Measurement of ‘Skin-Surface Friction and Abrasion’

An overview of recent research and future needs

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Talk Contents

- How big is the problem? Injury & Perception Data
- Mechanical Test Methods
- LU work evaluating the Securisport (& modified)
- Implications, Limitations and Recommendations

How Big is the Problem?

Medical ‘Injury’ Data. Issue of the **Definition** - time loss or treatment/attention. Burns and Abrasions under-reported..?

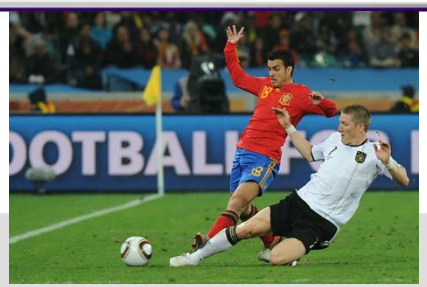
Many definitions of ‘abrasion’: Contusion, haematoma, graze, scrape, (turf) burn, erythema, exudation, laceration etc..

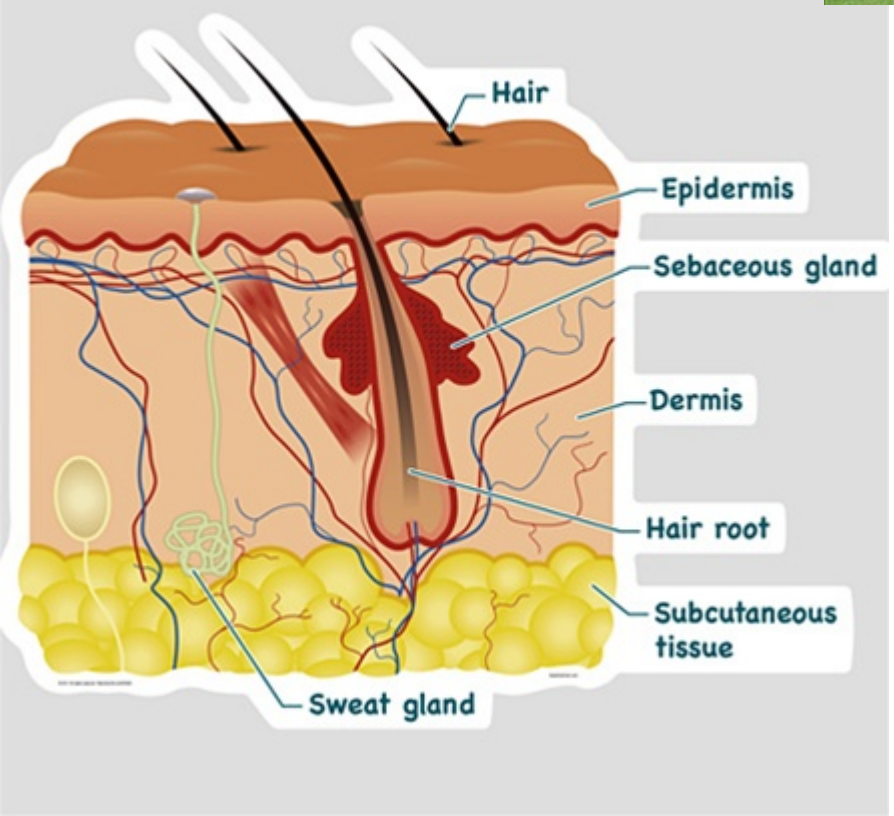
Player ‘Perception’ opinions generally negative re 3G skin friendliness

Not an emerging medical issue, but a ‘barrier’ and influences the game ‘style’?

Authors & Year	Surfaces/Sport Played	Sport/Level	Injury Definition	Abrasion Injury Rates
RPL – PRISP (2015, 2016 RFU/RPL/PRA)	Natural Grass & 3G	Premiership Rugby Union	Not defined	13-14 Season: approx. 8 times higher skin abrasions...119/1000hrs Natural v 15/1000hrs 3G (Only 2 were time loss) 14-15 Season, no difference in time loss or non-time loss
Van den Eijnde et al. 2014	Natural grass and 3G artificial turf.	Association football – amateur.	Not reported.	Developed an index to score skin damage from sliding on artificial turf. Based on abrasion, erythema and type of exudation.
Almutawa et al., (2014)	Natural grass and 3G	Professional association football.	Medical Attention.	Nature of skin injuries were collapsed, so includes lacerations 9.7% of all injuries on 3G artificial turf (3.7per 1000h) and 9.8% on natural grass (5.4 per 1000h).
Peppleman et al.,2013	Natural grass and 3G.	Association football – amateur.	Not reported.	Natural grass resulted in more erythema but less abrasions compared to artificial turf.
Ekstrand et al., (2011)	Natural grass and 3G	Professional association football.	Time loss.	Matches: 1.8% on artificial turf (0.06 per 1000h) 2.1% on natural grass (0.07 per 1000h) Training: 3.6% on artificial turf (0.81 per 1000h) 1.7% on natural grass (0.37 per 1000h)
Fuller et al., (2010)	Natural grass and 3G	Rugby Union – division 1.	Time loss.	Skin injuries accounted for 3.8% of all injuries on artificial turf and 3.6% on natural grass.
Soligard et al., (2010)	Natural grass and 3G artificial turf.	Association football – amateur.	Medical attention.	Abrasion injuries accounted for 2.4% (0.8 per 1000h) on artificial turf compared to 2.5% (1.0 per 1000h) on natural grass.
Hinton et al., (2005)	Natural grass and 3G	Lacrosse - amateur	Medical attention.	Abrasions accounted for 19.3% of all injuries on artificial turf and 0.5% on natural grass.

Skin damage…complex mechanisms

Very interesting work coming from Peppelman, van den Eijnde (PhD) on ‘player assessment’, rating skin damage, and finding new surrogates….

Player Perceptions of 'abrasion'

Authors & Year	Surfaces	Sport/Level	Perceptions re abrasion injuries
Burillo et al, 2014	Natural grass and 3G Turf 50-60mm pile. 3.9 years old.	Association football: 627 male subjects; 404 players, 101 coaches and 122 referees.	Skin abrasions were ranked as the biggest disadvantage 33.2%; 39.2% players, 19.8% coaches, 23% referees.
Roberts et al., (2014)	Condition of field or details were not recorded.	Professional association football:1129 players across 43 countries.	Over 60% felt that artificial turf fields were more abrasive
Felipe et al., (2013)	Natural grass and 3G Turf – no details.	Professional association football: 32 players and 25 coaches.	One of the main disadvantages was abrasion injuries from tackles.
Zanetti (2009)	Eight approved 3G artificial turf fields, 3 with SBR and 3 TPE infills.	Amateur association football: 1671 male players aged 15 - 35	Abrasion was the only factor judged to be worse on 3G than, plus type of infill, weather, & playing position influenced outcomes.
Fleming et al,. (2005)	Water based artificial turf	Hockey: 22 premier and first division players.	Player felt that drier pitches were more abrasive and unpleasant to fall on.

Mechanical Testing Methods

Official Tests

1. ‘Securisport’ (FIFA test 08) – determination of skin-surface friction (WR, RFL, AFL, GAA)

2. ASTM F1015-09 Relative Abrasiveness of Synthetic Turf

(related to ‘wear’ of a friable foam block, 89N manually pulled)

<u>Notable Publications/Research Projects on Mechanical Testing</u>

Sock et al, 2015/2016 Securisport and effect of infills (+ roughness)

Lenehan et al., 2015 Modified ‘linear’ tester & securisport

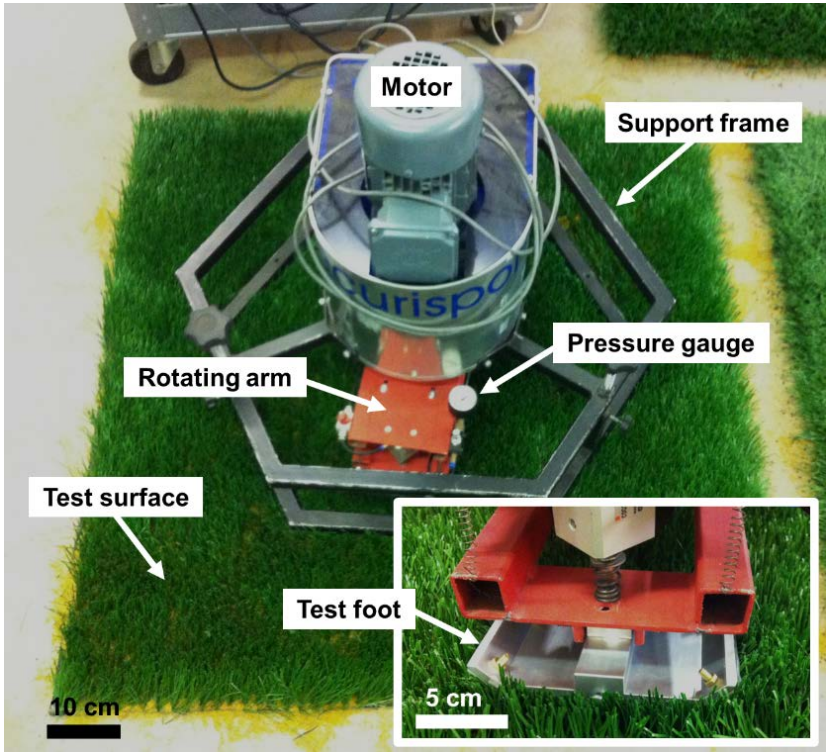
Ingham, 2013 Master’s thesis, Player sliding study (indirect securisport)

Sanchis et al, 2008 modified linear test & user forearm ‘perception’

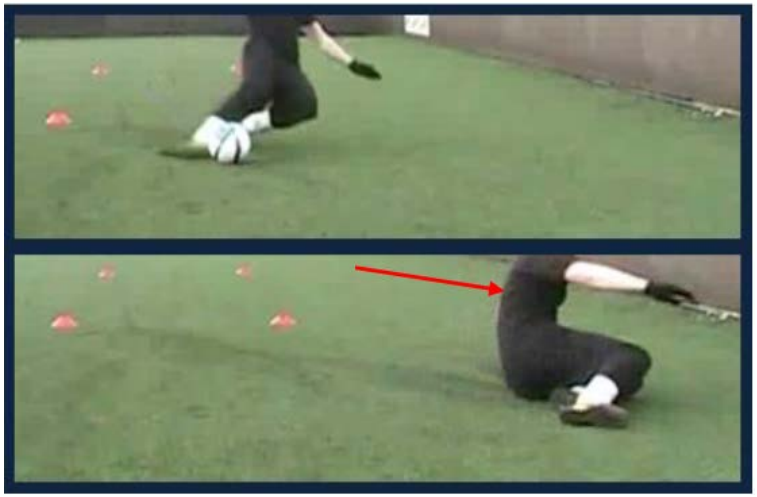
Verhelst 2007 & 2009, sliding tester (+ ‘skin’ temperature changes)

Industry Standard: FIFA-08

- Skin surface friction value between 0.35 – 0.75
- Skin abrasion value of ±30% (indirectly assessed)
- Criticised for lack of biofidelity
- Rotational movement
- Low constant speed (40rpm), 0.85m/s
- Low normal load (100 N)
- Silicon ‘Skin’ L7350 Maag Technic AG



Alternative Methods & Limitations



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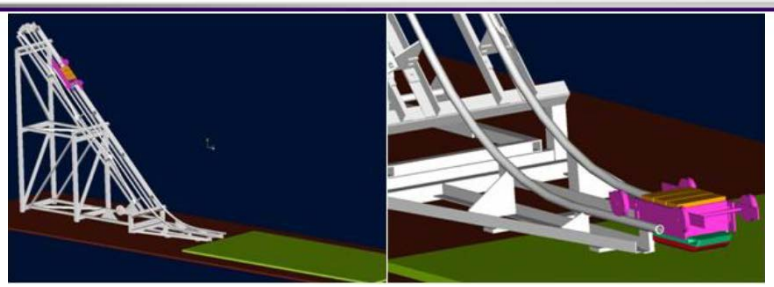

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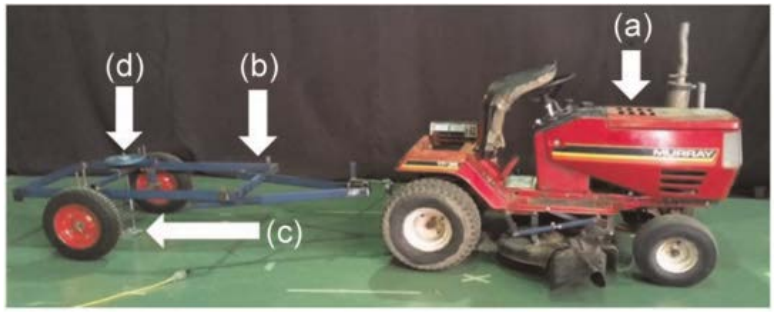

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- Ethical considerations: participants subjected to injury
- Large elaborate set-ups, unsuitable for use as industry standard
- Unjustified parameters used (normal loads and speeds)
- **Lack of knowledge on biomechanics of sliding motion**
- **Complexity of multiple-component AT surface**

[1]Ingham, C. 2013; MEng Sports Engineering Thesis, University of Strathclyde
[2]Int. Conf. Lat. Adv. High-Tech Texti. 2009; 90-95
[3]Proc. Inst. Mech. Eng. P J. Sports Eng. Technol. 2015; Tech. Note: 1-5

LU work Sock Peng – PhD (Securisport)

Aims

Contribute to the understanding of skin-turf interaction

Develop skin-friendly surfaces through materials engineering

Objectives

Study the effect of turf components on the overall AT friction

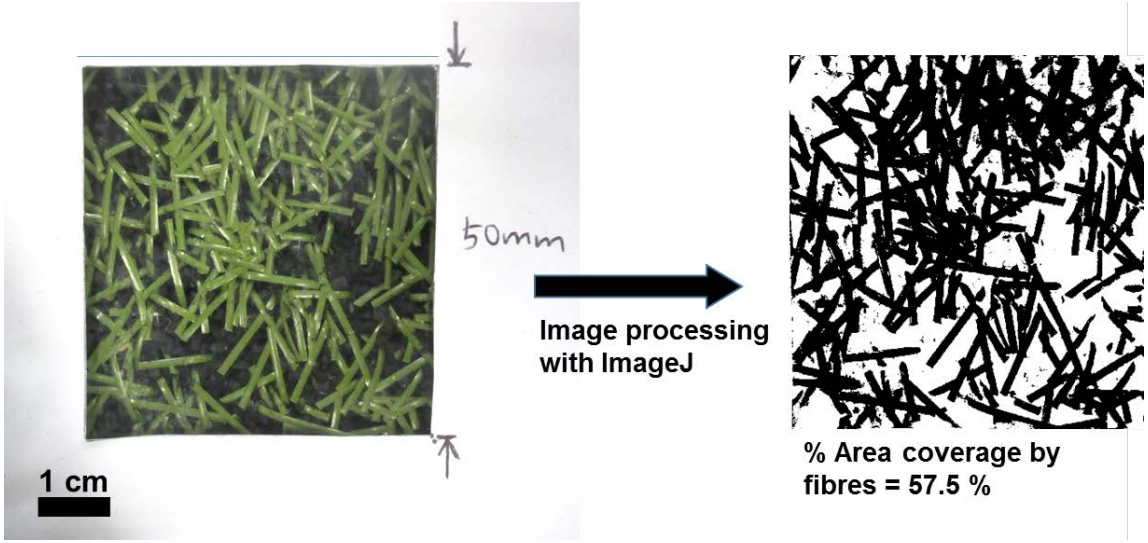
Critique available industry standards for AT skin-friction assessment

Employing strategy of material modification for improving skin-friendliness

Design appropriate bench-top assessment for product-skin friction measurement

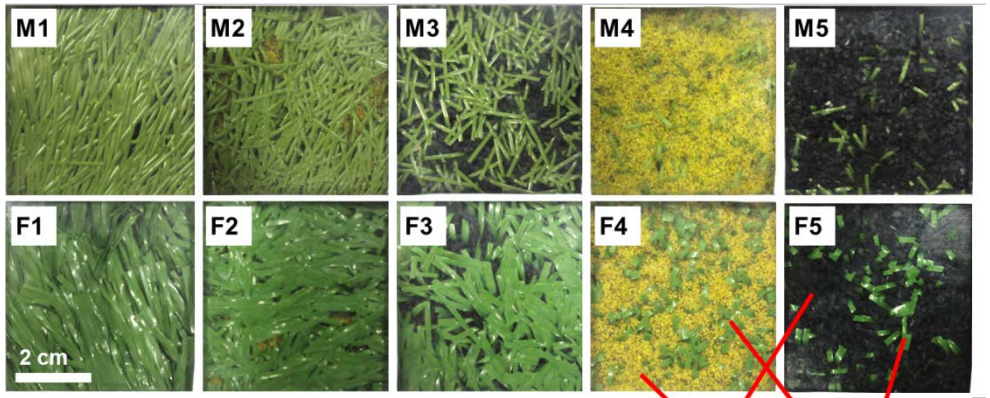
Securisport: Effect of Fibres and Infills

- **Hypothesis**: Friction between skin and AT is largely influenced by the carpet fibres
- **Objective**: To investigate the effect of various turf components on the overall frictional behavior of the AT surface
- Two carpets – Monofilament and Fibrillated
- Varying infill depths for sand and rubber
  - 20mm & 5mm free pile height

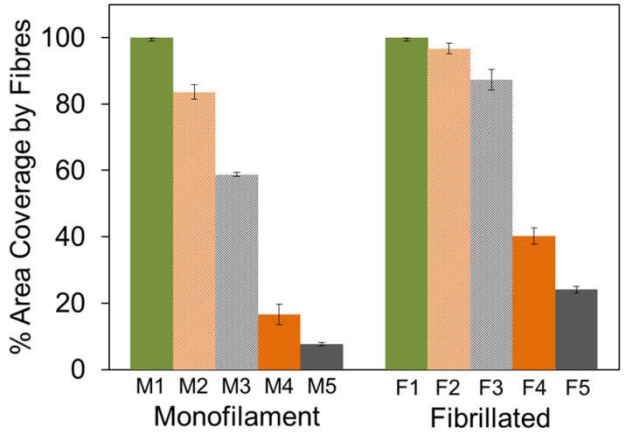


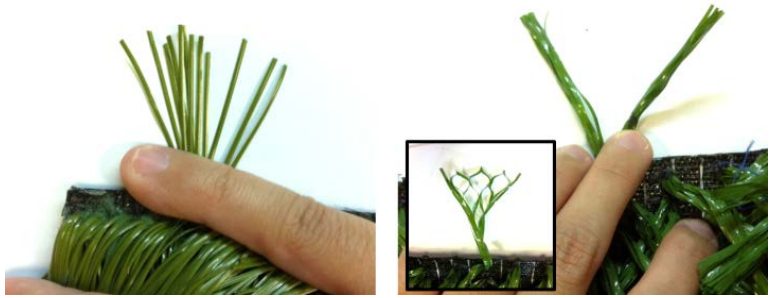
Test Methodology

No infill	Sand, 20mm FPH	SBR, 20mm FPH	Sand, 5mm FPH	SBR, 5mm FPH



Infill Free-pile





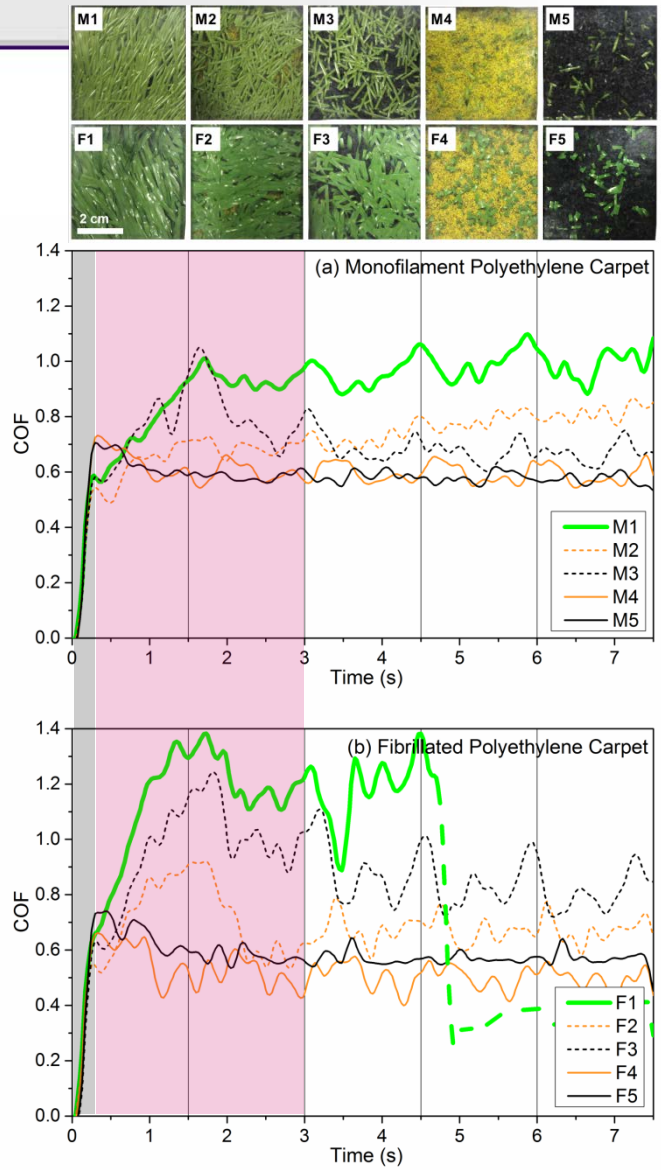
Securisport used in accordance to FIFA-08 guidelines (5 rotations)

Instead of single average COF value, <u>frictional profile against time was analysed</u>

<u>Surface Roughness</u> of 'skin' was measured, instead of abrasion %

'Abrasion' = 100 x [Fnewskin - Fabraded skin] / Fnew skin)

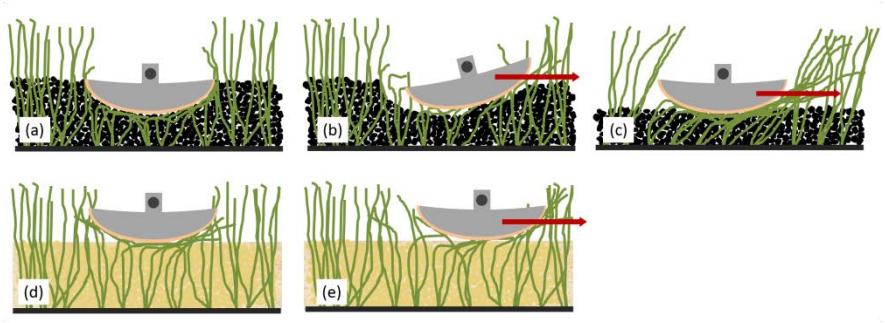
Results - Friction



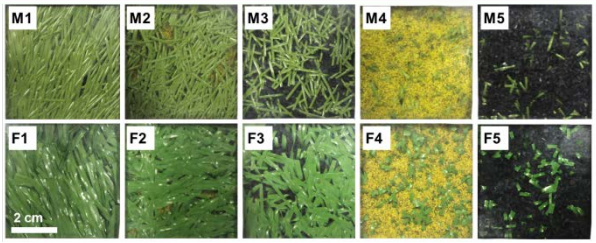
- COF profile:

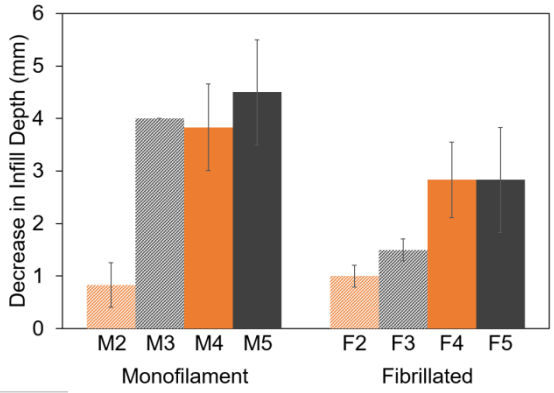
< 0.3 s	= Static friction
0.3 – 3.0 s	= Surface-specific behaviour
> 3.0 s	= Oscillates about steady-state value

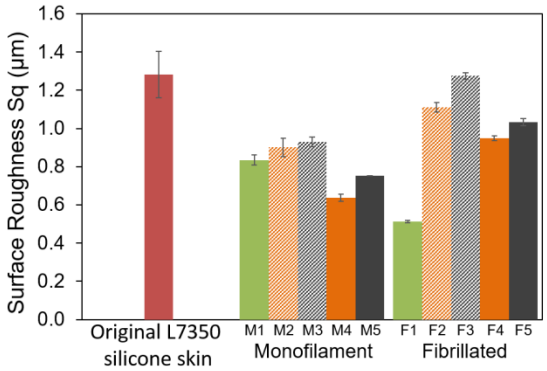
- Highest friction measured on F1 (Fib. Carpet only)
- COF of **partially-filled > fully-filled** surfaces
- COF of **Fibr surfaces > Monof surfaces**
- Almost identical profiles for fully-filled surfaces
- **Larger exposure of fibre length ⇔ Higher measured COF**



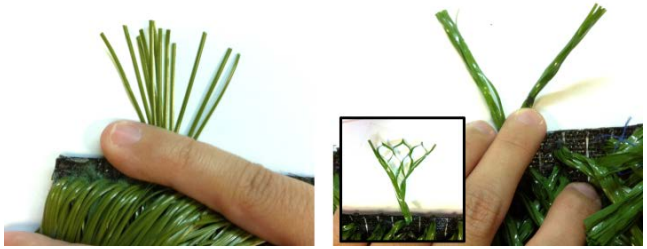
Results – Skin Damage (Abrasion)

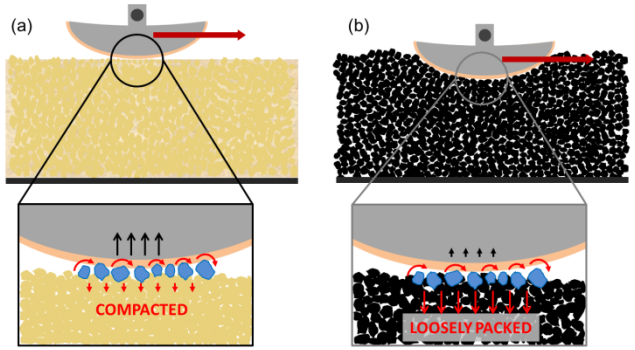






- Decrease in infill depth of **SBR > Sand**
- <u>Changes</u> in surface roughness for 'skin':
  - Carpet-only: **Fibrillated > Monofilament**
  - Filled: **Monofilament > Fibrillated**
  - **Fully-filled > Partially-filled**
  - **Sand > SBR**

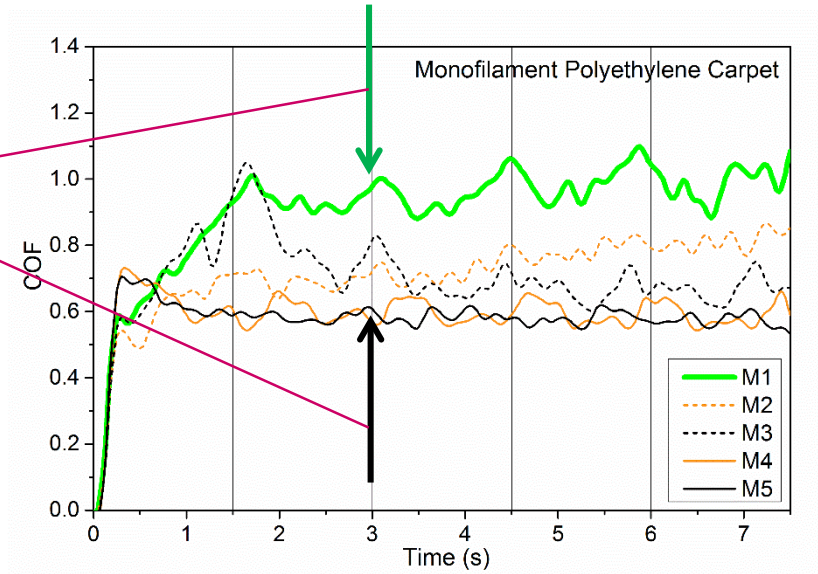




Evaluation of FIFA-08 Securisport

- COF profile provides **insights** to the **CHANGES** in friction across a trial of 5 rotations
  - Reporting an average COF value masks this information
- Original "Skin Abrasion" measurements involve large variance and errors
  - **Direct measurement** is more suitable (i.e. surface roughness)
- 'Skin' surface property **changes continuously** throughout the trial
  - Unable to provide conclusive results on both friction and abrasion simultaneously

Condition of 'skin' samples different



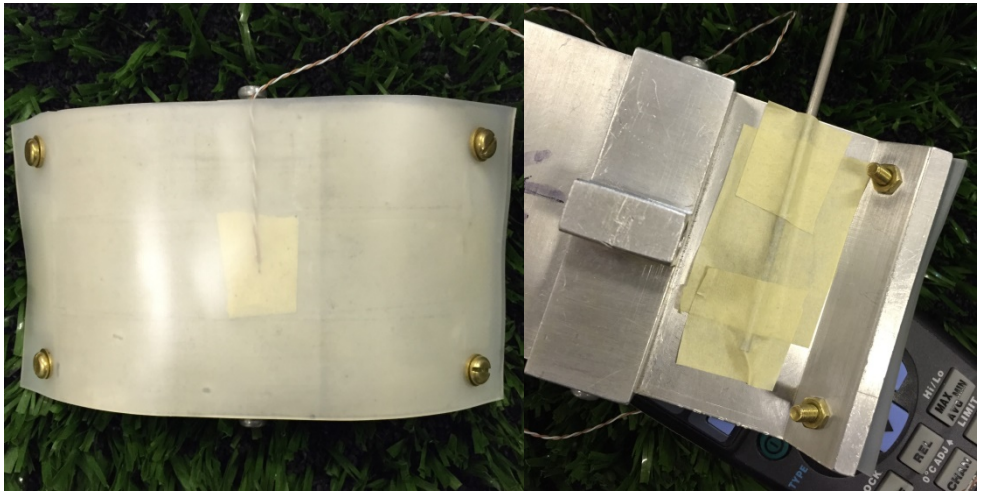
Securisport and Temperature

Monofilament and Fibrillated 60mm carpets

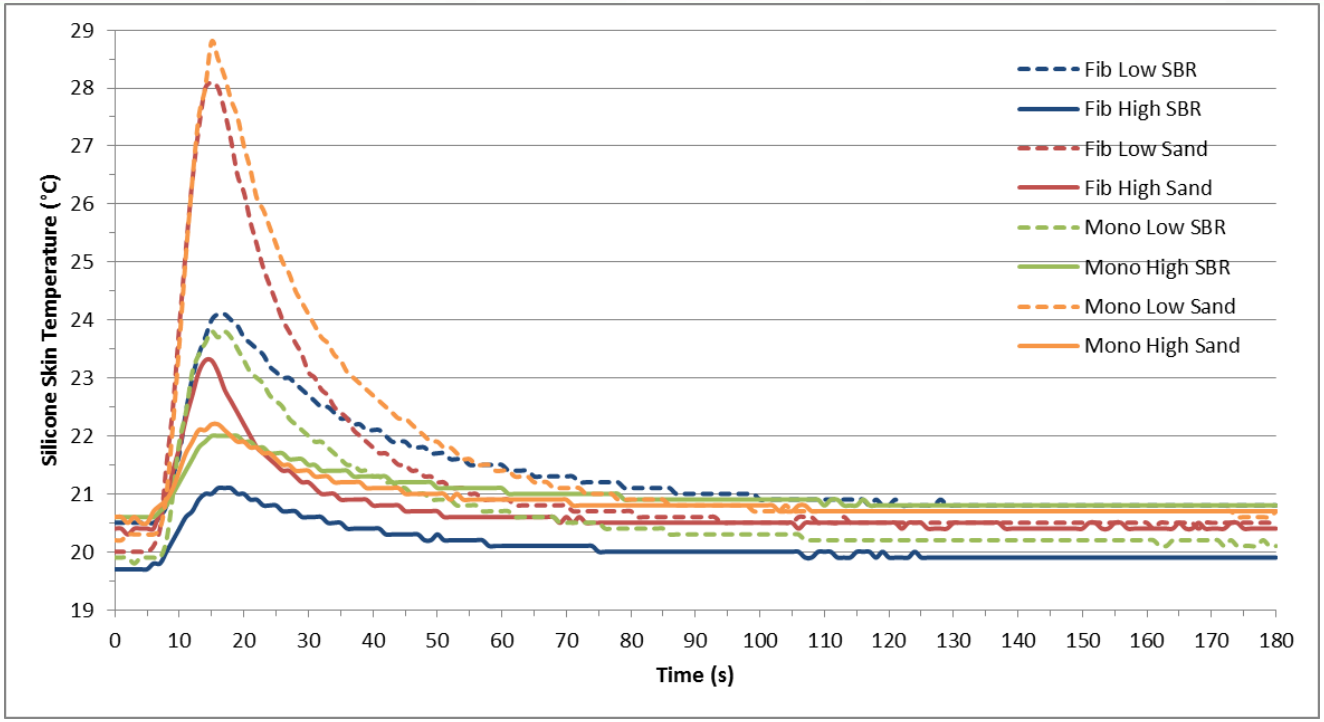
Low sand or rubber – 30mm

High sand or rubber – 50mm (~5mm FPH)

Two thermocouples were connected to a YC-747U Data Logger Thermometer which measured and recorded temperature at a rate of once every second (1Hz). The data logger was securely attached to the rotating arm of the Securisport



Securisport – instrumented for temperature



More FPH = more temp rise (higher CoF); Sand infill > rubber infill; Mono ~ Fibr.

SBR takes longer to cool than sand, lower thermal conductivity…?

Thermal conductivity (steady state conditions) W/(m K), example values

Rubber (nat) 0.13; Air 0.024; Dry sand 0.25, Polyethylene (low density) 0.33.

Some Conclusions

Ideally looking to evaluate differences in the 'surface system' friction & abrasion behaviour

- **In the Securisport test the silicone skin wears during the test, and gets <u>smoother</u> – changes the interface COF**
- **More fibre (more FPH) gave higher CoF, but lower 'abrasion'**
  - **more infill = more abrasion, sand > rubber**
- **COF ≠ Abrasion (from roughness change)**
- **Circular motion creates cumulative effects reworking same area of carpet…displaces infill, flattens fibres ?**

<u>Previous work</u> - Fibre type/compound affects temperature rise during sliding (Verhelst 2007/9), adding water reduced the temperature rise.

The yarn compound affects the CoF and abraded roughness of the skin (Sanchis 2008). For infilled systems increasing depth of infill caused an increase in abrasion (%) (Lenehan 2015).

Implications?

- Securisport is not ideal for qualifying skin-friction and abrasiveness of Artificial Turfs
- Other research has suggested linear motion is ‘better’
- Initial velocity and deceleration better..?
  - Fixed energy or fixed velocity/path profile?
  - Verhelst fixed energy (sledge fall height) – measured temperature rise & sliding distance
    - No relationship between temp rise, CoF and slide distance
    - Water reduced temperature rise
    - Nat turf gave lowest temperature rise
- Bibby 2016 - simple temp. measurements on the Securisport skin, gave useful additional insight into thermal behaviour and correlated with CoF (Peng 2015/16)

Knowledge limitations…many!

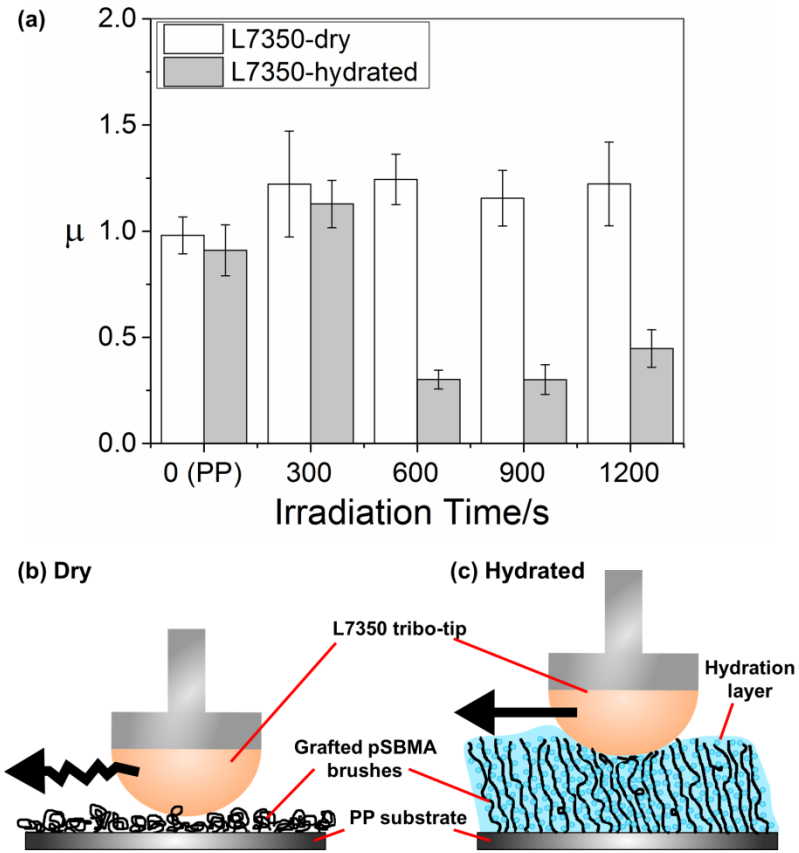
- Need appropriate input values for human movement to better critically appraise test design for biofidelity
- Need better understanding of injury mechanisms to evaluate/design test outcomes (& perceptions)
- Parameters – CoF, abrasion (damage), temperature etc.?
- Need an ‘effective’ skin substitute. Real skin properties not known for design of suitable substitute? Eijnde/Peppelman/Carre et al. + ??
- Little known on contribution of AT system components, complex interaction mechanisms? (Macro-micro)
- As yet not fully clear how best to measure likely ‘wear’/damage/abrasion, but we suggest direct ‘roughness approach useful’.
- Also need **more detailed reporting** of testing methods and turf system details from research programmes (all previous papers lacking!).

Some Recommendations

- Full scientific multidisciplinary research programme needed to answer all the many questions!
- Choice of interface ‘skin’ important – perhaps depends on level of sophistication required..?
- Test rig – linear motion, appropriate maximum velocity and change in velocity over a fixed distance. Static normal force (0.X BW), area (knee/thigh?) etc.
- Instrumented to measure resistance (Fh), skin ‘wear’ (level of sophistication?), interface temperature change, v time/path
- Questions…
- Industry: How useful has the Securisport test been? Are many artificial turf systems likely to be very similar…?
- Should natural turf be studied further as part of initial work?

Thank you - Questions?

Part 2: Modified Frictional Properties



- **Bench-top** tribological study instead of *in vivo* testing
  - Friction assessment using 'skin'
- Assessment under **ambient** conditions
- **Consistently high** frictional values for dry samples
- **Significant decrease** in friction for highly-modified surfaces
- Largest reduction in friction due to hydration = 78.8%
- Scalable, with module integration into existing production line

Notes

If it is postulated that human skin burns caused by sliding are affected by the heat generated at the interface then clearly temperature rise on the ‘skin’ is a useful and possibly important factor, possibly more important than the (average) system CoF.

It also may be postulated that in the Sanchis work the system CoF behaviour is observed to be different as the contact path is short relative to the other tests (0.4m versus 4-6m, Securisport travels a circular path average 0.2m radius hence = 1.22m per rev, 5 revolutions = approximately 6m, Lenehan’s method had a fixed traverse of 4m).

This might further suggest that a fixed velocity (and ideally deceleration) over a controlled contact ‘path’ length may be most suitable to directly compare friction and abrasion of different surfaces – even if this does not perhaps replicate real human sliding based on an initial velocity and energy.

Verhelst’s work (utilising temperature changes) showed that to measure a ‘worst case’ scenario (or upper part of the envelope) the velocity, mass and slide distance are all important factors for the test design.

Eijnde et al – temperature not key? But is for work done..??

Need to measure resistance (CoF), and temperature..??