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ITF International Tennis Federation

Development of a test device to measure the tribological behaviour of tennis shoe-surface interaction

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Part I – where it all started…

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Origins...

- 30 month research project funded by EPSRC, UK
- Combine biomechanics and mechanical engineering
  - Improve understanding of tennis-shoe surface interactions
  - Influences of injury-risk and performance

Complex problem...

- Range of player movements, complex interactions
  - Push-off, side-step, controlled slides
- Range of surfaces and conditions
  - hard court, grass, clay
- Excessive traction
  - overloading injuries
- Insufficient traction
  - loss of performance, slips

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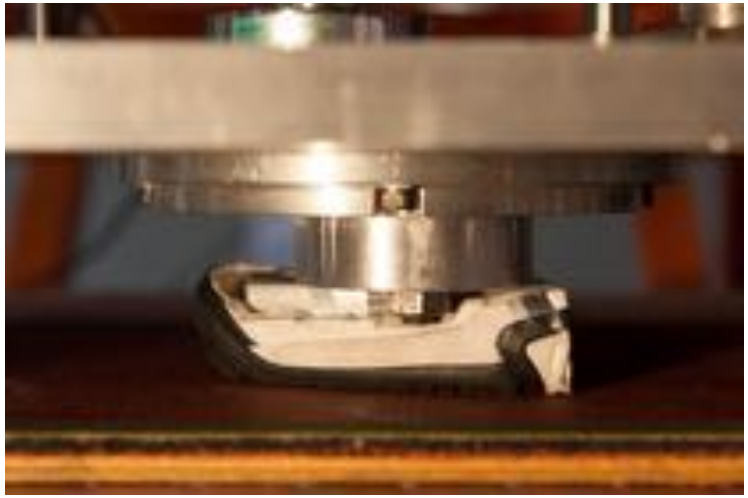
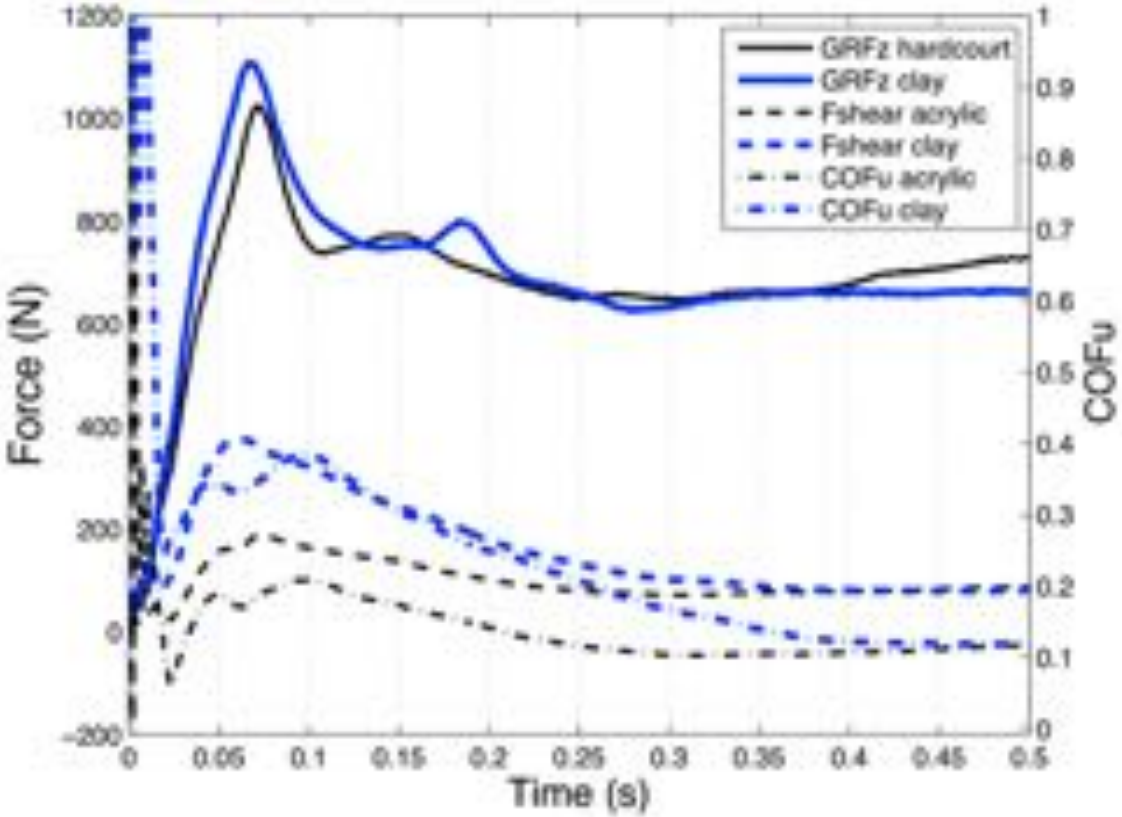
Combined approach...

- Biomechanical study – University of Exeter
  - observe and measure player movements
  - provide boundary conditions
  - reveal the most important aspects to replicate and examine further
- Mechanical testing study – University of Sheffield
  - replicate loads at key instance in movements
  - repeatable methodology
  - carry out parametric studies
    - hard court roughness
    - loads
    - shoe orientation
  - "push system to its limit"



Biomechanical Data...



Side jump movement
Damm *et al*., 2011

- F_{shear} greater on clay
- Further studies used pressure insoles and kinematics measurements
- Data used to form boundary conditions...

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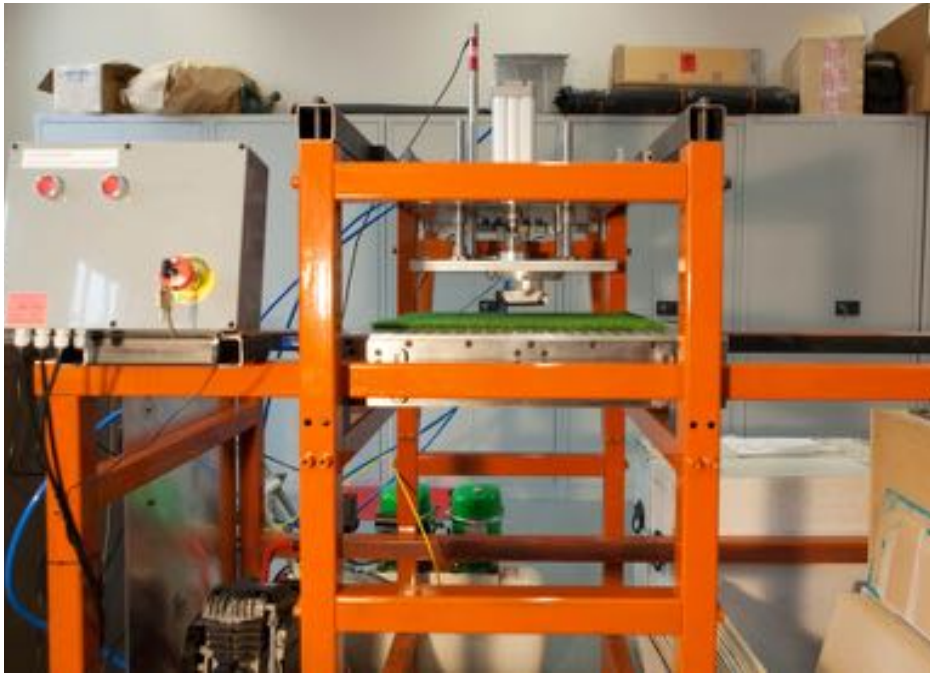
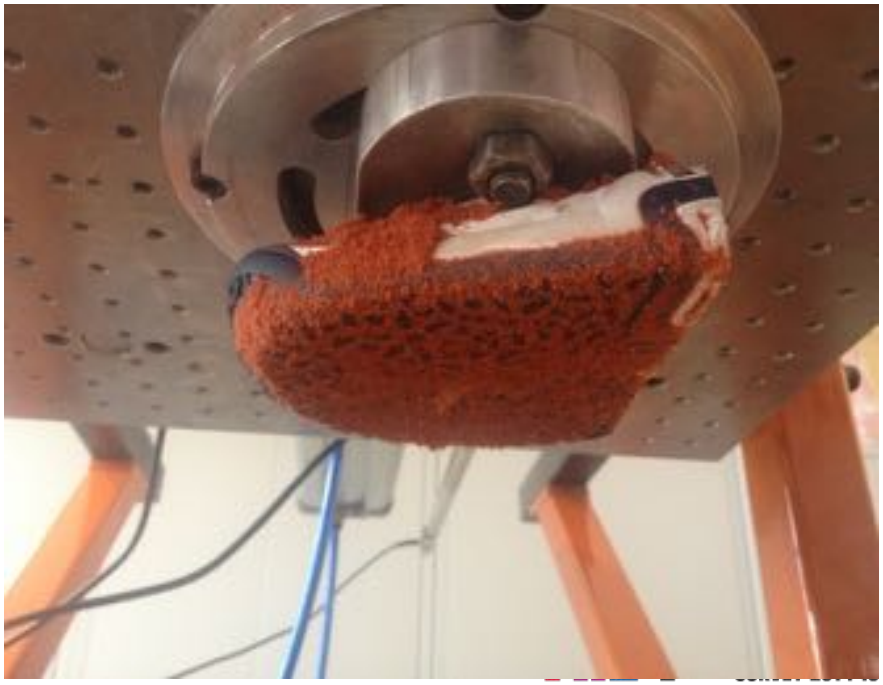
Development of lab rig...

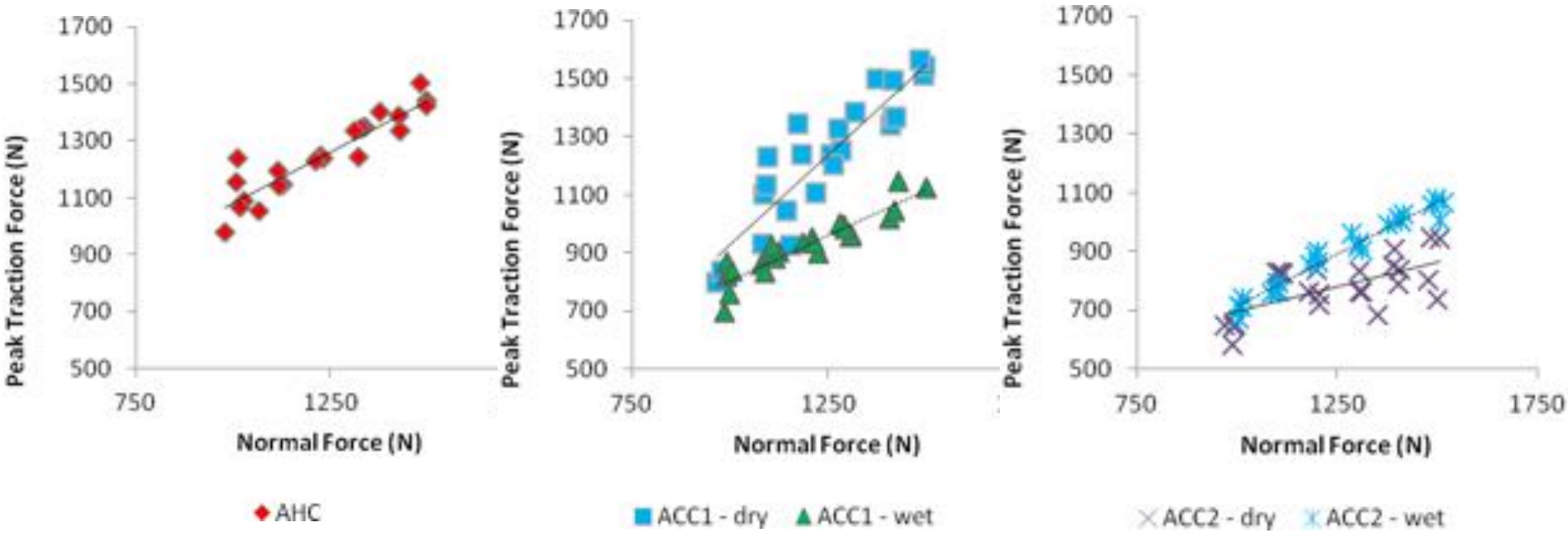
- Aim to measure traction developed at a normally loaded shoe-surface interface, as an applied shear force is increased
- Pneumatic rams, load cells and LVDTs





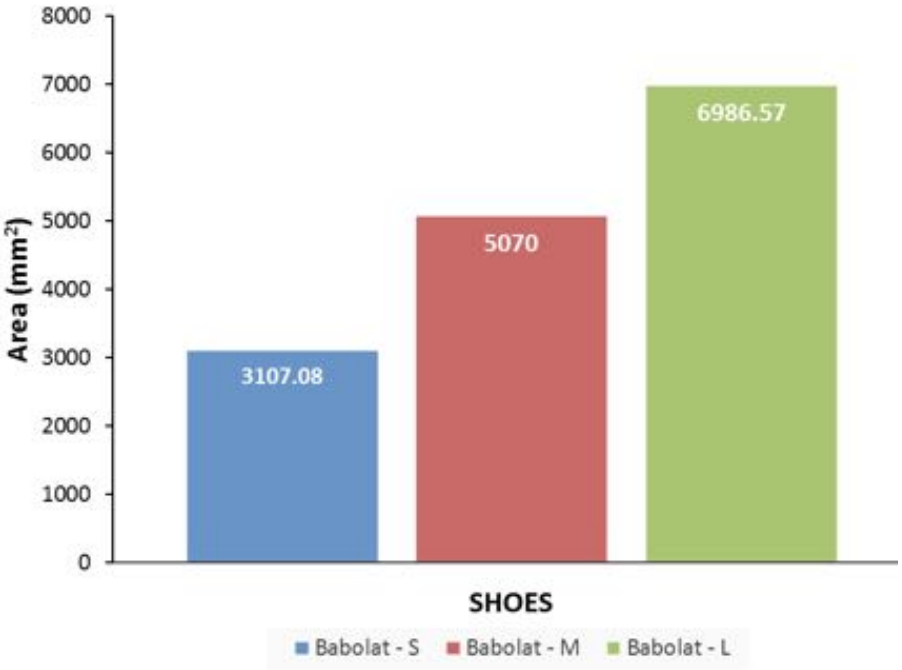
Development of lab rig...

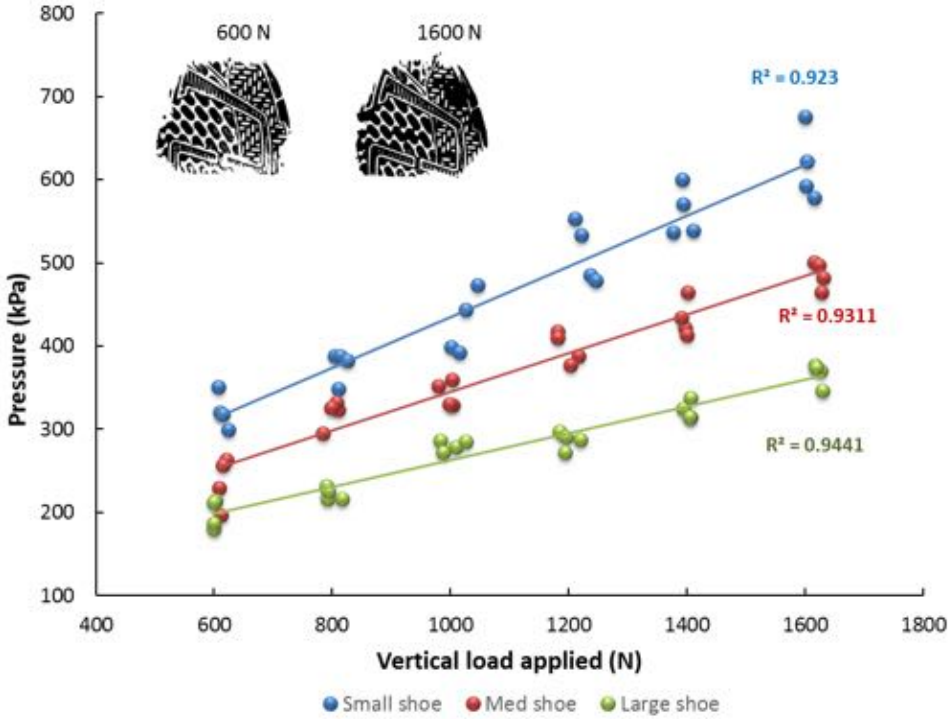
Comparison of different courts…



- Art. clays provide less traction than hardcourts
  - larger sand particles (ACC2) reduce traction
  - effect of moisture dependent on particle size
- Link back to biomechanical study
  - players confident to slide on ACCs in controlled manner

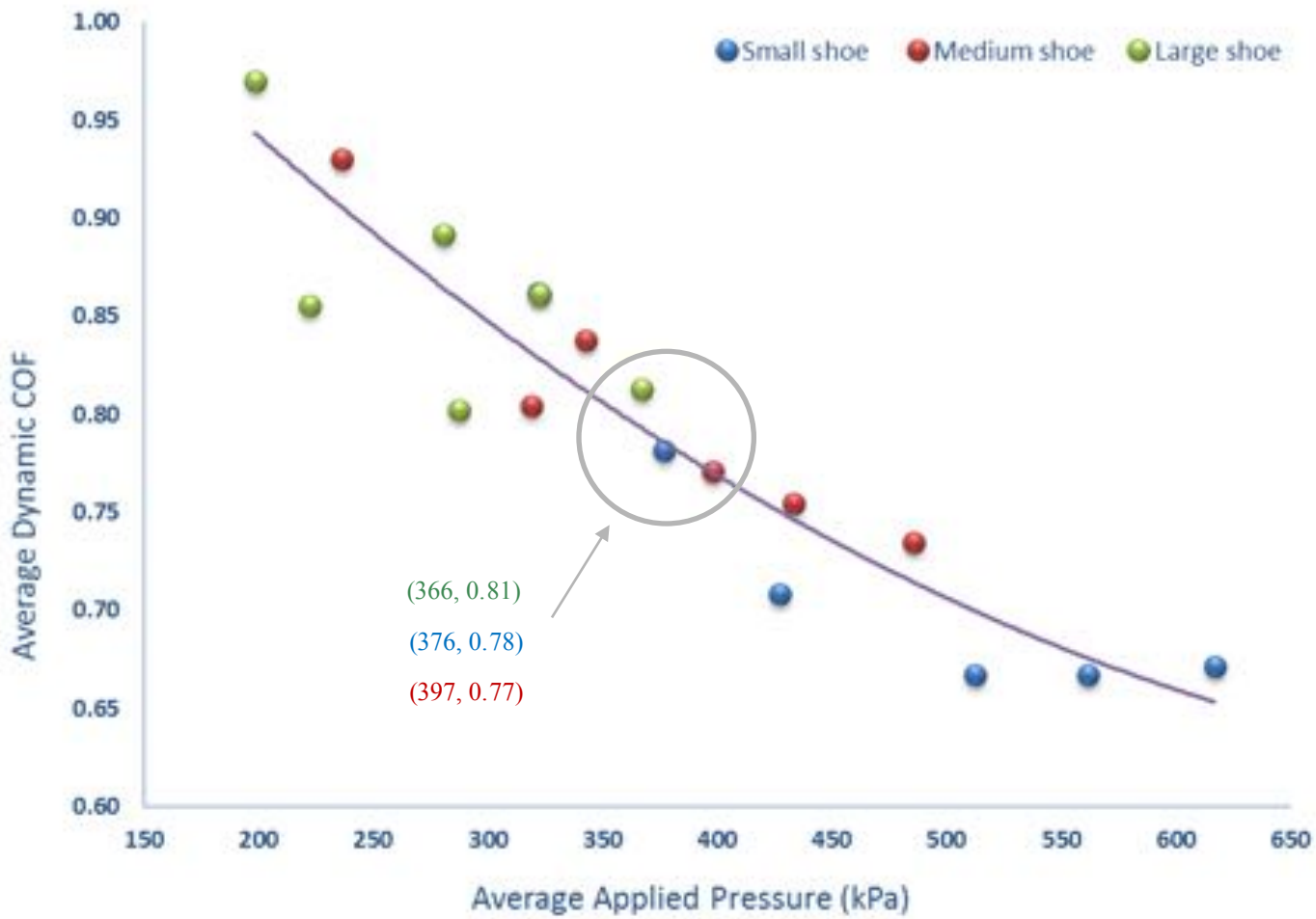
Effect of contact area…





- Three different sized shoes tested of same design
  - Areas measured and contact pressures calculated

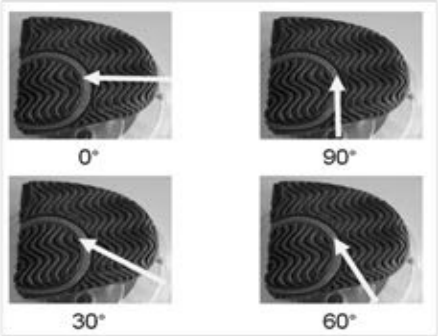
Effect of contact area…



- Conclusion:
  - If pressure is matched, similar friction behaviour is observed

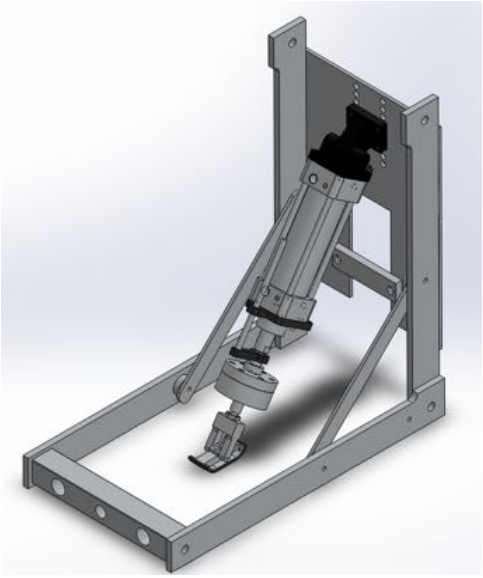
Other studies…

- Further studies with UoS Rig
  - Effect of ACC volume in-fill on traction, biomech and perception
  - Effect of shoe orientation on traction
  - Measurement of shoe temperature during sliding movements



- Further studies on tennis surfaces
  - Effect of clay court particle size on traction through field tests
  - Field testing of grass courts
  - All feeding into…

Part II – developing the device…



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"To me that's not tennis. Either I come out with football shoes or I invite Chuck Norris to advise me how to play on this court".

Djokovic, Madrid Open, May 2012

"It would be great if someone who was responsible for these things looked at it because there's nothing that I did wrong to cause me to slip." Azarenka, Wimbledon 2013

"All you think about is money." Nadal, US Open 2011

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Portable test device, Why?

- No regulations about shoe-surface interaction in tennis.
- Assess courts around the world and rate them (performance).
- Establish and study tribological mechanisms.
- Challenge to design portable equipment representative of match conditions.

Tribological Mechanisms

Structural (1,2)

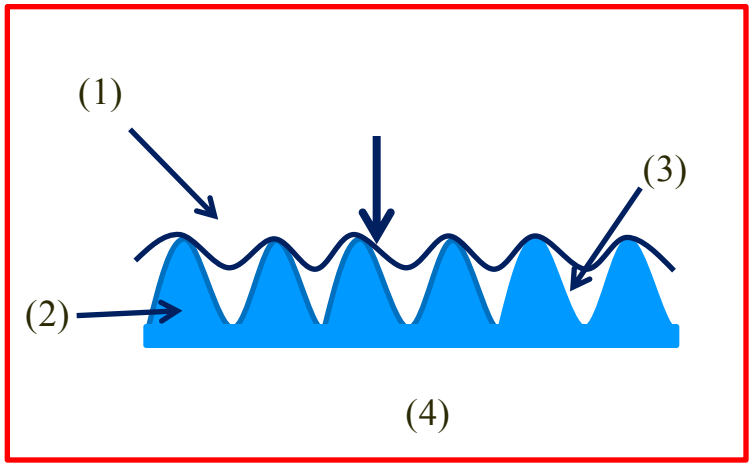
- Microstructure
- Geometry

Operational

- Kinetics
- Kinematics
- Duration

Interaction

- Contact mode
- Friction contributors (adhesion, hysteresis)

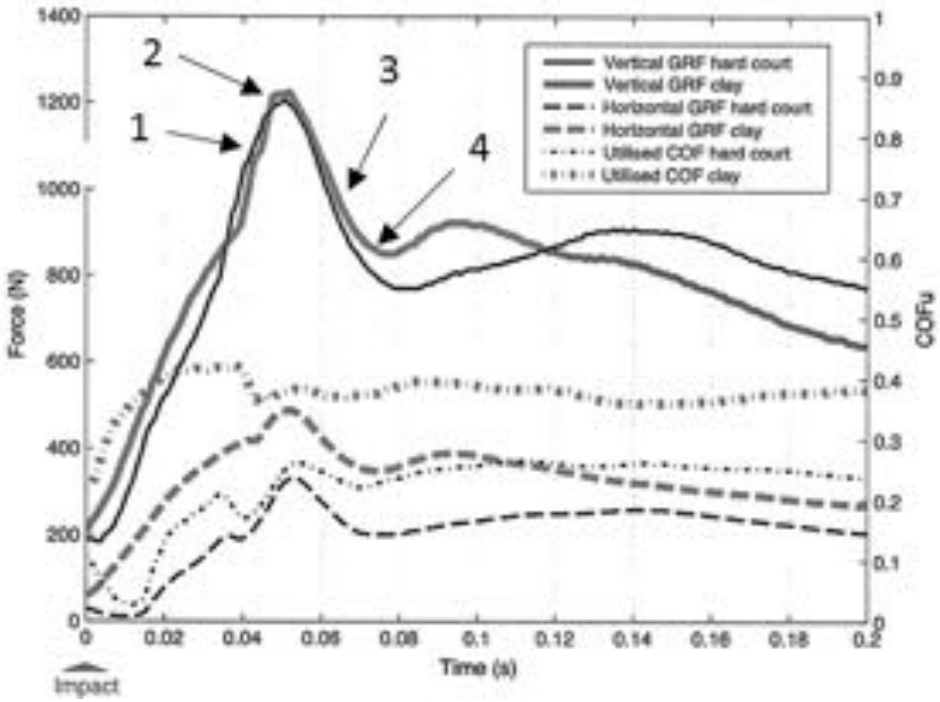


1 & 2 – Material pair
3 – Lubrication
4 – Environment

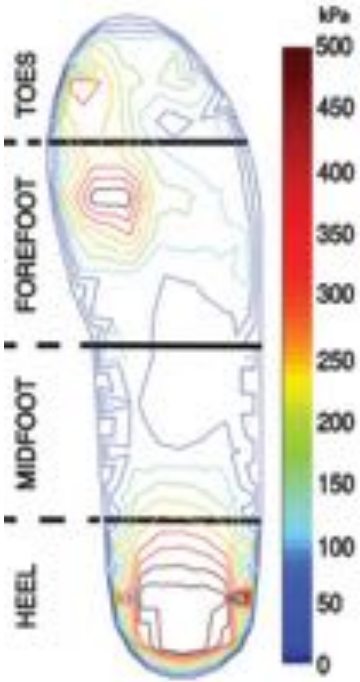
Friction

Wear

Biomechanical data



Damm et al. (2013)



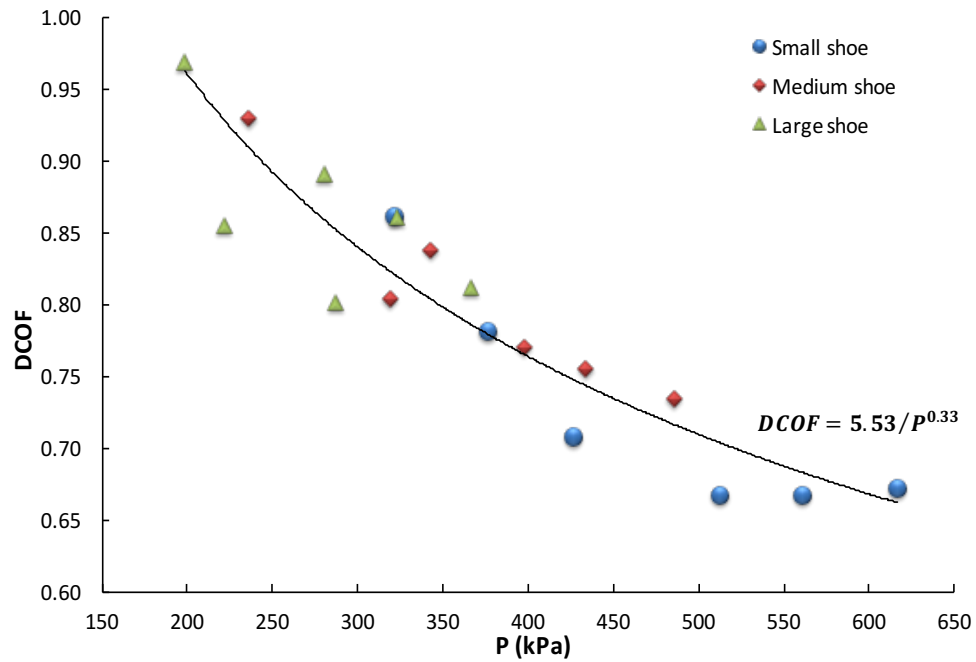
In-sole peak pressures:400 – 520 kPa

Damm et al. (2014) &
Girard et al. (2007)

Tribological Mechanisms

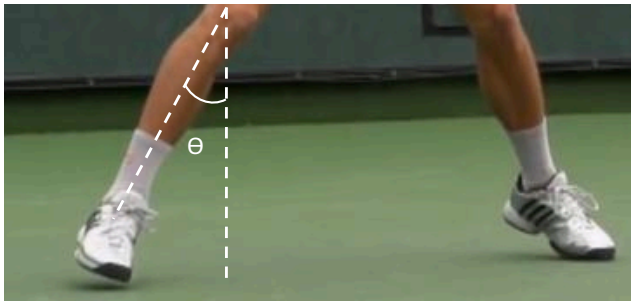
Effect on shoe-surface friction:

- Normal load.
- Shoe orientation.
- Surface roughness.
- Shoe outsole temperature.
- Contact area and pressure.

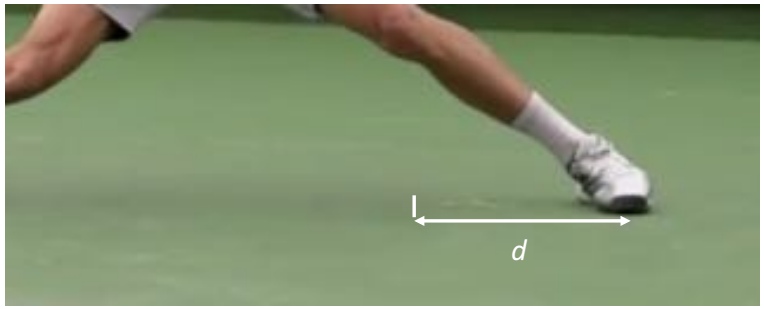


Development - parameters

Two movements:



Landing

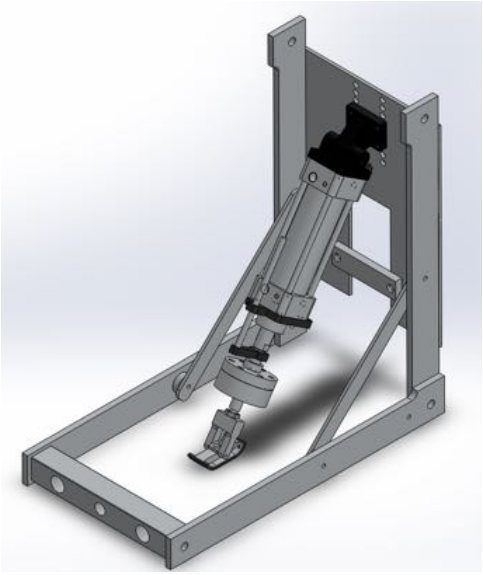


Sliding

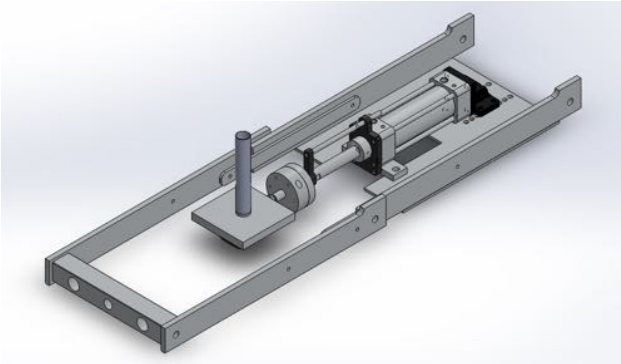
- Match in-sole peak pressures (250 kPa – 500 kPa)
- Light and portable
- Ability to vary shoe orientation.
- Standard test shoe

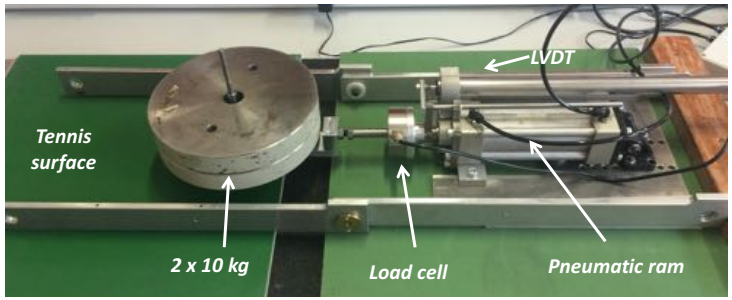
Development - prototype

Angled-ram

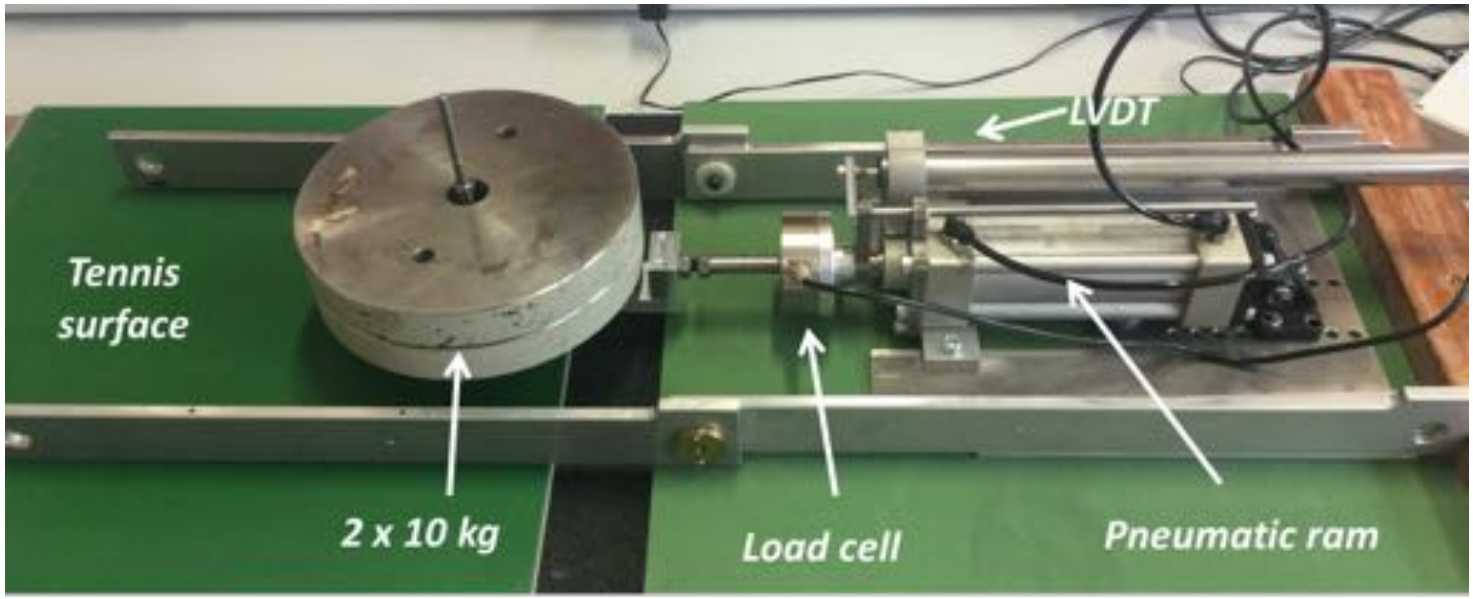


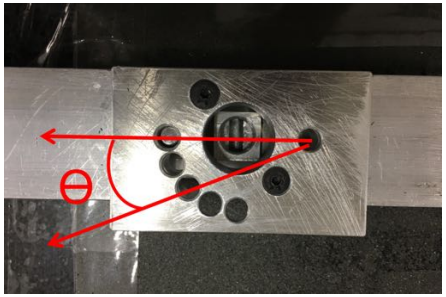
Sled

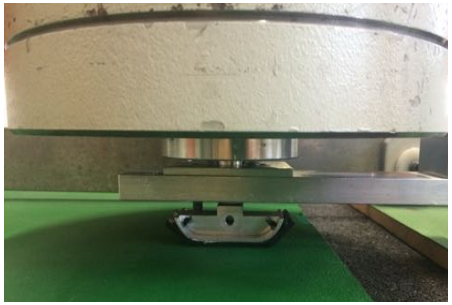




Development - prototype

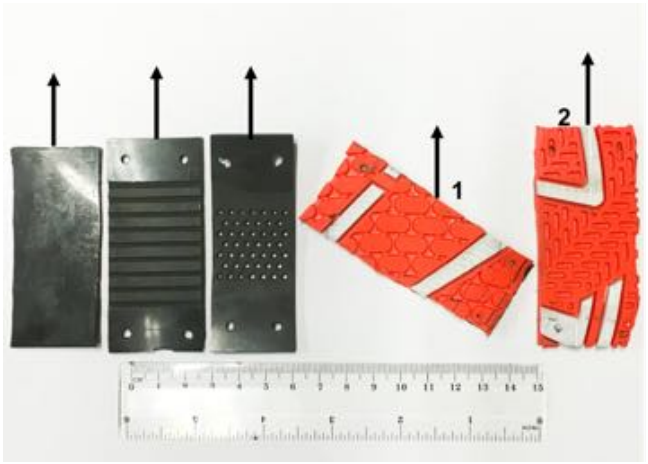


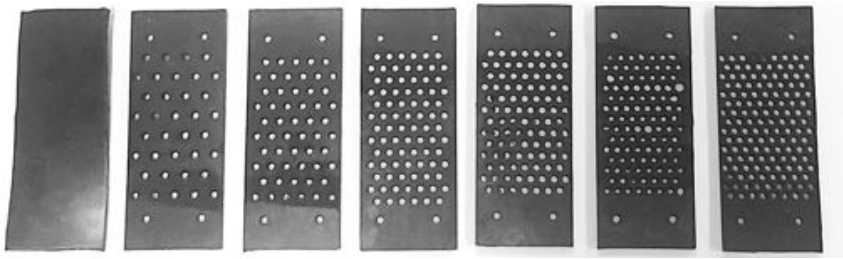


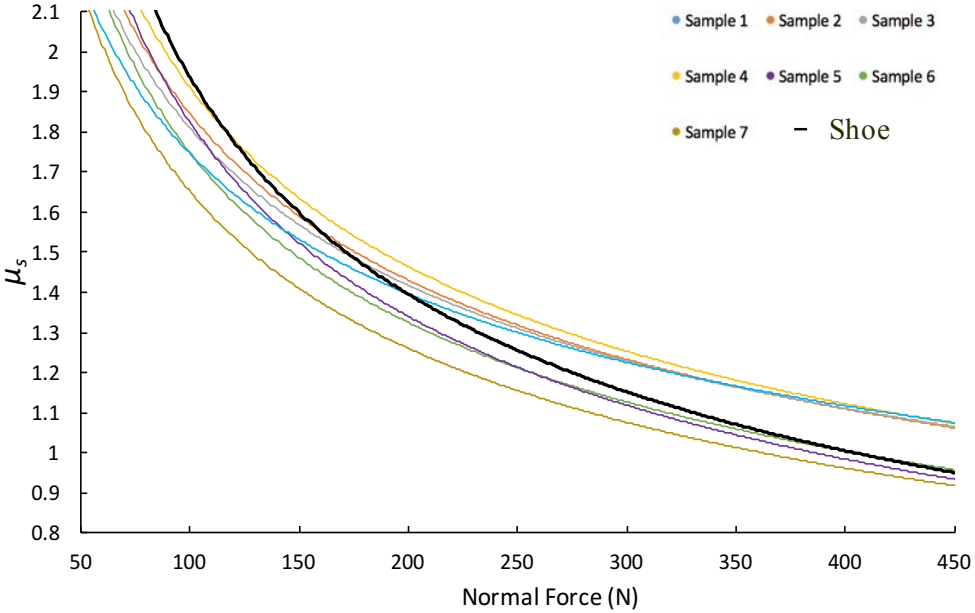


Development – Test shoe

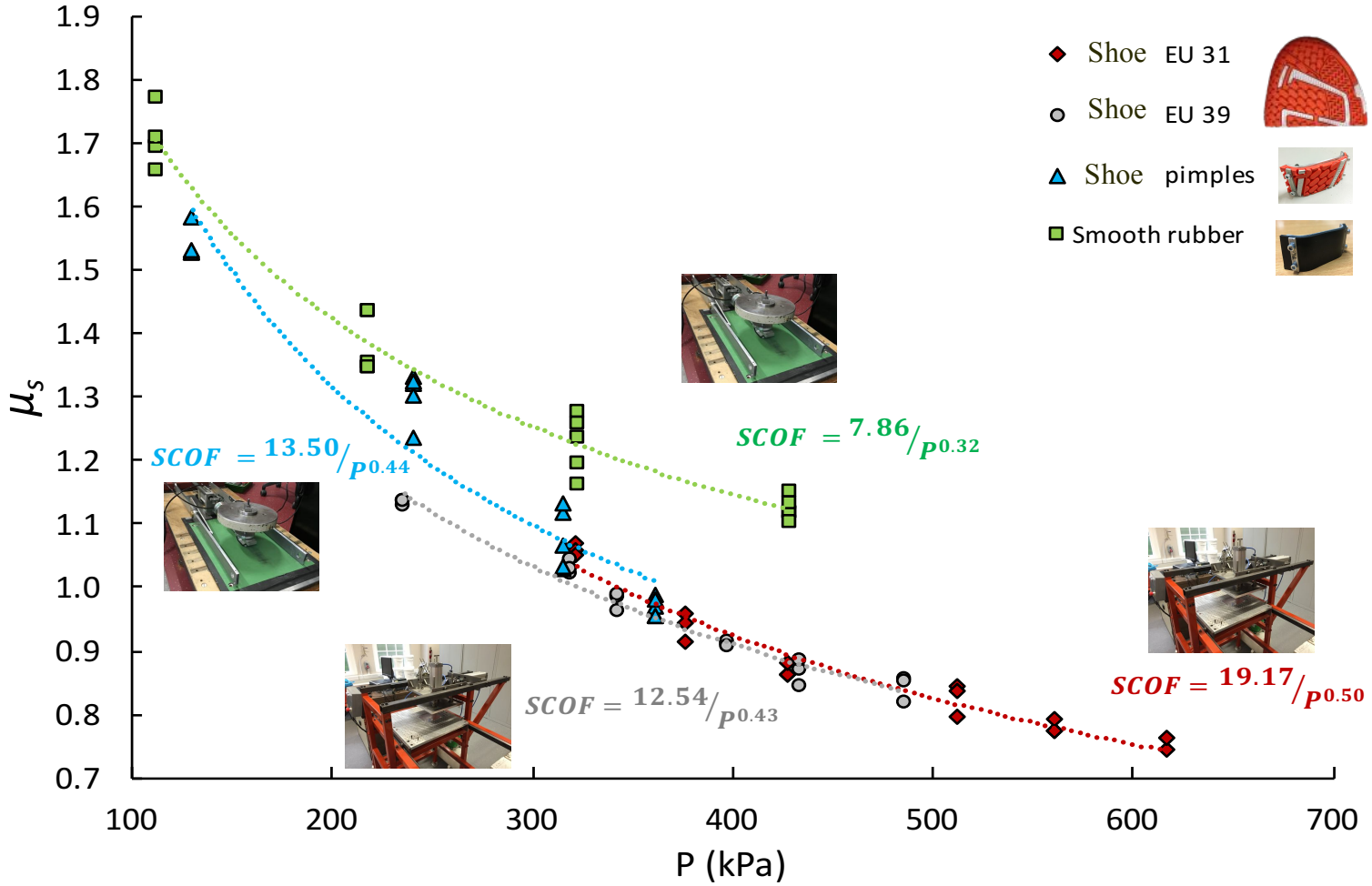
- Material characterisation.
- Tread analysis.







First validation - Sled



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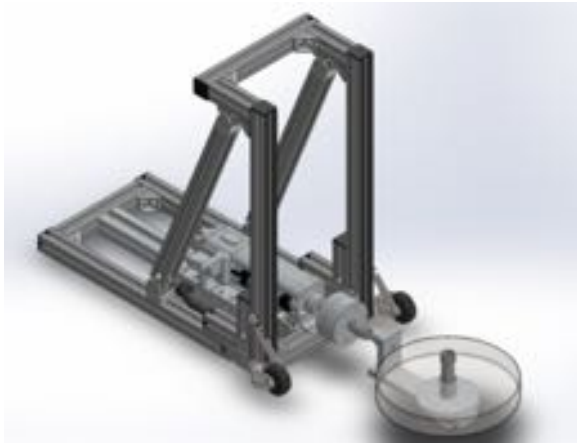
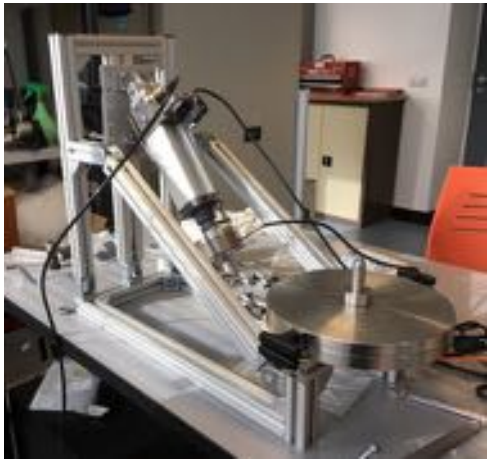
Development – Final device





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Acknowledgements

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adidas

Babolat

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Jamie Booth (UoS)

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