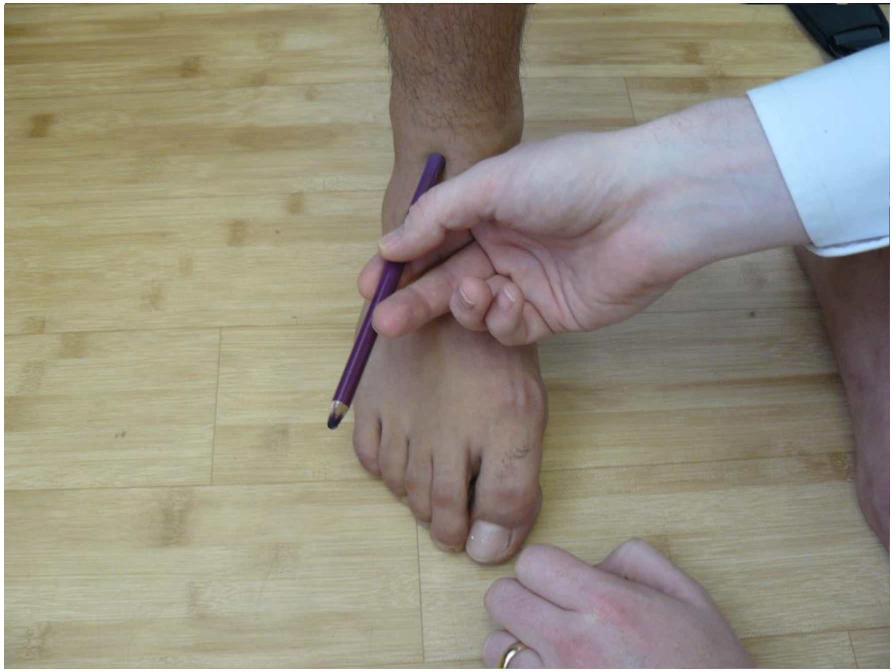
Useful for quick orthotics checks possibly?

Subtalar Joint Axis (STJA) Position

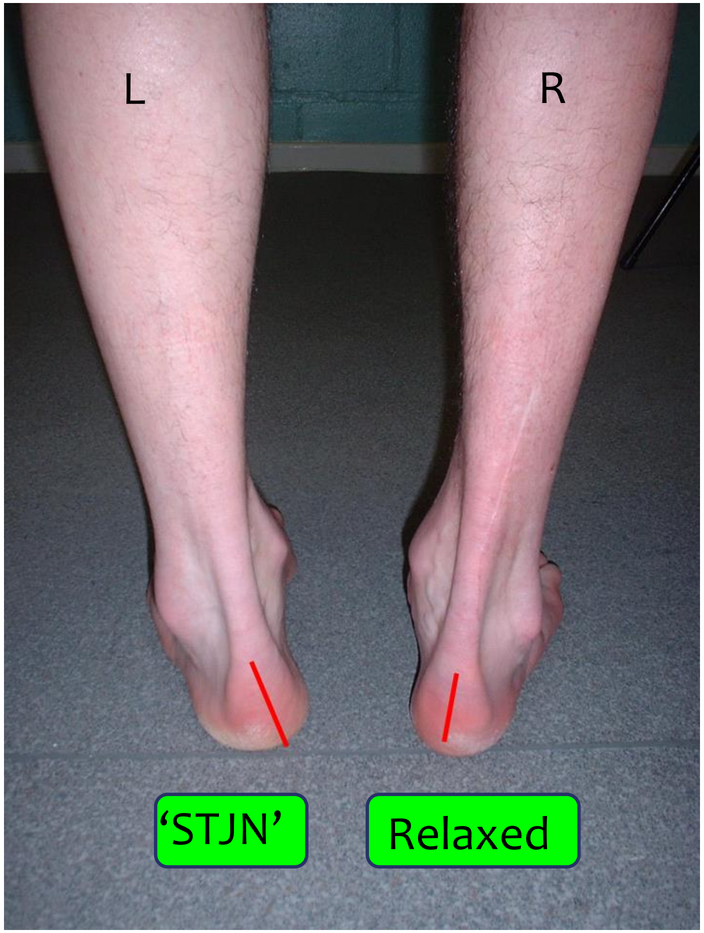
- Reliability and validity
- Payne C et al. **Position of the subtalar joint axis and resistance of the rearfoot to supination.** J Am Podiatr Med Assoc. 2003 Mar-Apr;93(2):131-5.
- The more medial the axis, the greater the force required to supinate the STJ
- The model on which determination of the subtalar joint axis is based may not be valid, but it might help determine how much force is needed to supinate a foot using foot orthoses.
- No relation established to gait or injury…

STJA POSITION

This is tricky, and you can't jam a sharpened knitting needle in the talar neck after a quick ice spray….



Large Rearfoot Varus and understanding the STJ – A clinical point



Symmetrical lower limb morphology

The right side remains approximately 10 degrees INVERTED to the floor yet is maximally pronated

If the rearfoot is 20 degrees inverted in 'STJN', with 10 degrees eversion available... it will still be 10 degrees INVERTED in stance often with a "nice arch"

When relaxed the foot looks supinated, but is in fact MAXIMALLY PRONATED

Why aren't we talking about Arch Height?

African Americans have significantly lower Calcaneal pitch (lower arches) than Caucasians ($p < 0.0001$) and Hispanics ($p < 0.0016$). (Castro-Aragon et al, Foot Ankle Int, 2009).

There is no significant incidence of foot injury or ability associated with any of these ethnic groups

We can stop using Arch height as a comparative indicator of foot function

Practical Weightbearing static examination

- Ankle Joint Dorsiflexion
- FPI-6
- Supination Resistance Test
- Maximum Pronation Test
- Navicular Drop Test
- Hubscher Test
- Observation of Position of Subtalar Joint Axis (STJA)

FPI-6

Foot Posture Index Datasheet

Patient name	***ID number***

	FACTOR	PLANE	SCORE 1 Date____________ Comment__________		SCORE 2 Date____________ Comment__________		SCORE 3 Date____________ Comment__________	
			Left -2 to +2	**Right** -2 to +2	**Left** -2 to +2	**Right** -2 to +2	**Left** -2 to +2	**Right** -2 to +2
Rearfoot	Talar head palpation	*Transverse*						
	Curves above and below the lateral malleolus	*Frontal/ transverse*						
	Inversion/eversion of the calcaneus	*Frontal*						
Forefoot	Prominence in the region of the TNJ	*Transverse*						
	Congruence of the medial longitudinal arch	*Sagittal*						
	Abd/adduction forefoot on rearfoot	*Transverse*						
	TOTAL							

Reference values
Normal = 0 to +5
Pronated = +6 to +9, Highly pronated 10+
Supinated = -1 to –4, Highly supinated –5 to -12

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Section 8iii

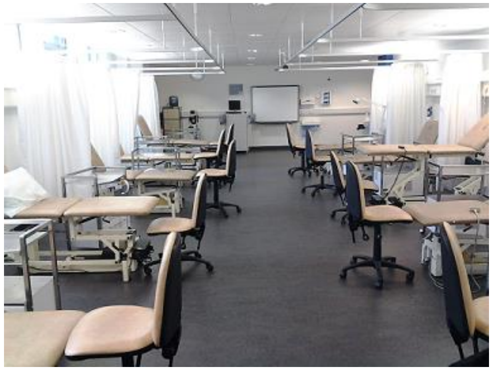
Dynamic Weightbearing Assessment

Assessing Dynamic Foot Function

Real Time Clinical Gait Analysis
(RTCGA)

Introduction - Clinical Gait Analysis

- The vast majority of these assessments are conducted by practitioners without immediate access to 'gait analysis equipment'. Methodology remains vague and varied, with no systematic or standardised process available to observe adult patients gait.



Clinical Measures of Foot Posture and Mobility are not associated with Foot kinematics when Walking

Buldt et al, JFAR. 2015

- If we want to know how people walk….
  ….why can't we watch them walk?

If we want to know how people walk….why can't we watch them walk?

Because at the moment that's not as easy as it seems, but that doesn't mean it cant be made to be as simple as it sounds…..

If we want to know how people walk….why can't we watch them walk?

- There have only been attempts to categorise visual gait patterns by researchers in the physical therapy and surgical communities for neurological disorders such as cerebral palsy, stroke or Parkinson disease (Taro et al, 2007; Roggendorf et al, 2012)
- Each of these assessment tools utilises observing gait markers which link to a particular gait dysfunction related to the specific disease process.

If we want to know how people walk….why can't we watch them walk?

- Even in this more specifically researched area, Taro et al (2007) state a critical issue is the lack of a standardised method of gait classification.
- There remains no systematic method of locomotion assessment for the general and sporting MSK caseload, even though lower limb function in gait is frequently linked to injury (Chuter et al, 2012; Glazer, 2009; Irving et al, 2007; Barton et al, 2011; Menz et al, 2013)

Clinical Gait Analysis

Clinical Gait Analysis

Putting it all together… when we assess Gait we look at:

1. Head Position
2. Arm Swing
3. Lower Back and Pelvis
4. Hip
5. Knee
6. Foot and Ankle

Clinical Gait Analysis

Putting it all together

1. Head Position
2. Arm Swing
3. Lower Back and Pelvis
4. Hip
5. Knee
6. Foot and Ankle

- This is all very well… but what are we actually looking for.
- Can we look for specific gait patterns in the adult MSK injury population.
- And if so, can we be reliable in their assessment
- And would it be valid?

Clinical Gait Analysis

"Pronation Patterns of Gait"

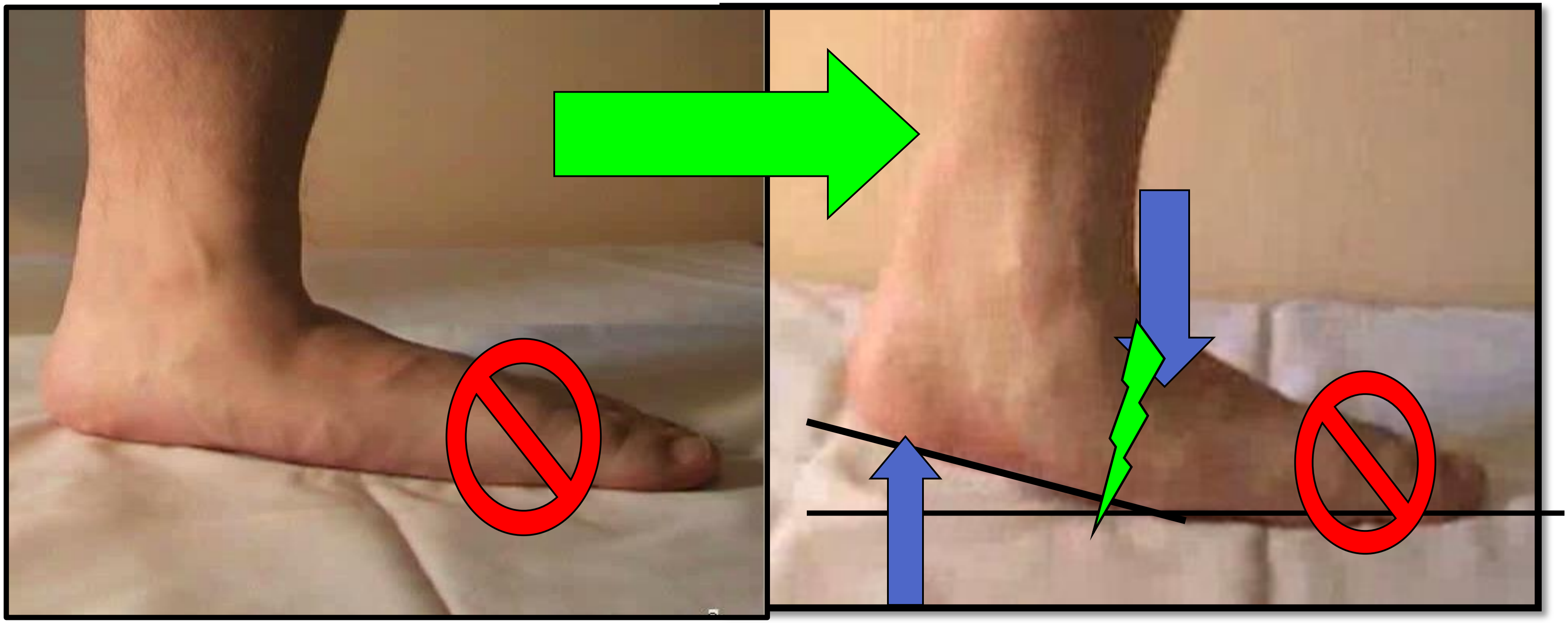
1. Excessive Pelvic Rotation
2. Vertical Heel Lift
3. Lack of Hip and Knee Extension
4. Reduced Arm swing
5. Abductory Twist
6. Lateral Propulsion
7. Lack of resupination
8. Side sway

These 'patterns' link into abnormal internal rotation (or lack of external lower limb rotation) and functional limitation of the 1st MTPJ.

Pronation patter gait dysfunction examples

- **excessive pelvic rotation**
- **flattened lordosis**
- **lack of hip extension**
- **vertical heel lift**
- **Abductory twist**
- **MTJ Dorsiflexion**
- **1st IPJ Dorsiflexion**
- **lateral column propulsion side sway**
- **Side sway**

FnHL and MTJ Dorsiflexion



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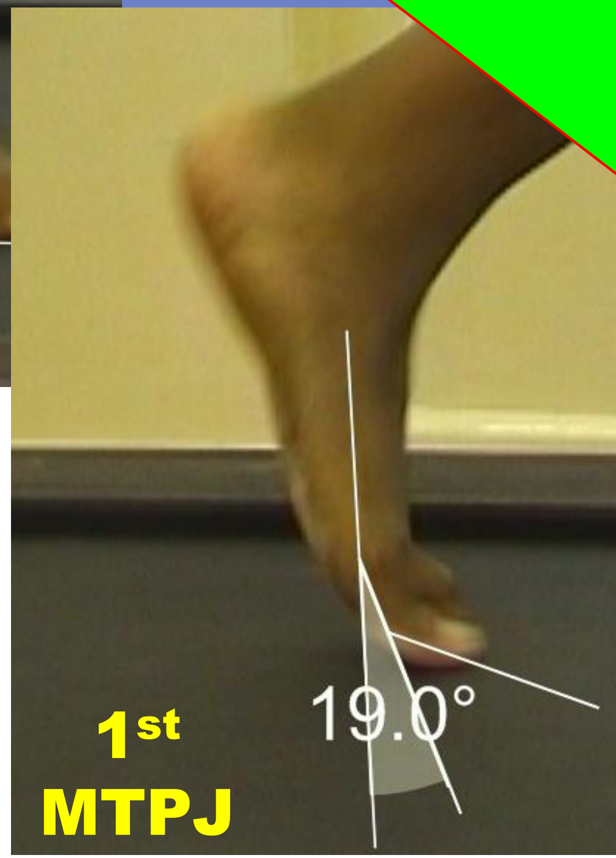

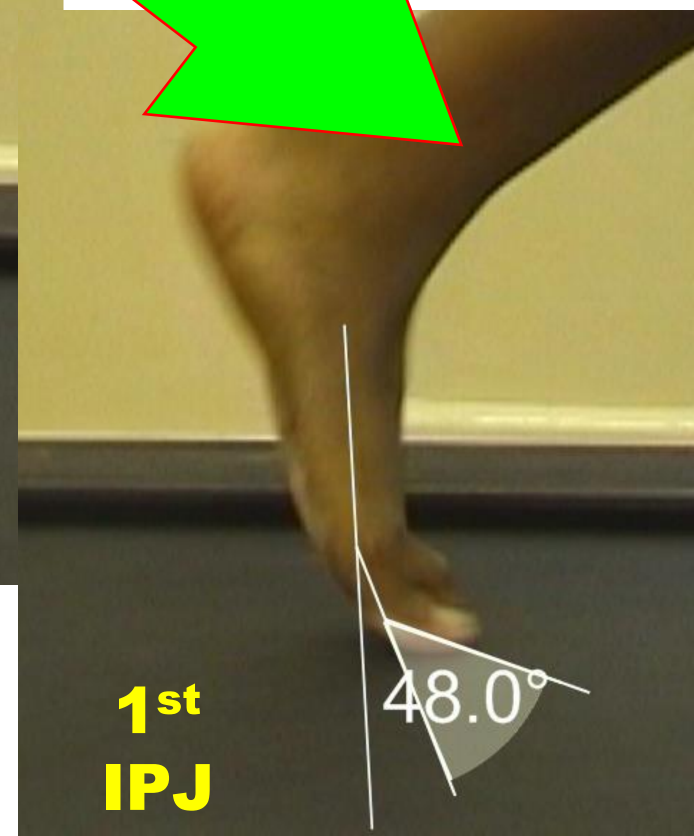

Munuera et al. Hallux interphalangeal joint range of motion in feet with and without limited first metatarsophalangeal joint dorsiflexion. J Am Podiatr Med Assoc. 2012 Jan-Feb;102(1):47-53.

Pronation pattern gait dysfunction examples

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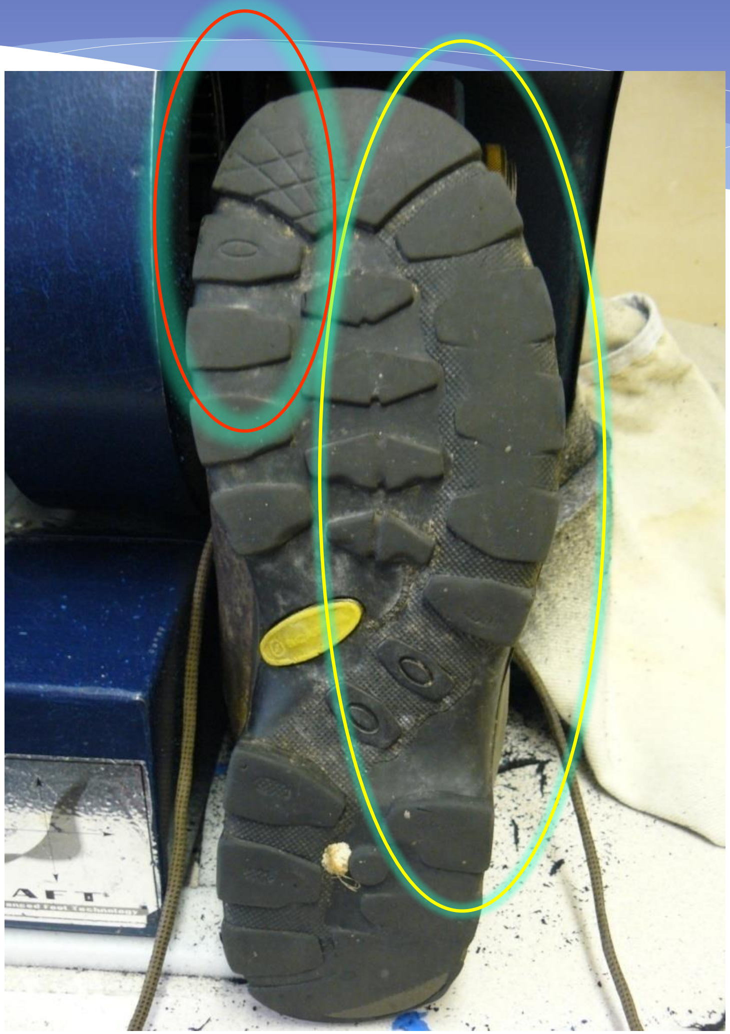
- **side sway**

Lateral column propulsion… Often seen as lateral shoe wear



Pronation pattern gait dysfunction examples

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- **MTJ Dorsiflexion**
- **1st IPJ Dorsiflexion**
- **lateral column propulsion**
- **side sway**

Clinical Gait Analysis

Supination Patterns of Gait

1. Lack of Pronation at contact phase
2. Reduced Hip and knee extension
3. Lateral Propulsion

These 'patterns' Would link into a lack of internal lower limb rotation and an inability to use the medial column of the foot due to an inverted foot posture.

Additional Gait Analysis Points

- **Head Position**
- **Shoulder position**
- **Arm Swing**
- **Trunk position and motion**
- **Pelvic position and motion**
- **Hip extension/flexion**
- **Knee position and motion**
- **Foot function**

Head Motion / Position

- **Frontal Plane**
- - Is the head tilted to either side or facing left/right

- **Sagittal Plane**
- - Kyphosis?
- - Is the head tilted forward? Pt looking at the ground?

Shoulder Motion/Position

- **Frontal Plane**
- - Is one shoulder higher than the other?

- **Sagittal Plane**
- - Is one shoulder leading? or moving anterior/posterior more?

Arm Swing

- **Frontal Plane**

- Same position right/left relative to the body

- Hand position the same

- **Sagittal Plane**

- Arm swing anterior / posterior symmetrical

- Occuring from shoulder or elbow

Trunk Motion/Position

- **Frontal Plane**

- Lateral trunk bending

- **Sagittal Plane**

- Flattened lumber lordosis
- Increased lumber lordosis

Pelvic Motion/Position

- **Frontal Plane**

- Tilt?

- **Sagittal Plane**

- Very Difficult

Hip motion/position

- **Frontal Plane**

- Different to stance angle?
- Wide or narrow base of gait?

- **Transverse Plane**

- Internally/externally positioned

- **Sagittal Plane**

- Adequate hip extension? Symmetrical?
- Hip flexion properly timed?

Knee motion / position

- **Transverse plane**

- Squinting patellae? symmetrical ?

- **Sagittal Plane**

- Correct flexion / extension timing? Symmetrical?

Foot position / motion

- **Frontal Plane**
- Eversion ➡ Inversion

- **Transverse Plane**
- Abductory twist?

- **Sagittal Plane**

- Heel to toe motion?
- Delayed / early heel lift?
- Propulsive phase?

And don't forget other reasons why people walk awkwardly…

- **Sometimes there's something else on their mind……**
- **Shyness at assessment**
- **Wanting to please or denial of injury**
- **Holding in stomach / out chest**
- **Just one of them days……**

Who said males can't multitask?!

Practical on RTCGA

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Section 8iv

Crossover

Crossover of all 3

The most common of these and one with most clinical significance and frequency, is **Leg Length difference**

Structural Leg Length Difference

- There is a broad range of “functional” and “structural” causes of LLD, and combinations of both
- These vary across professions and terminology
- For today, we can’t discuss all the various combinations and clinical methodologies and terminologies!

Structural Leg Length Difference (SLLD)

- “Structural, anatomical or actual LLD are synonymous terms and are diagnosed when either the femur or tibia is longer in one leg than in the other, as shown on X-ray.” (Mannello 1992)

Incidence of SLLD

- With combining available ‘accurate’ imaging research:

1. The mean SLLD = 5.23mm (n=573)

Incidence of SLLD

- With combining available 'accurate' imaging research:

1. The mean SLLD = 5.23mm (n=573)
2. The right leg is anatomically shorter more often (n=272)
3. There is no effect of gender (n=116)
4. There appears no correlation with height (n=247)

Incidence of SLLD

- With combining further imaging papers which looked at ranges of SLLD rather than mm increments (n= 2,978):

1. 41.3% had a SLLD of 0-4mm
2. 37.4 % had a SLLD of 5-9mm
3. 20% had a SLLD of 10mm
4. 15% had a SLLD of 10-14mm
5. 6.4% had a SLLD of greater than 14mm

(Knutson, 2005)

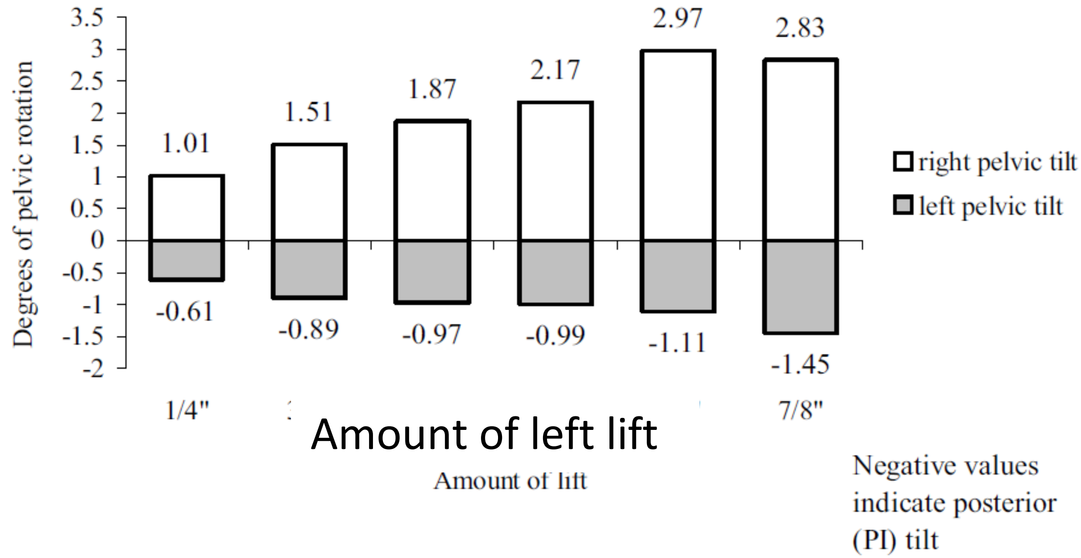
Incidence of SLLD

- 90% of the population have a SLLD of some amount (Korpelain et al, 2001)
- It has been calculated that in a population of 2.68 million, larger SLLD (in excess of 20mm) is present in 1/2000 of the population. (Guichet et al, 1991)

Effect of SLLD

- The most common effect stated is that of "pelvic torsion" in the frontal and sagittal planes (Knutson 2005)
- Cummings, 1993, found an almost linear relationship between imposed "foot lifts" and pelvic rotation. Motion was anterior on the shorter side.

Effect of SLLD



Cummings, 1993

- A later literature review (Cooperstein & Lew 2009) agreed with these findings. They concluded that across varying methodologies for measuring LLD and pelvic torsion, a consistent, dose-related pattern was identified in which the innominate rotates anteriorly on the side of a shorter leg and posteriorly on the side of the longer leg.

Effect of SLLD

- Walsh et al (2000) found that pelvic obliquity was the most common method of compensating for SLLD up to 22 mm. With larger amounts of leg length inequality, subjects begin to develop flexion of the knee in the long leg

Effect of SLLD – What about Scoliosis?

* Postural Scoliosis is often stated in the literature (Giles 1981, Merriman & Tollafield 1994, Subotnik 1999).

* Raczkowski et al 2010, diagnosed a functional scoliosis as one which develops due to a SLLD, and totally or partially resolves when leg length is equalised

* In their paper they treated 374 children with a SLLD under 2cm and a scoliosis, but also comment that SLLDs of less than 2cm "seldom cause a problem".

Effect of SLLD – Scoliosis?

- One paper from 1982 (Papaioannou et al) of adults (mean age 28) with large SLLD since childhood (mean 29.1 mm) found Lumbar scoliosis was minor in those less than 22 mm

- This value of around 20mm seems quite common in the theme of the clinical relevance of SLLD….

Effect of SLLD

- Needham R et al (2012) concluded in their paper that it is a common assumption that SLLD causes LBP by creating pelvic torsion and lumbar scoliosis

- BUT, in induced SLLD of 1,2 and 3cm differences in ROMs and patterns of movement for the pelvis and spine were “minimal”

How much SLLD is clinically significant

- If the effect of a SLLD is pelvic torsion and other effects such as scoliosis….does this link to lower back pain (LBP) or other lower limb pains?

- And if so, how much?

How much SLLD is clinically significant?

- Mannello (1992) concisely concluded that clinical significance is dependent on several factors, including the degree of inequality, the ability of the pelvis and spine to compensate and associated conditions or problems.

Clinical significance of SLLD and Symptoms

- Using the incidence studies, there was a combination of symptomatic (n=347) and non-symptomatic (n=165) samples.
- The mean SLLD in symptomatic was 5.1mm (SD 3.9)……and for asymptomatic 5.2mm (SD 4.2)
- From this, can we begin to infer that SLLD is actually not linked to lower back pain in this sample?

Clinical significance of SLLD and LBP

- When discussing the clinical significance SLLD, Friberg's 1983 study is most often cited
- Friberg collected data on 1,157 subjects; 798 with chronic LBP and a control group of 359 with no LBP
- His sample was **active military personnel**

Clinical significance of SLLD and LBP

- Friberg concluded "LLI was 5 mm or more in 75.4% of the patients with LBP and 43.5% of the controls. The difference is statistically significant.”

- However, if chronic LBP is caused by a 5mm SLLD, over 50% of the population would be expected to present with LBP? (Rather than 21%, Anderson 1999)

Clinical significance of SLLD and LBP

- In replying to letters to the editor highlighting a similar point, Friberg (1992) wrote, "... I have always pointed out that LLI of less than 5 mm has no relationship with lumbar scoliosis or back pain. I have also emphasized that even marked LLI *per se* neither produces LBP nor contributes to its development if a person is not continually exposed to prolonged standing or gait, e.g., during daily work, military training, and sporting activities"

- So, Friberg notes that 'normal' SLLD may only be clinically significant relative to certain conditions such as prolonged and/or repetitive loading, as in a military population

Clinical significance of SLLD and LBP

- These findings are supported by a recent study by Rannisto et al, 2015. Leg-length discrepancy is associated with low back pain among those who must stand while working. *BMC Musculoskeletal Disorders.*

"Our study found a significant association between LLD of 6 mm or more and low back symptoms. The association was apparent among meat cutters, who stand while working, but not among customer service workers, who mostly sit while working."

Clinical significance of SLLD and lower OA

- Murray & Azari. Leg length discrepancy and osteoarthritis in the knee, hip and lumbar spine. *J Can Chiropr Assoc 2015*

"There is a significant body of literature linking LLD and knee OA, and to a lesser extent hip OA. However, there is little research attention that has been paid to date to the relationship between mild LLD and OA of the lumbar facet joints or lumbar disc degeneration"

Clinical significance of SLLD and lower limb pain

- Golighty et al. Symptoms of the knee and hip in individuals with and without limb length inequality. *Osteoarthritis and Cartilage (2009)*

"LLI was moderately associated with chronic knee symptoms and less strongly associated with hip symptoms. LLI may be a new modifiable risk factor for therapy of people with knee or hip symptoms."

Clinical significance of SLLD and lower limb pain

- HOWEVER…..

Goss et al. Comparison of injury rates between cadets with limb length inequalities and matched control subjects over 1 year of military training and athletic participation. *Mil Med. 2006*

OBJECTIVES: To compare lower-limb overuse injury and low back pain incidence among cadets with and without limb length inequality (LLI) over 1 year of military training and athletic participation.

METHODS: A total of 1,100 cadets were screened for LLIs; 126 of 1,100 were identified to have a LLI of > 0.5 cm and were assigned a matched control cadet. Injury rates, numbers of visits to sick call, and numbers of days spent on medical excusal during a 1-year period were then compared for the 252 cadets.

RESULTS: There was no difference in prevalence of injury between the groups and no significant differences ($p > 0.05$) between the groups in injury rates, visits to sick call, or number of days spent on medical excusal.

CONCLUSIONS: These findings do not support any increased incidence of injuries in a young, healthy, athletic, military population with mild LLIs, compared with matched control subjects without LLIs, over 1 year.

Clinical significance of SLLD and LBP

- Although Friberg may present 5mm SLLD as clinically significant in an active population, other authors question if less than 30mm has any clinical significance (McCaw & Bates,1991. Reid & Smith,1984).

- The general lack of consensus is confusing clinically, but not exactly surprising when the complexity of the problem and symptoms linked to it are taken into account

Clinical significance of SLLD and LBP

- Soukka et al (1991), in a study of 247 working age men and women, examined and compared statistically matched groups with and without LBP.

- Their results showed no increased risk of back pain with a SLLD of 10–20 mm, and the relationship between SLLD of more than 20 mm and back pain was not conclusive.

Clinical significance of SLLD and LBP

- These results differ markedly from that of Friberg, prompting the letter-to-the-editor noted earlier.

- Both Friberg and Souka agree that the significance of SLLD may depend on the amount of prolonged and repetitive loading

How about adult onset SLLD

- Post THR, SLLD not only is associated with patient dissatisfaction, but also is the most common reason for litigation.

- SLLD after THR has been associated with complications including sciatic, femoral, and peroneal nerve palsies, low back pain, abnormal gait and dislocation (Meermans et al, 2011).

Research on adult onset SLLD

Hip Int. 2013 Jan-Feb;23(1):6-14. doi: 10.5301/HIP.2013.10631.

A review of symptomatic leg length inequality following total hip arthroplasty.

McWilliams AB[1], Grainger AJ, O'Connor PJ, Redmond AC, Stewart TD, Stone MH.

Author information

Abstract

Leg length inequality (LLI) following total hip replacement is a complication which features increasingly in the recent literature. The definition of LLI is complicated by lack of consensus regarding radiological measurement, clinical measurement and the incomplete relationship between LLI and associated symptoms. This paper reviews 79 reports relating to LLI post hip replacement, detailing definitions and classification and highlighting patient populations prone to symptomatic LLI. While there is no universal definition of LLI, there is a broad consensus that less than 10 mm of difference on AP view plain radiographs is clinically acceptable. There are few techniques described that consistently produce a postoperative LLI of less than this magnitude. Where postoperative LLI exists, lengthening appears to cause more problems than shortening. In cases of mild LLI, non-surgical management produces adequate outcomes in the majority of cases, with functional LLI cases doing better than those with true LLI. Operative correction is effective in half of cases, even where nerve palsy is present, and remains an important option of last resort. Poor outcomes in patients with LLI may be minimised if individuals at risk are identified and counselled appropriately.

So, does LLD link to LBP?

- It appears it may do ONLY in specific active populations or following surgery

- The significant amount in this population can be as little as 5mm, while other authors state less than 20mm is not significant

And these studies have all used ‘accurate’ imaging. Using imaging to measure SLLD is not ‘clinical’!

- How can **we** clinically measure SLLD, before even worrying if its linked to the patients symptoms.

- Are our methods”

1. Reliable?
2. Accurate enough (compared to imaging)

Structural Leg Length Difference

Methods of measurement

* Those with adequate research to include are:

1. Tape measure
2. Block standing

Structural Leg Length Difference

Methods of measurement

* An ideal measurement method should be reliable and accurate.
* Reliability is the variation between observers and within a single observer in obtaining the measurement
* Accuracy refers to the variation in measurement using a technique compared with the actual measurement

Structural Leg Length Difference

Methods of measurement

The use of accurate and reliable clinical and imaging modalities for quantifying SLLD is vital for planning appropriate treatment.

(Sabharwal & Kumar 2008)

Structural Leg Length Difference

Tape measure

* A tape measure is typically used to measure the length of each lower extremity by measuring the distance between the anterior superior iliac spine (ASIS) and the medial malleolus.
* It is referred to as the "direct" clinical method for measuring LLD

Direct SLLD measurement

However, differences in the girth of the two limbs, difficulty in identifying bony prominences and height differences in structures distal to the ankle mortise can contribute to errors using this clinical measurement tool.

Direct structural LLD measurement

- In a thorough review of reliability and validity in 2008, Sabharwal & Kumar concluded the direct method was a useful screening tool, but not as accurate as imaging

- Most papers concluded moderate accuracy, with ranges of error ranging from -3mm to +8mm commonly.

Direct structural LLD measurement

- However, (where studied) these same papers all show moderate to good inter and intra tester reliability

- It may therefore by fair to conclude we are often reliably inaccurate?

Structural Leg Length Difference

Block Standing

- Another method to measure SLLD is to level the pelvis of the standing patient by placing blocks of known height under the short limb. This is referred to as the “indirect” clinical method for measuring SLLD

Indirect Structural LLD measurement

Is it any better than the tape measure?

- Jonson & Gross (1997) reported good reliability, with the mean absolute difference in measurement being 1.7 mm for intraobserver and 2.2 mm between the two observers.

Indirect Structural LLD measurement

Is it any better?

- Hanada et al (2001) also found good reliability, BUT this method tended to underestimate LLD by an average of 5.1 mm.

Indirect Structural LLD measurement

Is it any better?

- In one of the largest studies yet, Lampe et al (1996) compared the agreement in measuring LLD between use of a tape measure and standing blocks with orthoroentgenograms in 190 children attending a limb lengthening clinic.

- 95% of the measurements using the wooden boards were within -14 and +16 mm of the results obtained using radiography.

- In this paper, the tape measure had significantly less agreement.

Indirect Structural LLD measurement

Is it any better?

- Harris et al (2005) compared assessment of SLLD using direct and indirect methods, and compared to CT scan measurement in 35 adults following femoral shaft fracture.

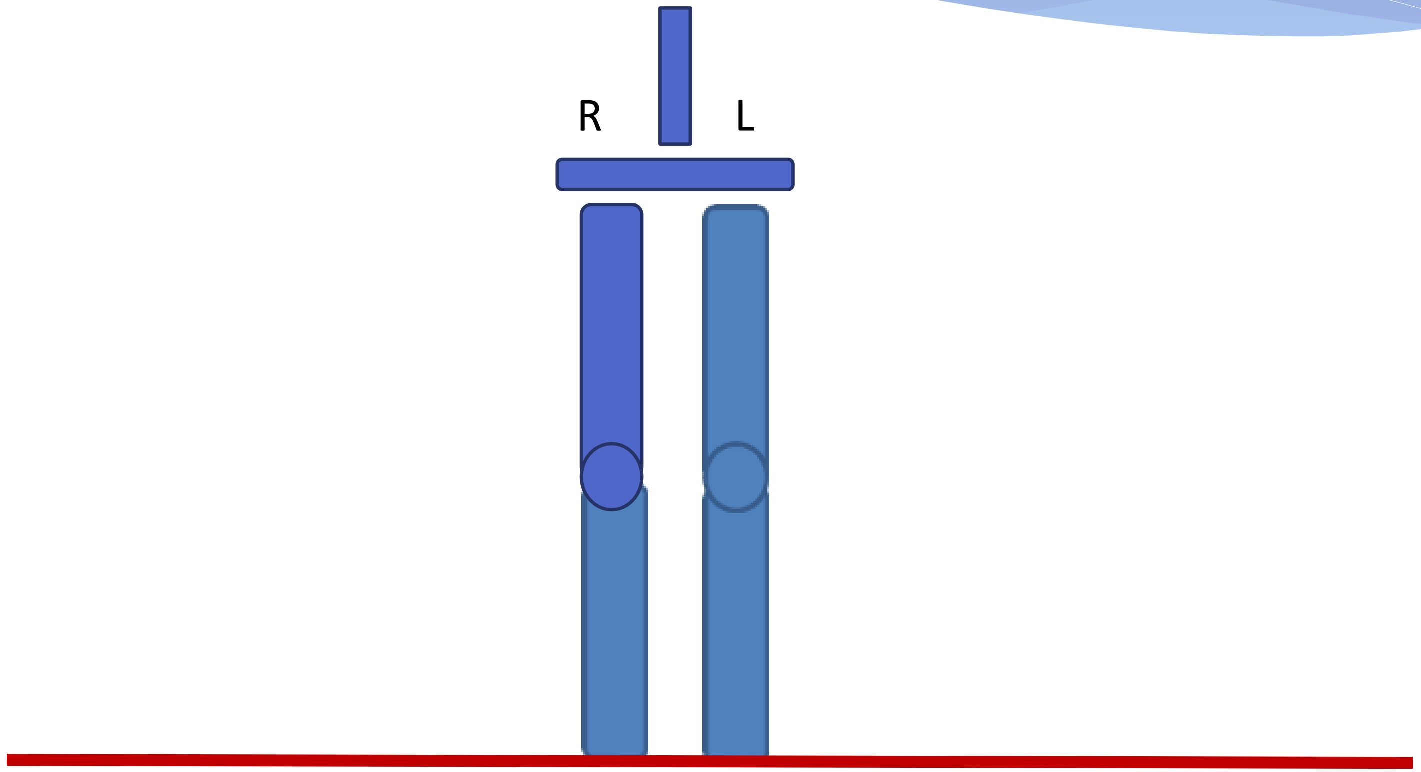
- There was a strong correlation between the two clinical methods ($p = 0.003$). There was no correlation between the CT scanogram and the two clinical methods with a mean absolute difference of 7.2 mm

Clinical measurement of SLLD

- This appears to show that for both the tape measure and block method, we tend to agree with ourselves and each other on clinical measurement….but that this clinical measurement may still not be actually accurate enough to base treatment on?
- We seems reliably inaccurate….

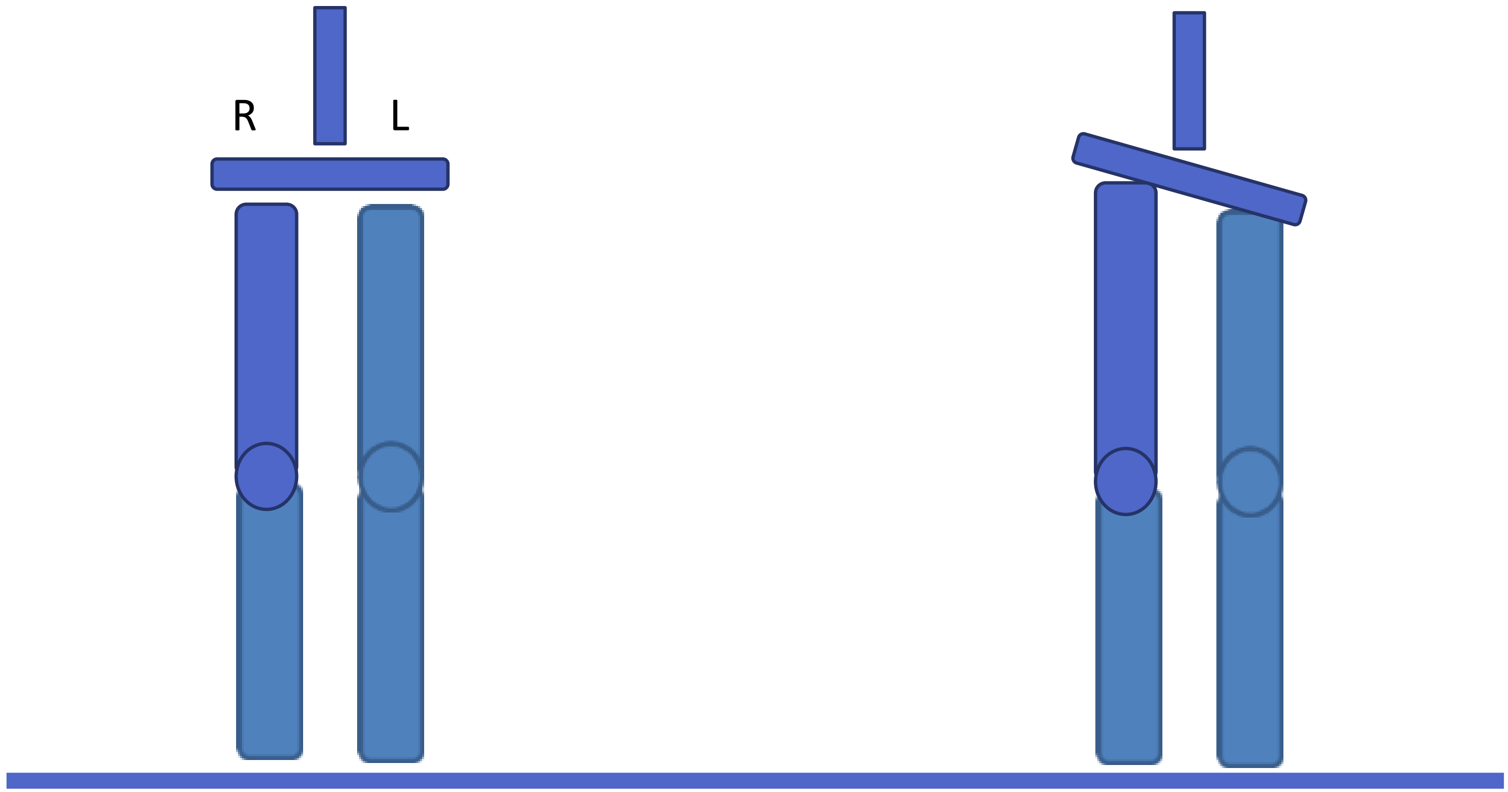
We appears reliably inaccurate….could we be 'under thinking' this?!

Clinical Presentation of SLLD when standing



No SLLD

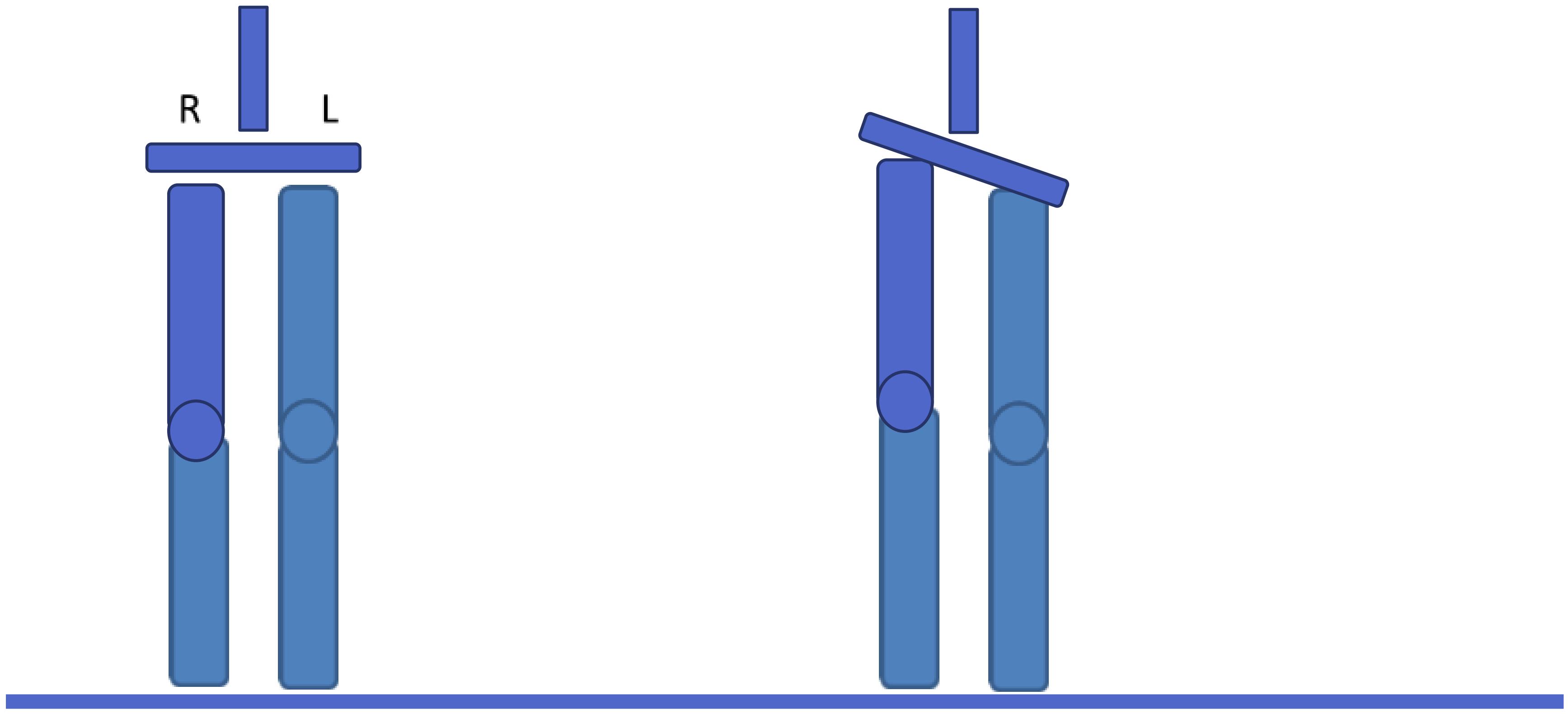
Types of SLLD



No SLLD

Longer Right Femur

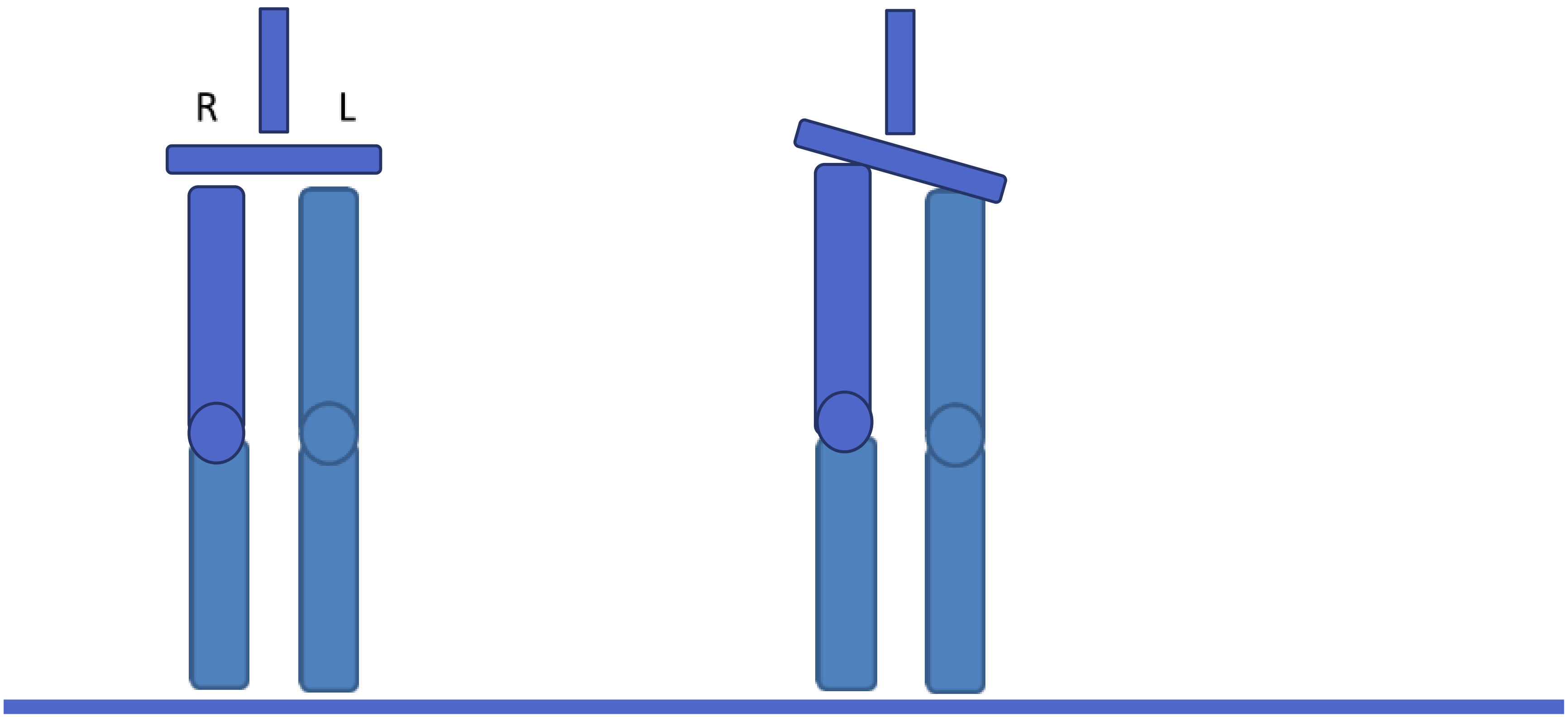
Types of SLLD



No SLLD

Longer Right Tibia

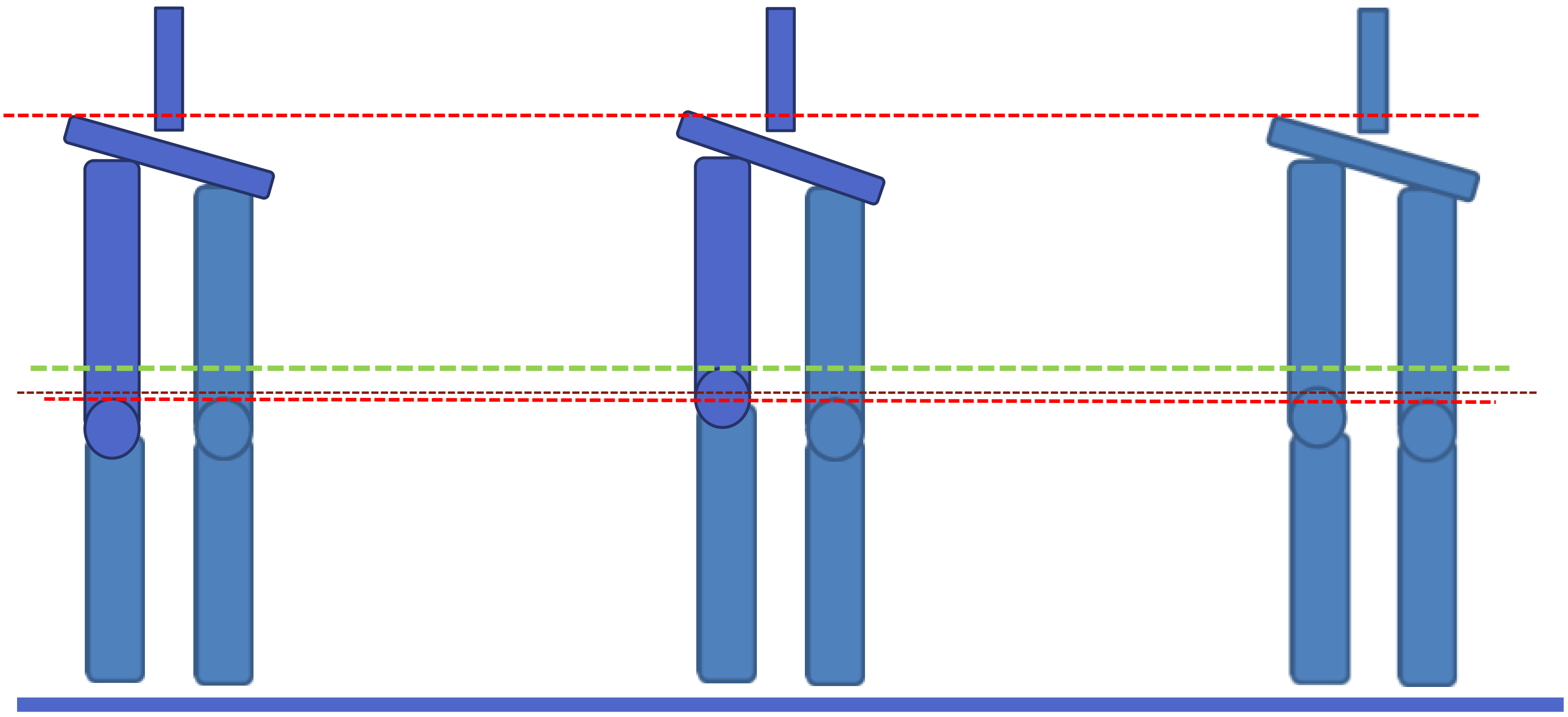
Types of SLLD



No SLLD

Longer Right Femur & Tibia

Types of SLLD

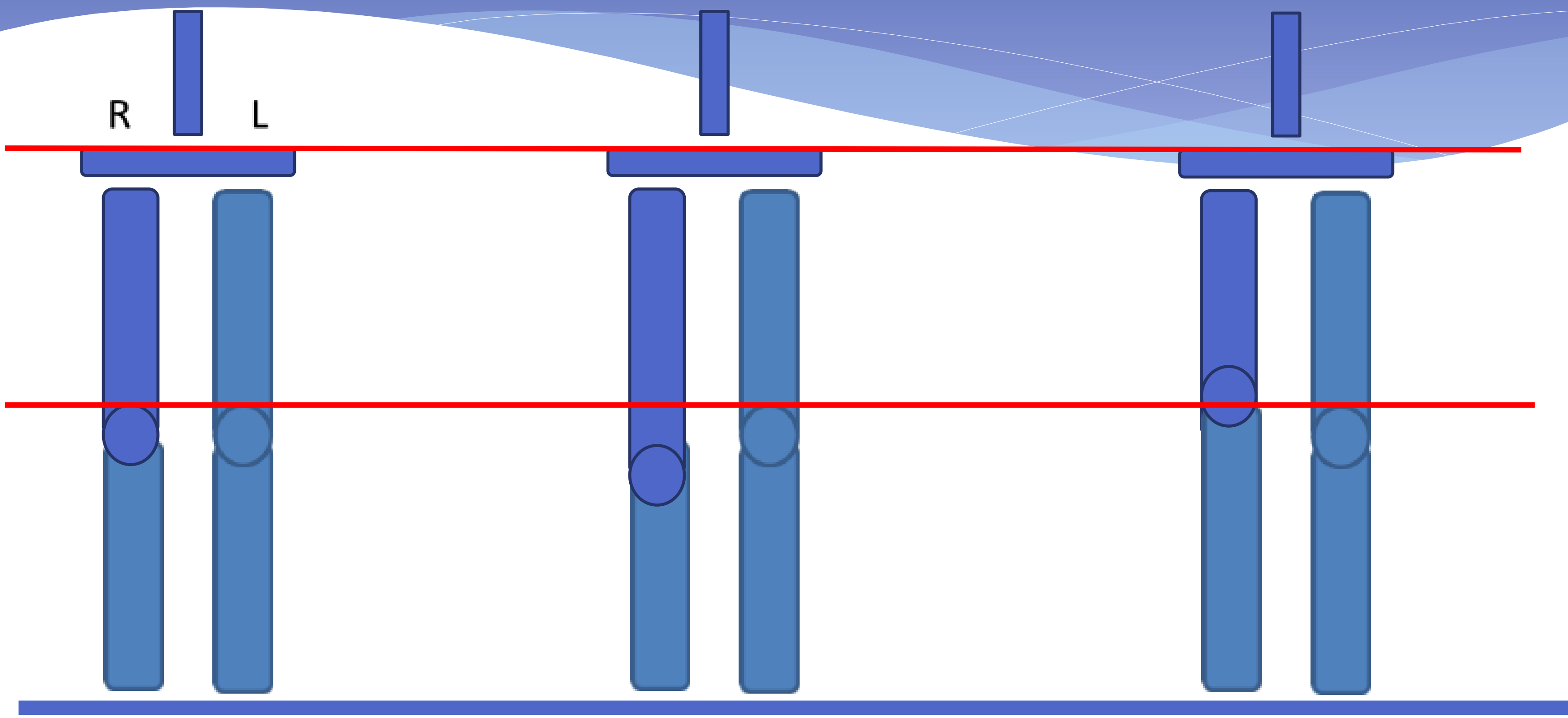


Longer Right Femur

Longer Right Tibia

Longer Right Femur & Tibia

How about these ones though…. Not within the scope of today!

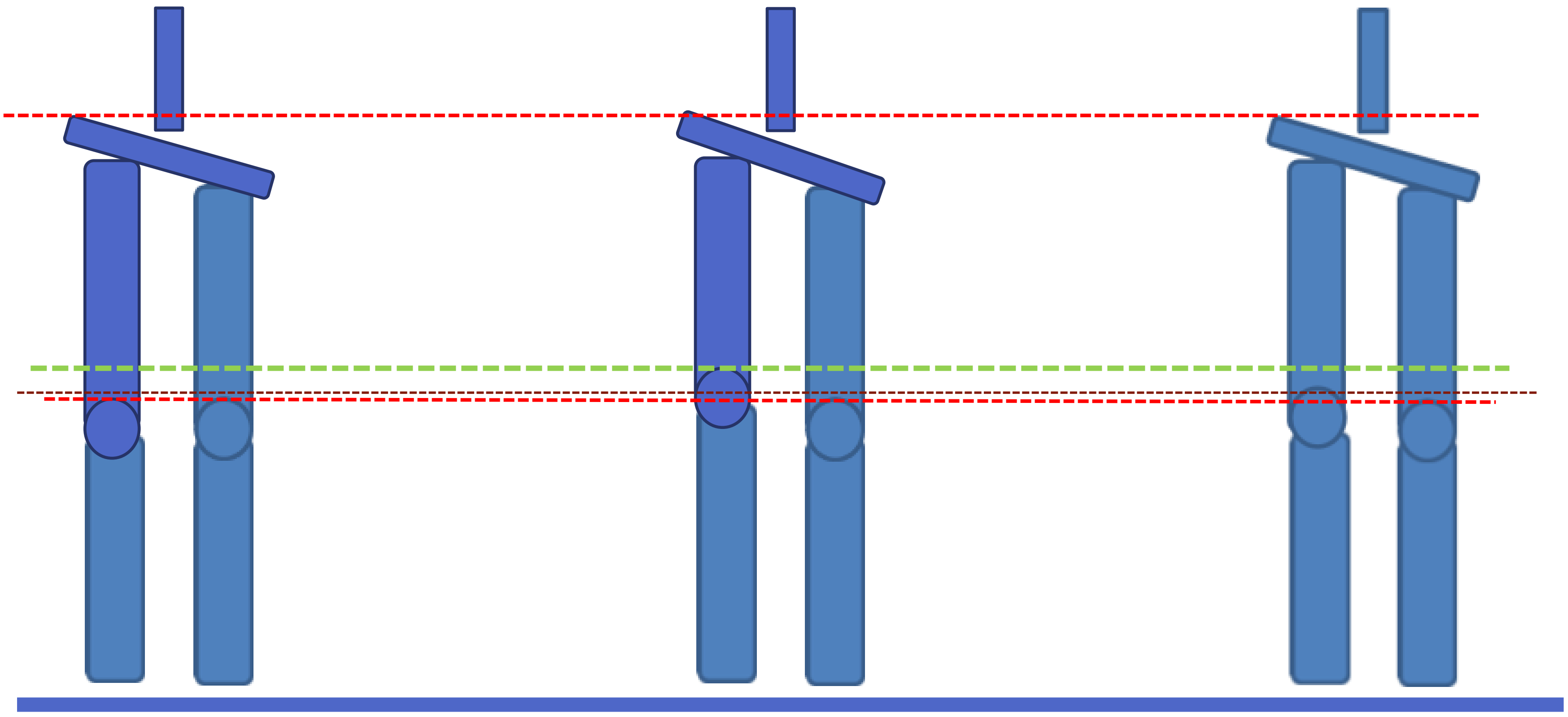


No SLLD

Long right Femur but short right Tibia

Long right Tibia but short right Femur

Types of SLLD



Longer Right Femur

Longer Right Tibia

Longer Right Femur & Tibia

What common conservative treatments do we use?

Treatment options:

- Heel raise

- Total foot raise

But, if there is a link to symptoms…is there a treatment?!

J Orthop Sports Phys Ther. 2007 Jul;37(7):380-8.

Changes in pain and disability secondary to shoe lift intervention in subjects with limb length inequality and chronic low back pain: a preliminary report.

Golightly YM[1], Tate JJ, Burns CB, Gross MT.

Author information

Abstract

STUDY DESIGN: Preassessment and postassessment of treatment intervention.

OBJECTIVE: To determine the changes in pain and disability secondary to shoe lift intervention for subjects with chronic low back pain (LBP) who have a limb length inequality (LLI).

BACKGROUND: Previous reports have suggested that LLI may be a cause of LBP Most prior studies of lift therapy for management of LLI in patients with LBP have lacked clear guidelines for clinicians regarding the implementation of shoe lift intervention.

METHODS AND MEASURES: Twelve subjects (6 male, 6 female) between the ages of 19 and 62 years with LLI (6.4-22.2 mm) and chronic LBP (1-30 years) participated. Visual analog scale pain ratings and disability questionnaire scores were acquired before and after lift intervention. Subjects determined their lift height based on resolution of LBP symptoms.

RESULTS: Subjects experienced relief of general pain symptoms (P = .0006) and pain associated with standing (P= .002) following lift intervention, with minimally clinically important (MCID) reductions in general pain for 9 of 12 subjects and MCID reductions in standing pain for 8 of 10 subjects. Subjects also had less disability on the disability questionnaire (P = .001) following the intervention, with 9 of 12 subjects experiencing MCID reductions in disability.

CONCLUSION: Shoe lifts may reduce LBP and improve function for patients who have chronic LBP and an LLI. Randomized controlled trials are needed to assess the efficacy of this intervention.

But, if there is a link to symptoms…is there a treatment?!

Arch Phys Med Rehabil. 2005 Nov;86(11):2075-80.

Conservative correction of leg-length discrepancies of 10mm or less for the relief of chronic low back pain.

Defrin R[1], Ben Benyamin S, Aldubi RD, Pick CG.

Author information

Abstract

OBJECTIVE: To study whether conservative correction in a leg-length discrepancy (LLD) of 10mm or less in patients with chronic low back pain (CLBP) can relieve pain.

DESIGN: Randomized, controlled intervention study, with a mean follow-up duration of 10 weeks.

SETTING: Physical therapy clinic of the national health services.

PARTICIPANTS: Thirty-three patients with CLBP were screened for an LLD of 10mm or less, which was measured with ultrasound. Patients were randomly divided into intervention and control groups.

INTERVENTION: In 22 patients, LLD was corrected by applying individually fitted shoe inserts. In 11 patients, LLD was not corrected.

MAIN OUTCOME MEASURES: Chronic pain intensity (visual analog scale) and disability score (Roland-Morris Disability Questionnaire).

RESULTS: Shoe inserts significantly reduced both pain intensity ($P<.001$) and disability ($P<.05$). A moderate positive correlation was found between LLD and the degree of pain relief after wearing shoe inserts ($r=.47$).

CONCLUSIONS: Shoe inserts appear to reduce CLBP and functional disability in patients with LLDs of 10mm or less. Shoe inserts are simple, noninvasive, and inexpensive therapeutic means that can be added to the treatment of CLBP.

Is there any research that they help?

- Larger samples and RCTs are still missing (samples in both papers are less than 25)

- But, even if used correctly and they 'equalise' the SLLD, then at least they can't do any harm?! Are we sure?!

J Am Osteopath Assoc. 2007 Sep;107(9):415-8.

Chronic psoas syndrome caused by the inappropriate use of a heel lift.

Rancont CM[1].

Author information

Abstract

Heel lifts are commonly recommended for patients to manage the pain and discomfort of leg length discrepancies. However, used inappropriately, orthotics can create additional pain instead of alleviating it. In the case described, a 79-year-old male physician used a recommended heel lift for a perceived leg length discrepancy after right hip arthroplasty. Six months postsurgery, chronic, intractable pain developed in his hip and groin. He underwent a battery of tests to locate the pain, but its source remained elusive. Osteopathic evaluation and radiographic examination revealed an absence of leg length discrepancy and the presence of chronic psoas syndrome. Osteopathic manipulative treatment was prescribed and heel lift therapy discontinued, and the patient reported complete remission from pain.

Is there any research that they help?

But what if even prescribed on the short side?!

J Am Osteopath Assoc. 2007 Sep;107(9):415-8.

Chronic psoas syndrome caused by the inappropriate use of a heel lift.

Rancont CM[1].

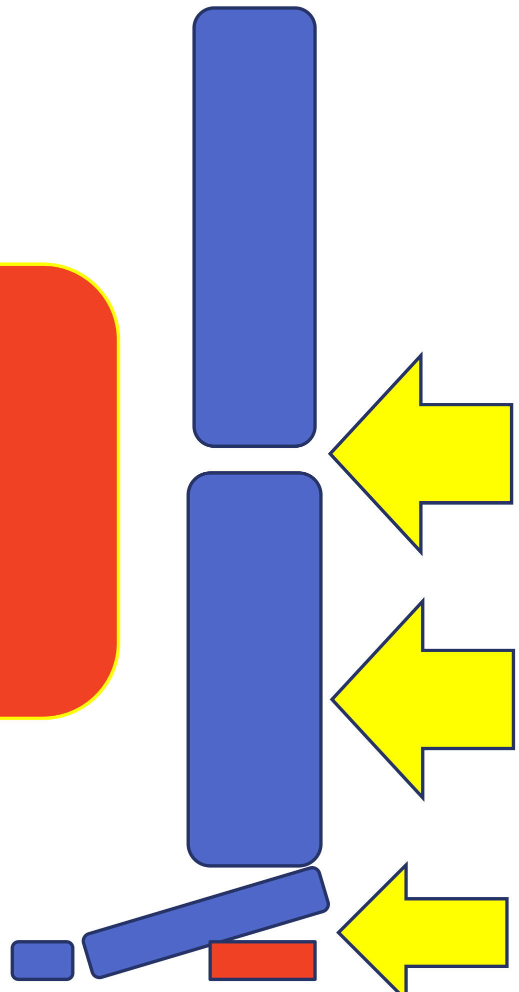
Author information

Abstract

Heel lifts are commonly recommended for patients to manage the pain and discomfort of leg length discrepancies. However, used inappropriately, orthotics can create additional pain instead of alleviating it. In the case described, a 79-year-old male physician used a recommended heel lift for a perceived leg length discrepancy after right hip arthroplasty. Six months postsurgery, chronic, intractable pain developed in his hip and groin. He underwent a battery of tests to locate the pain, but its source remained elusive. Osteopathic evaluation and radiographic examination revealed an absence of leg length discrepancy and the presence of chronic psoas syndrome. Osteopathic manipulative treatment was prescribed and heel lift therapy discontinued, and the patient reported complete remission from pain.

Complications of heels raises?

And after heel lift what happens?!



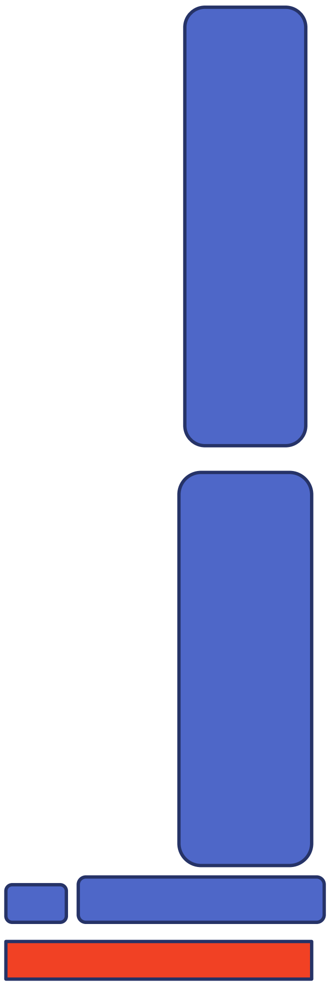
Asymmetrical increase in knee flexion moment resulting in possible:

1. Asymmetrical knee flexion in gait / function
2. Increased load on knee extensors
3. Resultant muscle balance and proximal insertion issues

Form follows function, meaning over time there may be asymmetrical posterior calf shortening

Heel raise causes ankle plantarflexion

Complications of total sole raise

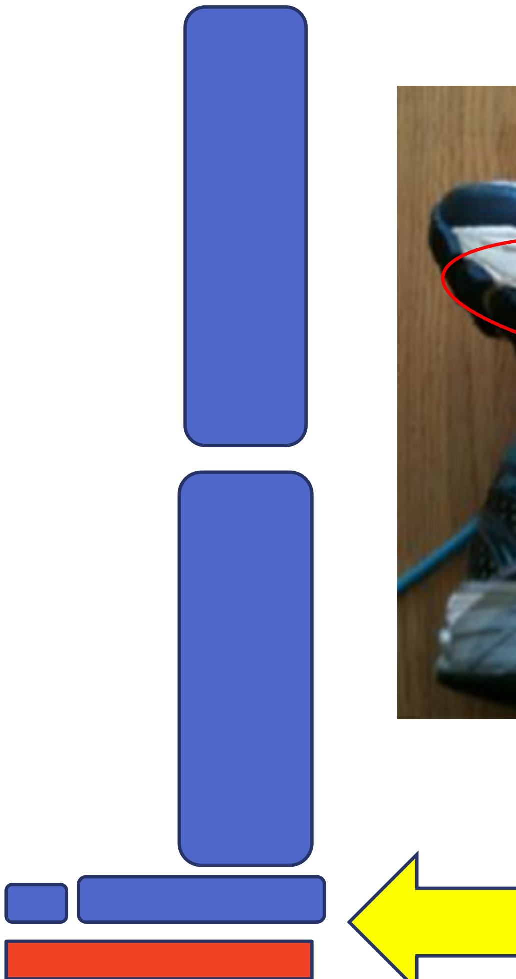


But, this right shoe with a 15mm heel raise is TWICE AS HEAVY as the left shoe. This may cause issues with:

1) Movement asymmetry
2) Asymmetrical fatigue

No Heel raise, no increase in ankle plantarflexion

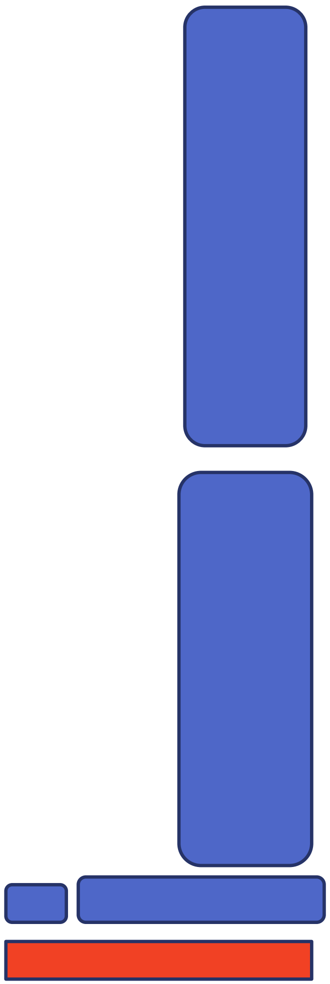
Complications of a total sole raise



With the additional cushioning, there may be asymmetrical proprioception

No Heel raise, no increase in ankle plantarflexion

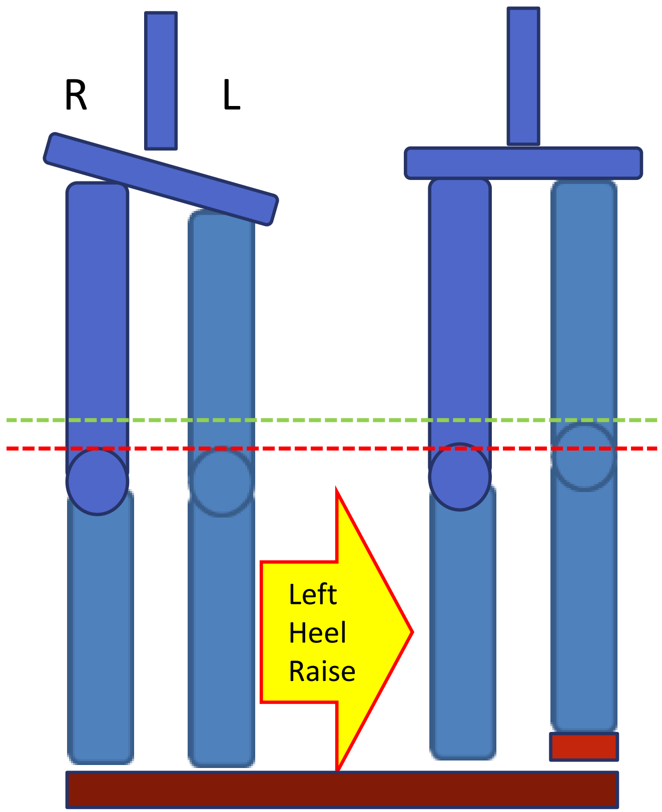
Complications of a total sole raise



With the increased cross sectional thickness of the forefoot sole, the toe box is stiffer, creating a functional limitation to using the third rocker. This will result in asymmetrical compensatory mechanisms

No Heel raise, no increase in ankle plantarflexion

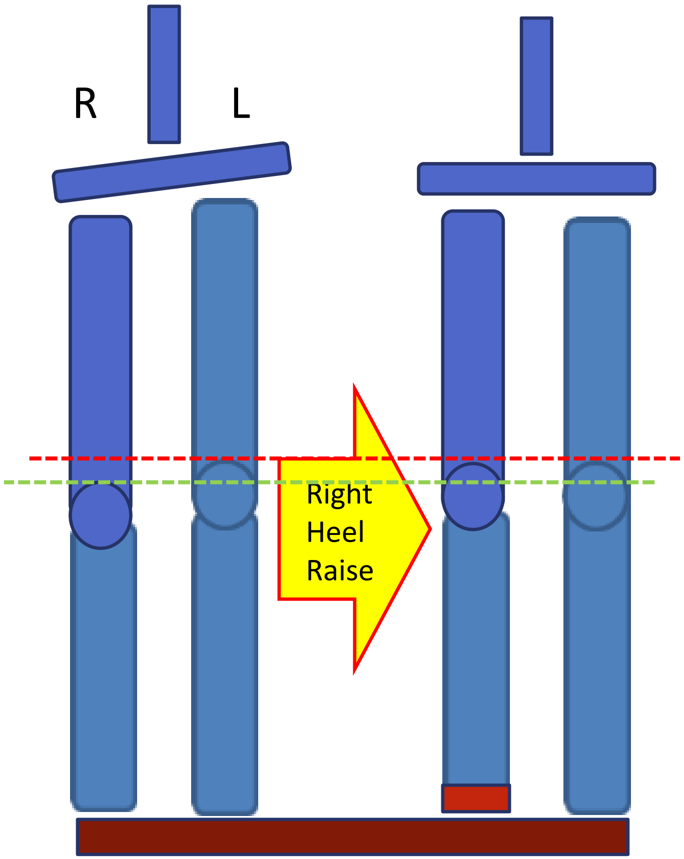
General Complications of non surgical treatment.



Having one knee higher than the other is another asymmetry that will effect the bending moment, torque and so muscle balance of the lower limb. Certain movements such as squatting, as well as running / walking, may be linked to adverse effects of this.

However, the above effect would be REDUCED if the patient had a short left tibia, possible meaning greater benefit in treating SLLD due to a short tibia rather than short femur. There is no research on this.

General Complications of non surgical treatment.



Longer Left tibia

Having one knee higher than the other is another asymmetry that will effect the bending moment, torque and so muscle balance of the lower limb. Certain movements such as squatting, as well as running / walking, may be linked to adverse effects of this.

However, the above effect would be REDUCED if the patient had a short left tibia, possible meaning greater benefit in treating SLLD due to a short tibia rather than short femur. There is no research on this.

Complications of non surgical treatment.

- Using heel or total sole raises do not therefore normalise patients gait with a leg length difference
- Although the compensatory mechanism due to the SLLD may reduce, others will be caused
- These may cause other chronic musculoskeletal conditions….but relieve the original one??

Where does this leave us?

1. A SLLD of approximately 5mm is mean in most studied populations

2. There is at present no strong link between SLLD and chronic LBP, and the kinematics of a SLLD are still uncertain.

3. We are **reliably inaccurate** when we measure it. If we do measure it clinically, we must accept margins of error in our treatment plan

So, lets be less negative about the clinical perspective of SLLD… because we've managed to get a CT scan measurement

1. BUT, we still have to be sure symptoms link to the SLLD

2. And if we are, the treatment we use WILL cause other gait / functional issues.

3. Patients must be aware of this.

Clinically, what can we conclude?

- In patients with a SLLD, take into account activity level and other factors which could be increasing its influence on symptoms
- If possible, get an imaging measurement
- Even then you need to weigh up the benefits and possible adverse effects to amount and choice of heel raise

Clinically, what can we conclude?

- As a rule of thumb, do as little raise as possible to improve the postural adaption and movement dysfunction you think links to LBP
- Combine heel and sole raise if required
- Check gait / movement has not worsened
- Build up slowly, not only to allow adaption, but to decrease the chance of ‘doing too much’

Practical on Crossover of all 3

<u>Leg Length difference</u>

Select a 'patient' for which we thought there my be a LLD, and do a complete assessment

Lets apply this to Orthotics

* And to common patient presentations

Symptoms and treatment plans

- Introducing orthotics

- Common MSK problems:

1. Plantar Fasciitis
2. Posterior tibial tendon dysfunction

In-shoe appliances....But how do they work?

- By reducing pronatory moments via applying force optimally

- By facilitating medial column propulsion

Temporary orthoses

- **Any padding / felt liners that reduces pronation moments without impinging on 1st ray function. E.g.:**

- Felt Medial Heel Wedges
- Felt 1st Ray Cut outs



What do we expect from an orthoses?

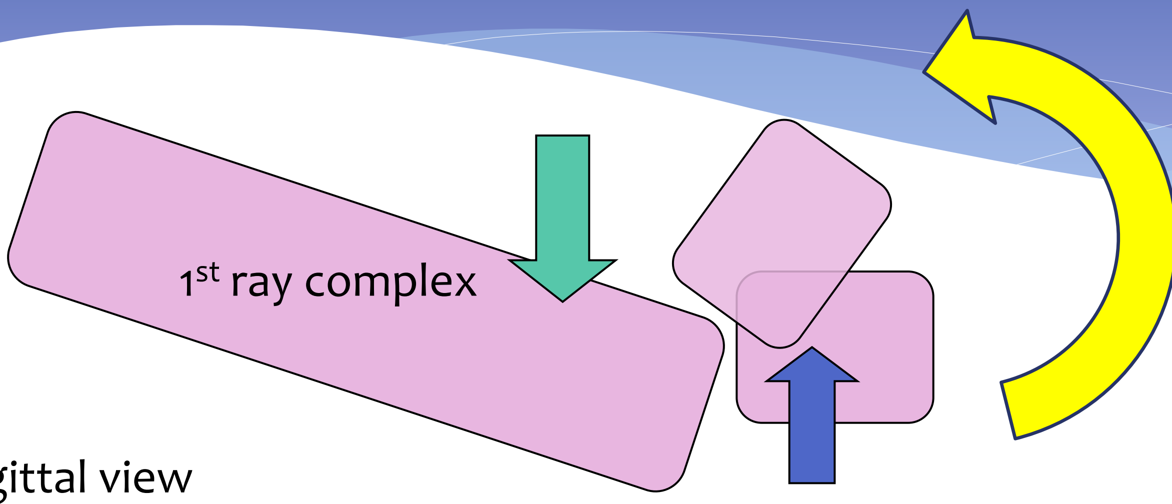
1. Not to make this worse and so have adverse effects elsewhere
2. Not to be uncomfortable
3. Not to wear down quickly or fall apart.
4. Not to need a different pair for every pair of shoes

Orthotics, from materials to prefabs, from courses to customs, are all driven by commercial interest......

‘The Superior man understands what is right, the inferior man understands what will sell’

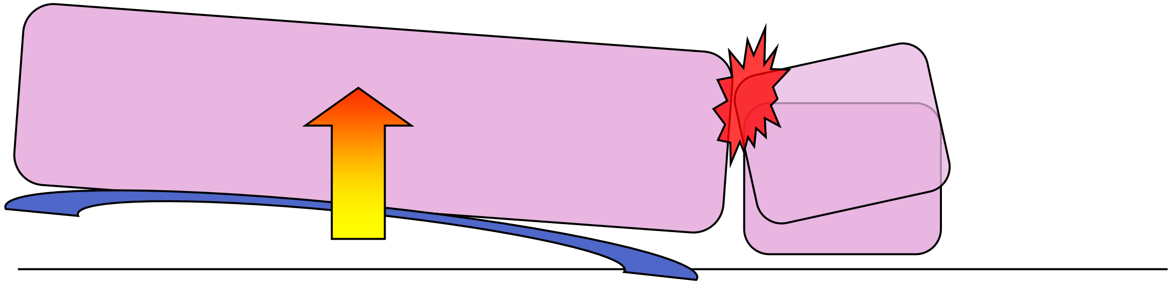
Confucius

Poorly fitting orthoses (non-custom AND custom) can cause a functional hallux limitus….



Normal Hallux dorsiflexion with first ray plantarflexion

Sagittal view



Functional Limitation of Hallux dorsiflexion due to an increase of dorsiflexory moments on the first ray from an 'incorrect' / high medial contour (arch) orthosis

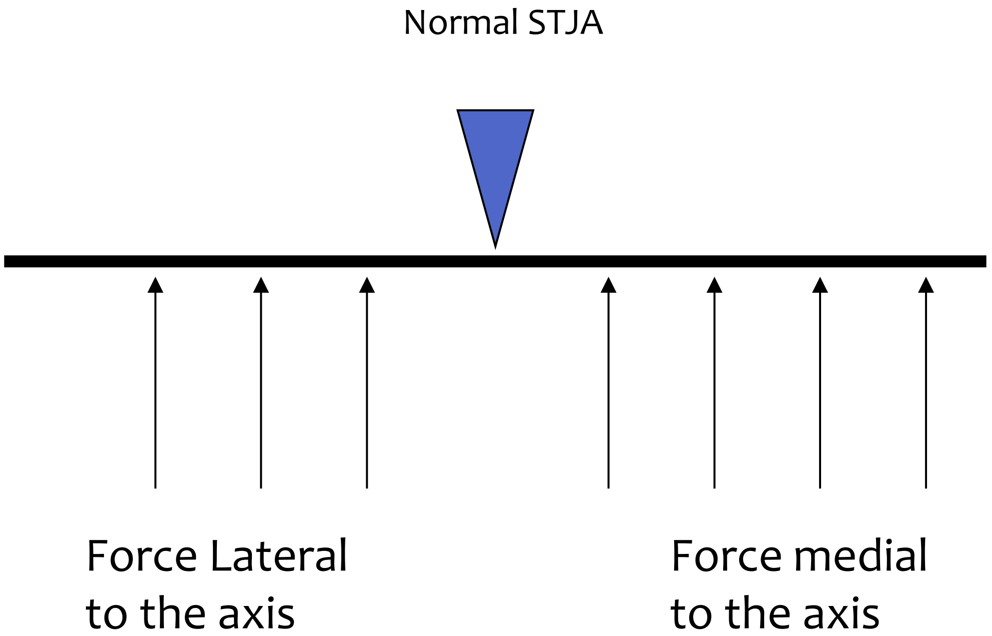
Instant Orthoses not from impressions

When should they be prescribed?

- Some situations warrant particular care in orthotic prescription. Examples include

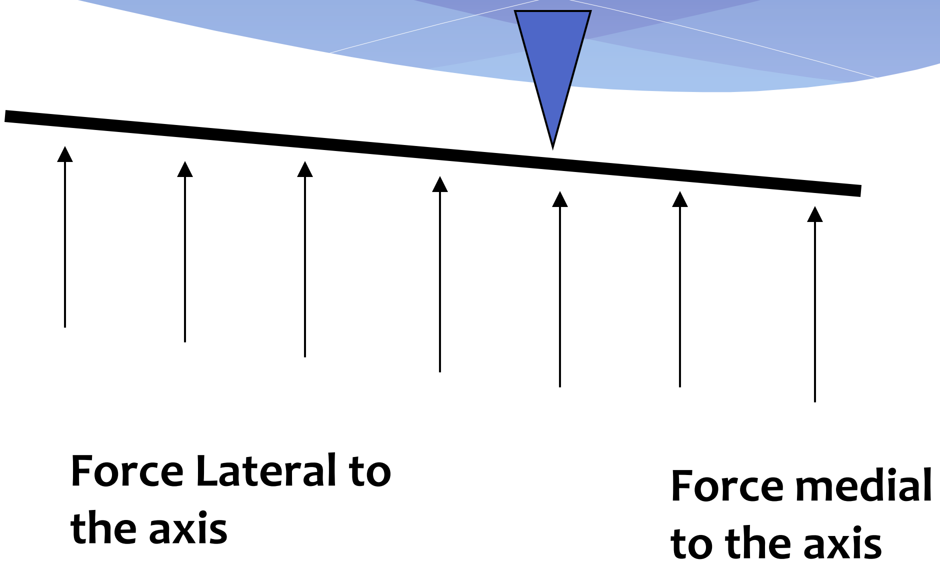
1. Neuropathy and/or peripheral vascular disease and/or gross deformity

Orthoses and normalising foot function



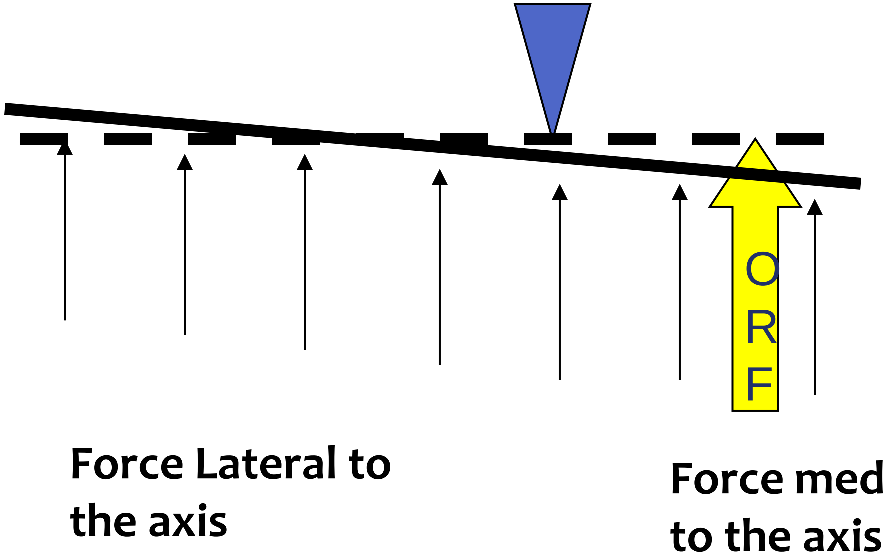
If the fulcrum, in this case a normal STJA, is in the middle of the see-saw and forces applied to the see-saw are equal and equidistant, **no motion will result**

Orthoses and normalising foot function



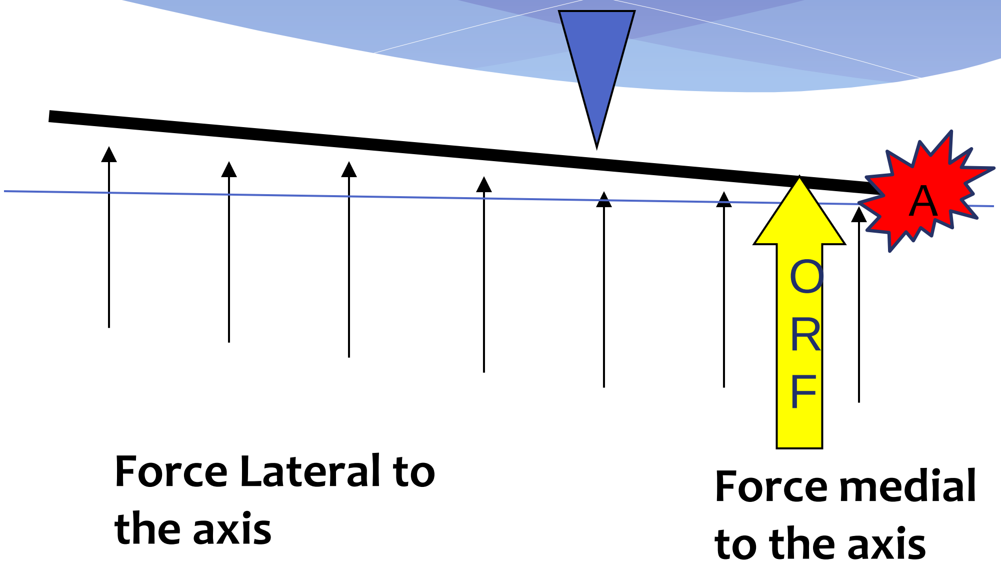
If the axis moves closer to one end of the lever, the lever will be longer on one aspect on the axis and the applied force increased. In this example, **a motion occurs around the axis (in this example, pronation).**

Orthoses and normalising foot function



The larger yellow arrow represents additional force from the orthosis, the ‘orthosis reaction force’. In this case the moment applied to the axis via the orthoses reaction force is great enough to ‘level the see-saw’ (in this example, reduce the pronation).

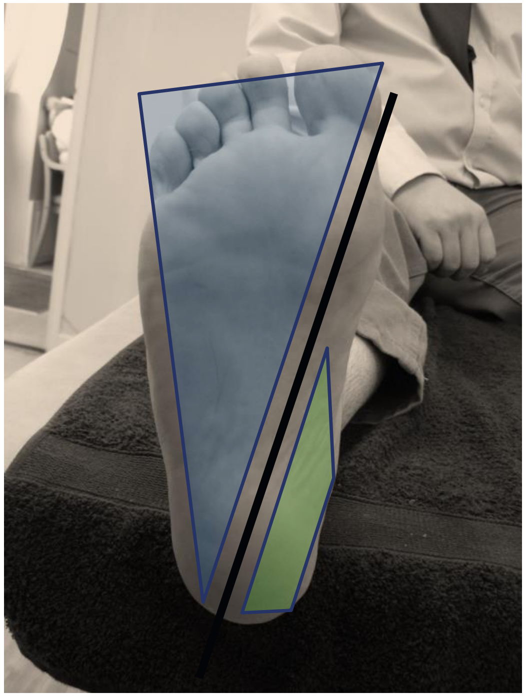
Orthoses and normalising foot function



The larger yellow arrow represents additional force from the orthosis, the ‘orthosis reaction force’. In this case the moment applied to the axis via the orthoses reaction force is not great enough to ‘level the see-saw’, However, pronatory moments would still have been decreased. This means the force applied at **‘A’** would still be decreased. Moment vrs Movement

Orthoses and normalising foot function

- By reducing pronatory moments via applying orthoses reaction force optimally



This is why podiatrists emphasise the importance of rearfoot ‘posting’ / wedging.

Rearfoot Posting

Plantar Fasciitis

“why does sleep hurt my feet?”

Plantar Fasciitis

- More than two million people receive treatment for plantar fasciitis in the United States each year PFEFFER G et al, Foot Ankle Int 1999.**20:** 214,
- 'Frequently' seen in athletic Warren. Sports Med.1999. 5:338-345 and military Sadat-Ali. Mil Med. 1998. 1:56-57 populations
- 10% or 'recreational runners' report having plantar fasciitis Chandler and Kibler. Sports Med. 1993. 5:344-352, and 159 out of 267 running injury patients had plantar fasciitis. Taunton et al. 2002. Br J Sports Med. 2002. 36:99-101
- Regardless of activity levels, Plantar Fasciitis is classed as a 'common' condition Lee. Phys Ther Sport. 2008. 10: 12-18.

What is the Plantar Fascia

- The plantar fascia is the investing fascia of the sole of the foot and forms a strong mechanical linkage between the calcaneus and the toes. There may be medial, lateral and central bands.

- The medial band is frequently implicated (Kaya1996) when in fact it is thin and virtually non-existent at the proximal level (Sarrafian 1987)

What is the Plantar Fascia?

- The lateral band is also quite variable and in some in some it is fully developed and relatively thick, however, for 12% of the population, it is completely absent.

- The central aponeurotic band is cited as the major structural and functional component (Wearing 2006) and therefore the most likely to be implicated in plantar heel pain.

What is the Plantar Fascia?

- The histological anatomy of the plantar fascia is relatively unknown.
- It is a dense connective tissue, likened to both tendon and ligament (Boabighi et al 1993)
- But with biochemical and histological differences to ligaments of the foot (Davis et al 1996)

What is the Plantar Fascia?

It is *similar to tendon and ligament but comprised of elongated fibrocytes embedded in the extracellular matrix consisting primarily of crimped collagen fibres*

What is the Plantar Fascia?

- Fibrocytes produce collagen, and form a 3D communicating network (Benjamin and Ralphs 2000) and it is currently believed this arrangement may be capable of sensing and responding to changes in load. In this way, the plantar fascia may have a sensory capacity

What is the Plantar Fascia?

- So…. In addition to passively transmitting force, the plantar fascia may act as an active sensory structure capable of modulating its composition in response to external demands

Chronic Plantar Heel Pain

- Why / how does it get injured?

- Despite the historical nomenclature of plantar fasciitis, and the direct assumption therefore of inflammatory processes, the histopathology reveals the condition is not primarily inflammatory. For this reason, it may be more accurate to refer to the condition as chronic plantar heel pain or CPHP

What is the role of the plantar fascia?

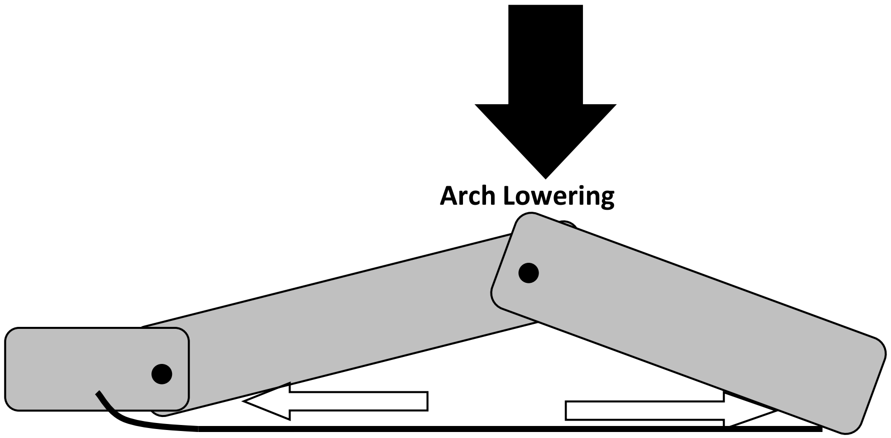
- The plantar fascia is a passive structure, essential to the normal function of the foot.
- Abnormal function of the foot is indicated as an aetiological factor in its injury
- Lets quickly recap this normal and abnormal function, specifically in relation to the role of the plantar fascia.

Basics of normal foot function….

1. The foot must coordinate the effect of lower extremity internal rotation with the impact at heel strike.
2. It must then reverse the direction of rotation by midstep and accommodate lower extremity external rotation
3. While simultaneously stabilizing itself to forces that can reach multiples of body weight prior to toe off
4. And permitting the entire body to pivot over it.

3. While simultaneously stabilising itself to forces that can reach multiples of body weight prior to toe off

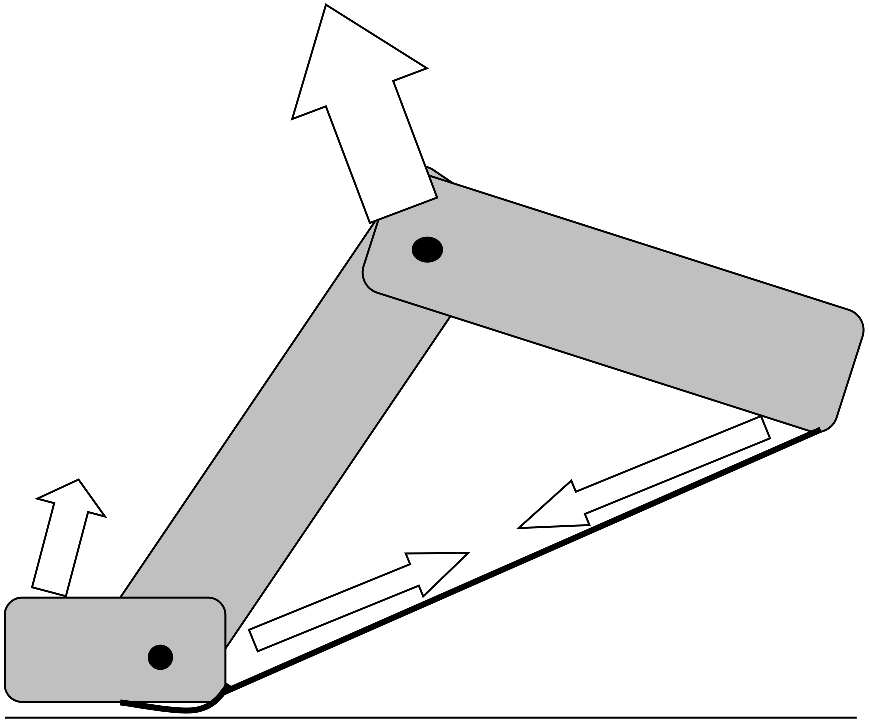
- **Stability at loading phase is accomplished via the *reverse* windlass mechanism**



• As the arch lowers it becomes longer and the plantar structures (in this example the plantar fascia, but also the plantar ligaments) become more taut. This in turn applies a compressive force longitudinally

3. While simultaneously stabilising itself to forces that can reach multiples of body weight prior to toe off

- **Stability at propulsive phase is accomplished via the windlass mechanism**



•As the foot supinates and the arch raises, tension is maintained in the plantar fascia via the 'winding' of the windlass around the 1st MTPJ.

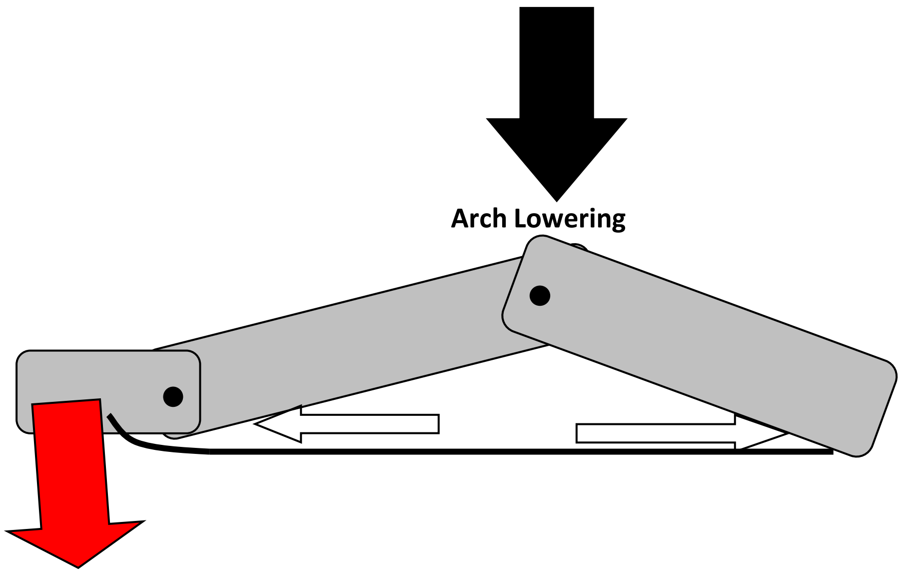
Plantar Fasciitis and Pronation

1. Pronating too hard, meaning the foot cannot resupinate.
2. Pronating too far, meaning there is lower limb functional malalignment.
3. Pronating too far, placing too much stress in the plantar fascia

↓

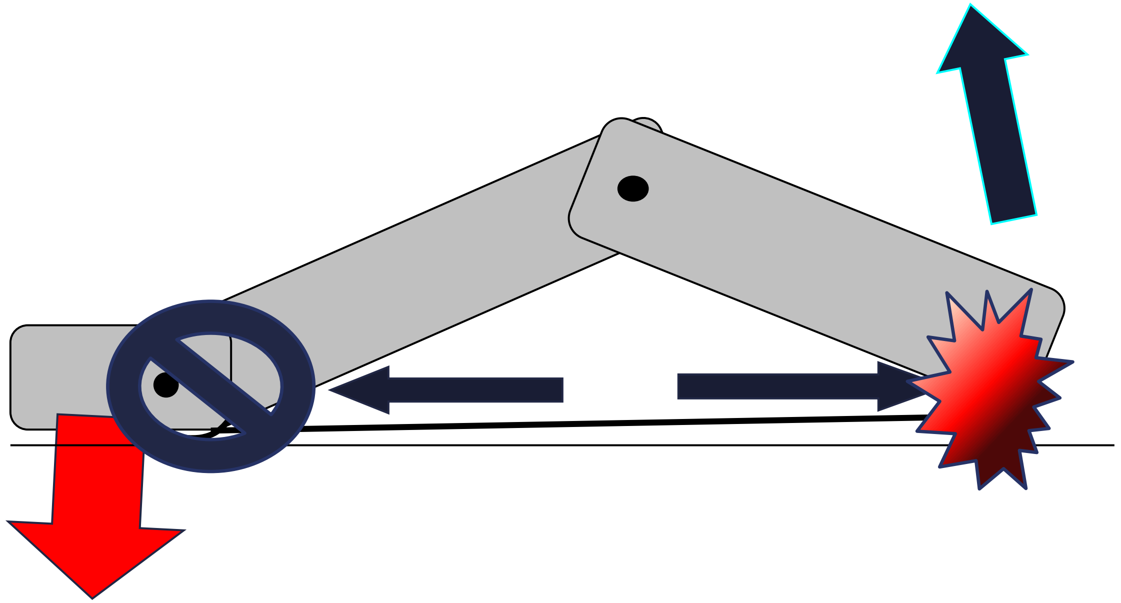
Reduced ability to pivot over the 1st MTPJ (functional hallux limitus)

3. Too much pronation limits hallux dorsiflexion via the reverse windlass



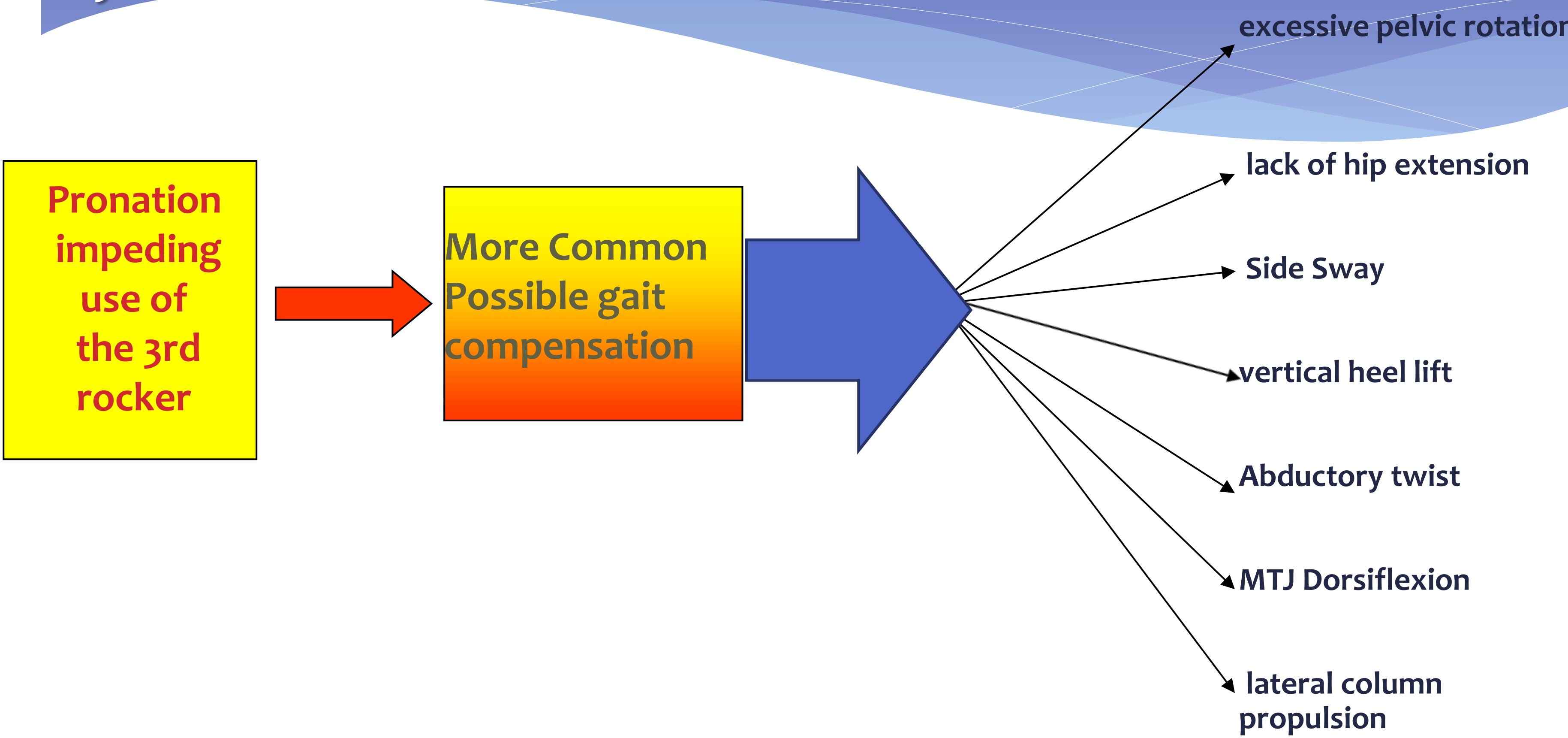
- **As the arch lowers it becomes longer and tensile strain in the plantar fascia increases, applying a plantarflexion moment on the digits. However, the greater the pronation, the greater the strain and the greater the plantarflexion moment**

3. Too much pronation limits hallux dorsiflexion via the reverse windlass, and as the heel tries to lift tension in the plantar fascia increases



- **As the heel tries to lift via hallux dorsiflexion, tensile stress will increase until dorsiflexion moments are greater than plantarflexion moments….or we compensate via gait dysfunction.**

As the heel tries to lift via hallux dorsiflexion, tensile stress will increase until dorsiflexion moments are greater than plantarflexion moments….or we compensate via gait dysfunction



Therefore, Anything that reduces pronation moments will reduce the strain in the plantar fascia

- And by doing so, decrease plantar fascia injury and reduce associated gait dysfunction

- **Therefore observing an improvement in gait dysfunction can be seen as a predictor to a successful outcome in treating plantar fasciitis**

CPHP– Evidence for Foot Orthoses prescription

* Aims:

1. Decrease stress in plantar fascia by decreasing pronation moments

2. Not to impinge on first ray function

3. CUSHION!!!

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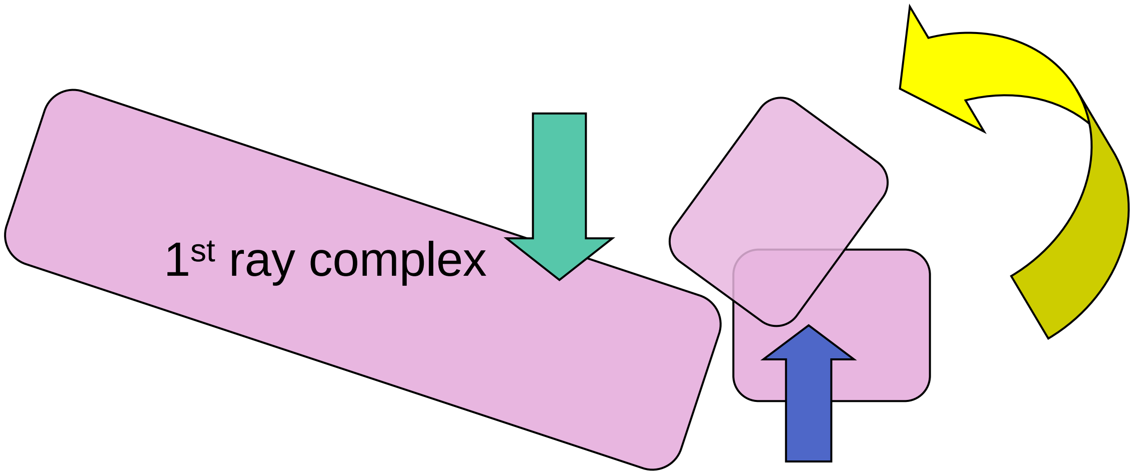
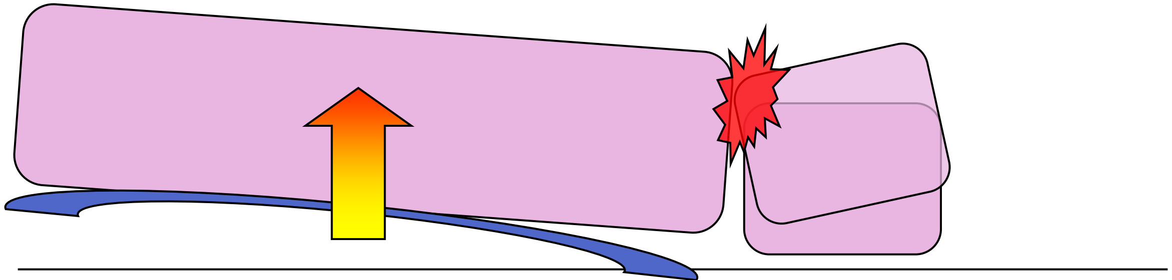
not to impinge on first ray function:



Normal Hallux dorsiflexion with first ray plantarflexion

Sagittal view



Functional Limitation of Hallux dorsiflexion due to an increase of dorsiflexory moments on the first ray from an ‘incorrect’ / high medial contour (arch) orthosis

CPHP– Evidence for Foot Orthoses prescription

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3. CUSHION!!!

Did he just Say ‘*cushion* ’ ?!

- CPHP may be related to degeneration, this being especially likely since the entheseal tissue in particular, is prone to degeneration

- The histopathological appearance of CPHP resembles the changes seen to articular cartilage during early stage OA with longitudinal fissuring of fibrocartilage, which then ossifies within the enthesis. Spur formation is likely to be a feature

Did he just Say ‘*cushion* ’ ?!

* According to McMillan at al (2009), “subcalcaneal spur formation is strongly associated with pain beneath the heel”

Did he just say '*heel spur* ' ?!!!!

- A recent meta analysis undertaken by Jill Cook and Craig Purdham (2011) demonstrated that CPHP participants are over 8 times more likely to show evidence of spur than the control group. A recent study by Johal and Milnar (2012) demonstrated that 89% of a symptomatic CPHP cohort had associated calcaneal spur.

Did he just say ‘*heel spur* ’ ?!

* In all of this, vertical compressive loading has been identified as to be as important as traction classically linked to over-pronation (Menz et al 2008, Cook and Purdham 2011)

He did! He said ‘*heel spur* ’ !

- Yes I did!
- ‘Plantar fasciitis’ is not primarily inflammatory in nature and therefore should be regarded as fasciopathy with the nomenclature of CPHP (chronic plantar heel pain)
- The enthesis is brittle and therefore susceptible, especially with aging
- Bending, shear and compression are probably as important as tensile load
- The presence of a calcaneal spur is important and strongly linked to CPHP

Cushioning……

- Understanding this means we may obtain better results with orthotics and general treatment planning if we combine reduction in tensile plantar fascia stress WITH heel pad cushioning….

CPHP– Evidence for Foot Orthoses prescription

Aims:

1. Decrease stress in plantar fascia by decreasing pronation moments
2. Not to impinge on first ray function
3. CUSHION!!!

- Custom foot orthoses have been shown to be effective in both the short-term and long-term treatment of pain. Parallel improvements in function, foot-related quality of life, and a better compliance suggest that a foot orthosis is the best choice for initial treatment plantar fasciitis (*Roos et al 2006, Hume et al 2008, Lee et al 2009, Lewis et al, 2015*)

Other interesting Papers:

- Walther et al (2011). Effect of different orthotic concepts as first line treatment of plantar fasciitisFoot Ankle Surg. 2013 Jun;19(2):103-7.

Conclusion: After 3 weeks custom hard orthotics (with a soft top cover) are superior regarding pain reduction and pain free time when compared to Soft orthotics . Non-supportive orthotics (Cushioning) did not demonstrate a significant effect in the test setup used.

Trigger Point Dry Needling

A single randomised controlled trial by Cotchett et al (2011) provide evidence for the effectiveness of dry needling for the relief of CPHP.

Plantar Fascia “stretches”

Stretching the plantar fascia for CPHP has been shown to be superior to traditional weightbearing GSAT (gastrocnemius soleus Achilles tendon) stretching. Three randomised controlled trials have now shown the effectiveness of plantar fascial stretching (Rompe 2010, DiGiovanni 2006, DiGiovanni 2003).

<u>Interesting Findings</u>: DiGiovanni 2003. After 2 years, the sample that specifically stretched the plantar fascia had less pain than the group who did not....but both groups STILL HAD PAIN AFTER 2 YEARS!!!

Strength Training

Phys Ther Sport. 2017 Mar;24:44-52. doi: 10.1016/j.ptsp.2016.08.008. Epub 2016 Aug 18.

Strength training for plantar fasciitis and the intrinsic foot musculature: A systematic review.

Huffer D[1], Hing W[2], Newton R[3], Clair M[4].

Author information

Abstract

The aim was to critically evaluate the literature investigating strength training interventions in the treatment of plantar fasciitis and improving intrinsic foot musculature strength. A search of PubMed, CINHAL, Web of Science, SPORTSDiscus, EBSCO Academic Search Complete and PEDRO using the search terms plantar fasciitis, strength, strengthening, resistance training, intrinsic flexor foot, resistance training. Seven articles met the eligibility criteria. Methodological quality was assessed using the modified Downs and Black checklist. All articles showed moderate to high quality, however external validity was low. A comparison of the interventions highlights significant differences in strength training approaches to treating plantar fasciitis and improving intrinsic strength. It was not possible to identify the extent to which strengthening interventions for intrinsic musculature may benefit symptomatic or at risk populations to plantar fasciitis. There is limited external validity that foot exercises, toe flexion against resistance and minimalist running shoes may contribute to improved intrinsic foot musculature function. Despite no plantar fascia thickness changes being observed through high-load plantar fascia resistance training there are indications that it may aid in a reduction of pain and improvements in function. Further research should use standardised outcome measures to assess intrinsic foot musculature strength and plantar fasciitis symptoms.

KEYWORDS: Heel pain (Heel); Intrinsic foot muscles (Intrinsic); Plantar fasciitis (Plantar); Resistance training (Strength)

PMID: 27692740 DOI: 10.1016/j.ptsp.2016.08.008

ESWT

- The results of the ESWT studies are equivocal, with Crawford et al (2008) reporting that ESWT is more effective than placebo but only reports a mean difference of 6% (reduction in heel pain)

More recent papers….

- Erduran et al. A complication due to shock wave therapy resembling calcaneal stress fracture. Foot Ankle Int. 2013 Apr;34(4):599-602.

But then…………

- Agil et al, 2013. Extracorporeal shock wave therapy is effective in treating chronic plantar fasciitis: a meta-analysis of RCTs. Clin Orthop Relat Res. 2013 Nov;471(11):3645-52

"ESWT is a safe and effective treatment of chronic plantar fasciitis refractory to nonoperative treatments. Improved pain scores with the use of ESWT were evident 12 weeks after treatment. The evidence suggests this improvement is maintained for up to 12 months."

Taping

Calcaneal taping was shown to be a more effective tool for the relief of plantar heel pain than stretching, sham taping, or no treatment (Radford et al 2006, Hyland et al 2006)

Steroid Injection

- The results from trials comparing steroid injections with placebo substances show
- No advantage in the active substance
- Only a short term improvement over placebo (Crawford and Thomson, 2008)

Other interesting Papers:

- Uden et al (2011). Plantar Fasciitis – to jab or to support? A systematic review of the current best evidence. J Multidiscip Healthcare.

Conclusion: Both functional foot orthotics and corticosteroid injections can lead to a reduction in pain associated with plantar fasciitis. While orthotics also increase functional outcomes, steroid injections may have side effects

Night Splints

- According to Bekler et al (2007), patients without previous treatments for plantar fasciitis obtain significant relief of heel pain in the short term with the use of a night splint, however, this application does not have a significant effect on prevention of recurrences after a two-year follow-up.

- However, Attard and Singh (2012) compared the effectiveness of a posterior AFO, which dorsiflexes the foot, with an anterior AFO, which maintains the foot in a plantigrade position, and came to the conclusion that "Plantar fasciitis night AFOs are poorly tolerated orthoses but their use can be justified in that the pain levels are reduced. **The anterior AFOs are more comfortable and more effective than posterior AFOs." !!!**

Surgery

Neufeld SK et al. Plantar fasciitis: evaluation and treatment. J Am Academy of Orth Surgeons. 2008 Jun;16(6):338-46

Findings: nonsurgical management of plantar fasciitis is successful in approximately 90% of patients. Surgical treatment is considered in only a small subset of patients with persistent, severe symptoms refractory to nonsurgical intervention for at least 6 to 12 months.

The general EBP approach to mechanical orientated plantar fasciitis is outlined below. This does not take into account specific situations or risk factors (e.g. tape allergy):

1. Orthoses (Reduce tensile stress and cushion), taping and specific plantar fasciitis stretches at initial assessment

2. 'Non-evidence based treatments' may also be used initially (as although there is a viable lack of research, there is not evidence to suggest these treatments do any harm.) For example, calf stretches, lateral rotator strengthening and footwear advice.

The general EBP approach to mechanical orientated plantar fasciitis is outlined below. This does not take into account specific situations or risk factors (e.g. tape allergy):

3. Combine the above with treatments based to irritate the area of Fasciosis to encourage healing. Examples include dry needling and extracorpeal shockwave therapy

4. If no benefit, prefabricated nightsplints are the next treatment option.

5. Steroid injections are an option if all conservative treatments fails, as is surgery.

Other interesting Papers:

Grieve R, Palmer S. Physiotherapy for plantar fasciitis: a UK-wide survey of current practice. Physiotherapy. 2016 Feb 12. [Epub ahead of print]

* 257 complete survey responses.
* Advice (92%), plantar fasciitis pathology education (81%) and general stretching exercises (74%) were most routinely used.
* Prefabricated orthotics, custom made orthotics and night splints were seldom always used.
* Commonly used outcome measures were pain assessment, functional tests and range of movement.

Posterior Tibial Tendon Dysfunction


Posterior tibial tendon dysfunction
(adult acquired flat foot)


Posterior tibial tendon dysfunction
(adult acquired flat foot)

Posterior Tibial Tendon Dysfunction - Classification As described by the Richie modification of the Johnson and Strom classification

- **Stage I.**, Stage I demonstrates little or no structural changes weightbearing or non-weightbearing. The presenting symptom is tendinitis associated with either symmetrical occurring or unilateral flatfoot. Usually, the patient can still raise the heel on the symptomatic side but with more difficulty. Symptoms of Stage I usually resolve with orthotics and physiotherapy, and this response is diagnostic of Stage I. The rearfoot remains flexible

Posterior Tibial Tendon Dysfunction - Classification As described by the Richie modification of the Johnson and Strom classification

Stage II . This is characterized by a change in the weightbearing morphology of the foot, particularly the lowering of the longitudinal arch and abduction of the forefoot distal to the midtarsal joint, producing the signature sign of too many toes. These changes are due to an actual tendinosis, not simply a tendinitis of the tendon. The patient can rarely perform a simple heel raise. These signs are usually a result of the attenuation or rupture of the tibialis posterior tendon. The rearfoot remains flexible.

Posterior Tibial Tendon Dysfunction - Classification

As described by the Richie modification of the Johnson and Strom classification

- **Stage III.** Characterized and easily differentiated from I and II by rigidity of the rearfoot. Forced weightbearing manipulation of the rearfoot into a more neutral position is not possible. Radiographs usually demonstrate moderate to severe arthritic changes at the posterior facet of the subtalar joint and degeneration of subchondral bone at the talonavicular joint. The simple heel raise fails

Posterior Tibial Tendon Dysfunction - Classification

As described by the Richie modification of the Johnson and Strom classification

Stage IV . This stage is classified as the most dramatic deformity and is resistant to any treatment options other than surgical fusions. The hallmark of this deformity is the severe valgus deformity of the talocrural joint, degenerative joint disease of the rearfoot joints and, in dramatic cases, fractures of the fibular malleolus secondary to the huge lever of the lateral deforming forces.

Posterior Tibial Tendon Dysfunction – Aetiological Factors

Direct trauma Laceration **Iatrogenic** Steroid injection **Structural / Anatomical** Os navicularis Rigid flat foot Flexible flat foot Osteophytic proliferation in malleolar groove Zone of tendon “hypovascularity” Shallow malleolar groove	**Inflammatory process causing tenosynovits** Rheumatoid arthritis Seronegative disease **Indirect trauma** Ankle fracture Eversion ankle sprain Acute avulsion off navicular TP dislocation **Other** Primary/ metastatic bone tumour

Posterior Tibial Tendon Dysfunction – Aetiological Factors

Foot posture influences the electromyographic activity of selected lower limb muscles during gait. Murley G et al**. Journal of Foot and Ankle Research.** 2009, **2:**35

During midstance/propulsion, the flat-arched group **exhibited increased activity of tibialis posterior** (peak amplitude; 86 versus 60% of maximum voluntary isometric contraction)
Effect sizes for these significant findings ranged from 0.48 to 1.3, representing moderate to large differences in muscle activity between normal-arched and flat-arched feet.

Posterior Tibial Dysfunction – Orthoses as Treatment

- Treatment depends upon stage of the condition
- Theoretically to apply enough supinatory moments via orthoses / splinting / footwear to reduce tissue strain and malalignment.
- What's the 'evidence'?

1) Kulig K, et al.Nonsurgical management of posterior tibial tendon dysfunction with orthoses and resistive exercise: a randomized controlled trial. Phys Ther. 2009 Jan;89(1):26-37.

As already stated there is relatively little research, but orthoses are universally recommened at all stages of Posterior Tibial Tendon Dysfunction.

1) Julie Kohls-Gatzoulis et al. Tibialis posterior dysfunction: a common and treatable cause of adult acquired flatfoot. *BMJ 2004;329:1328–33*

Suggests 'off the peg', 'custom made', 'UCBL', 'AFOs' depending on need and stage

2) Trnka HJ. Dysfunction of the tendon of tibialis posterior. J Bone Joint Surg Br. 2004 Sep;86(7):939-46.

Suggests 'Custom made' (with examples of materials) 'UCBL', 'AFOs' depending on need and stage. Mentions may need 'plantar dells' to allow for plantar exostosis (Commonly under the navicular)

What do we expect from orthoses?

1. Not to make this worse and so have adverse effects elsewhere
2. Not to be uncomfortable
3. Not to wear down quickly or fall apart.
4. Not to need a different pair for every pair of shoes

These are more difficult for PTTD, and become more so the more progressive the condition

1. Not to make this worse and so have adverse effects elsewhere
2. Not to be uncomfortable
3. Not to wear down quickly or fall apart.
4. Not to need a different pair for every pair of shoes

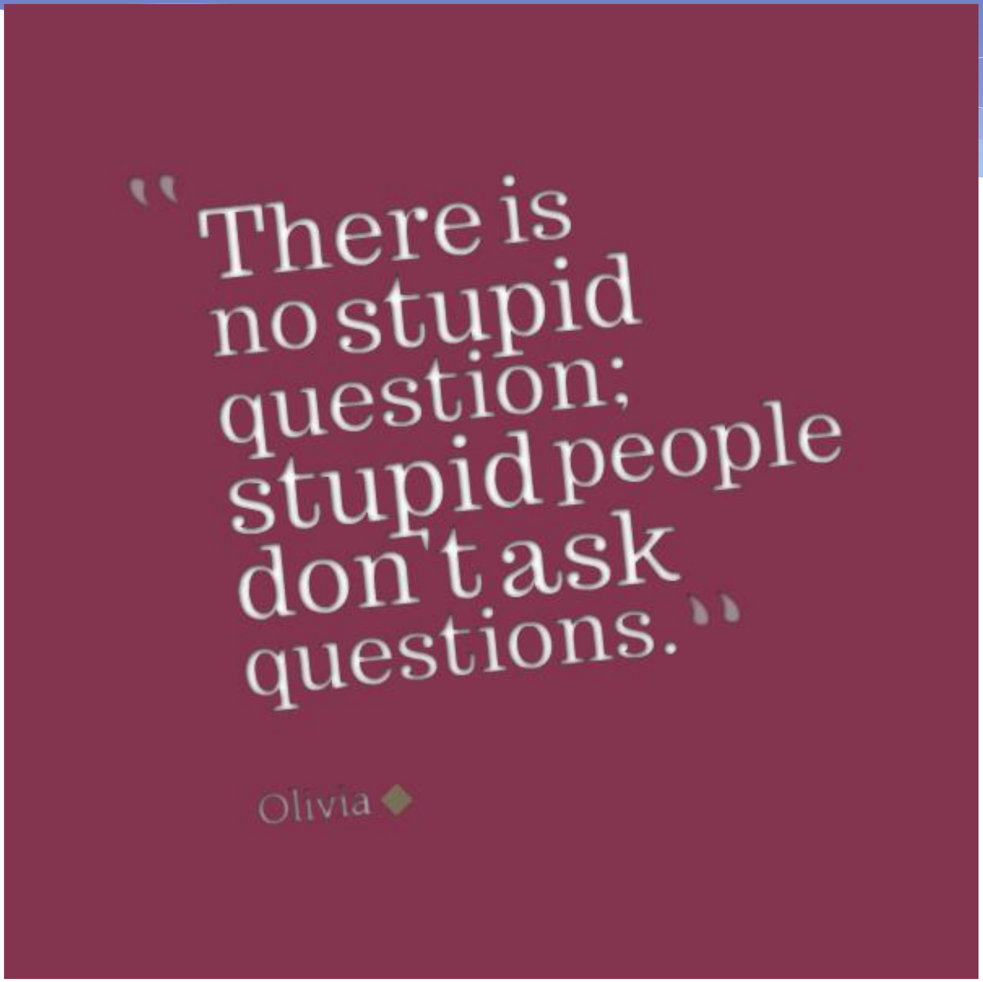
So, how should orthoses be prescribed?

* Theoretically to apply enough supinatory moments to reduce tissue strain and malalignment.

1. Harradine P D et al. A new method of increasing supinatory moments to a medially deviated subtalar joint axis - The Medial Oblique Shell Inclination. *Podiatry Now*. 2008 .11(3).
2. Harradine P D et al: The Medial Oblique Shell Inclination Technique. A Method to Increase Subtalar Supination Moments in Foot Orthoses. *J of the American Podiatric Med Assoc.* 2011. 101;6. 523-530

Suggests using specific custom shell inclines to optimise the applied orthotic reaction force to the axis of the Subtalar Joint. ***But how do they actually work???***

Questions


"There is no stupid question; stupid people don't ask questions."
Olivia