Is plaster casting necessary?

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Montreal, QC
Outline

• Background
• Method
• Static analyses
• Dynamic
• Limitations & Future Research
• Significance
Kinematic Measurement Techniques

• Optical Tracking
  ▫ Treats foot as a rigid segment
Multi-segment Foot Model

- Jenkyn & Nicol (2007)
- Skin motion artefact error
Radiostereometric Analysis (RSA)

...is the science of obtaining reliable three-dimensional measurements from a pair of two-dimensional radiographs in order to determine primarily geometric characteristics of an object. (Selvik, 1990)

In other words...it’s a high precision method that can measure micromotions of bone or other objects.
Traditional RSA

- Tantalum beads needed - invasive
- Embedded in bones during surgery

(Seslija 2009)  (Kedgley, 2009b)
Markerless RSA

- 3D in-vivo kinematics
- Healthy (non-surgical) individuals
- Validated in 2009 by Anne-Marie Fox (Allen) for the Wolf Orthopaedic Quantitative Imaging Laboratory (WOQIL)
Bi-planar fluoroscopy

- Fluoroscopy refers to the continuous acquisition of a sequence of x-ray images
  - *Essentially* a real-time x-ray movie of a patient

- Provides real-time video or still images for physicians
  - Follow exact location of catheter or guide-wire AND keeps surgery *non-invasive* for the patient
WOQIL Markerless RSA

- Two C-arm fluoroscopes
WOQIL Calibration

- Calibration frame
  - (Kedgley, 2009b)

- Distortion grid
  - (Kedgley, 2009b)
Experimental Set-up
3D Models
Final Step - Matching
WHY mRSA for the foot?

- No one has quantified motions of the foot with the same accuracy
- Motions between bones are discrete

(Norden & Frankel, 2001)
Foot Motion

- Occurs in 3 anatomical planes
  - Extension/flexion in sagittal plane
  - Adduction/abduction in transverse plane
  - Inversion/eversion in frontal plane

(Hamill & Knutzen, 2003)
Medial Longitudinal Arch (MLA)

- Concave arch along medial aspect of foot
  - Head of first metatarsal to calcaneal tuberosity

- Function
  - Shock absorption of vertical loads

(http://podiatryboards.web.officelive.com/footbones.aspx)
MLA Angle Measurement

- Based on Tome et al. (2006)
- Markerless RSA eliminates skin motion artefact
Orthotics

- Restrict and support medial column of foot

*Pes planus* (Barefoot)  *Pes planus* (Soft Orthotic)
Orthotics Casting

- Both not fully weight-bearing
- Subtalar joint neutral position (STN)

- Traditional
  - Plaster
- Modern
  - Foam box
    - Semi WB

http://www.physicaltherapyworks.com/orthotics.htm
Study Purpose

• Compare medial longitudinal arch angle
  ▫ 3 foot types:
    • Normal
    • Pes cavus (high arch)
    • Pes planus (low arch)
  ▫ 2 different casting methods
    • Foam box
    • Plaster
  ▫ 2 different orthotics
    • Soft (plastazote)
    • Hard (subortholen)

• Compare MLA barefoot & STN position
What we expected

- *Planus* participants show the largest BF angle
  - **LOWEST** arch
- Orthotics decrease the angle of all foot types
  - **HIGHER** arch
- No *significant* differences between casting methods
Eligibility Criteria

- 15 subjects (mean age 27.5)
  - 5 each foot type: normal, pes cavus, pes planus
- Normal participants
  - Asymptomatic
  - No previous foot or ankle issues
- Pes planus & pes cavus
  - Extreme low & high arches
- No severe issues with their gait
Static Stance
Dynamic Gait
Footwear

• Neutral cushioning running shoes
  ▫ Consistent footwear with orthotics

New Balance Model 882
Orthotics

• Foam box & plaster casting
  ▫ **Soft**
    • 4mm Plastazote shell layered with 35 durometer EVA
    • 25 durometer top cover
  ▫ **Hard**
    • 3mm RCH-500 shell layered with 55 durometer EVA
    • 25 durometer EVA top cover
Static - Barefoot *pes cavus*
Dynamic Lateral - Barefoot *pes planus*
Dynamic A-P
Static Barefoot & STN

• STN position significantly different from barefoot (p<0.05)
• Mean angle change of -11.3° (± 3.8°)

<table>
<thead>
<tr>
<th>MLA Angle (degrees)</th>
<th>Normal (5 Total)</th>
<th>Cavus (5 Total)</th>
<th>Planus (5 Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Barefoot</td>
<td>93</td>
<td>6.2</td>
<td>111</td>
</tr>
<tr>
<td>STN</td>
<td>83</td>
<td>9.1</td>
<td>101</td>
</tr>
</tbody>
</table>
BF between foot types

- *Pes planus* - Lowest arch

Surprising result:
- Normal - Highest arch!?
  - *Pes cavus* foot - highest navicular height (visual):
    - Oversupinated, weight support on lateral side causing rearfoot inversion (Xiong et al., 2010)
Interesting Discovery...

- Significantly longer vector for pes cavus (p<0.05)
Comparing Static to Dynamic

<table>
<thead>
<tr>
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<th>Medial Longitudinal Arch Angle (°)</th>
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<tr>
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<td>Mean</td>
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<tr>
<td><strong>Static:</strong></td>
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</tr>
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<td>111</td>
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<tr>
<td>Planus</td>
<td>128</td>
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<tr>
<td>Normal</td>
<td>97</td>
</tr>
<tr>
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<td>118</td>
</tr>
<tr>
<td>Planus</td>
<td>129</td>
</tr>
</tbody>
</table>
Normal

Foam Hard  Foam Soft  Plaster Hard  Plaster Soft

Higher Arch  Lower Arch
Pes Cavus

Higher Arch  ←  Lower Arch

-20  -15  -10  -5  0  5  10  15  20  25

A

B

C

D

E

Foam Hard  Foam Soft  Plaster Hard  Plaster Soft
Pes Planus

Higher Arch  Lower Arch

A  B  C  D  E

Foam Hard  Foam Soft  Plaster Hard  Plaster Soft
### Means

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Cavus</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$\theta$</td>
<td>$\Delta \theta$</td>
</tr>
<tr>
<td>Barefoot</td>
<td>97.4</td>
<td>-</td>
</tr>
<tr>
<td>Foam Hard</td>
<td>103.8</td>
<td>6.3</td>
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<tr>
<td>Plaster Hard</td>
<td>104.7</td>
<td>7.2</td>
</tr>
<tr>
<td>Foam Soft</td>
<td>105.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Plaster Soft</td>
<td>103.2</td>
<td>5.8</td>
</tr>
</tbody>
</table>

* No significant differences compared to BF*

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* Western Engineering*
Means (cont’d)

<table>
<thead>
<tr>
<th>Planus</th>
<th>θ</th>
<th>Δθ</th>
<th>MLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barefoot</td>
<td>128.6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Foam Hard</td>
<td>120.0a</td>
<td>-8.5</td>
<td>higher</td>
</tr>
<tr>
<td>Plaster Hard</td>
<td>124.8b</td>
<td>-3.8</td>
<td>higher</td>
</tr>
<tr>
<td>Foam Soft</td>
<td>124.4</td>
<td>-4.2</td>
<td>higher</td>
</tr>
<tr>
<td>Plaster Soft</td>
<td>124.1</td>
<td>-4.5</td>
<td>higher</td>
</tr>
</tbody>
</table>

\( a \) Notable difference versus barefoot (p=0.076)
\( b \) Significantly different versus barefoot (p=0.032)

Note: Foam device controlled motion better (mean) but larger SD.
Larger sample size might see reversal?!
# Plaster vs. Foam

## Foot Type (n=10)

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Cavus</th>
<th>Planus</th>
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<tbody>
<tr>
<td>BF</td>
<td>97.4</td>
<td>118.4</td>
<td>128.6</td>
</tr>
<tr>
<td>Foam</td>
<td>104.4</td>
<td>116.8</td>
<td>122.2</td>
</tr>
<tr>
<td>Plaster</td>
<td>103.9</td>
<td>116.4</td>
<td>124.4</td>
</tr>
</tbody>
</table>

## Combined (n=30)

<table>
<thead>
<tr>
<th></th>
<th>BF</th>
<th>Foam</th>
<th>Plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>114.8</td>
<td>114.5</td>
<td>114.9</td>
</tr>
</tbody>
</table>
# Hard vs. Soft

## Foot Type (n=10)

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<tr>
<td></td>
<td>BF</td>
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<td>97.4</td>
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<td>128.6</td>
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</tr>
<tr>
<td>Soft</td>
<td>104.1</td>
<td></td>
<td></td>
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## Combined (n=30)

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<td>Soft</td>
<td>114.8</td>
</tr>
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</table>
What’s the story?

- No significant difference between:
  - Foam box & plaster casting

- Significant difference between:
  - *Pes planus* barefoot & plaster Hard (p=0.032)
  - Notable outcome with foam Hard (p=0.076)
  - Foam device controlled motion better

- *Pes cavus*
  - Slightly higher arch with SOFT material
  - Small mean changes with all devices
What have we learned?

• Quantitative study
  ▫ No qualitative measures or functional outcomes
• Large SDs & differences
  ▫ Between foot types
  ▫ Within’ foot types
• Reason for mixed outcome measures with patients?
Limitations

- Small sample size per foot type
- Post-processing time is lengthy
- Some radiation exposure
Future Directions

• Improve manual matching procedure
  ▫ Edge detection algorithm

• Increase sample size
  ▫ Focus ONE foot type

• Compare with other foot measures
  ▫ MSFM or Arch Index
  ▫ Qualitative & functional outcomes
Significance

• Provides dynamic, *in-vivo* investigation of skeletal kinematics of the foot

• Findings suggest there is more to understand about the MLA and the effect orthotics have

• Imagine being able to see the foot and their motion in real time
Acknowledgements

- Pedorthic Association of Canada
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Questions
References


