The Biomechanics of Running on Artificial Turf

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Introduction

- Soccer injuries are a serious problem
  - 33% of total sports injuries in Netherlands (Vriend et al, 2005)
  - Similar injury incidence but different injuries on artificial turf (Ekstrand et al 2006)

- Surface properties affect dynamics and energetics of movement (Ferris et al., 1999; Kerdok et al., 2002)

- **Which parameter should we focus on?**

Surface stiffness as design parameter

- Humans adapt leg stiffness to surface stiffness (Ferris et al. 1999)
- Metabolic rate is positively related to surface stiffness (Kerdok et al., 2002)
- Tuned athletic tracks at 250 kN/m;
  - enhances speed and reduces injuries (McMahon & Green, 1979)
  - optimize energy return (Stafilidis & Arampatzis, 2007)

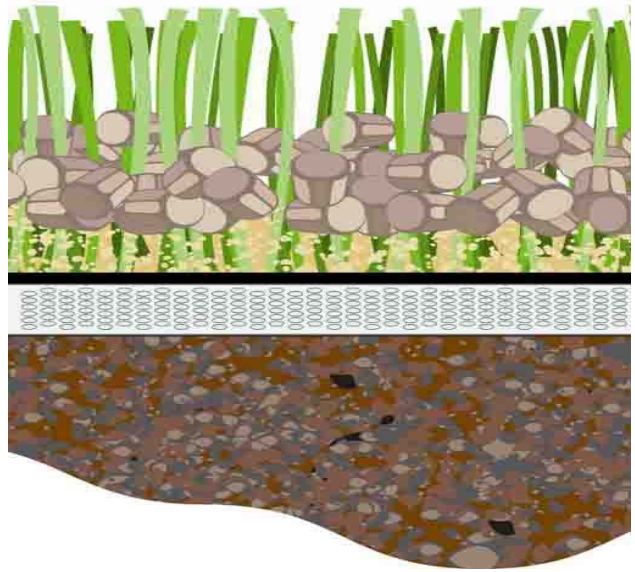
Aim

Evaluate the influence of pitch stiffness on loading experienced by players.

Methods (1)

- Pitch Design
  - 250 kN/m optimal according to McMahon's 1979 study
  - Design parameters; fibers, infill and e-layer

- Three target pitches
  - Soft (125 kN/m), Prestige 40 № XPS + 5 foam layers (Alveo)
  - Intermediate (250 kN/m), Tromsø 12mm sand + 15mm XPS + 1foam layer (Alveo)
  - Hard (500 kN/m), Evolution 10mm sand + 12mm XPS



Methods (2)

- Compression test
  - Test piece 23.5x23.5 cm loaded with circular plate (13.5 cm) on a Zwick, 1445 TM
  - Three trials; loading rate 10 N/s, peak load 2.36 KN
  - Tangent of load-deformation curve at 2.3 kN

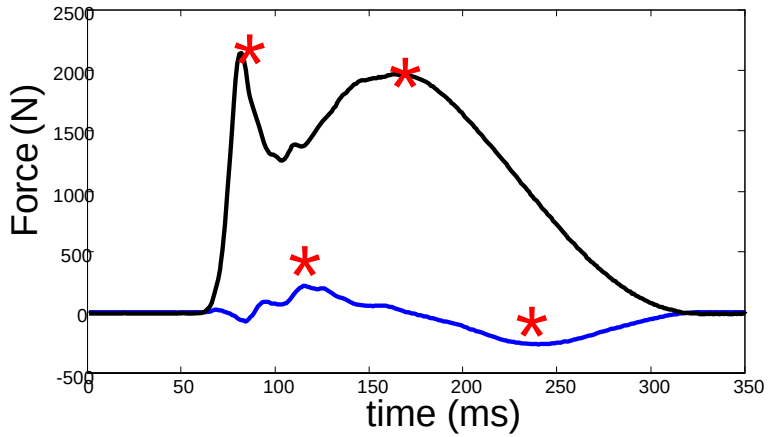
- Artificial athlete tests
  - Test piece 0.33 m^2
  - Three trials at two locations
  - Force reduction, vertical deformation & energy restitution

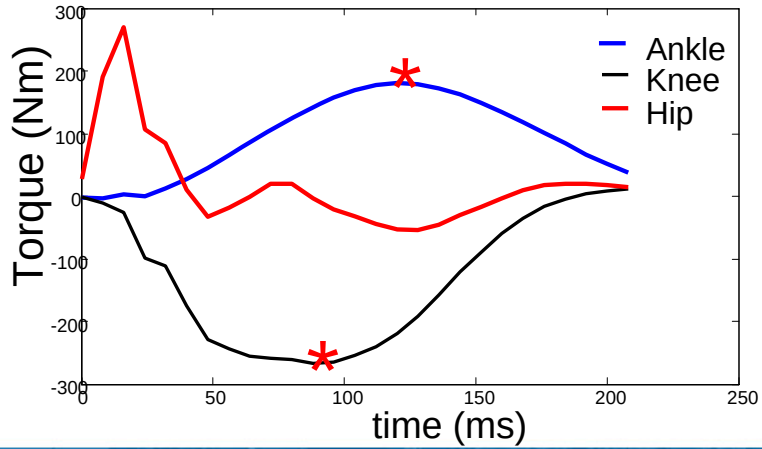
Methods (3)

- 10 soccer players (23 +/- 2 yr)
- 2 running conditions:
  - Jogging at 12 km/h
  - Running at 17.5 km/h
- Data acquisition
  - 2-D video analysis (100 Hz)
  - Ground reaction forces (1000 Hz)

Biomechanical Analysis

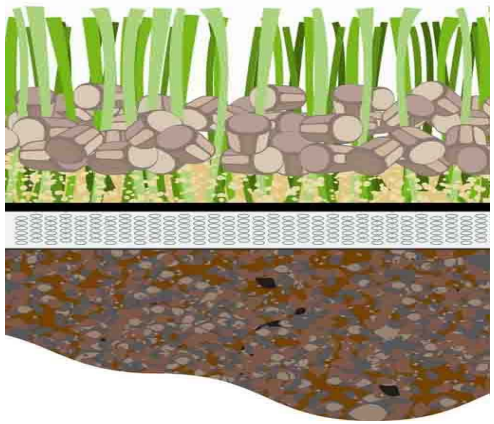
- Contact times and vertical stiffness
- Ground reaction forces
  - Peak vertical forces
  - Peak horizontal forces
- Inverse Dynamics
  - Maximum knee extension and ankle plantar flexion torque
  - Knee and ankle power
- Statistics
  - Repeated measures ANOVA ($P<0.05$)





Results; mechanical tests

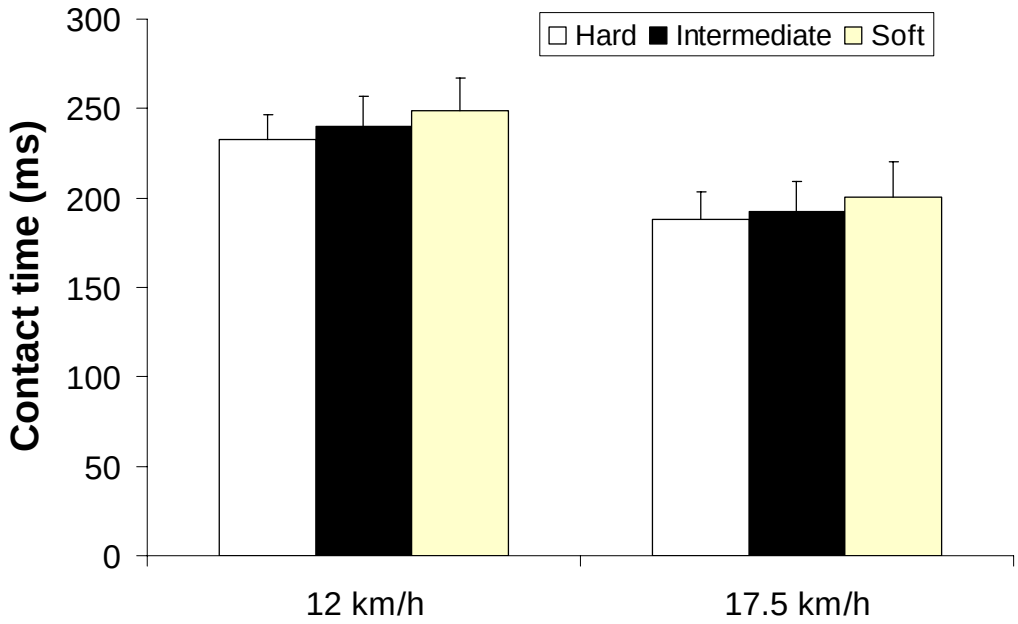
Pitch	Force Reduction (%)	Deformation (mm)	Static Stiffness (kN/m)
Hard	57	6.0	670
Intermediate	64	6.4	257
Soft	74	15.7	109



FIFA qualifications;

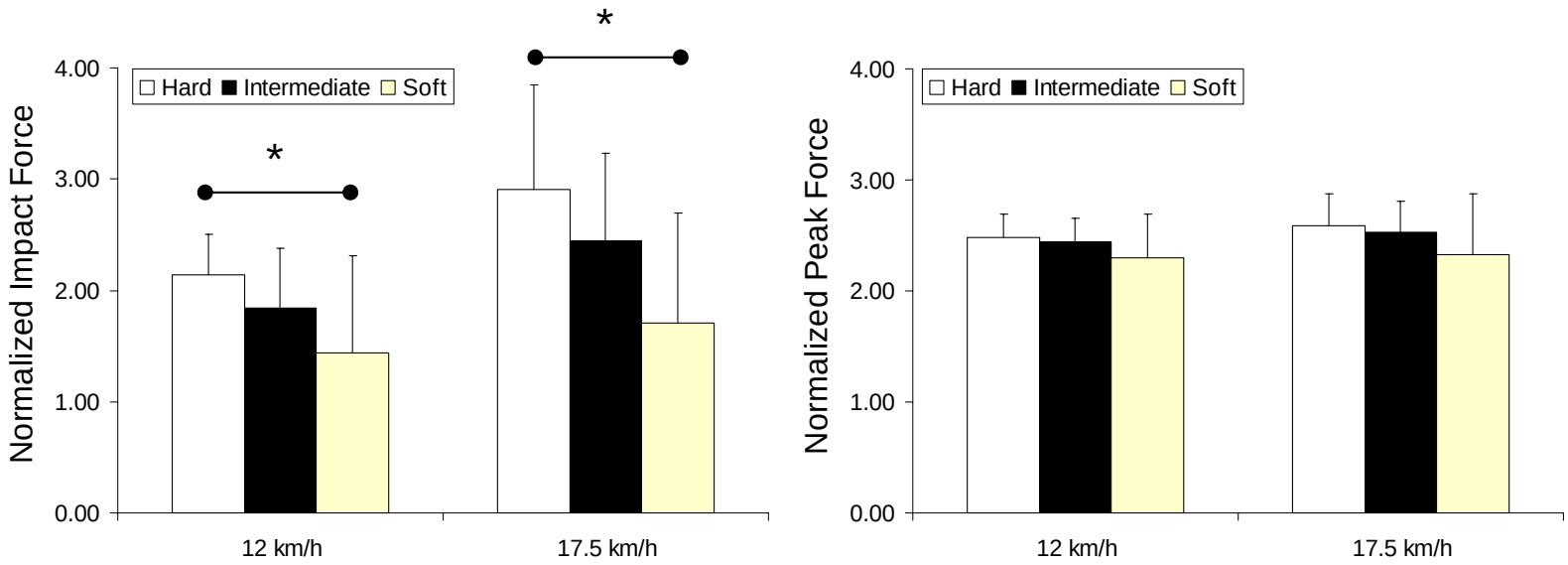
- Hard Surface; ~FIFA*
- Intermediate Surface; FIFA**

Results; contact time, vertical stiffness



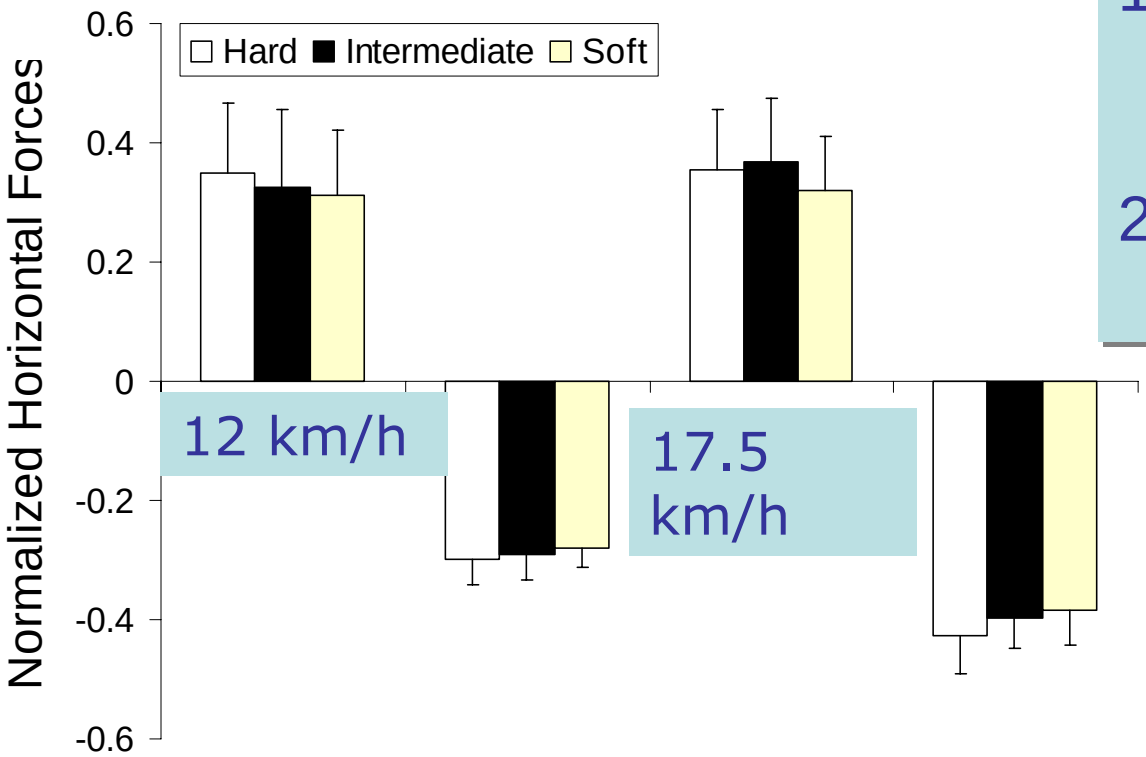
1. Significant effect (7%) of surface and speed on contact time
2. No effect on vertical stiffness

Results; vertical forces



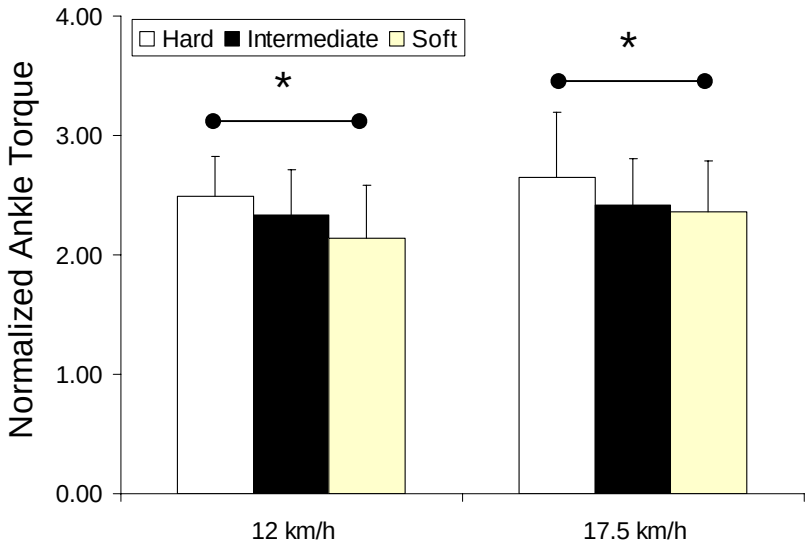
1. Significant effect (10-32%) of speed and surface stiffness on impact force
2. No effect of surface stiffness on active force

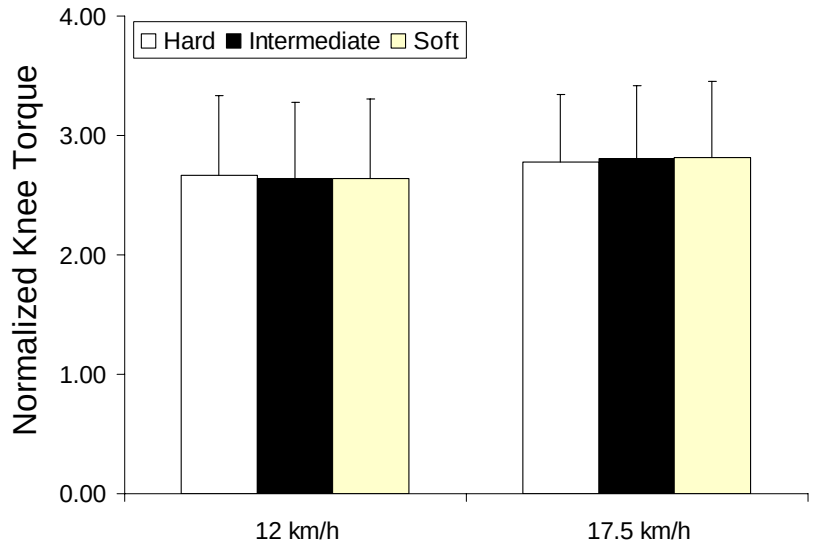
Results; horizontal forces



1. Significant effect (3-10%) of surface stiffness
2. No effect speed

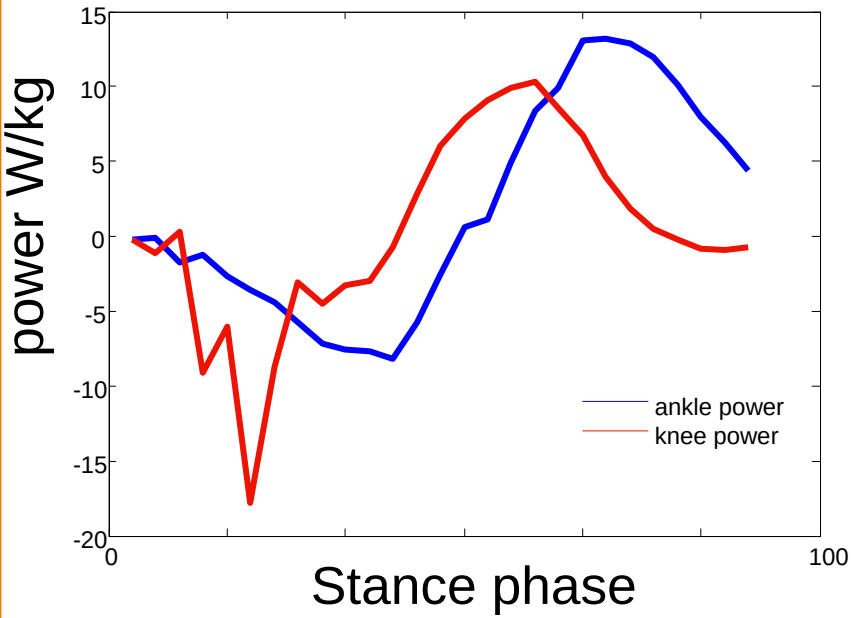
Results; joint torques

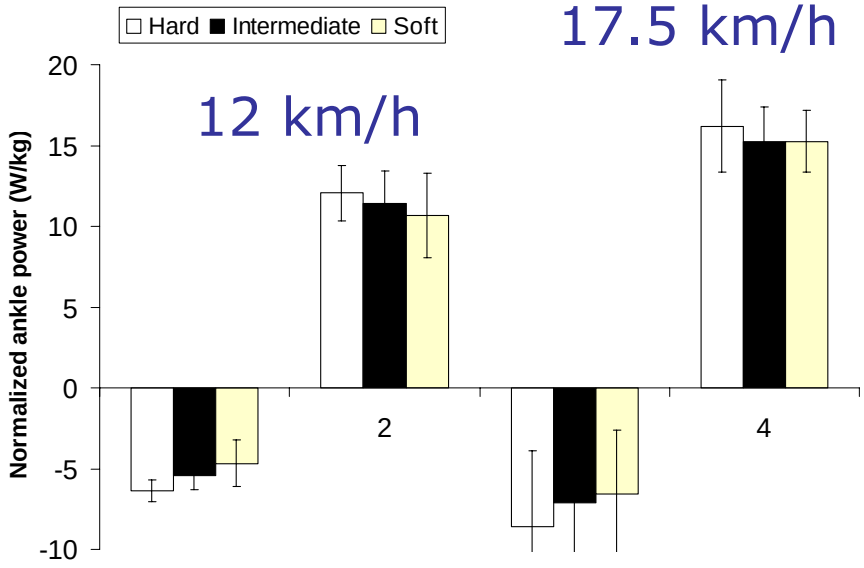




1. Significant effect of surface (12-16%) and interaction effect surface*speed on ankle plantar flexion torque
2. No effect on knee extension torque

Results; joint power





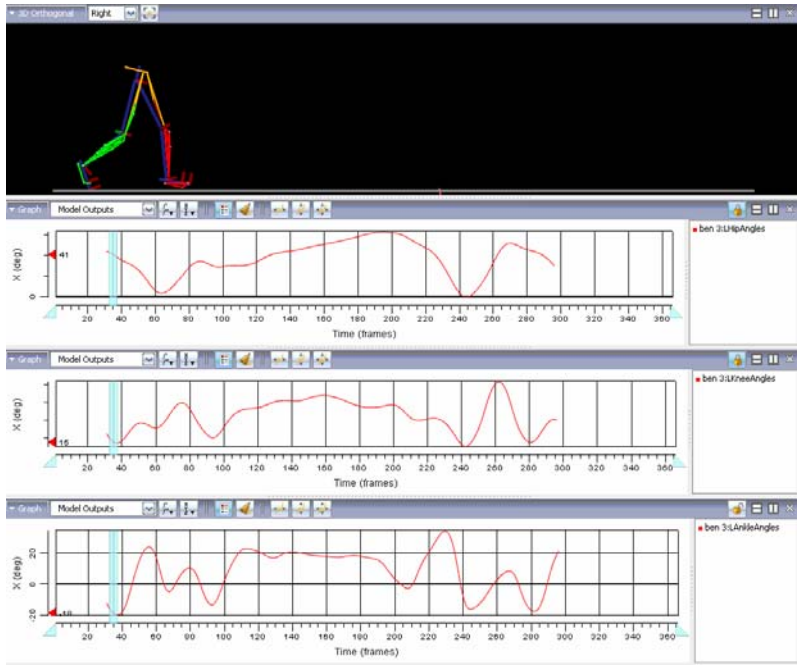
1. Significant effect (6-27%) of surface and speed on peak ankle power
2. Significant effect (9-22%) of surface and speed on negative power at knee during first half of stance phase

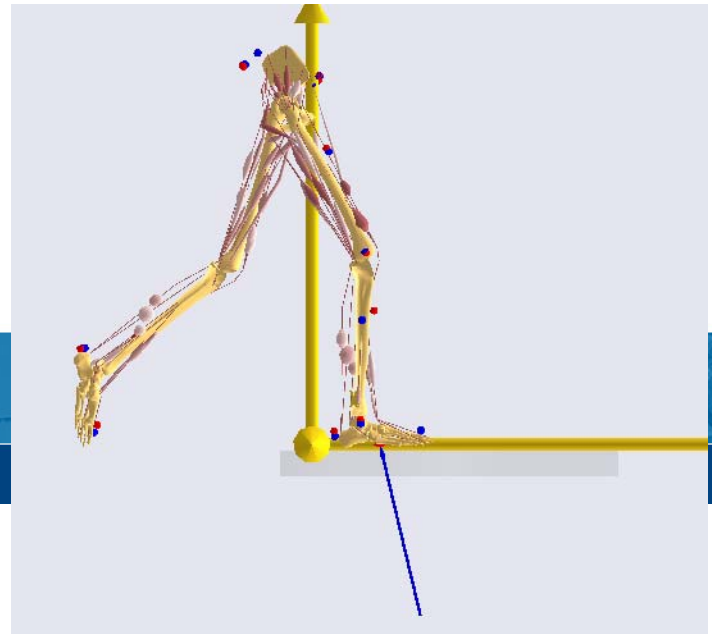
Discussion

- Surface stiffness has a significant effect on impact force and ankle torque, power and knee power
- Changes in surface stiffness are accommodated at the ankle
- Theoretical optimal surface stiffness coincides with FIFA** requirements

Ongoing work

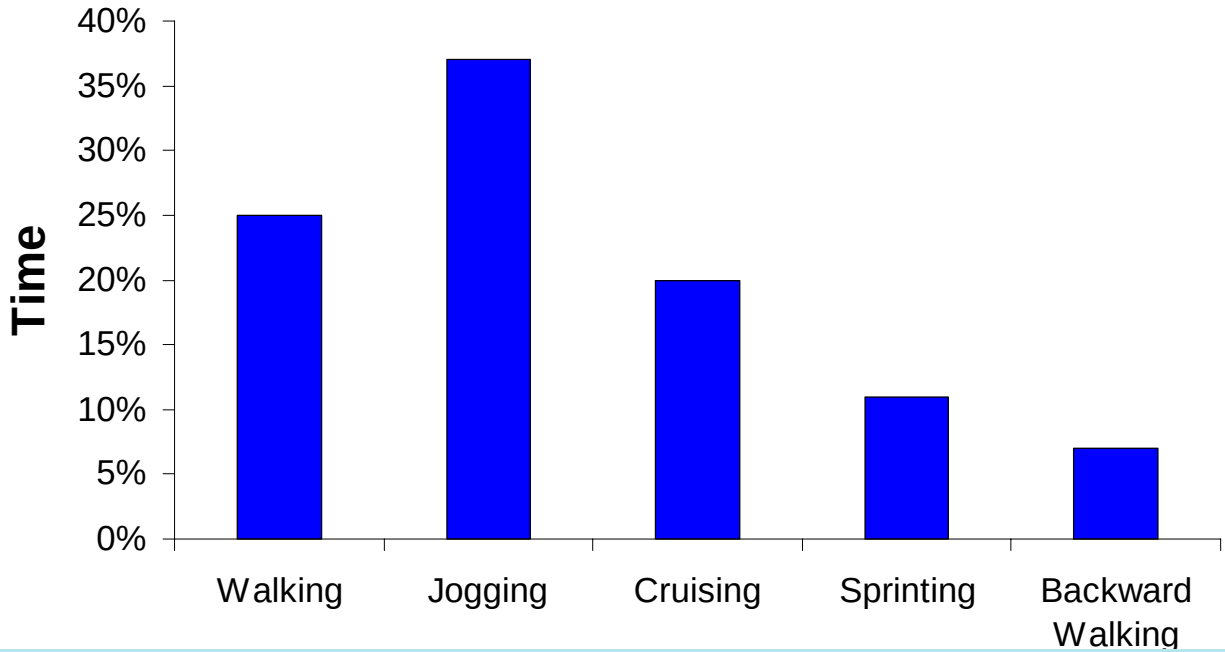
- Influence of surface on muscle loading
  - 3-D motion analysis
  - EMG
  - Multibody modelling
- Epidemiological studies on injury risk
  - 10 league teams
  - youth vs. professionals





Acknowledgements

Soccer = Running

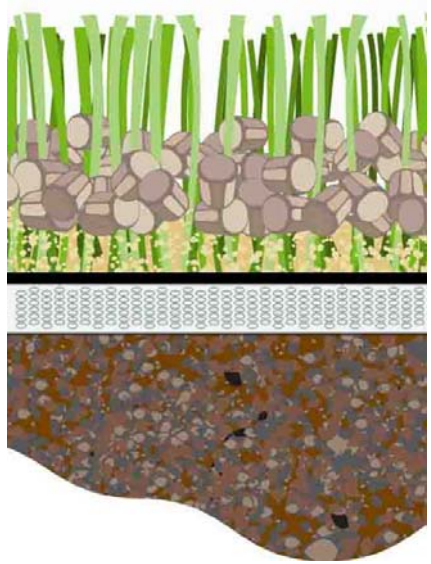


Performance requirements *(Shephard, 1999)*

- Distance 8-12 km
- 70 % Running
- Max Speed ~ 9 $m.s^{-1}$

Requirements for Artificial Turf System

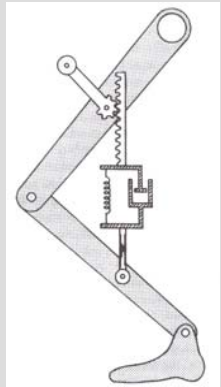
	Natural Grass Dry	Natural Grass Wet	FIFA *	FIFA **
Force reduction (%)	40	65	55-70	60-70
Energy restitution (%)	39	18		
Vertical deformation (mm)	2.0	3.8	4-9	4-8
Rotational grip (Nm)	40	30	25-50	30-45
Ball rebound (m)	80	60	60-100	60-90

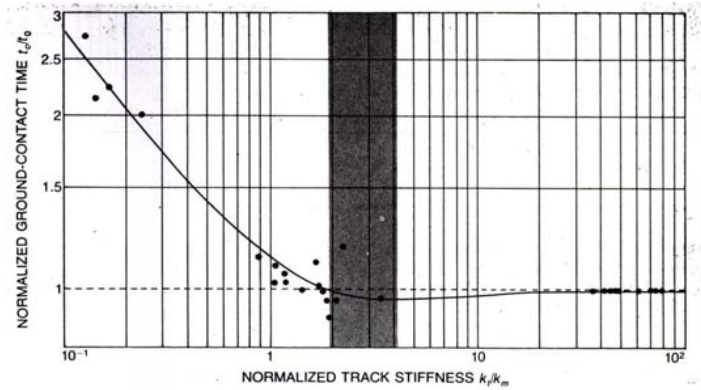


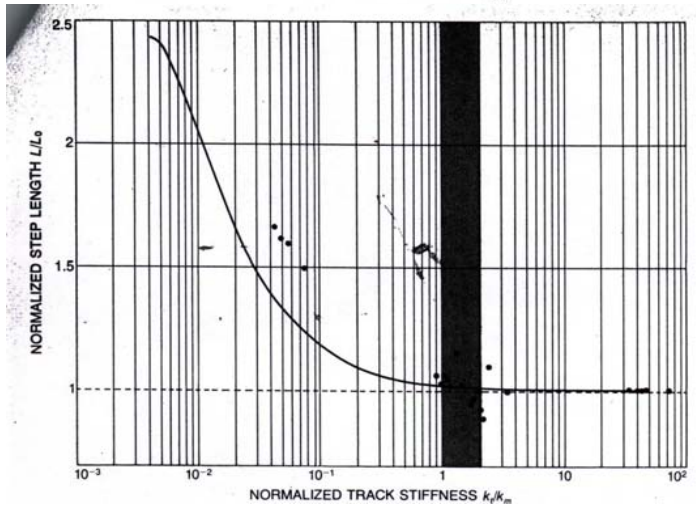
Surface stiffness as a design parameter

McMahon & Greene (1978)

- Model human/surface interaction
- Optimize athletic track stiffness for speed







Surface stiffness of 250 kN/m;

- Optimal for speed and reduces injuries *(McMahon & Green 1978)*
- Optimal for energy return (*Stafilidis & Arampatzis 2007)*