Biomechanical and Mechanical Testing of Playing Surfaces

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Overall Aim of Research

- To improve understanding of shoe-surface-player interaction
Presentation Structure

• Research examples
• Summary
• Suggested directions for interdisciplinary study
Tennis Surfaces: Running Study

- Berlin Artificial Athlete
- ITF categorisation

Drop Test Results

- shoe1: 4, 6, 8, 10, 12
- shoe2: 16
- PU1: acrylic, PU2: turf

peak g

- shoe1: 8, 6, 6, 4
- shoe2: 16, 12, 10, 8
- PU1: acrylic, PU2: turf
Peak Loading Rate

- Peak loading rate (N.s⁻¹)
- *p<0.05

- con, PU1 acrylic, PU2, turf, con, PU1 acrylic, PU2, turf

- shoe1
- shoe2

* p<0.05
Peak Lateral Heel Pressure

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>shoe1</th>
<th>shoe2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td></td>
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<tr>
<td>PU1</td>
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<tr>
<td>Acrylic</td>
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<tr>
<td>PU2</td>
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<tr>
<td>Turf</td>
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</tbody>
</table>

* p<0.05
Conclusions

• For the surfaces studied, similar impact loading occurs during running

• The choice of shoe has potential to influence impact loading on the test surfaces

• Weak biomechanical support for the large differences between surfaces indicated by Berlin Artificial Athlete

• Investigation of different movement patterns suggested
Biomechanical response to systematic changes in surface cushioning properties while performing a tennis specific movement in a basic neutral shoe.

Stiles & Dixon, JSS, in press
Human response to changes in surface cushioning

- Systematically altered surface cushioning while maintaining a consistent top surface
- Surface conditions spanned a large range of impact reduction
- Removed the influence of a sports shoe by using a neutral cushioned shoes (plimsolls)
- 10 subjects performing running forehand footplant
Change in GRF profiles

- Acrylic only
- Rubber and acrylic
- Thin foam and acrylic
- Thick foam and acrylic
Surface cushioning ability (Drop test)

Cushioning Ability

- Acrylic: Low
- Rubber: Low
- FThin: Very High
- FThick: Very High

Surfaces
Peak Impact Force (Fz)
Peak Loading Rate

![Graph showing peak loading rate for different surfaces: Acrylic, Rubber, F Thin, and F Thick. The graph includes lines for different samples (s1 to s10) and a mean line. The y-axis represents BW.s⁻¹, and the x-axis represents surfaces.](image)
Cushioning Perception

Hennig et al., 1996

Supreme Rubber F Thin F Thick

Cushioning Perception Chart

Acrylic Rubber F Thin F Thick

Mean

Data Points: s1, s2, s3, s4, s5, s6, s7, s8, s9, s10
Results Summary

Using selected variables, biomechanical classification of surface cushioning ability matched classifications derived from mechanical tests

- Peak rate of loading
- Peak heel pressure
- Peak and average heel pressure loading rate
Conclusions

Biomechanical findings support the use of mechanical methods of surface cushioning assessment

Suggested:
Where possible, both mechanical and biomechanical assessment of surface cushioning should be performed

Advised that peak impact force should not be used as a lone indicator of surface cushioning

(Stiles & Dixon, JSS in press)
Study of Natural Turf
Soil Dynamics Laboratory

- developed for testing of agricultural machinery

- potential for biomechanical testing of human subjects?

Dixon, James and Low (2006) *Sports Eng*
Shoe-Surface Conditions

• Surface densities
  – 1460 kg.m$^3$ (‘soft’ soil: Surface 1)
  – 1590 kg.m$^3$ (‘hard’ soil: Surface 2)

• Footwear
  – traditional studs (‘studs’)
  – molded studs (‘molded’)
  – synthetic turf boots (‘synthetic’)

Biomechanical Data Analysis

- 6 steps per subject
- ‘cushioning’
  - peak resultant force
  - peak force at the heel
Mechanical Characterisation

- **Surface hardness (Clegg Hammer)**
  - ‘soft’ soil (Surface 1): 125 g
  - ‘hard’ soil (Surface 2): 235 g

- **Penetration resistance**
  - ‘soft’ soil (Surface 1): 1200 kPa
  - ‘hard’ soil (Surface 2): 1800 kPa
Biomechanical Results

* p<0.05
Conclusions

• For the natural surfaces studied, differences in heel pressures detected

• Shoe selection not influential on impact loading on the test surfaces

• Biomechanical support for the large differences between surfaces indicated by mechanical testing

• Consideration of more realistic conditions
Biomechanical Assessment of Natural Turf in the Laboratory

- Examples of natural turf research in the field (Coyles et al., 1998; Eils et al., 2004)

- Limited research incorporating natural soil media in the biomechanics laboratory
Conditions

3 turf conditions: clay, sandy, rootzone

1 boot model
Methods

Portable Plastic Trays

- 0.37 m
- 0.57 m
- Sand Rootzone
- Turf (ryegrass)
- Tray
- Runway
- Force plate tray

Dimensions:
- 0.08 m
Data Collection

- Running
- Turning
Data Collection: Turning

- Left leg
- Right leg
- Force plate tray

Turning Entry Exit
Results

Typical vertical (Fz) and horizontal (Fy) ground reaction force time histories

Running

Turning
Results: Running impact force

![Graph showing peak impact force (BW) for Clay, Sandy, and Rootzone surfaces.]
Running impact loading rate

![Graph showing the impact loading rate for different surfaces: Clay, Sandy, and Rootzone. The graph compares the loading rate (BW.s⁻¹) across different samples (s1 to s8) and a mean line.]
Running braking force

![Bar chart showing peak braking force (BW) for different surfaces: Clay, Sandy, and Rootzone. The chart indicates that the braking force decreases as the surface changes from Clay to Rootzone.]
Results: Turning impact force

![Graph showing peak impact force (BW) for different surfaces: Clay, Sandy, and Rootzone. The graph indicates that the peak impact force is highest for Sandy and lowest for Clay, with Rootzone in between.]
Results: Turning impact loading rate
Turning braking force

- Peak braking force (BW)

Surface: Clay, Sandy, Rootzone
Results So Far…

• No significant differences in peak impact or peak braking force across turf conditions

• Significant (p<0.05) differences in peak loading rate across turf conditions
Summary

• Biomechanical testing:
  – Loading rate of impact force
  – Peak heel pressures

• Mechanical testing
  – Synthetic surfaces: Berlin AA; drop tests
  – Natural turf: density; penetration; hardness
Surface Characteristics

• What are the specific differences between surfaces that influence the player?
  - Stiffness & Damping
  - Traction
  - Spatial and temporal uniformity

• How do these influence the player?

• How are these quantified?
Future Interdisciplinary Study

• Measurement of loads at different levels: