Biomechanics: past, present and future
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Biomechanical Research pre – 1980s
- ‘Mainstream’ biomechanics
- Basic modelling
- Winter, Eilfman, Lapidus,
- Wright et al. Close, Isman, Inman

Clinical biomechanics pre 1980s
- Podiatric biomechanics - 1971 a vintage year
  - Root, Orien and Weed
  - Sgarlato, Compendium of podiatric biomechanics. CCPM San Francisco
  - Valmassy

Root derived orthoses
- Root/modified Root Device
- Blake’s Inverted Device
- Kirby’s Medially Skived Device
- Tri-plane wedge

Biomechanics in the 90s
- Reliability studies
- Questioning the dogma
- Competing theories
- Emergence of evidence

Modern day biomechanics
Complex modelling

Multisegment foot models
- Eg Oxford multi (3) segment foot model
- Heidelberg ‘functional segment’
- Used in conjunction with standard models for hip, knee and ankle
- Problems with shod
- Mainly kinematics only

Modelling – finite element and others

AnyBody -Glasgow Maastricht

Does Science help us to understand how foot orthoses work?
- Change Foot Motion versus Modifying Internal Foot Forces
Changing Foot Motion

- Biomechanical Theory and some gait studies suggest:
  - Foot Pain - Relates to ↑ Rearfoot pronation.
- Supported by comparative studies between healthy pain free "normals" and foot pain groups.

![Hindfoot Frontal Plane Kinematics](image)

PhD Results: Greater Rearfoot Eversion (pronation) in participants with midfoot pain (n=15). Compared to control group of norms (n=15).

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Methodology</th>
<th>Biomechanical Measurements</th>
<th>Results</th>
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Foot Orthoses Change Foot Motion

- Gait Studies in normal healthy and pathological groups:
  - Concentrated on rearfoot pronation
  - Show mixed results:

  + 3° to - 5° Change of rearfoot eversion (pronation)

Changing foot motion

- Selection of Gait Studies:
  - The results are variable in rearfoot eversion (pronation):
    - 2° to 5° Reductions - 10 studies
    - 0 to 1° Reductions - 5 studies
    - 0 to 3° Increases - 8 studies

  + 3° to - 5° Change of rearfoot eversion (pronation)

How do Foot Orthoses Work?

Changing Foot Motion

versus

Modifying Internal Foot Forces
Internal Foot Forces
Difficult to measure
- Common Surrogate Measures - Foot Pressure
- Abnormal Foot Pressure patterns with Foot Pathology
  E.G. Midfoot OA and Healthy Groups
  (e.g. Midfoot OA and Healthy Groups: Rao et al. 2011, Menz et al. 2010)
  Relationship between foot pressure & symptom severity

Finite Element Models
Normal External Foot Pressure compared to Internal Foot Forces

Difficult to measure
- Relationship between foot pressure & symptom severity
  E.G. Midfoot OA and Healthy Groups

Abnormal Foot Pressure patterns with Foot Pathology

Common Surrogate Measures - Foot Pressure

Direct Bone Stress Measurement
Strain Gauges - Highly Invasive
Used mainly in cadavers & some (brave) humans
- Foot Orthoses Can Alter Bone Forces
- Reductions Compression, Tension & Shear Strain
- Metatarsal and Tibia Bones

Modern clinical practice – what do we know?
- Weak evidence for foot orthoses in managing a range of MSK conditions.
- Some effects on patient reported outcomes – but equivocal in different conditions
- Effects on kinematics more limited than expected ... and vary between patients!
- Reasonable data in some specific conditions

Clinical knowledge - summary
The effects of orthoses on the mechanical function of the foot
- Cushioning reduces pressure – indicated for callus and ulcers
- U’s and wings reduce force and pressure – as above plus internal stresses.
- New viscoelastic materials also reduce high frequency force
- Contoured devices are good at redistributing force (and pressure)
- Large changes in internal distribution of forces within the foot are likely brought about by FFO therapy.
- FFO’s change foot kinematics in a predictable manner but foot kinetics are too difficult to measure as yet.
- The effect of altered foot mechanics on kinematics and kinetics of proximal structures is small.
- Locally the effects are large
- Contoured devices are probably not interchangeable with other approaches such as flat FFOs and taping.

A few predictions...
Imaging in biomechanical research

- Standalone – ultrasound, MRI
- Combination techniques

3D bone volumes
3D volume abnormal bone marrow lesions

Markerless technologies
Markerless (ish) technologies

Likely clinical developments

The future:
- Instrumented stocking, scanner room or stereography?
  - Joint motions and forces
  - Pressures (triplanar)
  - Temporal and spatial measures
  - Real time
  - Less than £5 per assessment
- Clinical – PROMS in practice, systematic datasets, affordable dynamic quantification, internal imaging

Thank you