Practical Podiatric Biomechanics

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Plan for the Day

• 09.30 Introduction and Functional Anatomy
• 09.45 Normal and abnormal foot function
• 10.30 Static analysis
• 11.15 Break
• 11.45 Dynamic analysis
• 12.45 Lunch
• 13.45 Gait dysfunction in relation to injury
• 14.30 Treatment plans for specific MSK injury
• 15.15 Break
• 15.45 Introduction to running injury and trainers
• 16.45 Conclusion
Initially we need a Terminology and anatomy recap

- **VARUS** - A position of inversion
- **VALGUS** - A position of eversion
- **PRONATION** - A single motion comprising of Abduction, Eversion and Dorsiflexion
- **SUPINATION** - A single motion comprising of Adduction, Inversion and Plantarflexion
- **FOREFOOT** – Structures distal to the Midtarsal joint
- **FIRST RAY** - 1st metatarsal, medial cuneiform & navicular
Functional Anatomy Revision

- Ankle Joint
- Subtalar Joint
- Midtarsal Joint
- 1st Ray
- 1st MTPJ
Ankle Joint (Talocrural Joint)

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

*a triplanar joint*

<table>
<thead>
<tr>
<th></th>
<th>Frontal plane</th>
<th>Transverse Plane</th>
<th>Sagittal Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronation</td>
<td>Eversion</td>
<td>Abduction</td>
<td>Dorsiflexion</td>
</tr>
<tr>
<td>(arch lowering)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supination</td>
<td>Inversion</td>
<td>Adduction</td>
<td>Plantarflexion</td>
</tr>
<tr>
<td>(arch raising)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
The Subtalar Joint

• Measured in the frontal plane, average ROM of 30 degrees with a 2:1 ratio of inversion to eversion
Normal STJ and Foot Function

Pushing on the STJ Axis does not result in inversion (supination) or eversion (pronation) of the STJ
Normal STJ and Foot Function

Pushing on the medial side of the STJ Axis causes inversion / supination
Normal STJ and Foot Function

Pushing on the lateral side of the STJ Axis causes eversion / pronation
But what if the axis was NOT in the ‘middle’.....but Medial
..... Or Laterally  (A laterally deviated STJ Axis)
So motion around the STJ is a type 1 lever

The see-saw STJ axis analogy

Force Lateral to the axis

Force medial to the axis

Normal STJA
Moments across the STJ axis

(A ‘moment’ is just a rotational force)

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 of the axis and the applied force increased. In this example, a motion occurs around the axis (in this example, pronation).
Dorsal estimation of STJ Axis
Subtalar Joint – Closed Kinetic Chain

• **STJ PRONATION** causes the leg to internally rotate.

• **STJ SUPINATION** causes the leg to externally rotate.

A Medially Deviated STJ axis

- Example of a Medial STJ Axis and application of Ground Reaction Force (GRF) in a patient with Adult Acquired Foot, stage II-III.
Midtarsal Joint

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

• The medial column of the foot, distal to the MTJ

• Made up of the 1\textsuperscript{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 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
Before understanding abnormal, we must understand normal
‘Normal’ and ‘Abnormal’ within the historical perspectives and teachings of ‘Podiatric Biomechanics’

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
### Theoretical Perspective

<table>
<thead>
<tr>
<th>Criteria for Normalcy</th>
<th>Foot Morphology Theory</th>
<th>Sagittal Plane Facilitation Theory</th>
<th>Tissue Stress Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>The STJ passes through neutral at key stages of the gait cycle</td>
<td>The foot functions as a pivot allowing adequate hip extension and correct posture</td>
<td>The foot functions in a way that does not result in abnormal tissue stress and injury</td>
<td></td>
</tr>
</tbody>
</table>

| Casting Methodology | 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)....

.......lets look at what we all tend to actually agree on.
Agreed Basics of normal foot function....

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

- **1) CONTACT** - The Hip is internally rotating (*in relation to the floor/foot*) and the Foot pronating.

- **2) MIDSTANCE & PROPULSIVE** – The Hip is externally rotating (*in relation to the floor/foot*) and the foot supinating.
1.&2. The foot must coordinate the effect of lower extremity internal and then external rotation.

- **1) CONTACT** - The Hip is internally rotating *(in relation to the floor/foot)* and the Foot pronating

- **2) MIDSTANCE & PROPULSIVE** – The Hip is externally rotating *(in relation to the floor/foot)* and the foot supinating
3. While simultaneously stabilising itself to forces that can reach multiples of body weight prior to toe off

• **Stability**
  Stability refers to a condition where an object tends to be less likely to undergo translational or rotational motion when subjected to the effects of externally applied forces

• How does this relate to heel lift?
The Windlass Mechanism

Another large group hands on!
Seated with both feet resting on the floor.

1) Passively dorsiflex the hallux and observe your arch

2) Actively maximally pronate your foot, repeat above and observe functional stiffness in the 1st MTPJ

3) Dorsiflex the 1st MTPJ maximally passively with a relaxed foot, then pronate the STJ and feel graded increase in hallux plantarflexion moment
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

• Simplified 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. This in turn applies a compressive force longitudinally
Other structures that have their origin and insertion crossing the MTJ will also become more taut with pronation (arch lowering)

- The Long and short plantar ligaments (Calcaneocuboid ligaments)

- The Spring ligament (Calcaneonavicular ligament)
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

- Simplified model demonstrating the dynamic windlass:

  - 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.
4. And permitting the entire body to pivot over it.
4. And permitting the entire body to pivot over it.

• It’s **Not** like this!

• But, we need it to work like this....
4. And permitting the entire body to pivot over it – The 3 rockers

- 1) Via the round underside of the heel

- Position to start stance with heel rocker
- Shock absorption
- Weight-bearing stability
- Preservation of progression
4. And permitting the entire body to pivot over it - 3 rockers

2) Via Ankle Dorsiflexion

- Progression over stationary foot
- Limb and trunk stability
4. And permitting the entire body to pivot over it. – 3 rockers

3) Via dorsiflexion of the digits, preferably the 1st MTPJ due to
   • The suitability of this joint to pivot under load
   • Winding the medial band of the plantar fascia

• Progression of body beyond supporting foot, supplying essential hip extension
Recap of normal foot function

Although presented ‘in order’, there is an overlap of these segments
Principles of Abnormal Foot Function – ‘Over Pronation’

What goes wrong....?
Defining “OVER-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)
1. Pronating too hard, meaning the foot cannot resupinate.

- The foot should supinate in midstance, allowing external rotation of the hip at this stage (in relation to the floor). If this does not occur, compensatory gait mechanisms may be employed.

- Examples include:
  1) Abductory twist
  2) Reduced external hip rotation
2. Pronating too far, meaning there is lower limb functional malalignment.

- A commonly used example here is excessive internal hip rotation with excessive pronation. This often presents as a ‘squinting patella’.
3. Too much pronation limits hallux dorsiflexion via the reverse windlass windlass

- Simplified model demonstrating the pathological 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 with excessive force. This causes a functional hallux limitus (FnHL)
3. Too much pronation limits hallux dorsiflexion via the reverse windlass and ALSO...dorsiflexing the first ray

Normal Hallux dorsiflexion with first ray plantarflexion

Functional limitation of hallux dorsiflexion due to limited first ray plantarflexion with pronation
The more a foot pronates, the more functionally limited hallux dorsiflexion appears to be.


Too much pronation can cause gait dysfunction by impeding dorsiflexion at the 1st MTPJ (a functional hallux limitus)
Therefore, to improve abnormal foot function we would simply aim to:

1. Reduce dorsiflexory moments on the first ray
2. Reduce pronatory moments across the STJA

Can we do this with Orthotics?
1) Shells are cut narrow or positive casts are modified so as not to impinge on first ray function:

**Normal Hallux**: dorsiflexion with first ray plantarflexion

**Orthotic induced FnHL** due to an increase of dorsiflexory moments on the first ray from an ‘incorrect’ / high medial contour (arch) orthosis.
1) Shells are cut narrow or positive casts are modified so as not to impinge on first ray function:

- Full Width
- First ray cut out, 25% of first ray covered
2) So we want to reduce pronatory moments by applying a ‘push up’ (force) on the medial side of the axis
But in a ‘pronated foot’ the STJA is often not in the middle of the foot, but is medial.....
But in a ‘pronated foot the STJA is often not in the middle of the foot, but is medial…..

So we only want to ‘push up’ (apply an orthotic reaction force) HERE……
2. Posting applied to the medial side of the STJA at the rearfoot
Therefore, to improve abnormal foot function we would simply aim to:

1. Reduce dorsiflexory moments on the first ray
2. Reduce pronatory moments across the STJA

How about not using orthotics.....!!??
2) Reduce pronation (and so some first ray dorsiflexion) via....

‘Stability’ or ‘Motion Control’ Trainers

Footwear designed to reduce pronation was concluded in a recent systematic review to be effective in reducing the pronation magnitude (Cheung et al, 2011)

Increased medial sole EVA density (or similar) provides ‘dynamic varus wedging’

Decent ‘upper’ stiffness

And don’t let them got old!
2) Reduce pronation (and so some first ray dorsiflexion) via....

Aiming to strengthen lateral rotators and so reduce pronation (Snyder et al, 2008)

Aiming to reduce Ankle Equinus and reduce compensatory pronation (Radford et al, 2006)

Aiming to strengthen the Tibialis Anterior and reduce pronation (Galbraith & Lavallee, 2009)
Why aren’t we talking about Static analysis of ‘over pronation’

By “STATIC ANALYSIS” are we actually talking about arch height assessment?
Why aren’t we talking about Static analysis of ‘over pronation’

So Low arches are pronators, and high arches are supinators, and in the middle arches are normal! Easy!!!???
Why aren’t we talking about Static analysis of ‘over pronation’

And if low arches are over-pronators....and over pronation leads to injury and an inability to walk well...then I can just assess static arch height!!??
Why aren’t we talking about Static analysis of ‘over pronation’

But wait.....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).

Does this explain why athletes of African Origin Can’t run?
Why aren’t we talking about Static analysis of ‘over pronation’

Arch height is not an indicator of function or injury (Hamill 1989)
BUT......

• Although static tests are quick and convenient, are they actually useful?

• Is there any point in the examination being convenient if it does not supply useful data on which to base a clinical diagnosis and treatment plan?

• Reliability issues and....

• Validity issues. It is the static assessment of a dynamic structure.....
Brief Practical Examination of the Foot – Why do we do them?

- Static tests are quick and convenient
- Static tests require no walkway
- Static tests commonly require no expensive equipment
- Historically we have always done them
- Mostly, we think they give us reliable and valid data on which to base diagnosis and treatment plans...

1) How hard is the patient pronating?
2) How far is the patient pronating?
3) Is there a functional hallux limitus?
Other options for Static Analysis of Gait dysfunction related injury:

So...arch height and rearfoot position alone aren’t good indicators of static foot function. But what about:

1. The Maximum Pronation Test
2. The Supination Resistance Test
3. The Navicular Drop Test
4. The Foot Posture Index – 6 (FPI-6)?
5. The Hubsher Test?
How Hard is the Patient Pronating?

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*
# How Hard is the Patient Pronating?

## The Supination Resistance Test

<table>
<thead>
<tr>
<th>Grade</th>
<th>Finding</th>
<th>Foot function clinical ‘assumption’ / possible cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>With moderate effort, the foot is easily supinated onto its lateral border</td>
<td>Abnormally small pronatory forces, Possibly a supinator</td>
</tr>
<tr>
<td>Moderate</td>
<td>With moderate effort, the foot is supinated slightly</td>
<td>Normal</td>
</tr>
<tr>
<td>Hard</td>
<td>With moderate effort, the foot cannot be supinated</td>
<td>Abnormally large pronatory forces</td>
</tr>
</tbody>
</table>
How Hard is the Patient Pronating?

The Supination Resistance Test

Reliability


  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.
How Hard is the Patient Pronating?

The Supination Resistance Test

Validity


• 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

• No studies in relation to gait.............
How Hard is the Patient Pronating?

**STJ axis position**

- Reliability and validity


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

Clinical Estimation of the STJA had not been tested for reliability
How far is the Patient Pronating?

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.
**How far is the Patient Pronating?**

**The Maximum Pronation Test**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Finding</th>
<th>Foot function clinical ‘assumption’ / possible cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximally Pronated</td>
<td>Less than 2 degrees rearfoot eversion</td>
<td>No reserve of pronation, therefore abnormally pronated</td>
</tr>
<tr>
<td>Not maximally pronated</td>
<td>Greater than 2 degrees rearfoot eversion</td>
<td>Reserve of pronation, therefore not maximally pronated</td>
</tr>
</tbody>
</table>
How far is the Patient Pronating?

The Maximum Pronation Test

Reliability and Validity

No papers forthcoming on either reliability or validity

BUT:


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....validity????
How far is the Patient Pronating?

**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.
How far is the Patient Pronating?

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 congruency to standing relaxed.

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

Foot size issues
How far is the Patient Pronating?

The Navicular Drop Test

Reliability


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
How far is the Patient Pronating?

**The Navicular Drop Test**

*Validity*


Static measures of navicular drop were not found to be uniformly predictive of dynamic function during walking or running. Functional navicular drop measurements underestimated the dynamic measures in all foot types, while subtalar neutral drop overestimated dynamic measures for individuals with neutral and hypermobile foot types.
Is there a Functional Hallux Limitus?

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*
Is there a Functional Hallux Limitus?

The Hubscher Test

<table>
<thead>
<tr>
<th>Grade</th>
<th>Hallux dorsiflexion</th>
<th>Effect on proximal structures</th>
<th>Foot function clinical ‘assumption’ / possible cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nil</td>
<td>Nil</td>
<td>Marked FnHL</td>
</tr>
<tr>
<td>1</td>
<td>Slight</td>
<td>Nil</td>
<td>FnHL</td>
</tr>
<tr>
<td>2</td>
<td>Yes, with resistance</td>
<td>Slight arch raising with limited external leg rotation</td>
<td>Normal</td>
</tr>
<tr>
<td>3</td>
<td>Yes, with limited resistance</td>
<td>Complete arch raising with obvious external leg rotation</td>
<td>Possible supinator</td>
</tr>
</tbody>
</table>
Is there a Functional Hallux Limitus?

The Hubscher Test

No Reliability testing on the current grading system

For validity:

Static testing for foot posture....the FPI-6

- Barton et al (2011) found ‘fair association’ between pronated foot posture and association with dynamic maximum rearfoot eversion (pronation).

- Chuter (2010) found the FPI-6 was able to predict the variance in rearfoot eversion in 85% of cases

- However, McPoil et al (2008) concluded that Intrarater reliability was high but interrater reliability was only moderate. The FPI-6 should be used with extreme caution and may actually have limited value, especially from a research perspective.
Brief Practical Examination of the Foot – Why do we do them?

• Static tests are quick and convenient
• Static tests require no walkway
• Static tests commonly require no expensive equipment
• Historically we have always done them

Mostly, we think they give us reliable and valid data on which to base diagnosis and treatment plans...?
Gait Analysis.

Gait Dysfunction possibilities:
- Excessive pelvic rotation
- Lack of knee extension
- Vertical heel lift
- Adductor shortening
- WOW Derangement
- Internal adductor impingement (造成了解剖学障碍)
Gait Analysis

- 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
Pelvic motion / position

- Transverse plane
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?
GAIT DYSFUNCTION IN RELATION TO INJURY AND PATIENT PRESENTATION

Common presentation of MSK related issues in routine and expanded scope podiatric practice (some in more depth than others):

1. Flexible Pes Planus
2. Hallux Limitus
3. Plantar Fasciitis
4. Posterior Tibial Tendon Dysfunction
5. PatelloFemoral Pain Syndrome (with running lecture)
Flexible Paediatric Pes Planus

• A common concern in podiatric and paediatric settings

• No universally accepted definition of paediatric flatfoot (Evans M, 2008)

• Consistent inclusions are that of a “valgus heel” and “flattened medial longitudinal arch” (Staheli L, 1987)

• Prevalence estimates have a broad range, which is not surprising with the lack and variation in specific definitions.

• Also, it is possible to have a low arch and not be maximally pronated OR to have a high arch and be maximally pronated......
Flexible Paediatric Pes Planus

• This means if we worked solely on a “high arch is good, low arch is bad” assessment criteria we may be treating what does not need to be treated, and not treating what does.....

• Normal ethnic deviations in arch height.....
Bearing this in mind the most current treatment pathway for flexible paediatric flat foot is as follows:

- **TREAT**
  Symptomatic typical paediatric flexible flat foot

- **MONITOR and TREAT depending on clinical judgement**
  Asymptomatic Non-development typical paediatric flexible flat foot

- **LEAVE ALONE**
  Normal developmental typical paediatric flexible flat foot.

(Evans M, 2009)
Flexible Paediatric Pes Planus

- However, this treatment guideline has not be accepted without some controversy. (Bresnahan, 2009)

- ‘The greater risk to the pediatric patient is to "do nothing" while the child is young and allow the abnormally pronated foot to follow a life-long course that will often lead to any of several "developmental" conditions in adulthood, such as a painful flatfoot, bunions, hammertoes, and possibly knee and hip arthritis. The effects of a lifetime of weightbearing on an eccentrically loaded foot will almost certainly lead to secondary sequelae as a result of the body’s compensatory mechanisms.’
Flexible Paediatric Pes Planus

- In reply, Evans M (2009) stated “Finally, let me be very clear. In the absence of symptoms, the clinician prescribing customized foot orthoses for a child with flat feet is on very thin ice”

- Why only customized? If I prescribed some prefabricated orthotics which did not fit, were not comfortable and made the patient (who did not need them anyway) have to switch to large boots...would that be OK then?
Flexible Paediatric Pes Planus

● Another issue may be the definition of ‘symptoms’.

- Kirby (1992) and Lin et al (2001) have both cited flexible paediatric pes planus as a possible aetiological factor in children with gross motor skill development delay

- Symptoms may therefore link to other aspects of childhood than “just pain”.
Flexible Paediatric Pes Planus

- **What to prescribe.....**

- Reduce pronatory moments adequately WHILE NOT causing secondary issues such as impinging on first ray function

- As always, do no harm
Flexible Paediatric Pes Planus

- **What to prescribe.....**

  - Use appropriate FO modification to reduce pronatory moments (rearfoot posts, shell inlines, firm materials etc)
  - Consider child's choice of footwear, activity levels and growth
  - If private practice, recurrent cost needs to be explained to parents / guardians.
Hallux limitus
Hallux Limitis / Rigidus

- **Grade I**: limited motion of the first MPJ, mild pain, no significant degenerative joint disease (DJD), minimal osteophyte

- **Grade II**: limited motion, pain, early DJD, osteophyte

- **Grade III**: limited motion, pain, DJD, osteophyte

- **Grade IV**: joint ankylosis, end stage DJD
Conservative Care

• In addition to antiinflammatory medications, the nonoperative approaches to the treatment of hallux limitus include efforts to increase or restrict motion of the first MPJ.

• One may incorporate physical therapy to mobilize functional motion loss of the first MPJ.

• Indications for custom orthotics with accommodations to increase first MPJ range of motion include cases with a functional hallux limitus without much evidence of joint degeneration. These are typically the younger patients without a long history of joint pain.

Conservative Care

• Most patients with chronic joint pain will respond better to efforts to limit stress and motion through the first MPJ. One can decrease stress by utilizing orthotics with a Morton’s extension, stiff-soled shoes, a metatarsal bar and rocker-bottom shoes.

• Use intra-articular steroid injections sparingly. The goal of conservative treatment is to allow an active lifestyle with minimal to no pain in the first MPJ. If one cannot achieve this with the aforementioned options, consider surgery.
Often linked to lateral transfer lesser mtpj pain

But so its functional hallux limitus....and our treatment aims therefore must differentiate between a functional and actual limitation in gait. Stiff soled rocker shoes.....or reduce pronation moments and first rays dorsiflexion moments for:

1. Lesser MTPJ capsulitis
2. Plantar pedal Neuraligia (including Mortons neuroma)
3. Ulcers sub lesser MTPJs
4. HDs sub lesser MTPJs
5. Arthritic lesser MTPJs
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.


• Regardless of activity levels, Plantar Fasciitis is classed as a ‘common’ condition Lee. Phys Ther Sport. 2008. 10: 12-18.
What is the Planta?r 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.

• Let's quickly recap this normal and abnormal function, specifically in relation to the role of the plantar fascia.
Agreed 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

- Simple model demonstrating 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
- Simple model demonstrating the dynamic windlass

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.
Defining “OVER-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

- Simple model demonstrating the pathological reverse windlass mechanism

- 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

- Simple model demonstrating the reverse windlass mechanism and increased tensile strain in the plantar fascia with ‘over pronation’

- 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.

Functional hallux limitus impeding use of the 3rd rocker

More Common Possible gait compensation

- excessive pelvic rotation
- lack of hip extension
- Side Sway
- vertical heel lift
- Abductory twist
- MTJ Dorsiflexion
- lateral column propulsion
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!!!
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!!!
not to impinge on first ray function:

Normal Hallux dorsiflexion with first ray plantarflexion

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

• Aims:

1. Decrease stress in plantar fascia by decreasing pronation moments

2. Not to impinge on first ray function

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 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)*
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).

**Interesting Findings:** 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!!!
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)
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)
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.”**

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 Fasciosisis 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.
Posterior Tibial Tendon Dysfunction
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

<table>
<thead>
<tr>
<th>Direct trauma</th>
<th>Inflammatory process causing tenosynovitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laceration</td>
<td>Rheumatoid arthritis</td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>Seronegative disease</td>
</tr>
<tr>
<td>Steroid injection</td>
<td></td>
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<tr>
<td>Structural / Anatomical</td>
<td>Indirect trauma</td>
</tr>
<tr>
<td>Os navicularis</td>
<td>Ankle fracture</td>
</tr>
<tr>
<td>Rigid flat foot</td>
<td>Eversion ankle sprain</td>
</tr>
<tr>
<td>Flexible flat foot</td>
<td>Acute avulsion off navicular</td>
</tr>
<tr>
<td>Osteophytic proliferation in malleolar groove</td>
<td>TP dislocation</td>
</tr>
<tr>
<td>Zone of tendon “hypovascularity”</td>
<td>Other</td>
</tr>
<tr>
<td>Shallow malleolar groove</td>
<td>Primary/ metastatic bone tumour</td>
</tr>
</tbody>
</table>
Posterior Tibial Tendon Dysfunction – Aetiological Factors


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’?

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


*Suggests ‘off the peg’, ‘custom made’, ‘UCBL’, ‘AFOs’ depending on need and stage*


*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
A lot of these are actually very 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.


*Suggests using specific custom shell inclines to optimise the applied orthotic reaction force to the axis of the Subtalar Joint.*
The medial oblique shell inclination (mosi)
Posterior Tibial Dysfunction - other Treatment

- Physiotherapy and Splinting
Posterior Tibial Dysfunction - Treatment

• Orthopaedic Team Referral
Introduction to running...and runners
Vertical force vs time for the rearfoot striker
Running versus Walking

• Biomechanics of running versus walking is very different

• We need to understand this so treatment planning and our understanding of injury can be specifically tailored to the activities of the individual
What makes running different?

- Increased magnitudes of ground reaction force
- Increased magnitudes of subtalar joint pronation
- Kinematics of the hip, knee, ankle and metatarsophalangeal joints different
Running is a repetitive activity

- Running one mile: 1,500 foot strikes
What causes increased magnitudes of pronation motion and velocity?

- Increased running limb varus

- Velocity of striking the ground is increased in running versus walking
Increased impact forces in running

• In walking, maximal GRF is 1.25 – 1.5 times bodyweight

• In running, maximal GRF is 2.5-3.0 times bodyweight
Common running injuries: diagnosis, aetiology and treatment

- 95% of running injuries are overuse

- These are always due to “training errors” ie. Overstressing the system or the system can't cope with the stress
Common running injuries: diagnosis, aetiology and treatment

• Subjects statically classed as demonstrating ‘excessive pronation’, when running:


So, if the injury relateds to the below, then methods of reducing pronation should help….

• Subjects statically classed as demonstrating ‘excessive pronation’, when running:


Patellofemoral Pain – Is there a place for a foot up approach?
Is there a place for a foot up approach?

• Does everybody with PFPS need orthotics?

• Does nobody with PFPS need orthotics?

• If anybody with PFPS does need foot orthotics... then who?
What’s the idea behind the foot up approach?

• There is growing evidence for the efficacy of foot orthoses prescription when treating individuals with PFPS.


• Traditionally, foot orthoses have been advocated for PFPS based on the premise that they are needed to reduce excessive foot pronation.
What’s the bigfoot idea?

• Tiberio (1987) proposed that excessive or prolonged foot pronation (rearfoot eversion) during the stance phase of gait would result in greater tibial internal rotation.

• This would in turn delay or reduce the tibial external rotation relative to the femur required to allow knee extension through midstance.

• To compensate, the hip (femur) would need to rotate internally to a greater degree, thereby also increasing hip adduction and dynamic Q angle.
What’s the bigfoot idea?

• These tibial and femoral kinematic variations are thought to be detrimental to the PFJ owing to the associated reduced contact area and increased lateral PFJ compression (Wilson T, 2007)
Does research show there’s a link?

• Barton et al (2011) found fair association between pronated foot posture (as indicated by the FPI) and a stronger association with dynamic maximum rearfoot eversion (pronation). However, prospective studies are required to determine whether this relationship is causal.
Should orthotics to reduce pronation only be supplied to patients with over pronation?!

- Greater peak rearfoot eversion predicts foot orthoses efficacy in individuals with patellofemoral pain syndrome.

- “The best way to cure sea sickness is to sit under a tree”
- The late, Great, Spike Milligan
But what of other methods to reduce pronation / internal lower limb rotation?
Could it be that straight forward?


“medially posted insoles significantly reduced rearfoot eversion and eversion velocity in runners with and without PFP.”
Could it be that straight forward?

- Insoles, however, had only a small influence on tibial and knee kinematics. Assuming a biomechanical aetiology for PFP, these data suggest that insoles may bring about their symptomatic relief at the knee not only by altering its transverse plane kinematics, but perhaps by influencing other variables.

- Other such variables include effects of foot orthotics in the sagittal plane (MacLean et al, 2006) and muscle recruitment patterns (Nawoczenski and Ludewig, 1999).
Is there a place for a foot up approach?

- Does *everybody* with PFPS need orthotics? ....No

- Does *nobody* with PFPS need orthotics? ....No

- If *anybody* with PFPS needs foot orthotics... then *who*?
  .......People who dynamically over-pronate, but we need much more research!
All about trainers.....

• Many varieties

• Many ‘sub varieties’!!!

• ...and they don’t all do what they say on the box.
How does the classification work?

Motion Control

Control

Stability

Neutral

Weight