Computational modelling of the Athlete/Surface Interface

and

the understanding of surface-related injury

Colin Walker

University of Strathclyde,

Glasgow, UK.

Outline of presentation

- Surface-related injuries
- Computational models
- What do we do with the results?
- Where do we go next?

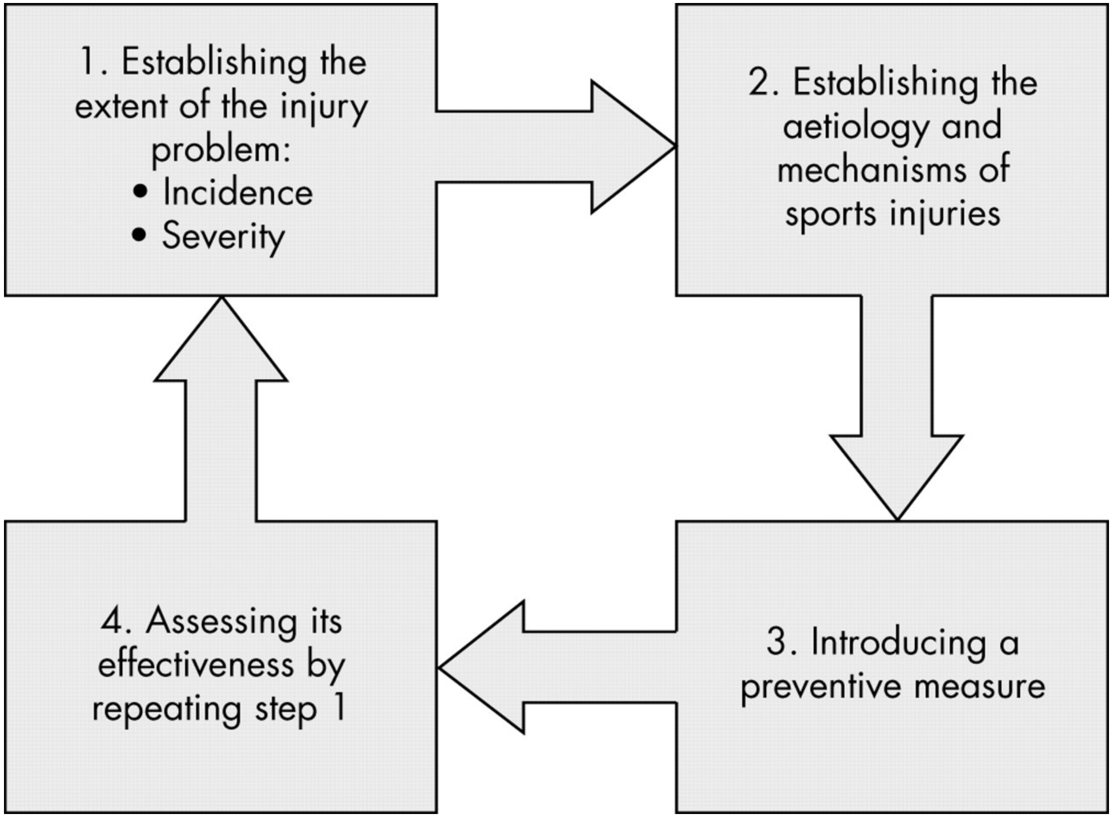
Contact injuries are not part of the brief for this review

The Athlete/surface interaction is not easy to define.

Note:- foot placement, rotation of the leg, direction of thrust.

Four step sequence for injury prevention research

(Bahr & Krosshaug 2005)



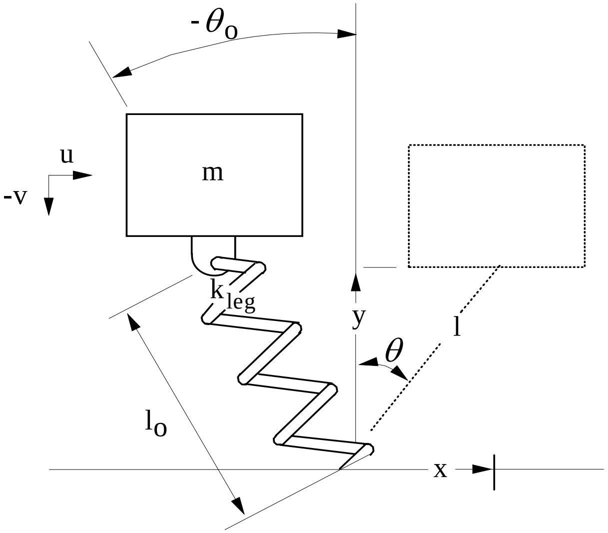
1. Establishing the extent of the injury problem:
   - Incidence
   - Severity
2. Establishing the aetiology and mechanisms of sports injuries
3. Introducing a preventive measure
4. Assessing its effectiveness by repeating step 1

Surface-related injury

- Surface-related injury encompasses all injury not associated with player impact .
- We include: wear-and-tear from running on tarmac, from twisting, from joint instability, shin splints, joint damage, tendon rupture, muscle tears.
- In fact, there are few detailed statistics as to what proportion of total injuries relate to surface effects.

Achilles tendon rupture – common, but not really surface-related

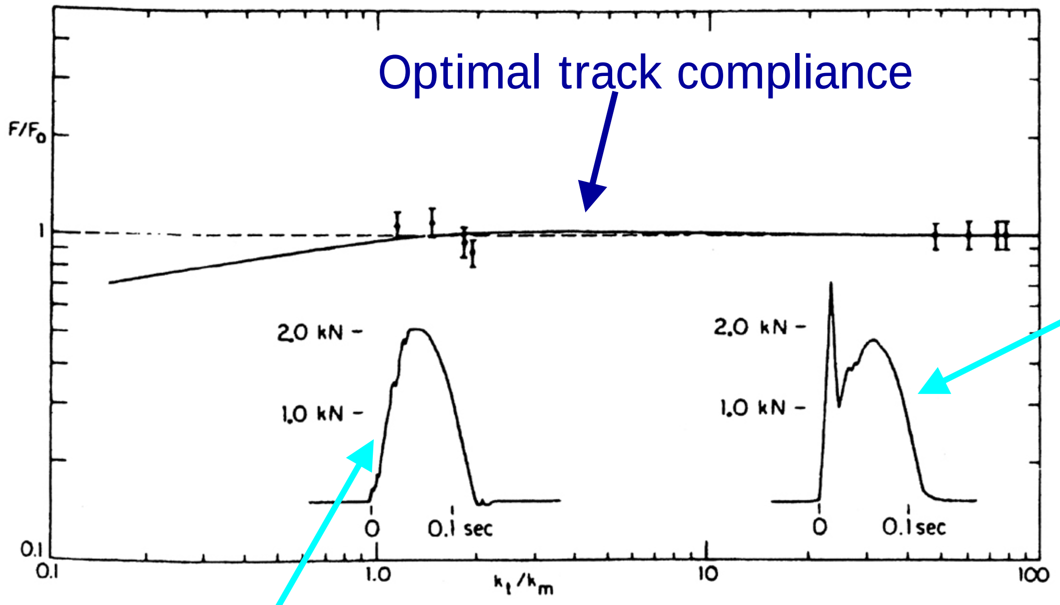
Computational models - 1



Schematic of the McMahon/Greene running leg model

This model can be used to investigate the ground force reaction as a function of the track compliance – the ground is modelled as a simple spring.

Ground reaction force as a function of track stiffness



Optimal track compliance

At high track stiffness, the grf shows an impact peak

At an intermediate track stiffness, the impact peak does not appear.

(McMahon & Greene, 1979)

Conclusion from this simple model

- Underfoot compliance of the order of 100-200kN/m can reduce the impact peak at heelstrike.
- This model does not imply the mechanism behind this effect – it is purely a mechanical response.
- The question arises – can one design shoes that will achieve this desirable result? – so far the answer is “no”. (with current materials, it implies that the heels would need to be at least 50mm high).

More complex spring/damper model (Voloshin et al, 1994)

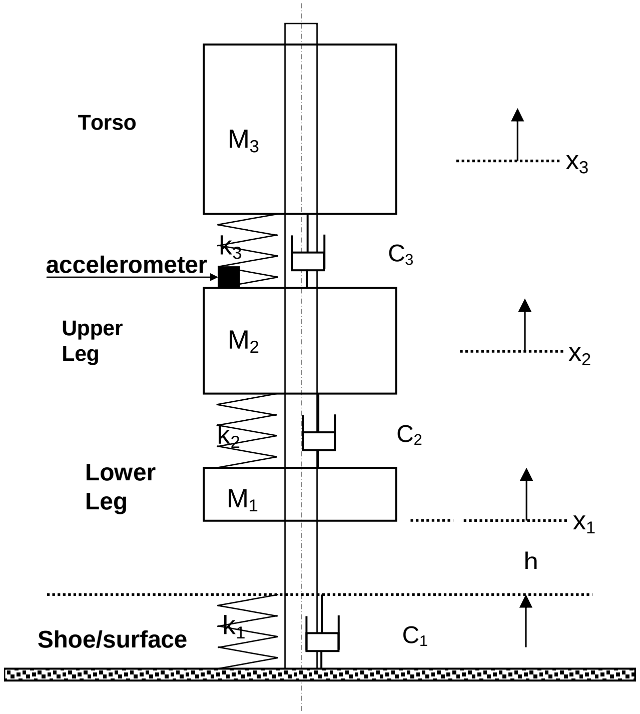


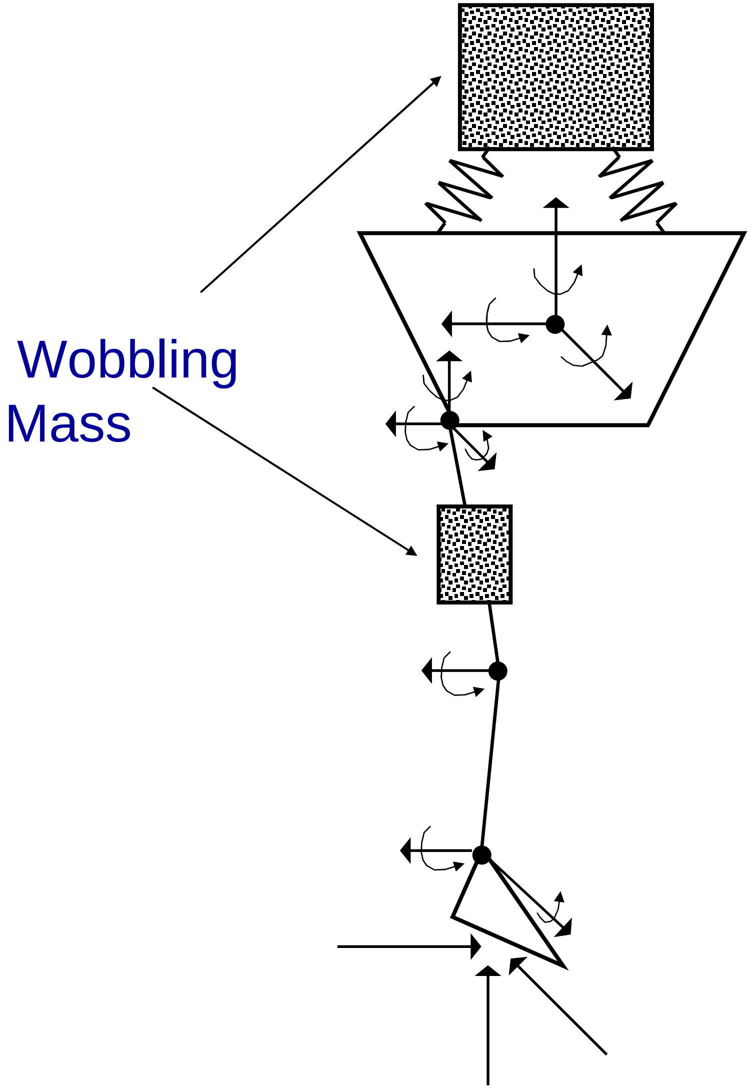
Figure 5a

Three Component Model for heelstrike transients
(Voloshin & Kim, 1994)

The results from this model were checked against a physical analogue that was dropped onto a solid surface.

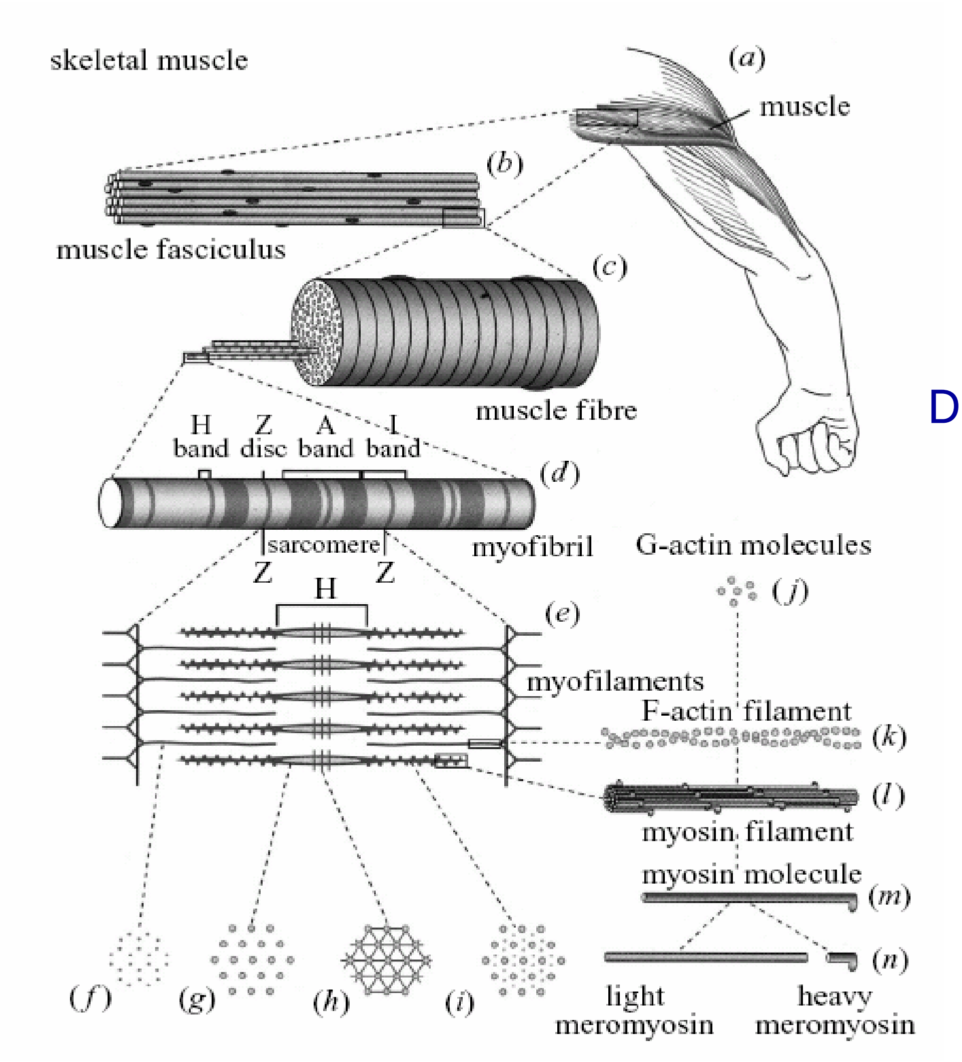
- It was found that within the chosen limits of the parameters, it was possible to reduce the impact peak by using a high damping material for the “surface”.
- This is a significant finding, but no shoe has a sufficient level of damping to achieve the effect.
- Surfaces such as natural turf and 3G artificial pitches *do* have high enough damping to eliminate the impact peak.

In general, movement is complex, 3-dimensional and spontaneous



Model to analyse the knee loading resulting from a sidestepping manoeuvre – 16 muscles - 12 defining parameters per muscle.

(McLean et al 2003)

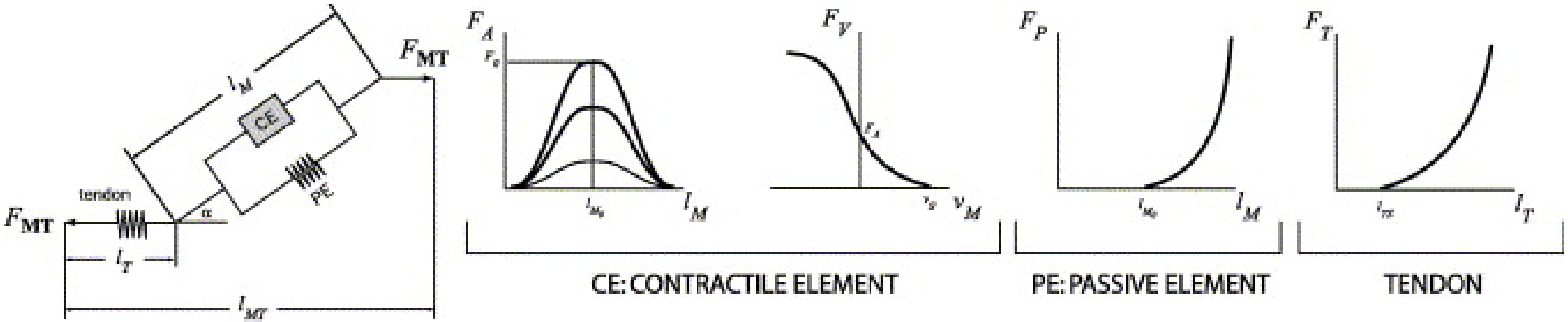


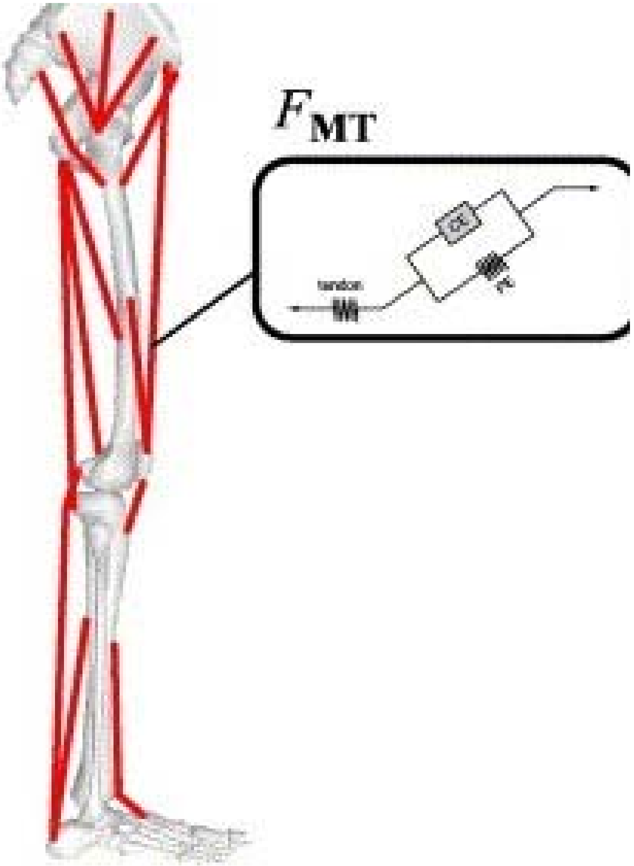
Detailed structure of muscle

(Epstein & Herzog 2003)

Muscle properties

- Each muscle represented by a three – term Hill model

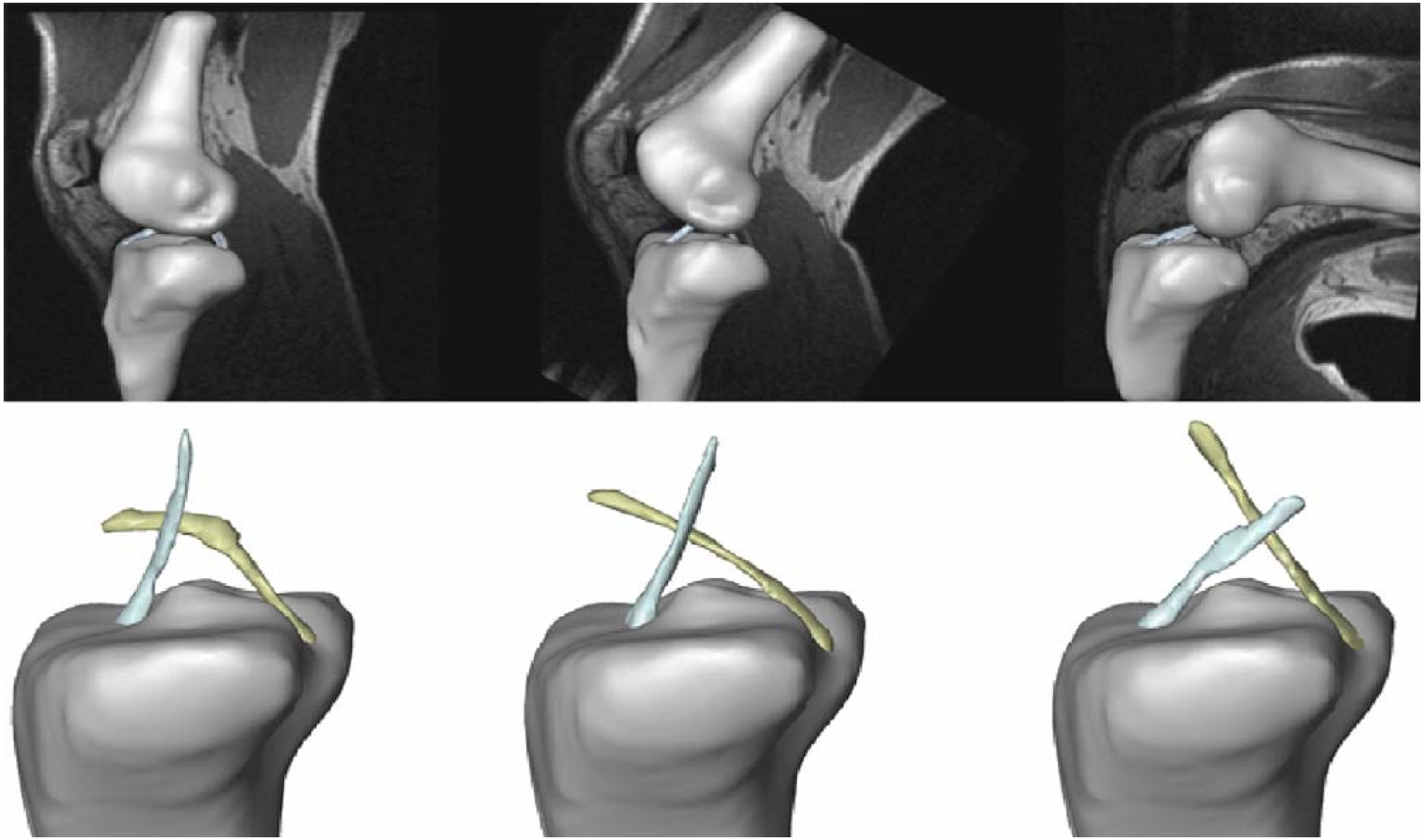




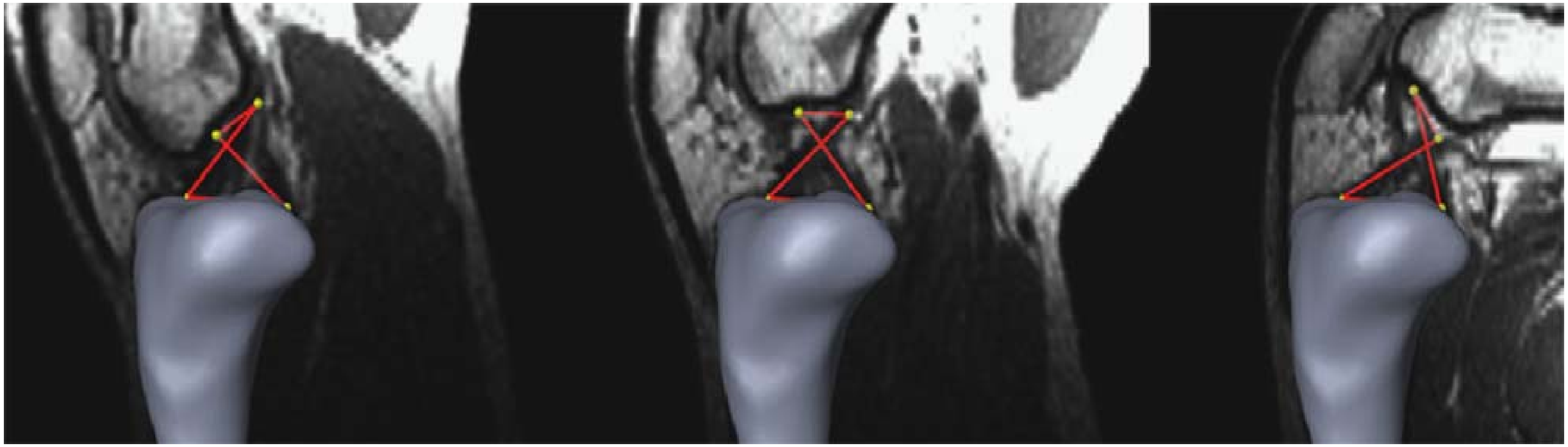
Typical set of muscle groups
for a 2-D or 3-D model of leg
movement

MRI scan of the knee and reconstruction of the cruciate ligament insertions

(note laxity of the PCL at 0º flexion)



4-bar linkage model of the knee motion



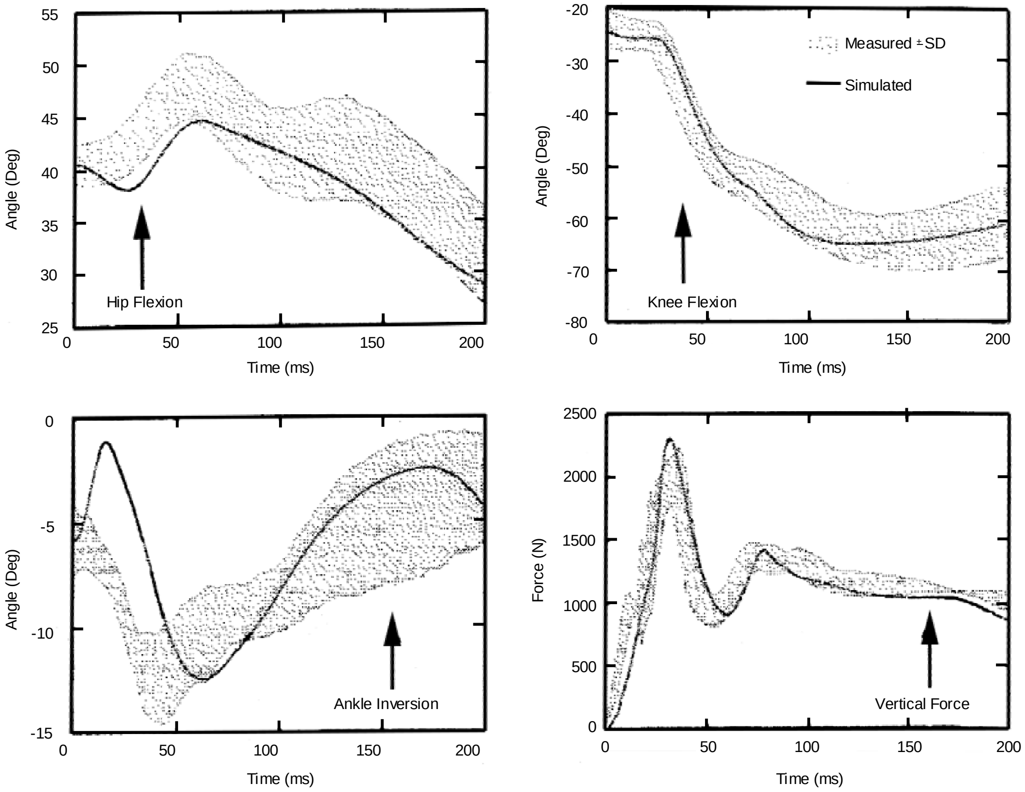
Heller et al, Jnl of Biomechanics, 2007

Method of solution

- The athlete is observed carrying out a sidestep
- This data is used as the template against which the model is compared to derive the detailed muscle properties.
- We may then access the details of the force-time relationships for each muscle.

Comparison between measured and computed data for the first 200msec. of stance for key movements : a) hip flexion, b) knee flexion, c) ankle inversion d) ground reaction force

(solid line is model, dotted area is experiment)

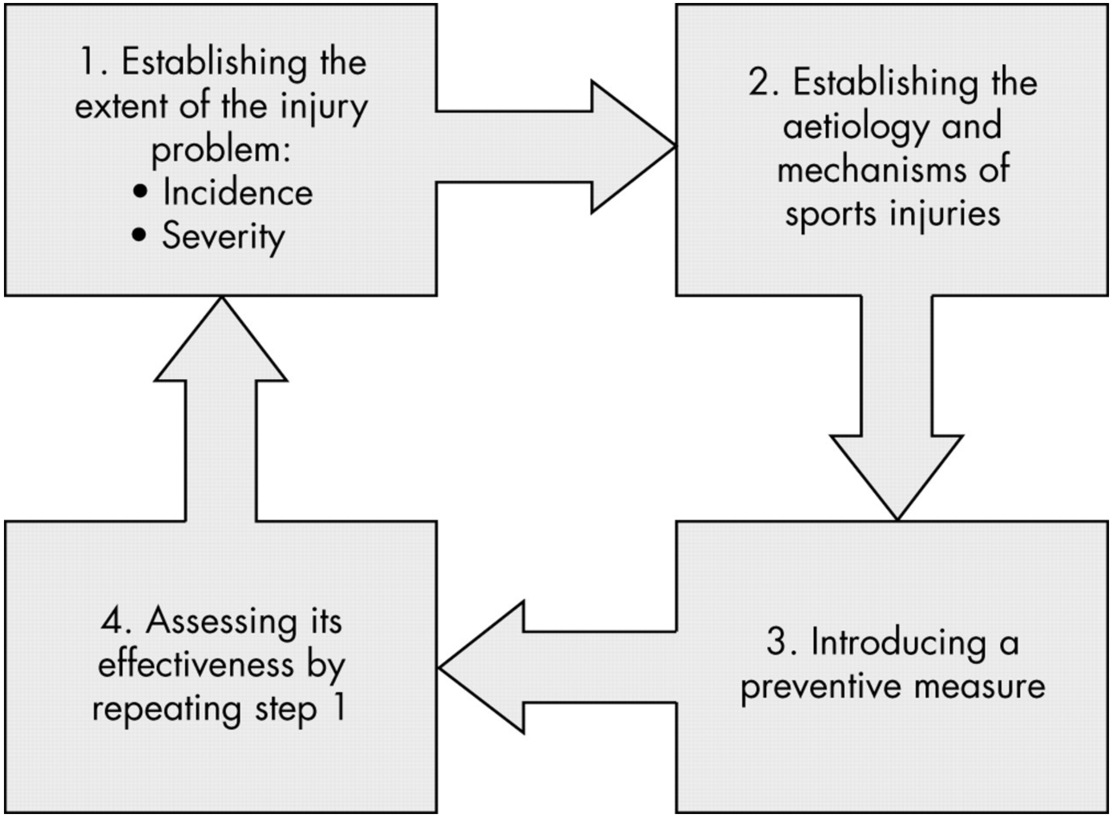


Outcome

- From the analysis, we obtain plots of muscle force as a function of time.
- Given that we *can* validate the output, how do we use it?
- Do we know what we are looking for?
- In fact, the predicted muscle forces are likely to be a credible set of data, but...
- We do *not* know what muscle force or combination of forces will result in injury.

Four step sequence for injury prevention research

(Bahr & Krosshaug 2005)



1. Establishing the extent of the injury problem:
   - Incidence
   - Severity

2. Establishing the aetiology and mechanisms of sports injuries

3. Introducing a preventive measure

4. Assessing its effectiveness by repeating step 1

Relative risk factors for knee injury in various sports

(Majewski et al, The Knee, 2006)

Sport	**Total number of knee traumas**	**Active members of regional sports clubs**	**Coefficient (Knee traumas/active members)**
Squash	124	5181	2.39
Ski	2020	186568	1.08
Handball	516	143870	0.36
Badminton	63	19529	0.32
Soccer	2715	846112	0.32
Dance	110	35218	0.31
Volleyball	198	74225	0.27
Hockey	19	6733	0.13
Track and field	145	145984	0.10
Tennis	295	433723	0.07
Swimming	31	55689	0.05

The way forward (once the epidemiology results are available)

Computation of muscle forces and neural timing

Compare with athlete and surface

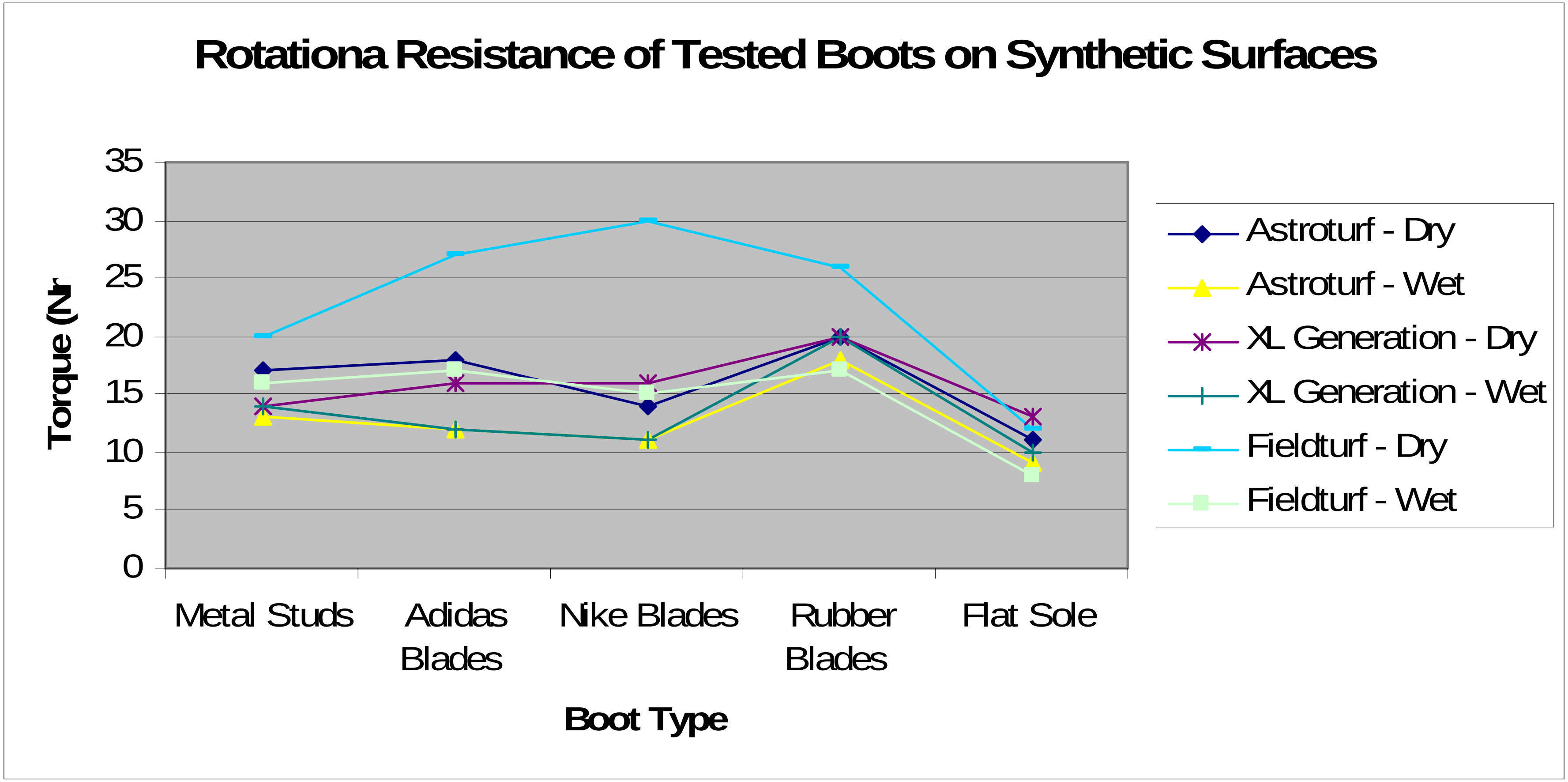
Define envelope of stable operation

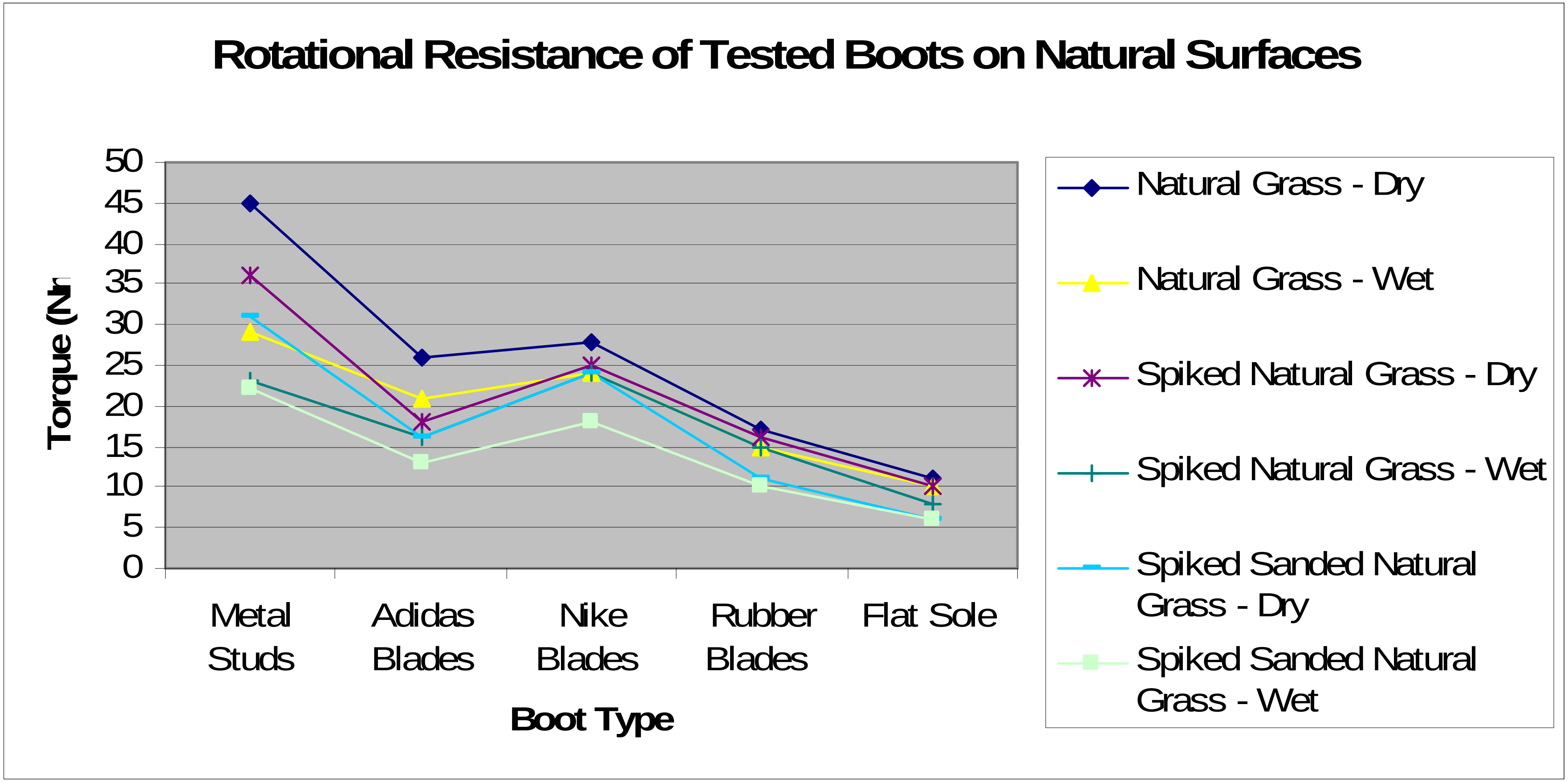
Look for injury – provoking sets of parameters

and potential avoidance strategies

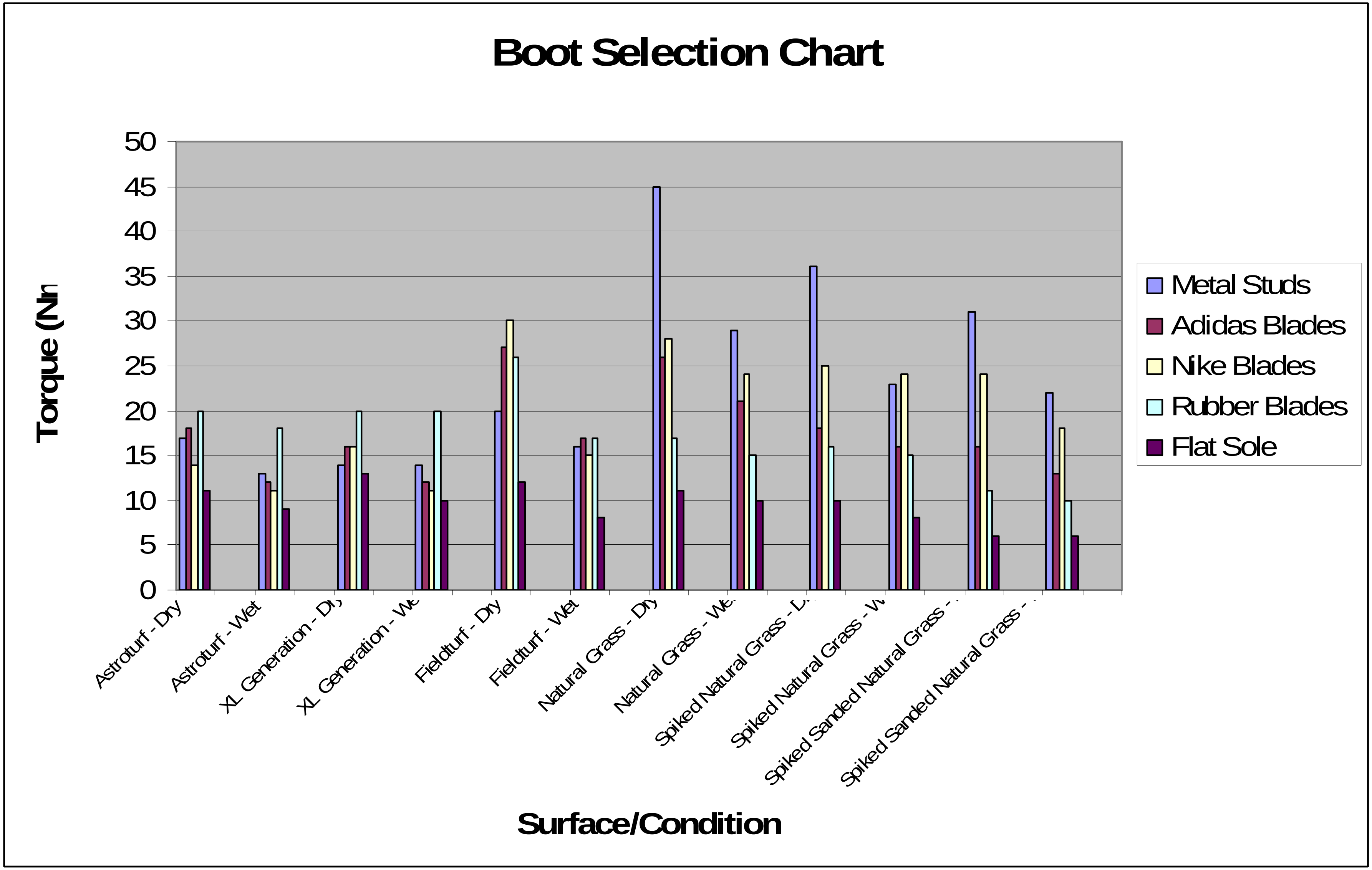
Portable rig to measure stud pattern torque on pitches

Results of torque testing on synthetic surfaces





Test facilities courtesy of Inverness Caley Thistle FC


Boot Selection Chart
Torque (Nr
50
45
40
35
30
25
20
15
10
5
0
Astroturf - Dry
Astroturf - Wet
XL Generation - Dr
XL Generation - We
Fieldturf - Dry
Fieldturf - Wet
Natural Grass - Dry
Natural Grass - We
Spiked Natural Grass - D
Spiked Natural Grass - W
Spiked Sanded Natural Grass -
Spiked Sanded Natural Grass -
Surface/Condition
Metal Studs
Adidas Blades
Nike Blades
Rubber Blades
Flat Sole

Conclusion

- Computation of athlete/pitch interaction is now well-developed
- Times for solution are now short enough to be useful.
- The epidemiological data that is required to make full use of the computation is gradually becoming available.
- Information on the properties of pitches is still in a state of development.
- In the future, models will use MRI and physiological data to ensure realistic results
- Most success has been obtained with models that have a well-defined objective.