Biomechanical response to variations in natural turf surfaces during running and turning

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Introduction

- Important health benefits gained from participation in sport and exercise

  DOH, 2004

Traditional sports at elite and recreational level, e.g. hockey, soccer, tennis, rugby, cricket, lacrosse

Require adequate sports facilities

…….appropriate, affordable and safe.
Artificial Turf

**Hockey:** Natural to Artificial turf 1970’s

*Spencer et al., 2004*

Lack of Natural Turf Replication

Reluctance of some sports to change to artificial turf due to loss of playing characteristics
The Case for Natural Turf

1. Maintain fundamental characteristics of sports such as soccer, rugby, golf, cricket and lacrosse

2. Protect green spaces in the built environment

Meeting Surface Provision

Advancement in construction and sustainability of natural turf to meet surface provision for training and competitive use in sports
Natural Turf Testing

Assessment of...
- studded footwear on artificial turf  
  Morag & Johnson, 2001
- grip performance during cutting manoeuvres in the field  
  Coyles et al., 1998
- plantar pressures during sports specific movements in the field  
  Eils et al., 2004

Lack of research
Specific Research

An Initial Investigation of Human-Natural Turf Interaction in the Laboratory

Stiles, Dixon & James, 2006
Aim:
Human response to variation in turf condition

Advancement in construction and sustainability of natural turf surface requires

Increased understanding of how humans respond to variations natural turf properties (Biomechanical)

Increased understanding of how turf responds to variations in sports specific human movement. (Mechanical)

Hypothesised that a surface with the highest mechanical hardness and shear strength would yield the highest peak impact forces and peak rates of loading.
## Methods

<table>
<thead>
<tr>
<th></th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clay Loam</strong> (Heavy clay soccer pitch)</td>
<td>27</td>
<td>44</td>
<td>29</td>
<td>1294</td>
</tr>
<tr>
<td><strong>Sandy Loam</strong> (Intermediate sandy pitch)</td>
<td>13</td>
<td>28</td>
<td>59</td>
<td>1517</td>
</tr>
<tr>
<td><strong>Rootzone</strong> (Modern, elite turf pitch)</td>
<td>1</td>
<td>1</td>
<td>98</td>
<td>1736</td>
</tr>
</tbody>
</table>
**Methods**

8 male participants (soccer/rugby)

**Session 1:** Running (3.83 m.s\(^{-1}\) ± 5%)

**Session 2:** Turning, (sub-maximal, subject specific speeds)

10 trials / condition

Right-footed contact with force plate (AMTI, 960 Hz)

Standard metal studded boots (UK, 10, 11 &12)

**Ethical approval obtained from School of Sport and Health Sciences, University of Exeter**
**Mechanical Testing - Before and After measures**

**Clegg Hammer**
Hardness (peak deceleration – ‘peak g’)
Three test sites on tray used to obtain measure of average hardness

**Dielectric probe**
(e.g. a Theta Probe, Delta-T, Cambridge)
Determines the volume of water per unit volume of soil as a percentage (vol%)

**Cruciform Shear Vane**
Measures shear strength. Inserted to depth of 33 mm and rotated to soil failure (kPa; BS1377-9, 1990)
Results - Running

Mechanical property: Hardness

![Bar chart showing hardness differences in various turf conditions.](chart)

- **Hardness Before**: Represents the hardness values before any changes or treatments.
- **Difference in Hardness**: Indicates the change in hardness after the treatment.

- **Clay**: Heavy clay soccer pitch.
- **Sandy**: Intermediate sandy pitch.
- **Rootzone**: Modern, elite turf pitch.

* * sig difference after (p<0.05)
Results - Running

Mechanical property: Shear

![Bar chart showing shear values for different turf conditions.](chart.png)

- **Clay**: Shear (kPa) before running
- **Sandy**: Shear (kPa) before running
- **Rootzone**: Shear (kPa) before running

*sig difference after (p<0.05)*

- **Heavy clay soccer pitch**
- **Intermediate sandy pitch**
- **Modern, elite turf pitch**
Results - Running

Typical ground reaction force-time history

- Peak impact force
- Impact phase (Hardin et al., 2004)
- Peak active force
- Peak rate of loading
- Peak braking force

Force (N)

Time (s)
Results - Running

Peak loading rate

Significant difference between clay and rootzone ($p<0.05$)

(RMANOVA and post hoc Tukey test)
Results - Running

Biomechanical and Mechanical Summary

<table>
<thead>
<tr>
<th>Turf Condition</th>
<th>Clay</th>
<th>Sandy</th>
<th>Rootzone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak LR</strong> (BW.s⁻¹)</td>
<td>* 84.67 (±22.9)</td>
<td>96.74 (±29.1)</td>
<td>* 101.48 (±23.3)</td>
</tr>
<tr>
<td><strong>Peak braking force</strong> (BW)</td>
<td>-0.21 (±0.07)</td>
<td>-0.22 (±0.09)</td>
<td>-0.22 (±0.08)</td>
</tr>
</tbody>
</table>

**Time (s)**

**Force (N)**

**Hardness (peak g)**

**Shear (kPa)**
Results - Turning

Mechanical property: Hardness

![Bar graph showing hardness for different turf conditions.]

- Heavy clay soccer pitch
- Intermediate sandy pitch
- Modern, elite turf pitch

Difference in Hardness
Hardness Before

* sig difference after (p<0.05)
Results - Turning

Mechanical property: Shear

![Bar chart showing shear values for different turf conditions](chart.png)

- **Clay**: Shear (kPa)
- **Sandy**: Shear (kPa)
- **Rootzone**: Shear (kPa)

* sig difference after (p<0.05)

**Turf Conditions**

- Heavy clay soccer pitch
- Intermediate sandy pitch
- Modern, elite turf pitch
Results - Turning

Typical ground reaction force-time history

![Graph showing typical ground reaction force-time history with peaks for impact and braking forces. The graph includes a line for Fy and Fz forces over time.](image-url)
Results - Turning

Peak loading rate

No significant differences (p<0.05)

RMANOVA
Results - Turning

Biomechanical and Mechanical Summary

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<tr>
<td><strong>Peak impact force (BW)</strong></td>
<td>2.32 (±0.2)</td>
<td>2.25 (±0.2)</td>
<td>2.33 (±0.2)</td>
</tr>
<tr>
<td><strong>Peak LR (BW.s⁻¹)</strong></td>
<td>111.09 (±27.2)</td>
<td>101.63 (±25.5)</td>
<td>98.90 (±17.0)</td>
</tr>
<tr>
<td><strong>Peak braking force (BW)</strong></td>
<td>-0.88 (±0.06)</td>
<td>-0.89 (±0.07)</td>
<td>-0.88 (±0.06)</td>
</tr>
</tbody>
</table>
Discussion - Two-pronged approach

Mechanical:
Sig’ differences in hardness and shear between ‘clay’ and ‘rootzone’ (‘sandy’ condition - subtly different)

Biomechanical:

Running - PKLR sig. higher on ‘rootzone’ compared to ‘clay’ (similar hardness before testing, clay harder after)

Turning - No sig. differences in PKLR
- Different pattern of response in PKLR across surfaces compared to running
- Higher horizontal braking forces compared to running (supports Stiles, Dixon & James, 2006)
Conclusion

Hypothesis rejected
PKLR’s for running and turning demonstrate conflicting patterns of response with variations in surface mechanical properties

Observations

Turning
- performed at faster pace
- elicited greater braking forces (4 x)
- consistent braking forces across conditions
- greater implications for turf degradation
- assess movement on more extreme turf conditions
Future Research

Ground reaction forces are not the only measure of human response

Alternative measures of human response

- 3D kinematic analysis
- Pressure insole analysis

Overall Aims

- Increase understanding of human-natural turf interaction
- Engineer a more sustainable natural turf surface
References


Clegg, B. (1976), Australian Road Research Bureau Proceedings, 8, 1-6


Department of Health (2004), Department of Health, Physical Activity, Health Improvement and Prevention.


