



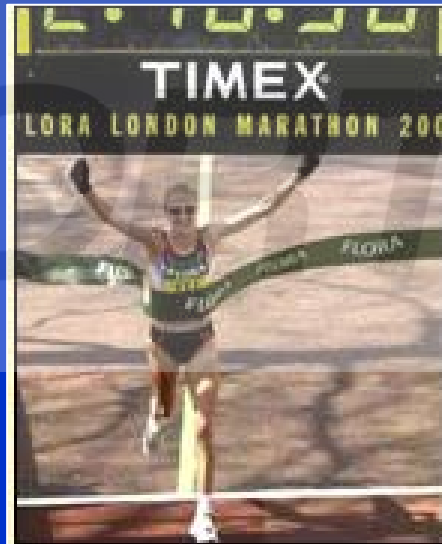
# Biomechanical and Mechanical Testing of Playing Surfaces

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University of Exeter, UK

# Overall Aim of Research

- To improve understanding of shoe-surface-player interaction



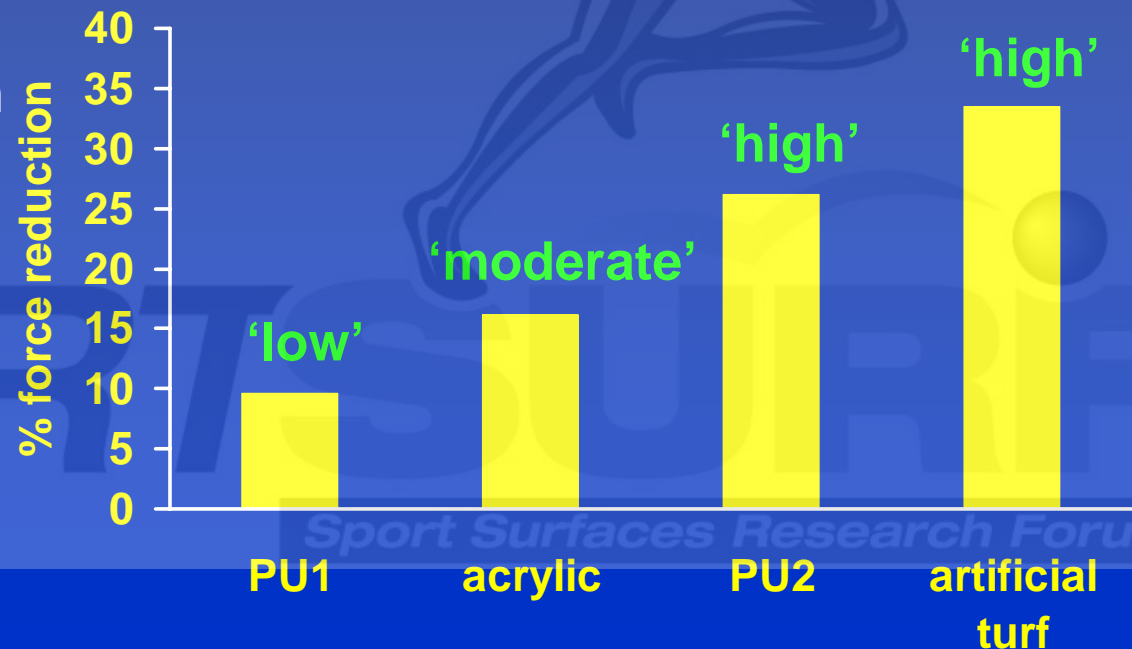
# Presentation Structure

- Research examples
- Summary
- Suggested directions for interdisciplinary study

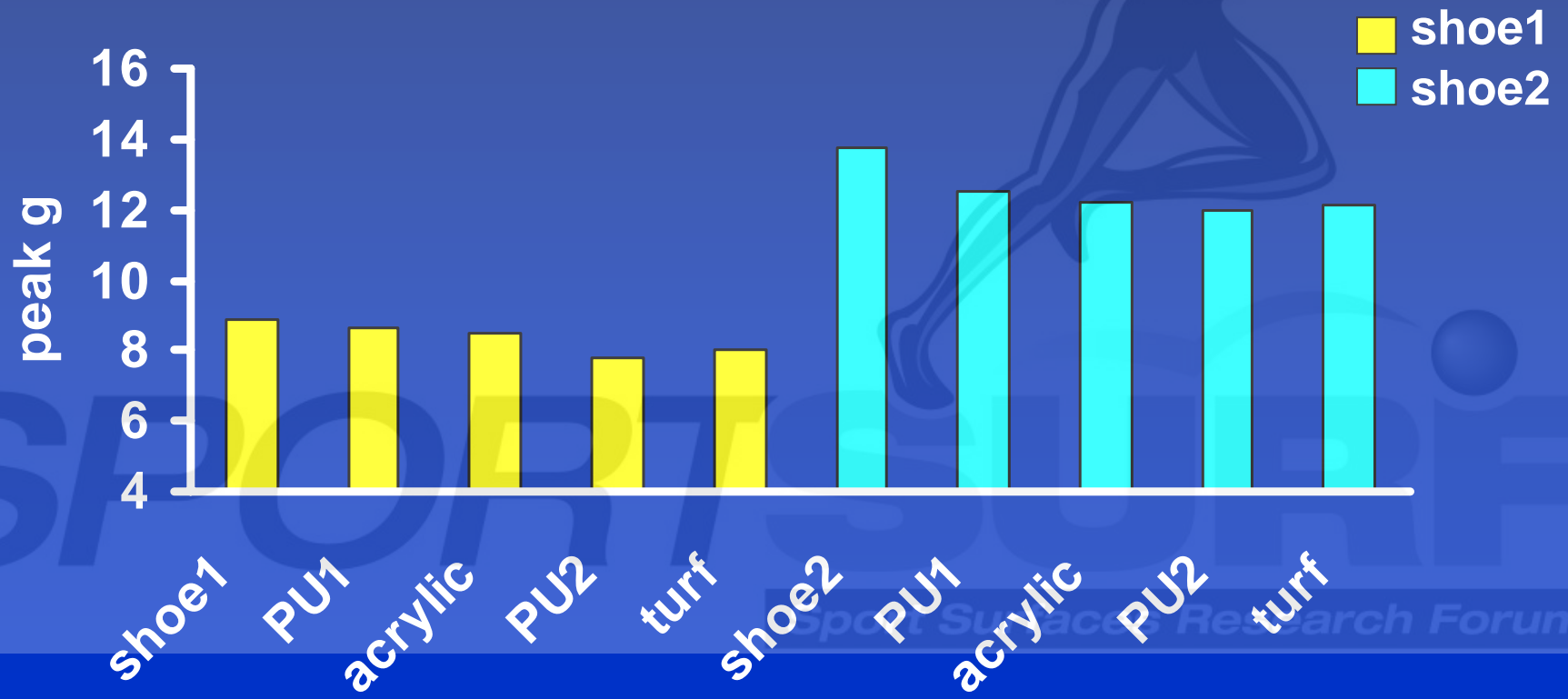
# Tennis Surfaces: Running Study

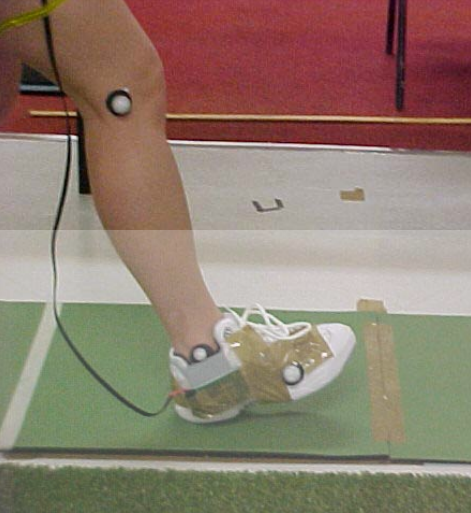


- Berlin Artificial Athlete
- ITF categorisation

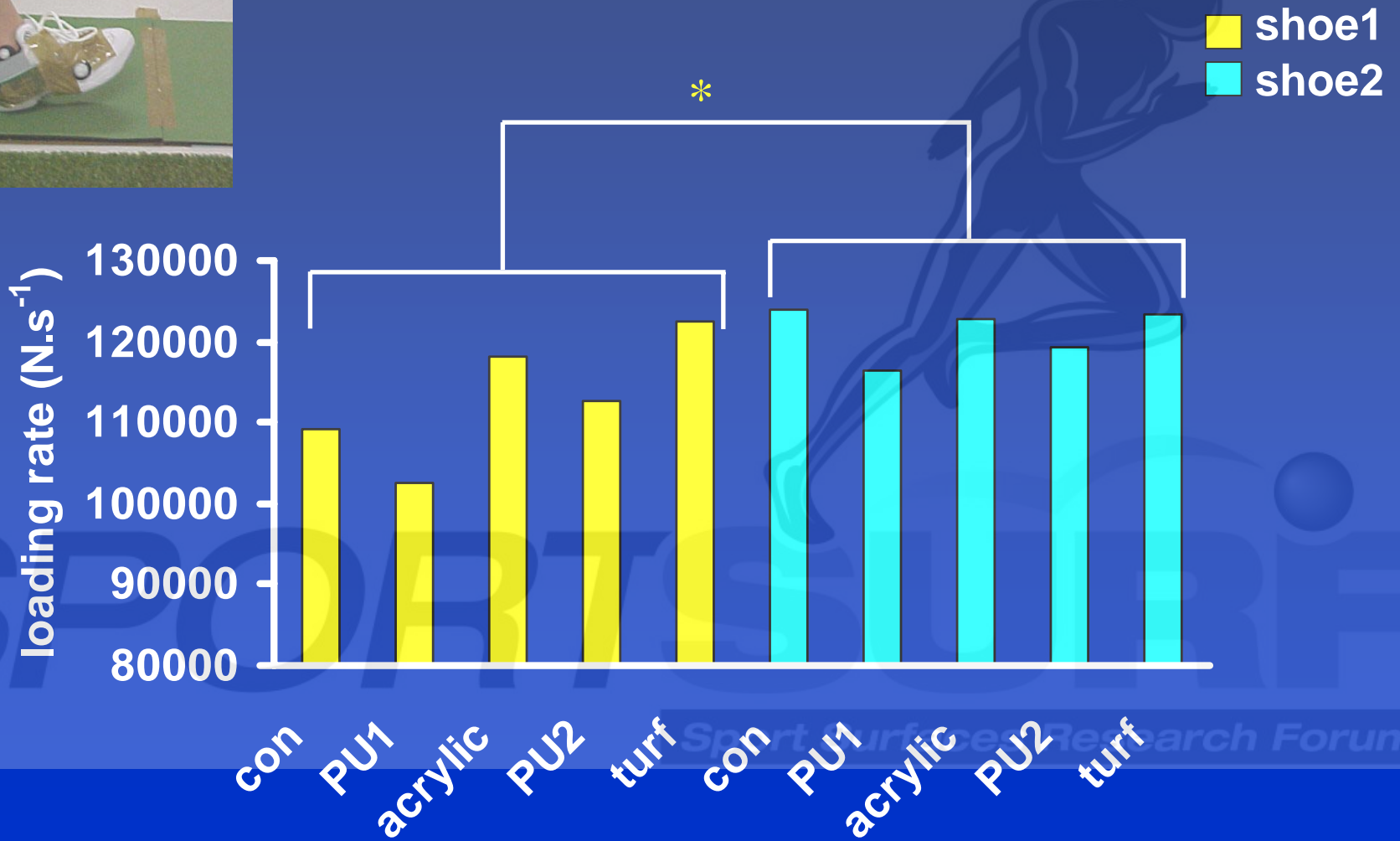


# Drop Test Results



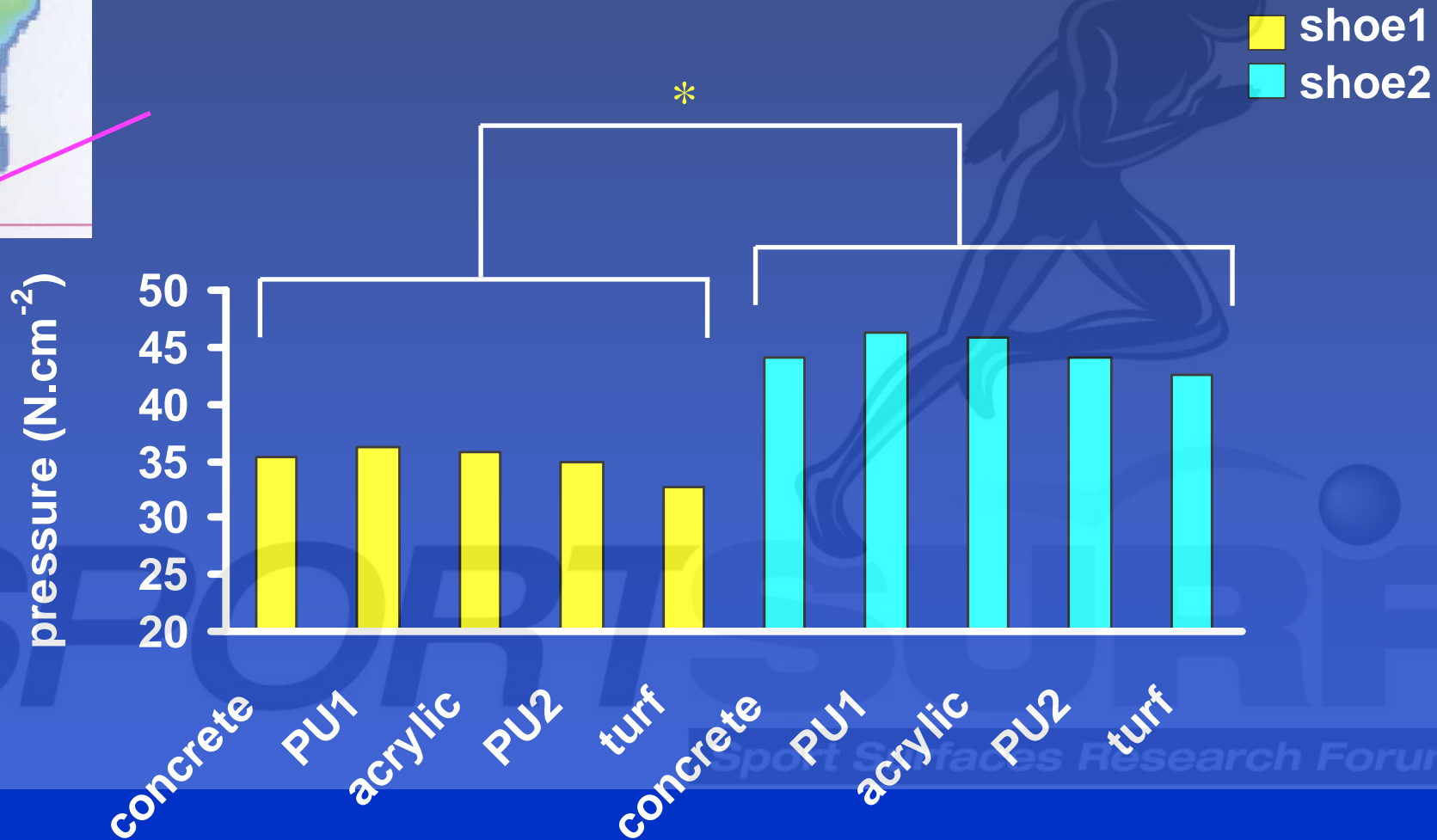
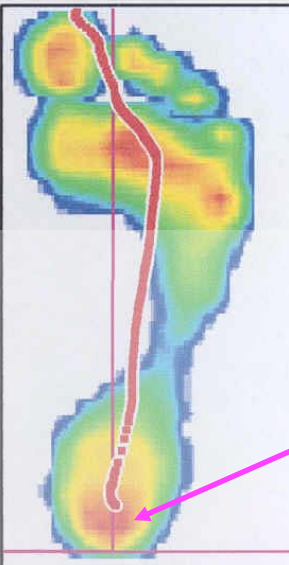


# Peak Loading Rate



\* p<0.05

# Peak Lateral Heel Pressure



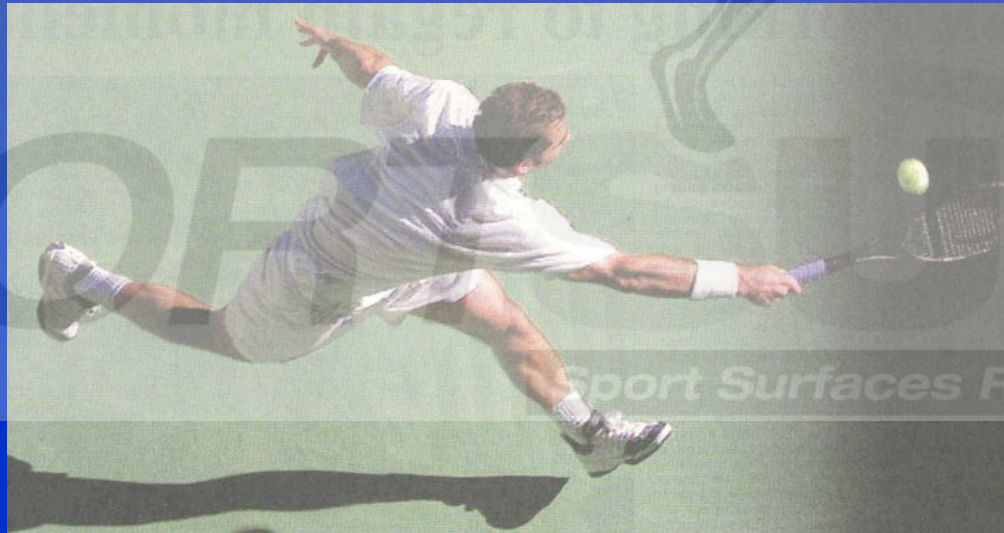
\* p < 0.05

# Conclusions

A blue silhouette of a runner in mid-stride, positioned on the right side of the slide, partially overlapping the text.

- 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**



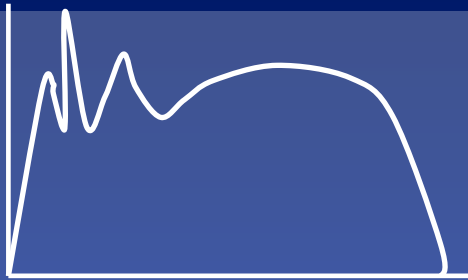
*Stiles & Dixon, JSS, in press*

# Human response to changes in surface cushioning

A blue silhouette of a runner in mid-stride, positioned on the right side of the slide, partially overlapping the title and the list of bullet points.

- 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
- SPORTS SCIENCE FORUM*

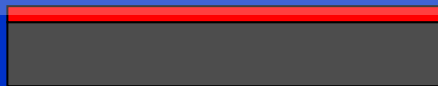
# Change in GRF profiles



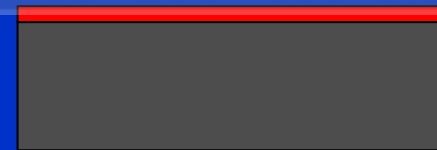
Acrylic only



Rubber and acrylic

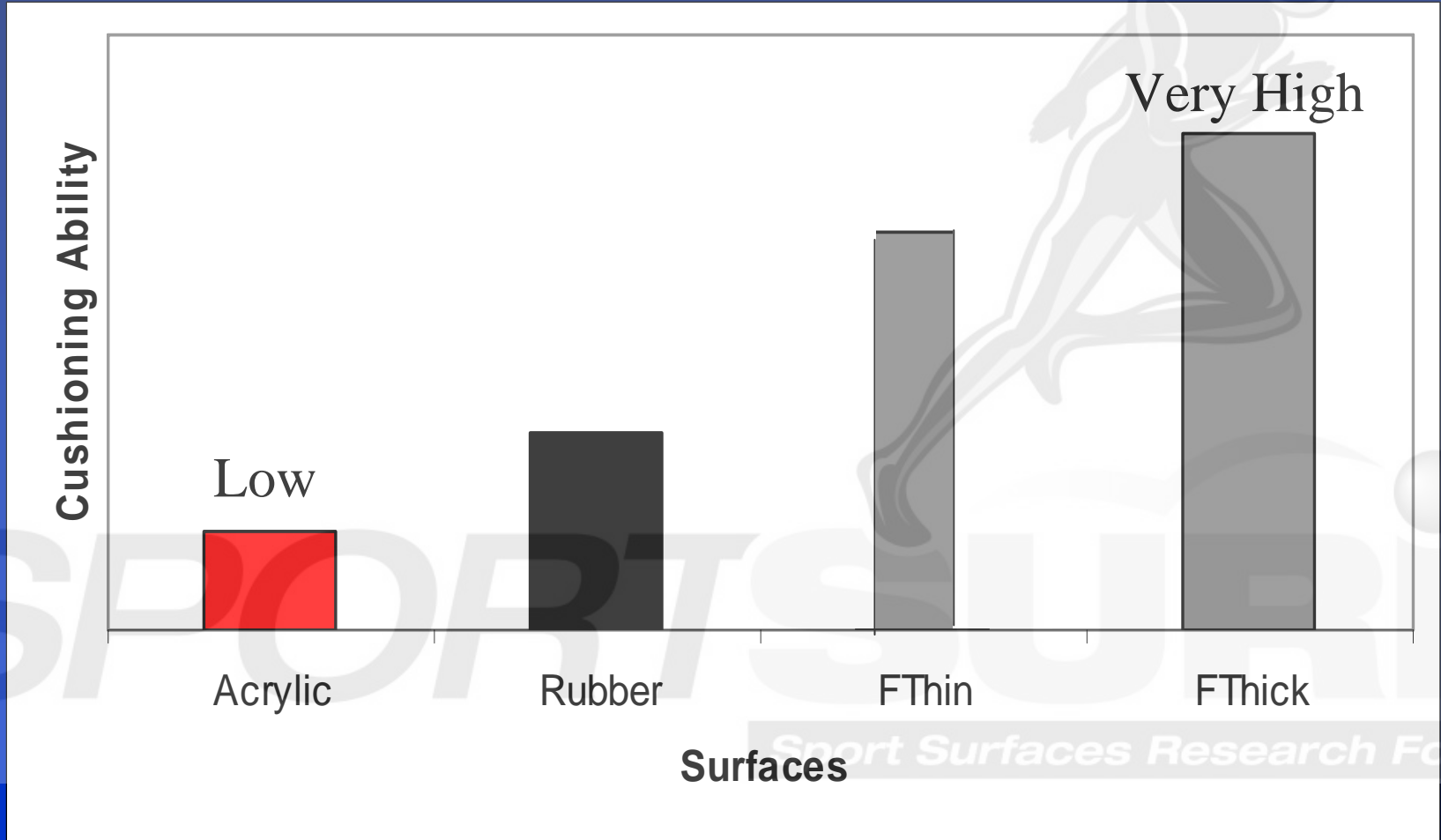


Thin foam and acrylic

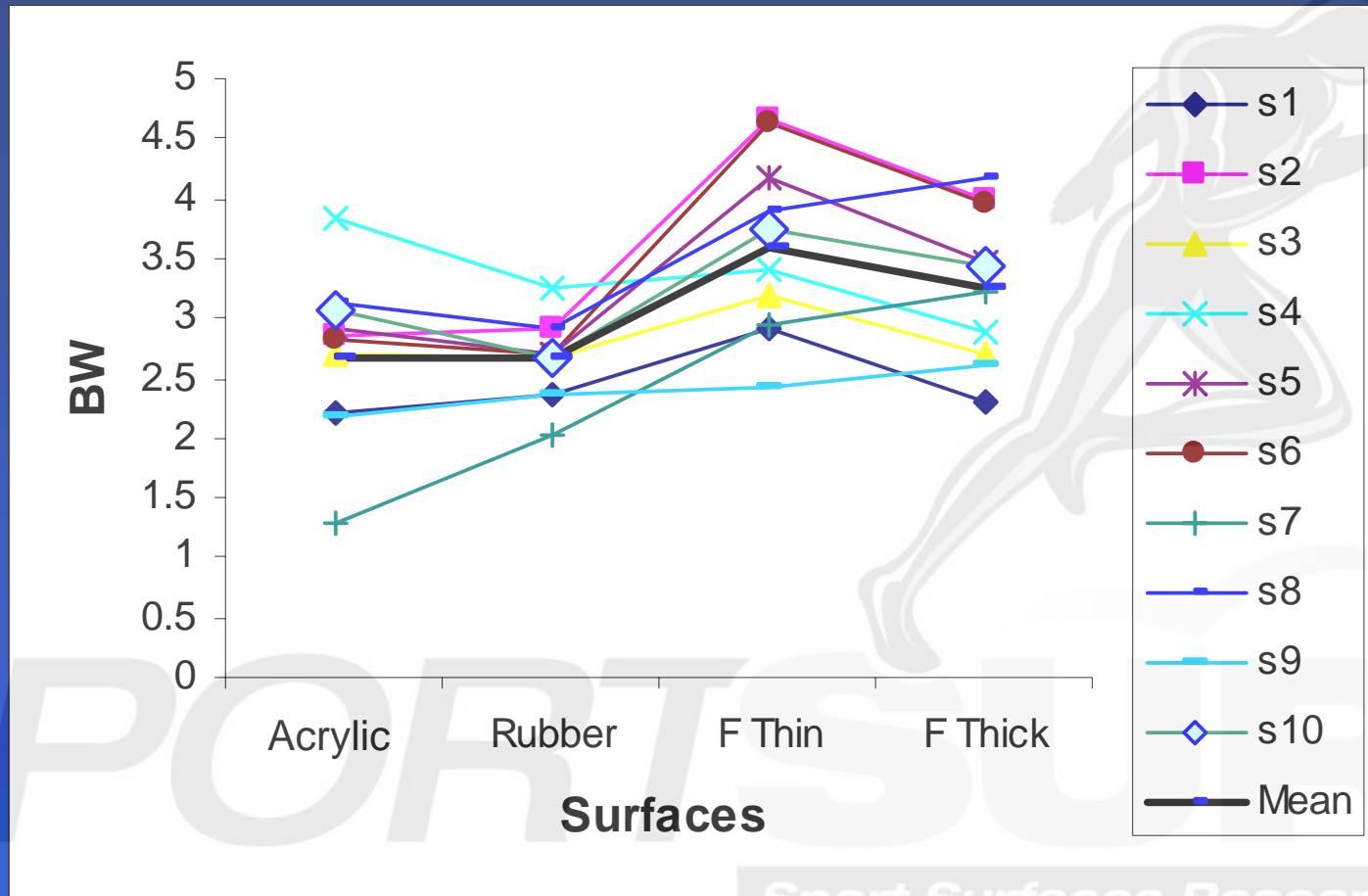


Thick foam and acrylic

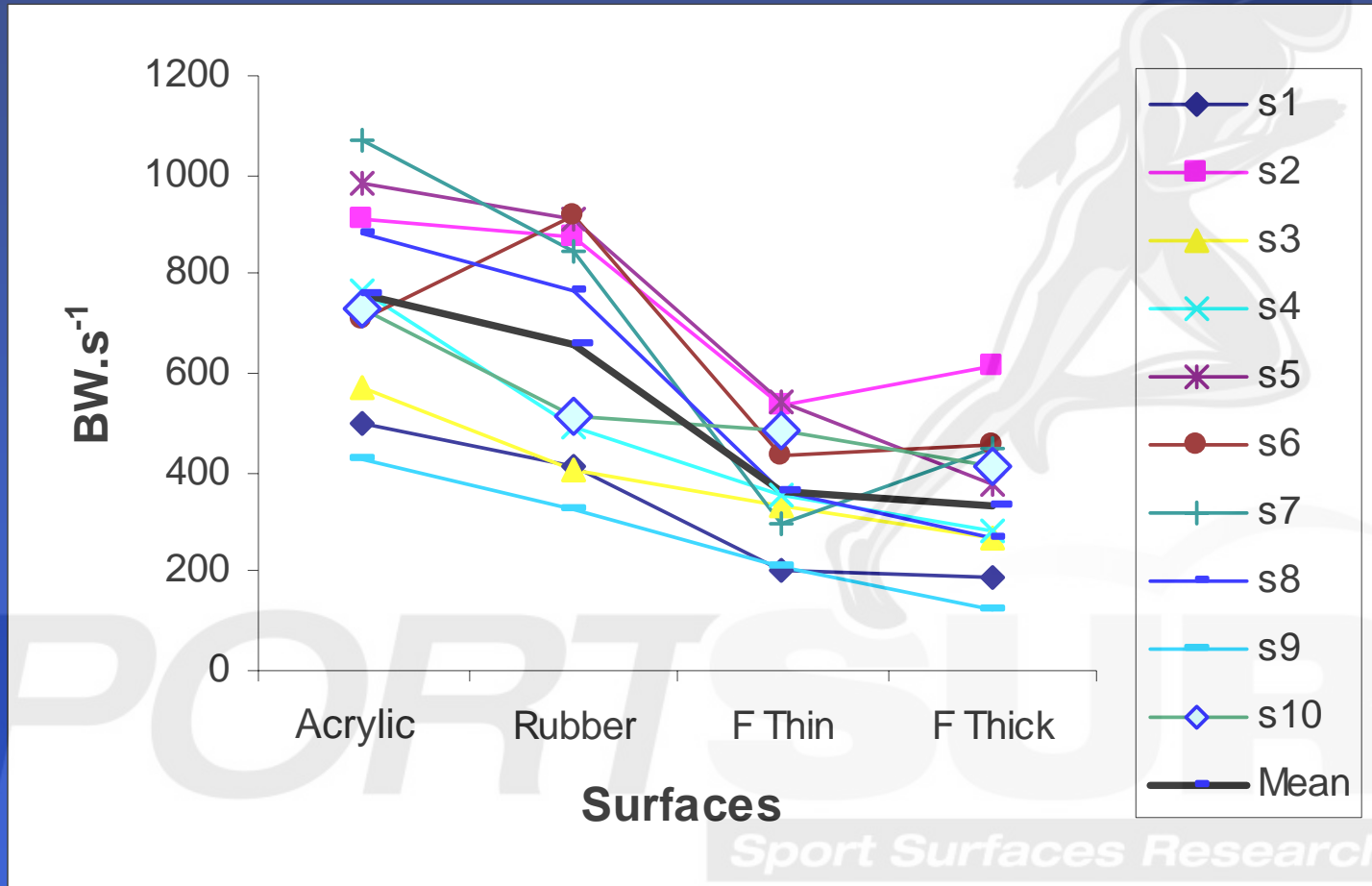
# Surface cushioning ability (Drop test)



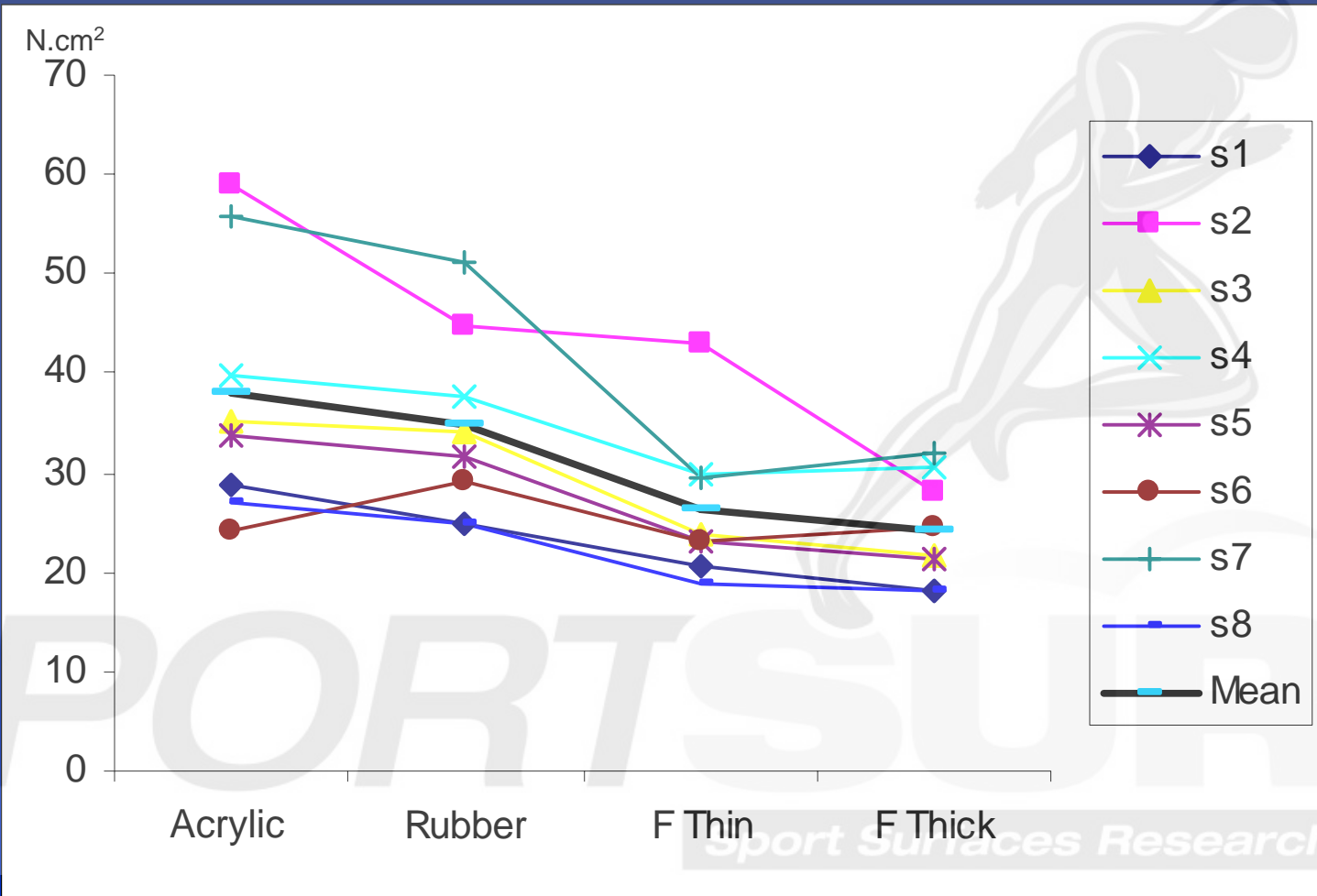
# Peak Impact Force (Fz)



# Peak Loading Rate

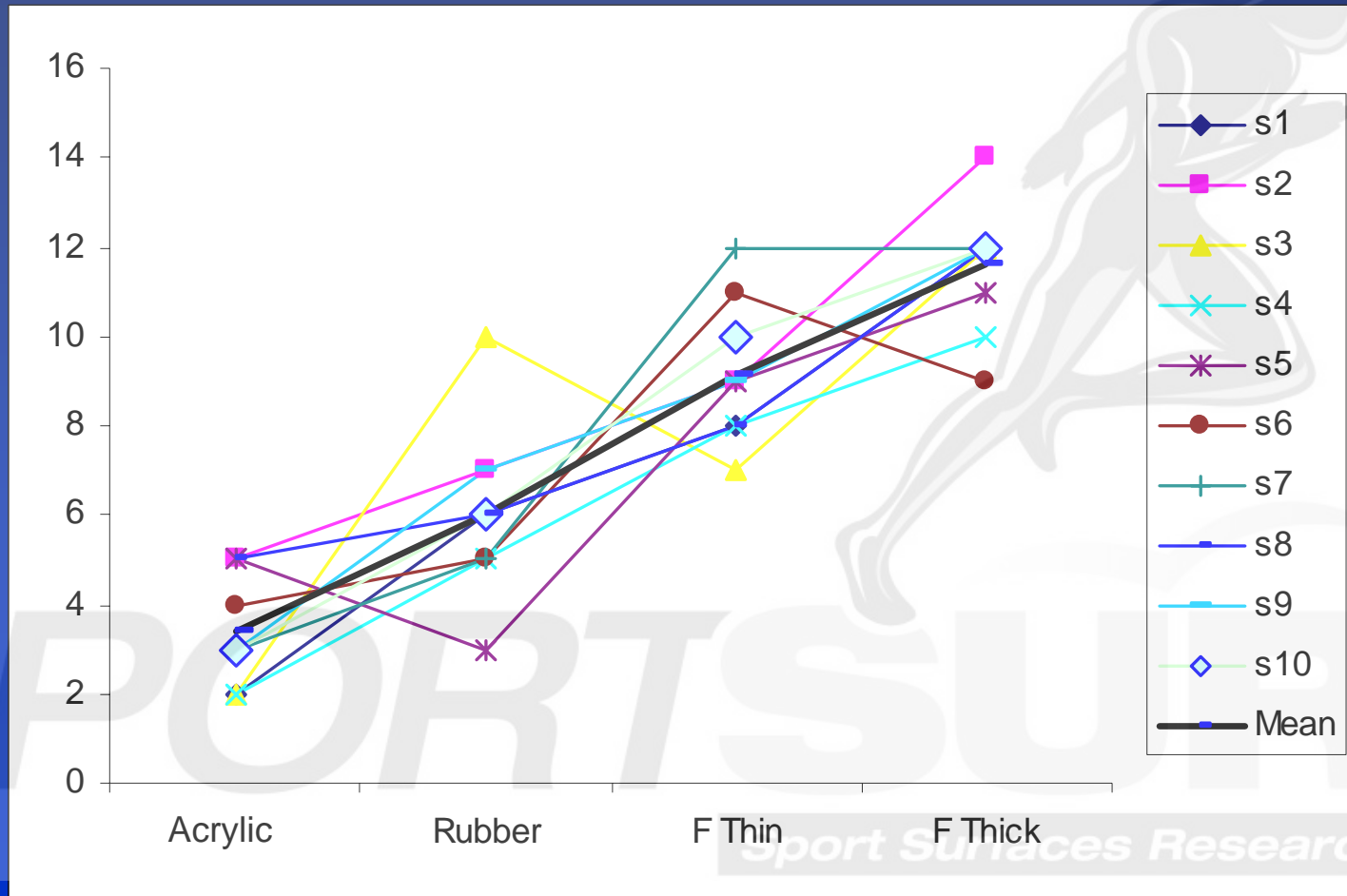


# Peak Heel Pressure



# Cushioning Perception

Hennig et al., 1996



# 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

*Sport Surfaces Research Forum*

*(Stiles & Dixon, JSS in press)*

# Study of Natural Turf



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# Soil Dynamics Laboratory

↓ developed for testing of agricultural machinery



↓ potential for biomechanical testing of human subjects?

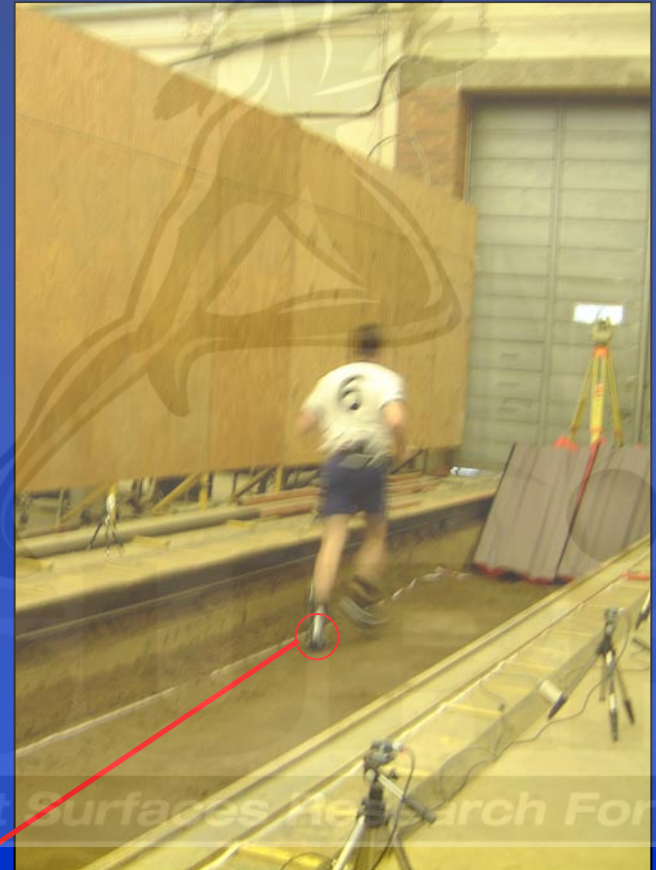
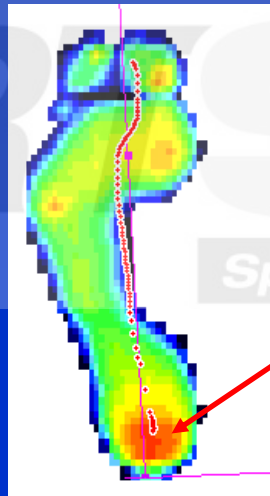
# Shoe-Surface Conditions

- **Surface densities**
  - 1460 kg.m<sup>3</sup> ('soft' soil: Surface 1)
  - 1590 kg.m<sup>3</sup> ('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

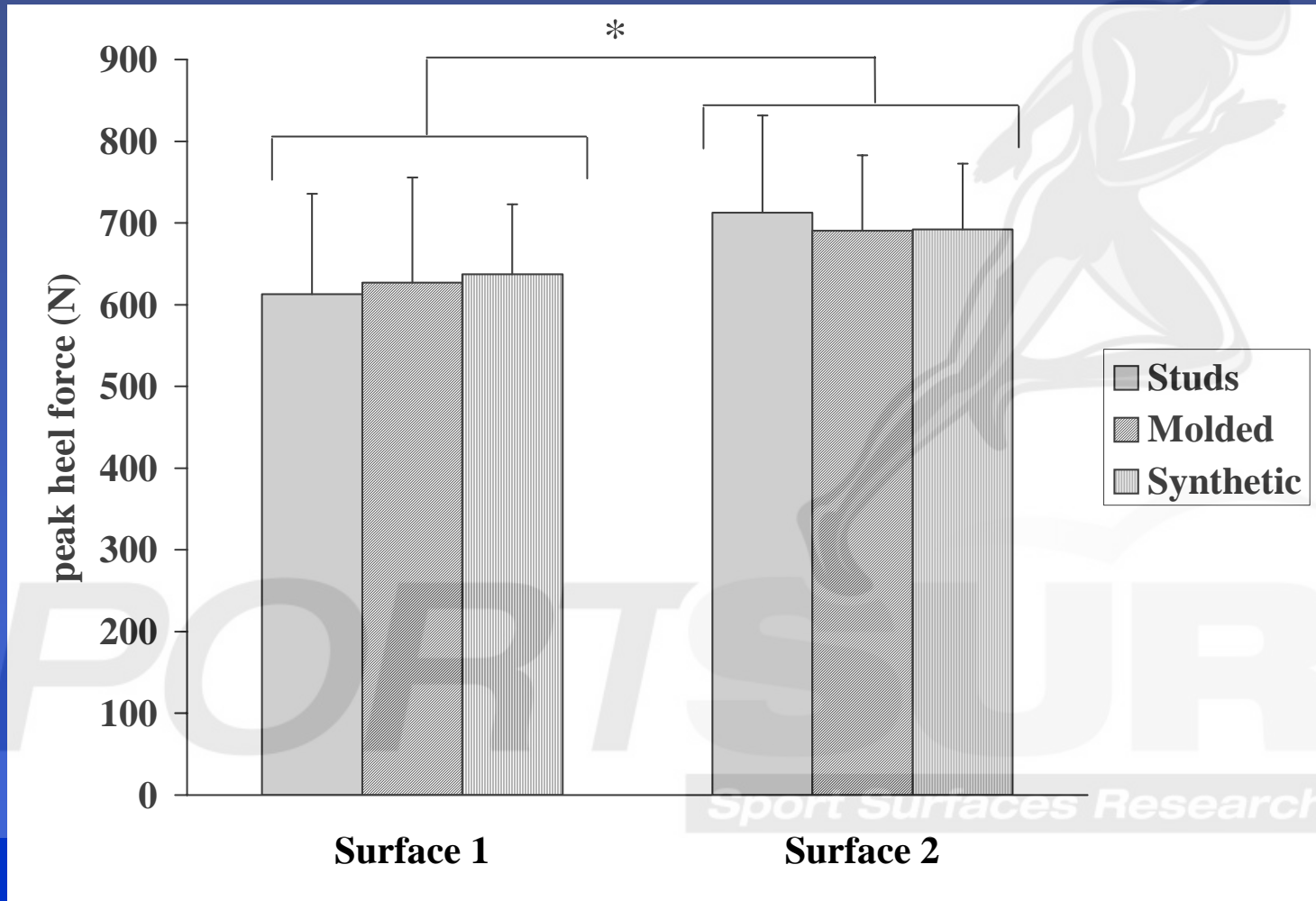


# Mechanical Characterisation

- **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

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# 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



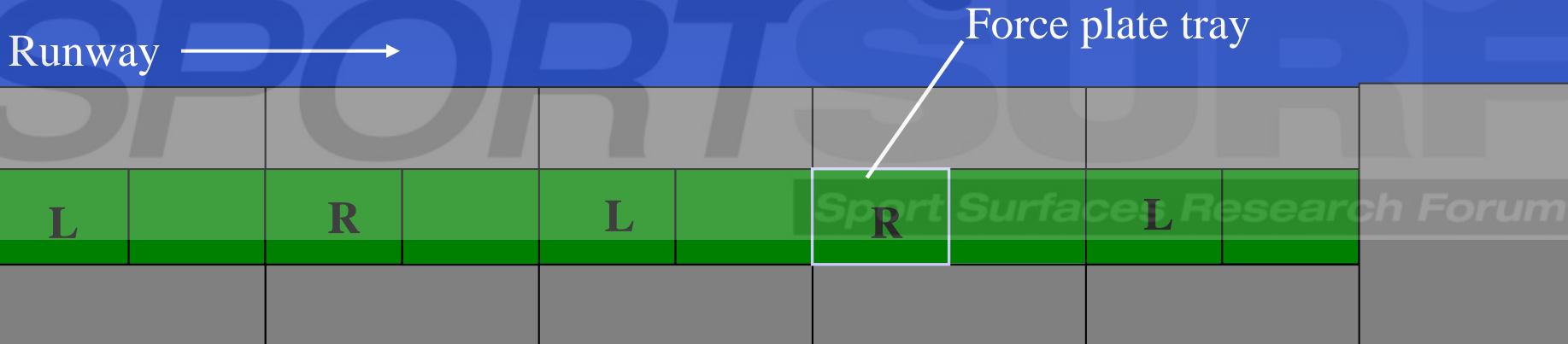
**3 turf conditions: clay, sandy, rootzone**



**1 boot model**

# Methods

## Portable Plastic Trays





Force plate  
tray

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# Data Collection

- Running
- Turning



# Data Collection: Turning

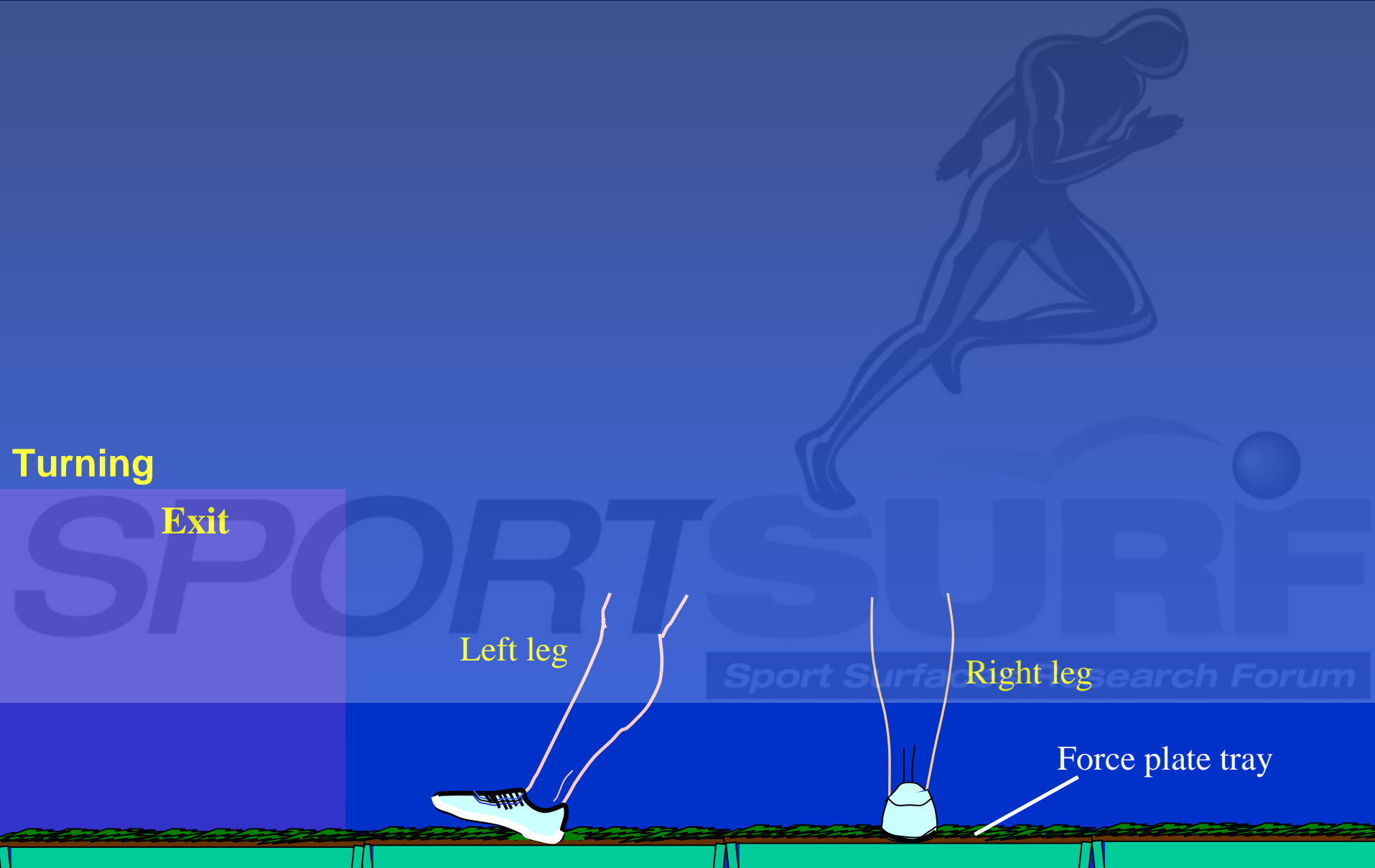
Turning

Exit

Left leg

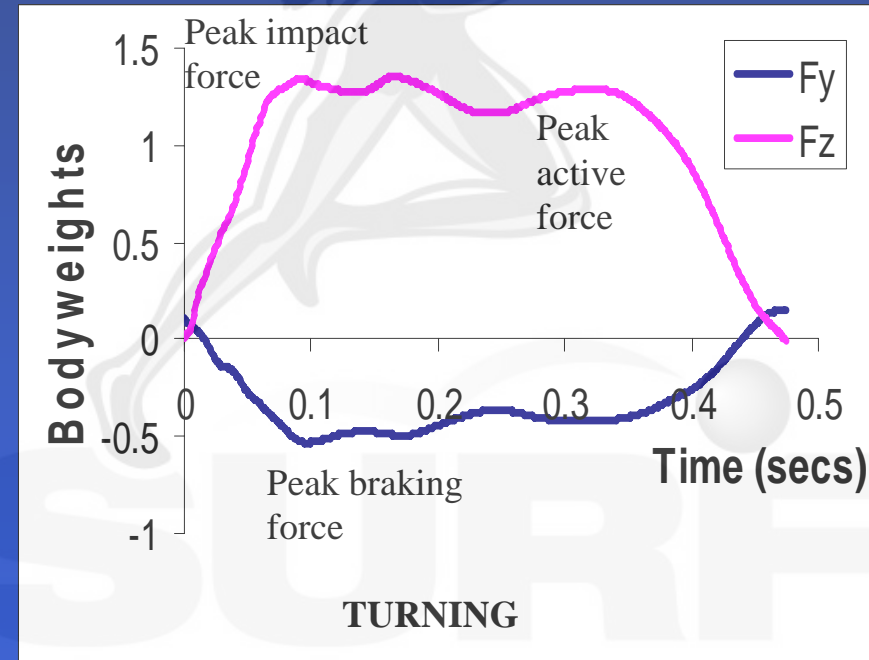
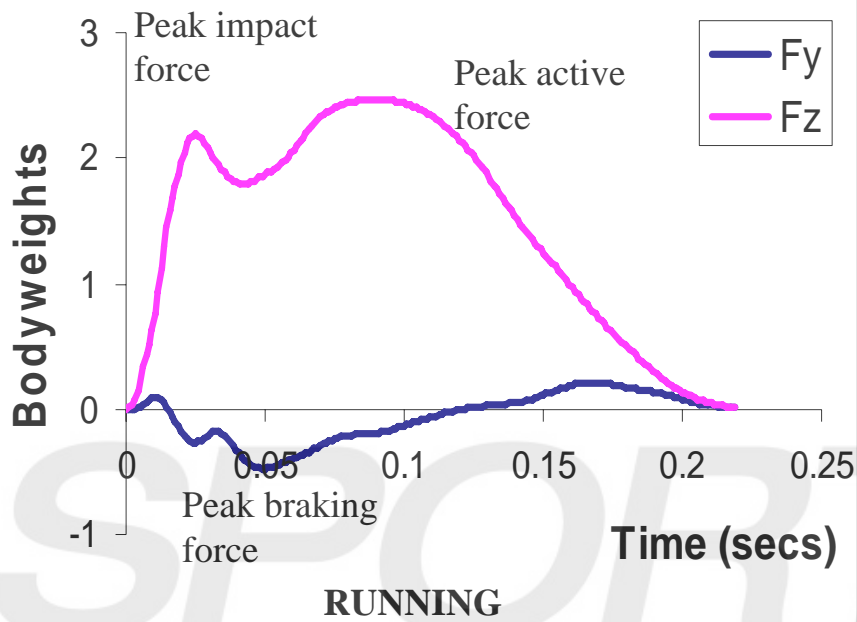
Right leg

Force plate tray



# Results

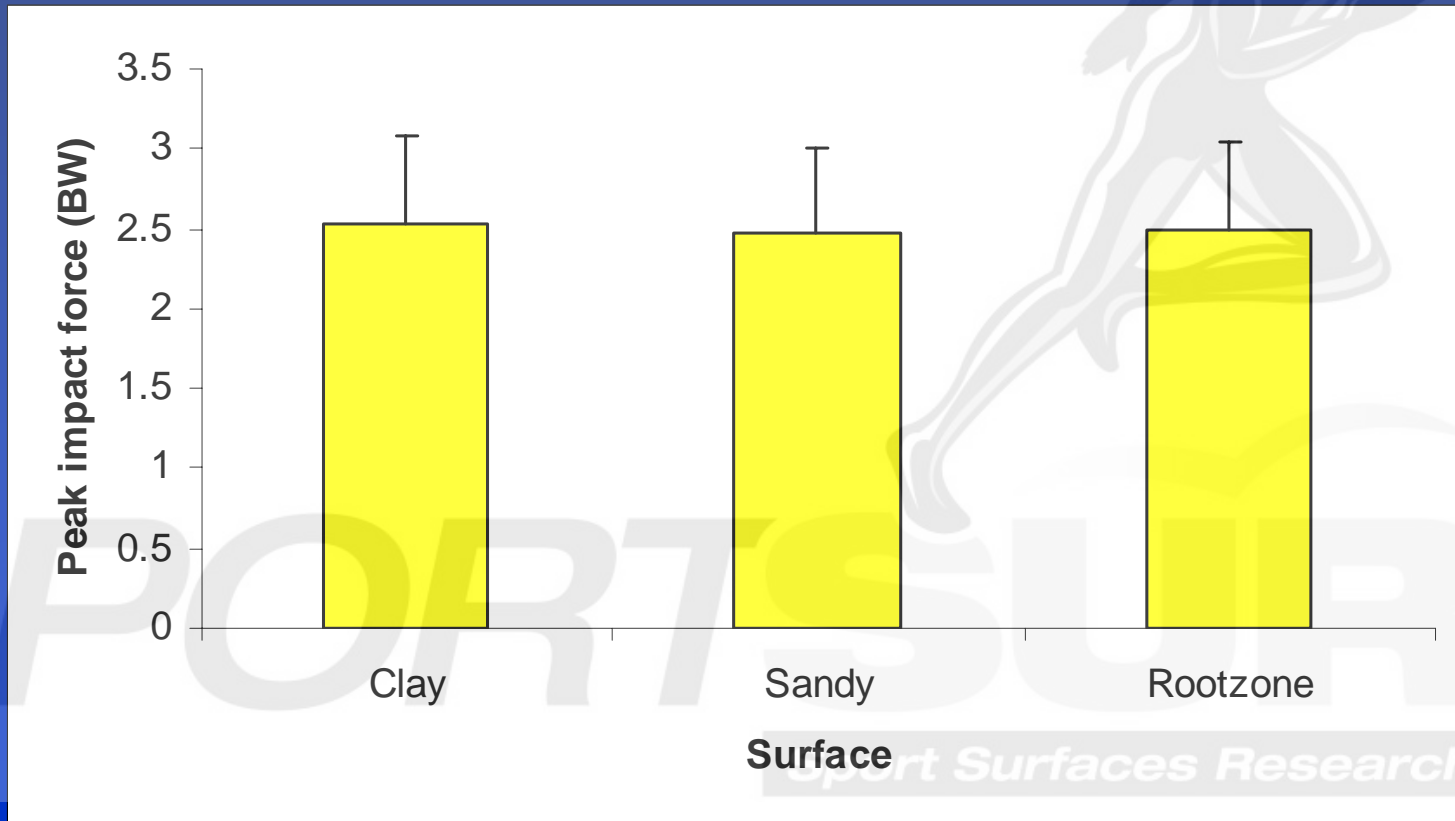
Typical vertical ( $F_z$ ) and horizontal ( $F_y$ ) ground reaction force time histories



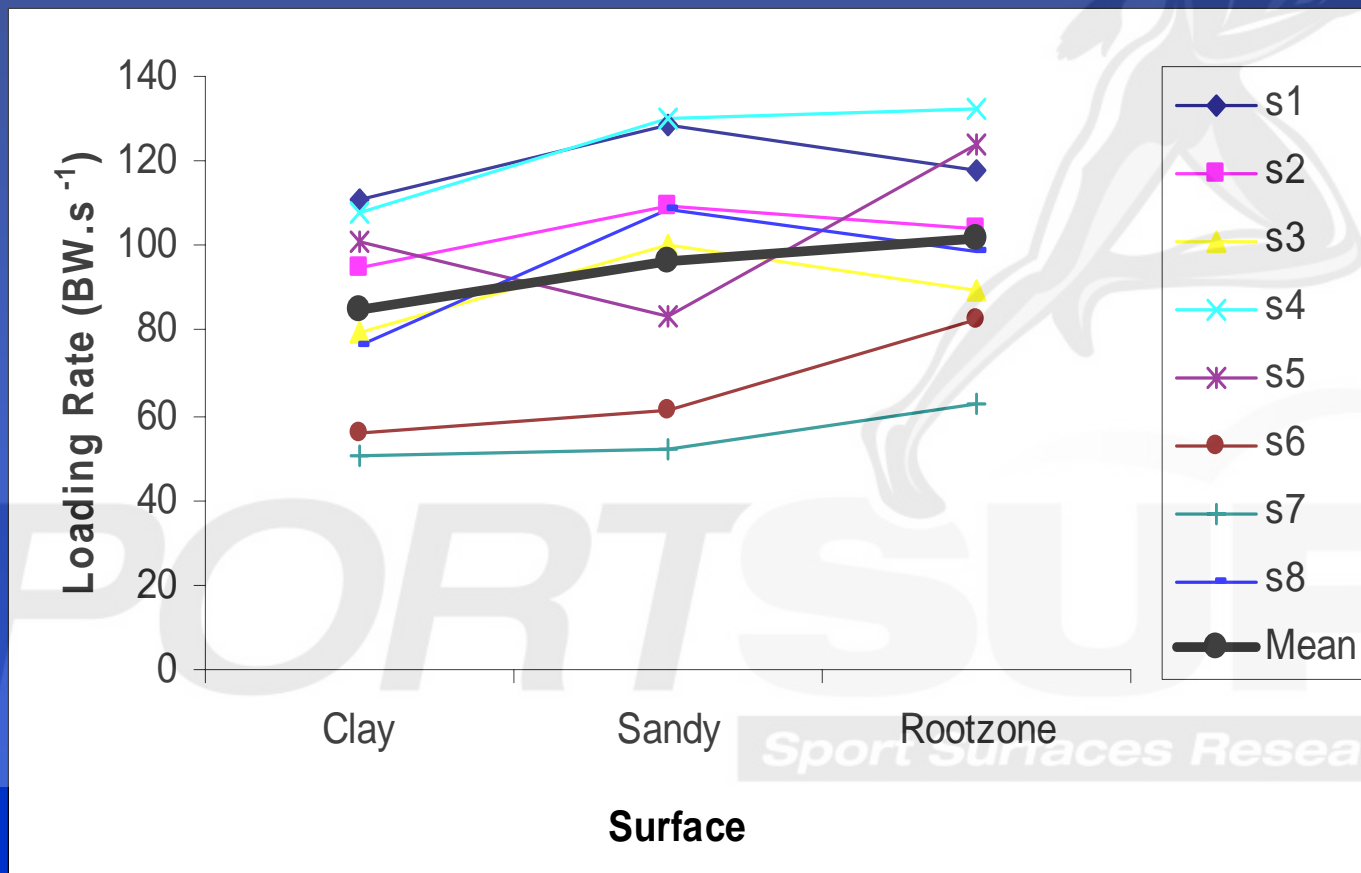
Running

Turning

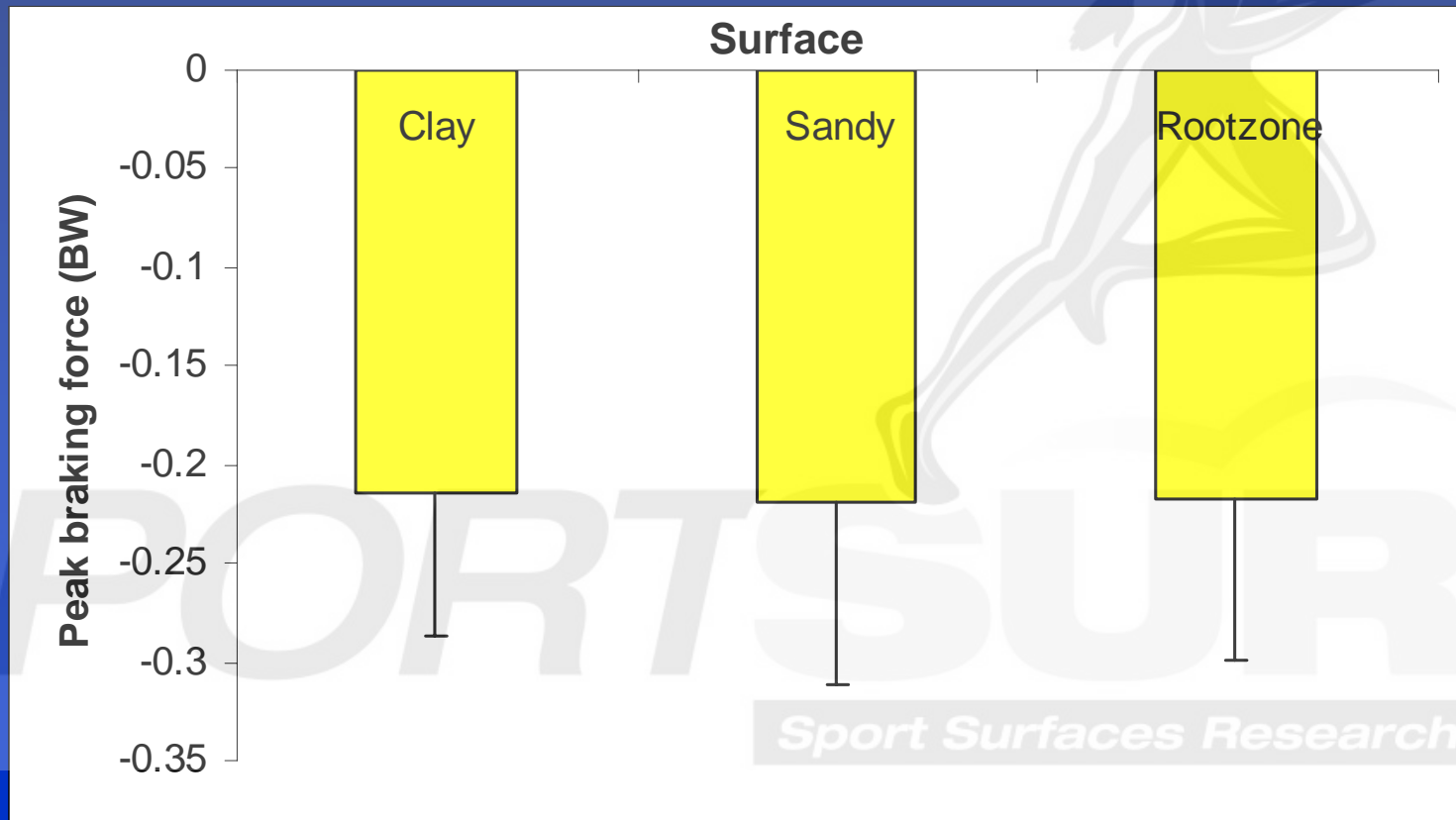
# Results: Running impact force



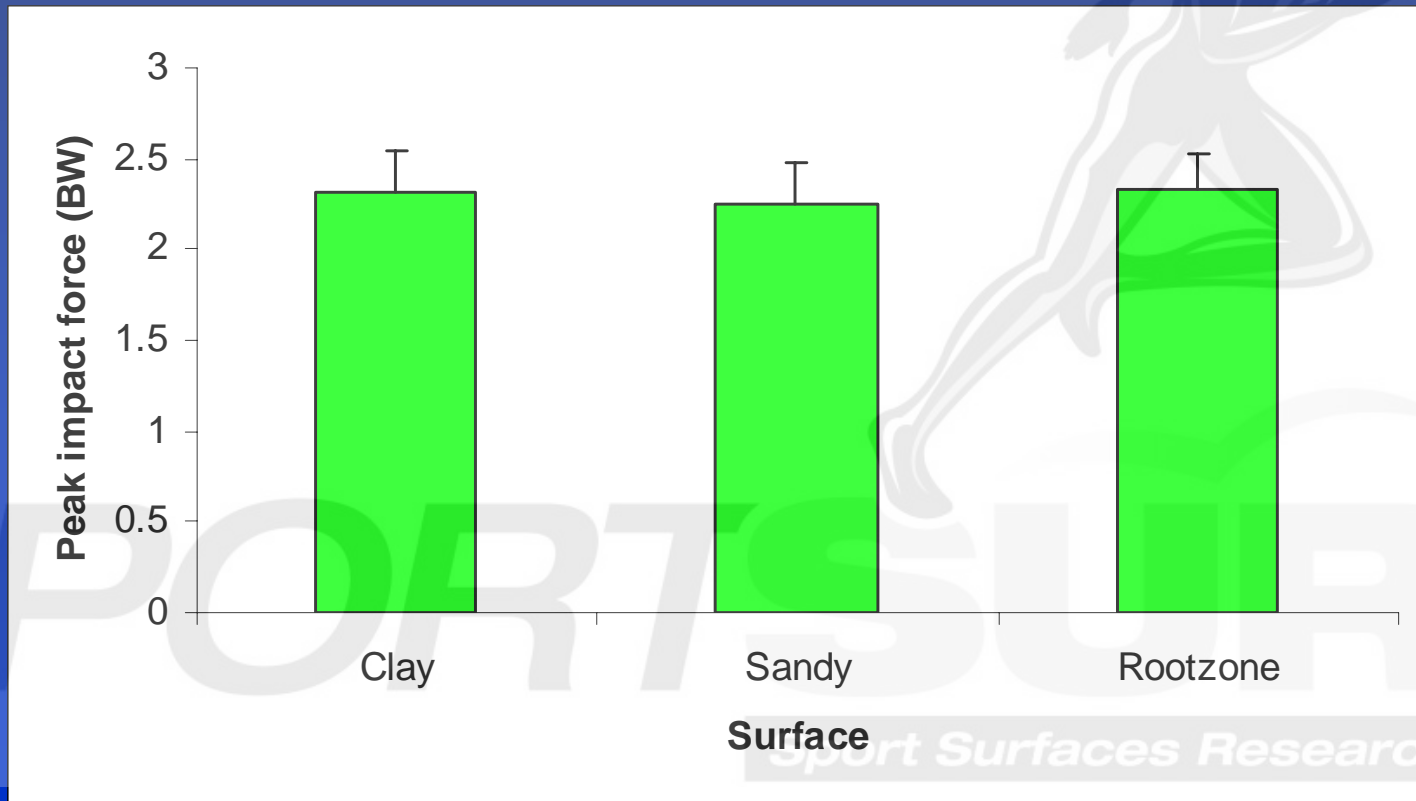
# Running impact loading rate



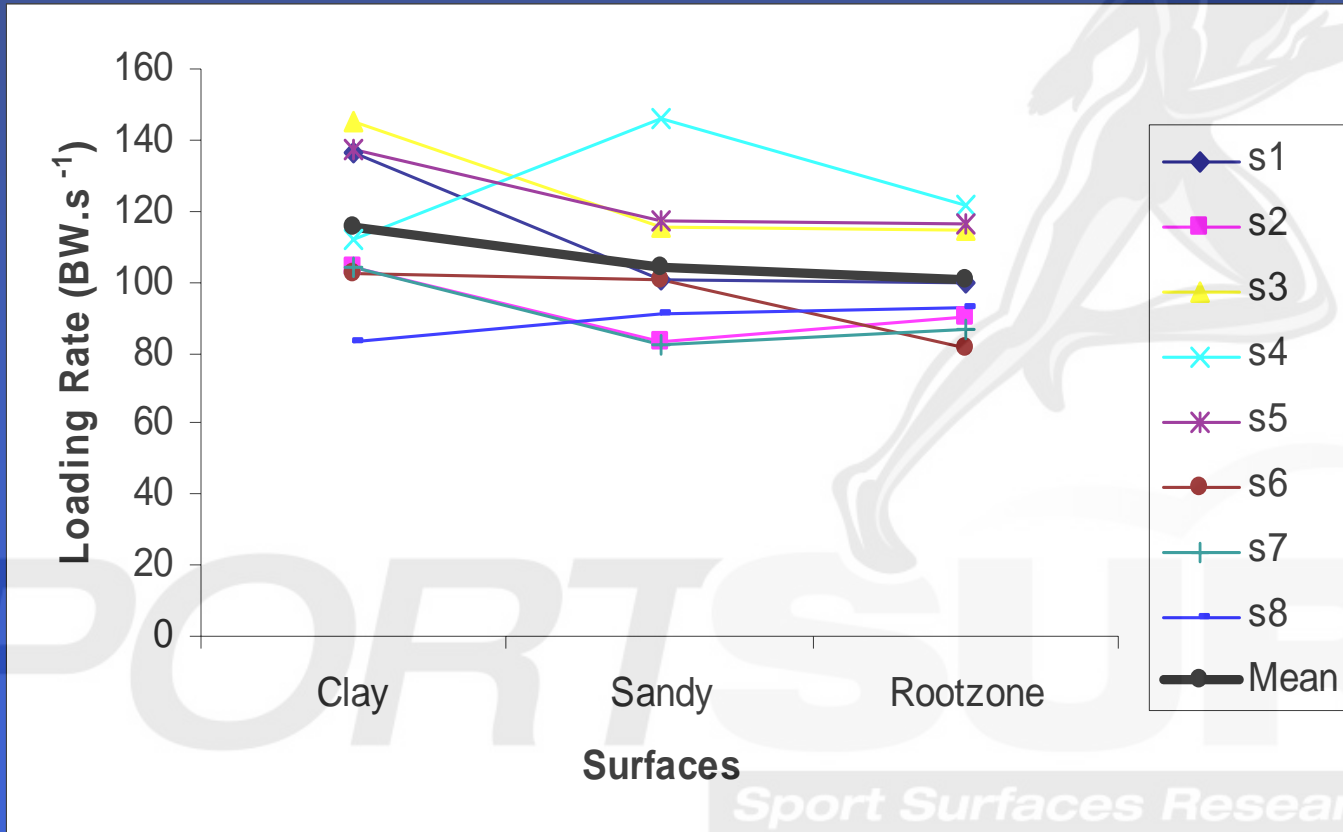
# Running braking force



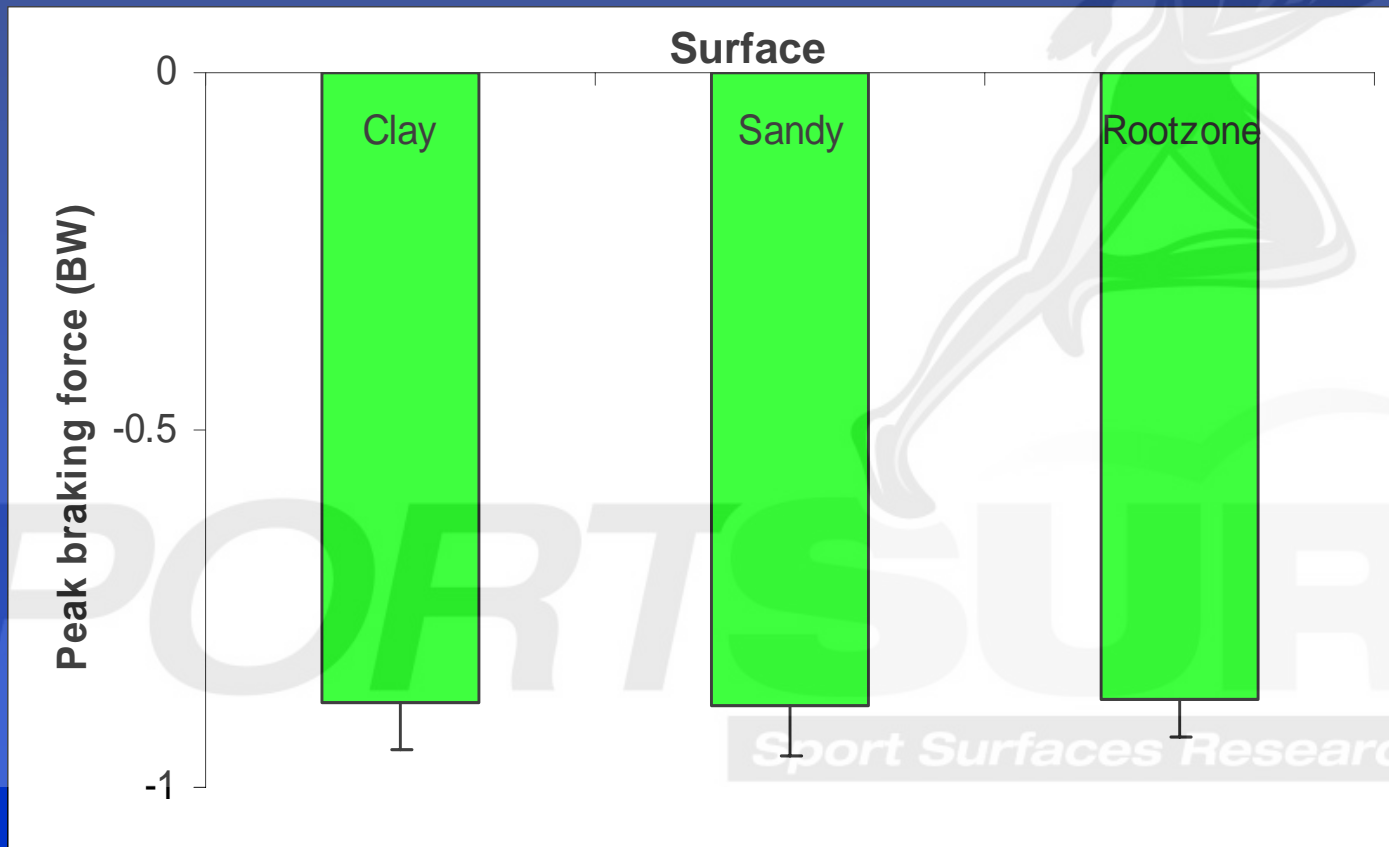
# Results: Turning impact force



# Results: Turning impact loading rate



# Turning braking force



## Results So Far...

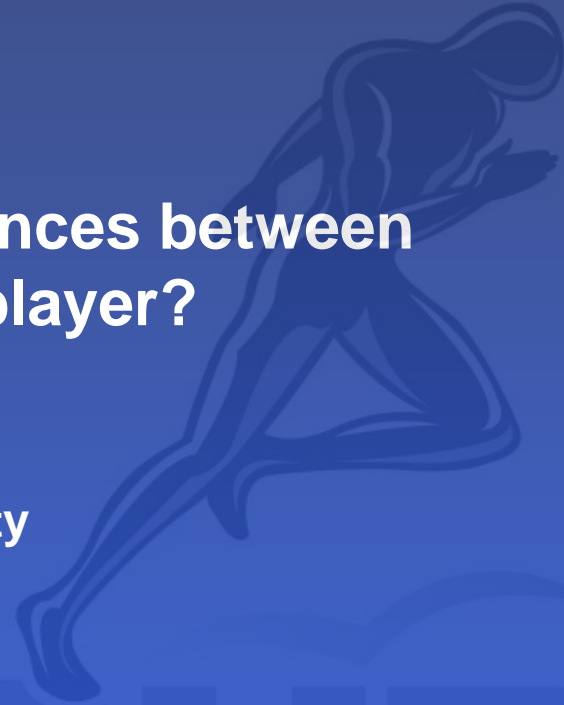
- No significant differences in peak impact or peak braking force across turf conditions
- Significant ( $p < 0.05$ ) differences in peak loading rate across turf conditions

# 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?



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# Future Interdisciplinary Study

- Measurement of loads at different levels:

