Development, validation and enhancement of a new device for testing soccer shoes under game relevant loading conditions

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Motivation

Introduction – Traction and ACL-injuries

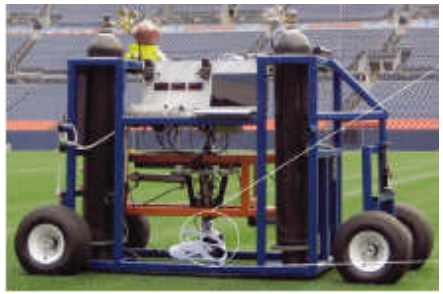
<u>Typical injury mechanism:</u>

- planted foot
- slight flexion of the knee joint
- valgus position of the lower leg
- internal rotation

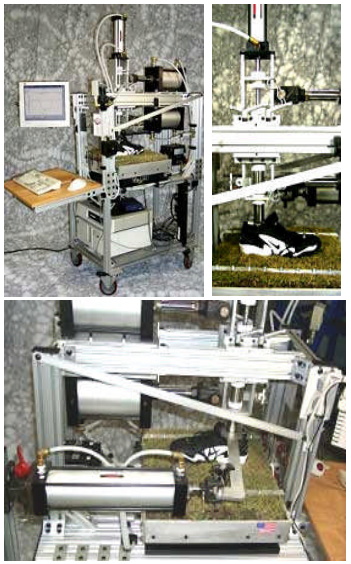
Introduction - Known traction test devices

Test Device "Pennfoot“
[McNitt et al., 1997]

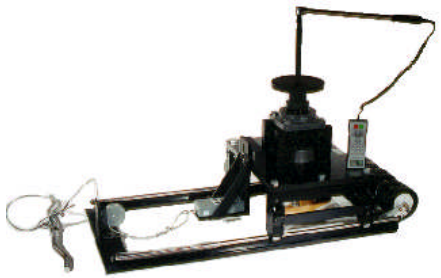
RMIT Traction Test Device
[Barry et al., 1999,2000]



Boise State TurfBuster
[Sabick et al., 2009]

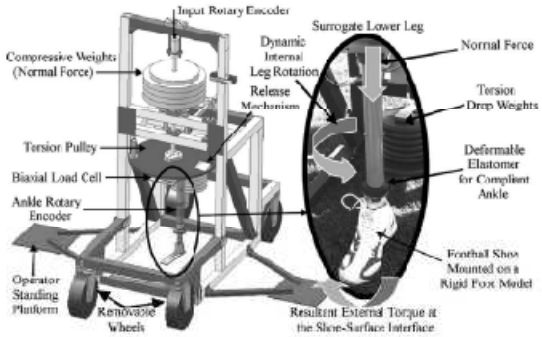


Traction Measuring Device
[BREG Inc., Ca, USA]



Exeter S2T2,
[www.exeter-research.com/S2T2.html]

Torque Wrench
[Vachon, 2004]

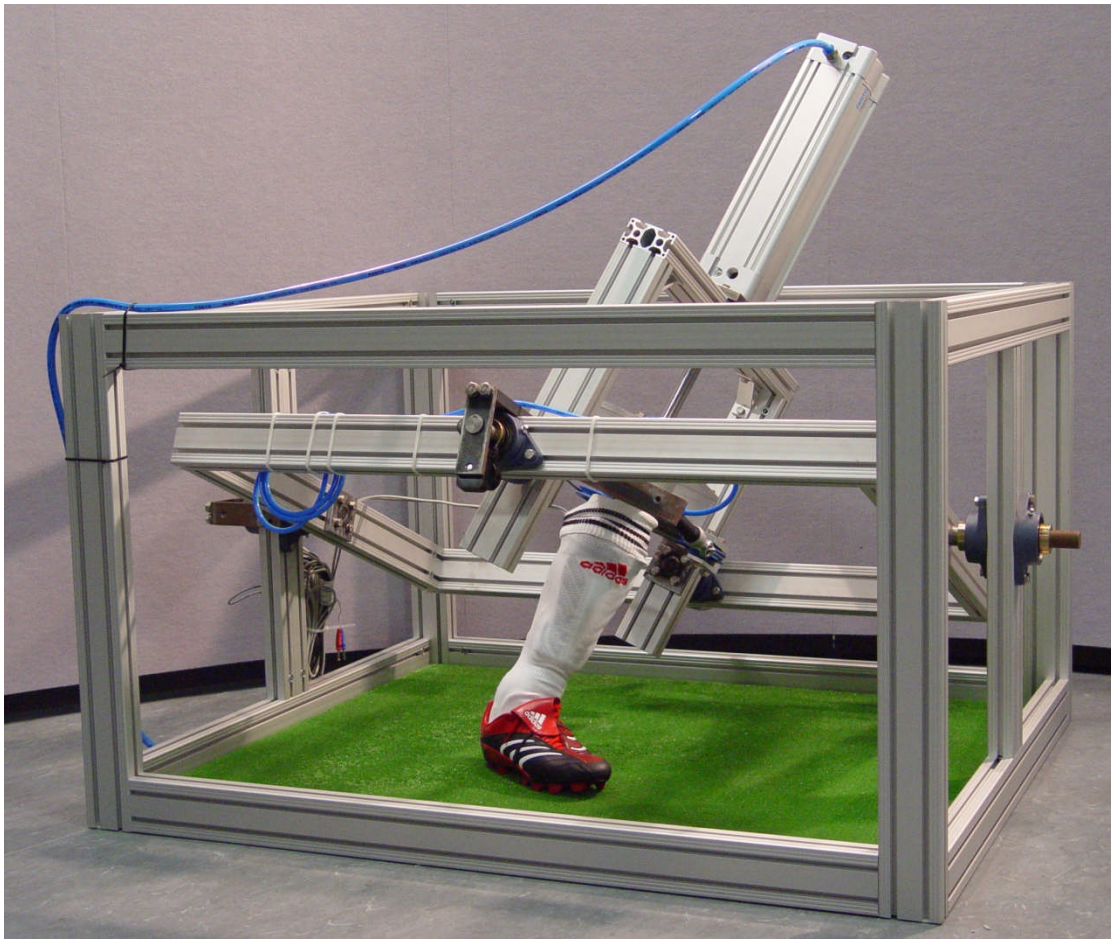


Testing apparatus
[Villwock et al., 2009]

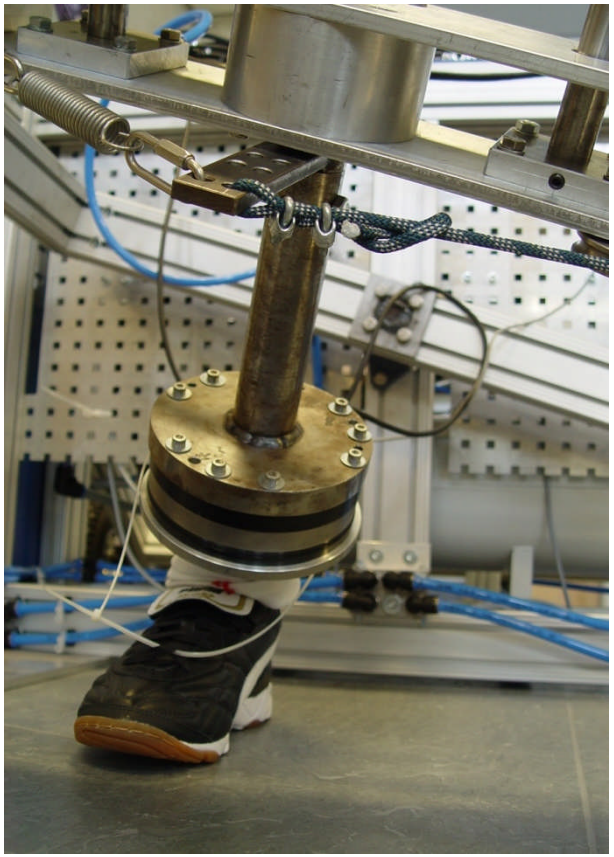
Design requirements for a new device

- Simulate (different) game relevant loading conditions.
  - Load application onto the boot along anatomical axis (varus/valgus, flexion/extension).
  - High preloads (worst case scenarios) => high stiffness.
- Torque application while the tibia is in a tilted position with respect to the foot.
- Realistic loading of the shoe (plantar pressure distribution).
- Measurement of resulting loads transmitted to the tibia.
- Portable design for field tests.

First prototype



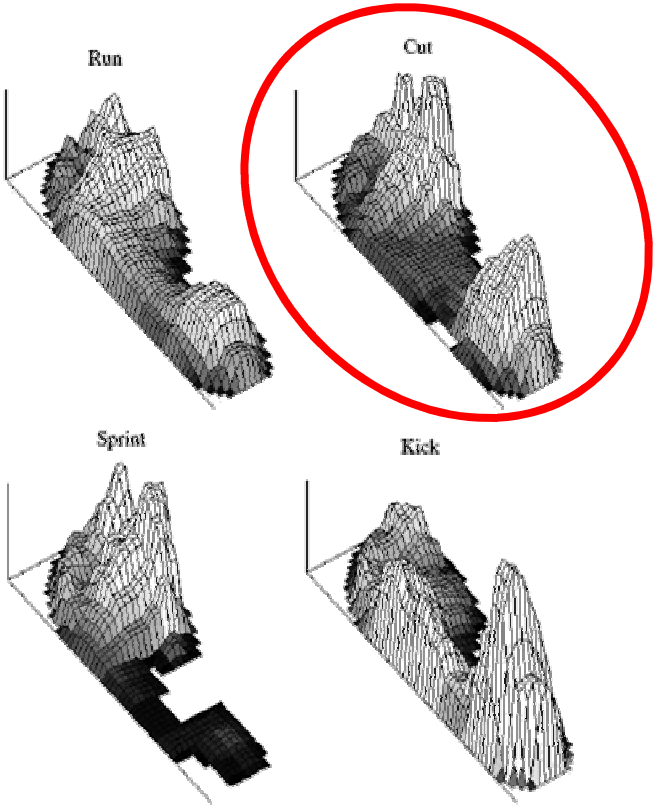
Problems



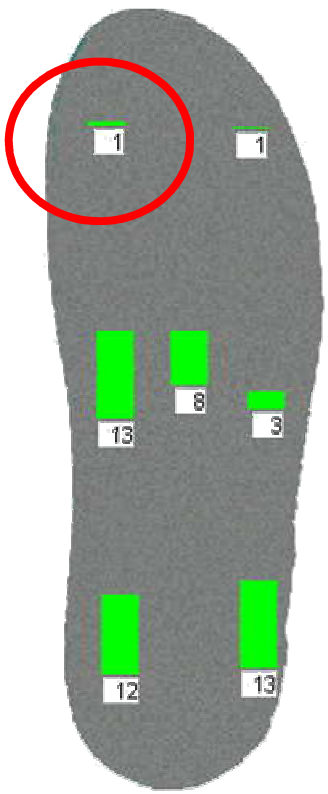
- No loading of metatarsus and fore foot.
- Main load on medial part of the heel.
- Rotation only on the heel.

⇒ External plunger forces foot down.

Validation I - plantar pressure distribution



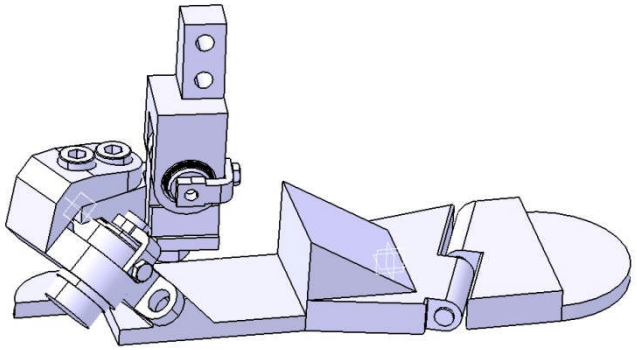
Eils et al., 2004



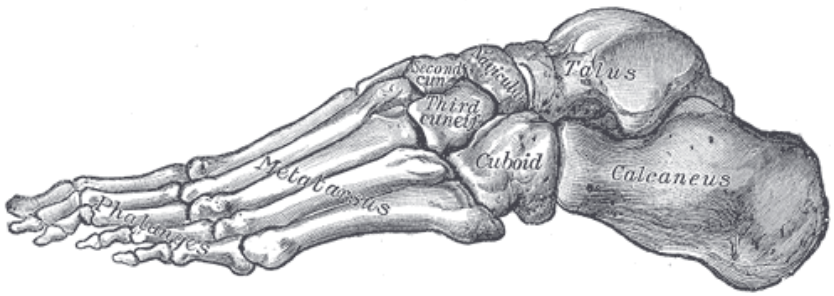
- Reduced load (1,5xBW).
- Almost no load on medial toe.
- Shift of plantar pressure to medial side in metatarsal area.
- (too) high loading of the heel.

Optimization – Foot and Ankle I

- New development of the foot and ankle model.
- Loading of metatarsal and fore foot.
- Adjustment of plantar pressure distribution.
- Dimensioning for high preloads.

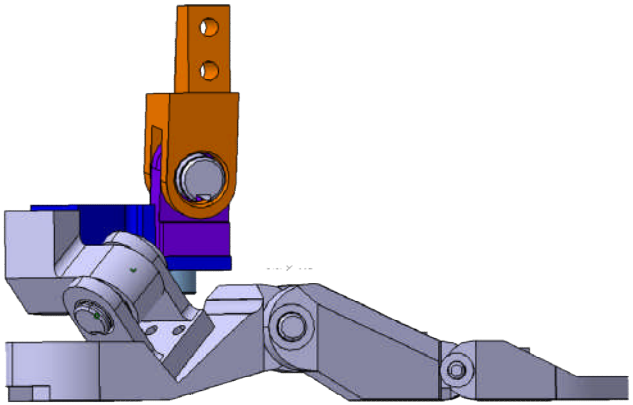


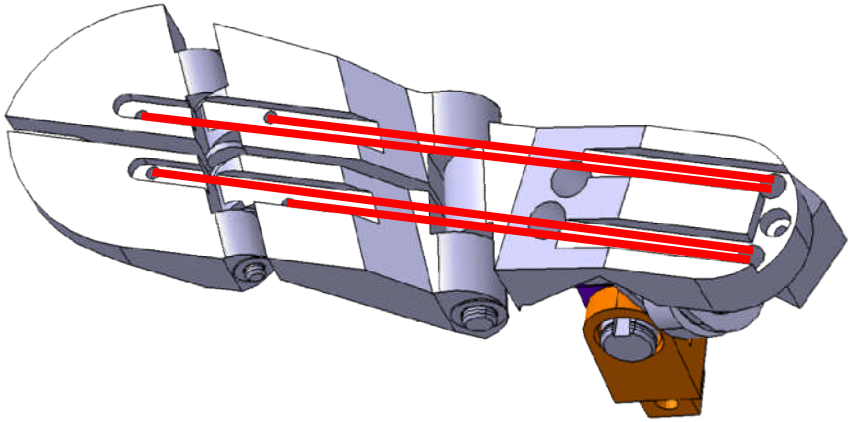
old model of foot and ankle



anatomical reality of the foot

Optimization – Foot and Ankle II





- Replication of the arch of foot.
- Decoupling of medial and lateral side of the foot (along longitudinal foot axis).
- Replication of plantar tendons.
- More solid design of the ankle joint while keeping anatomical joint axes.
- Optional (small) plungers for punctual force application.

Validation II

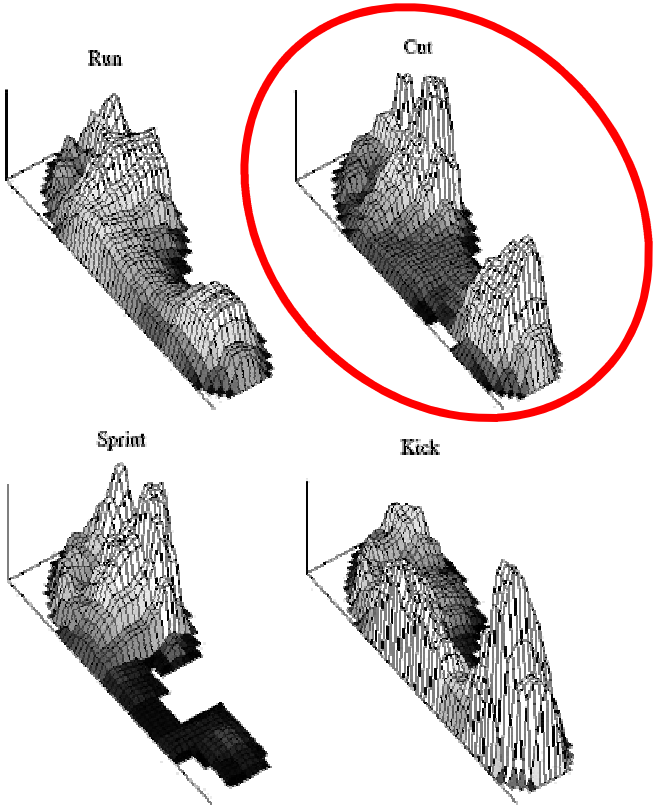
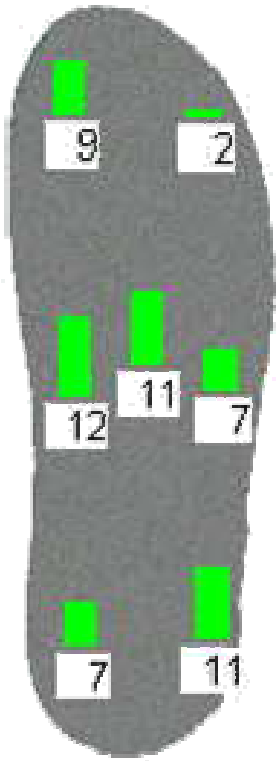


Figure 3. An example of the characteristic peak pressure pattern of the four tested movements in soccer.



- Reduced load (1,5xBW).
- Peak load at medial toe.
- Shift of plantar pressure to medial side in metatarsal area.
- Less loading of the heel.

TrakTester

Pneumatic cylinder

Lifting mechanism with wheels

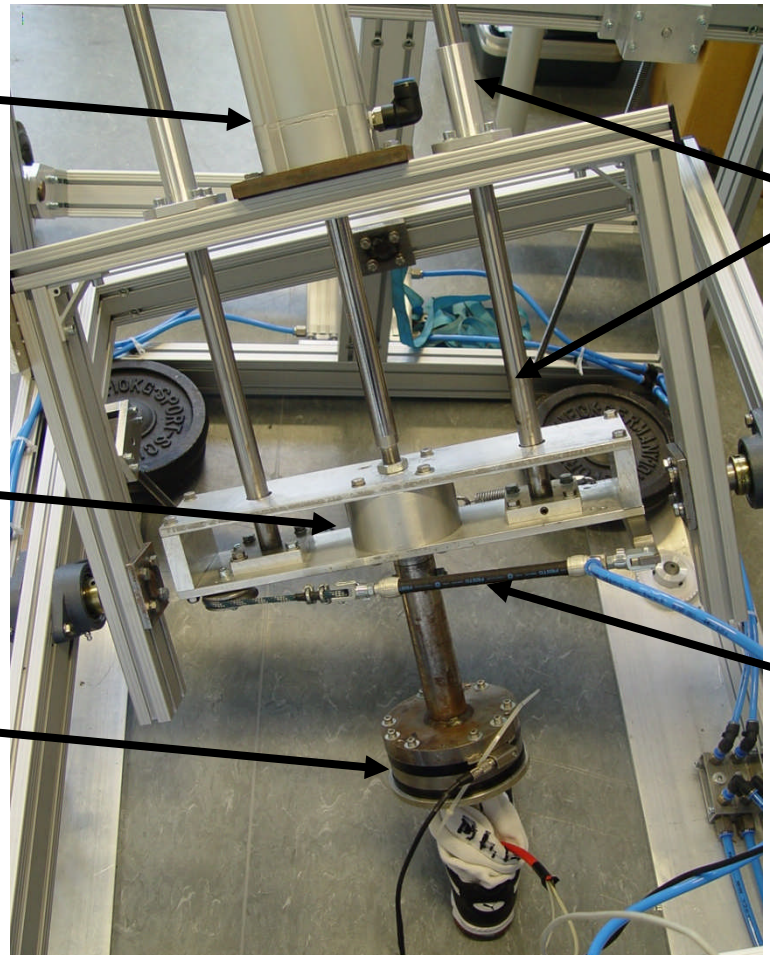
Inshoe-pressure measurement

Control and DAQ via notebook & NI LabView

Pneumatic control module

TrakTester – some details

Tests with axial preloads between 800N and 2400N



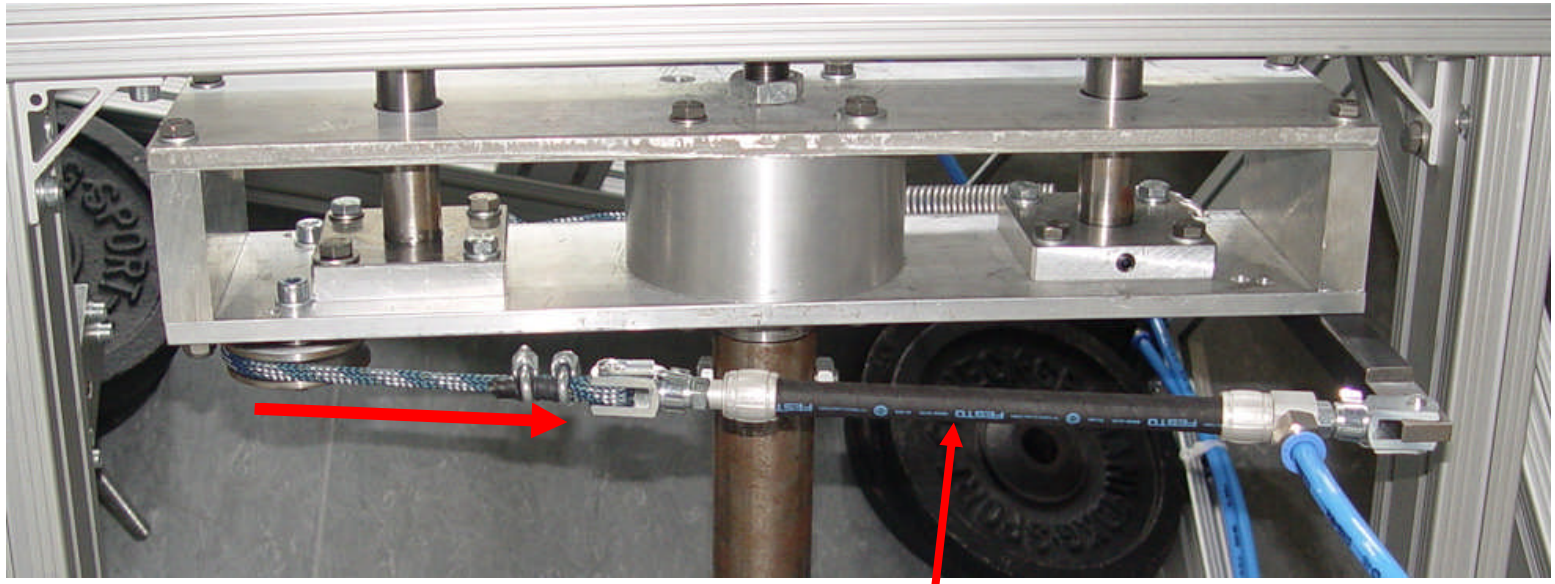
Linear bearing

Bearing

Pneumatic muscle

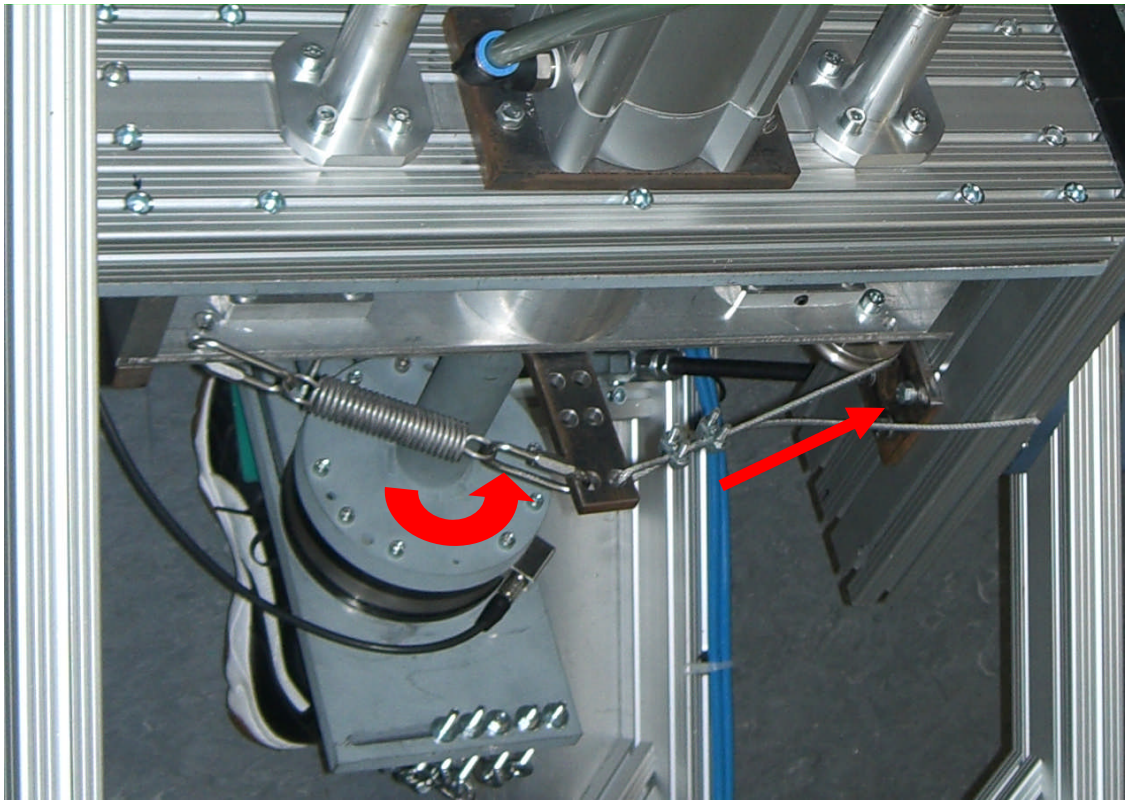
6-comp load cell

TrakTester details – Torque generation



Muscle
contraction

TrakTester details – Torque generation



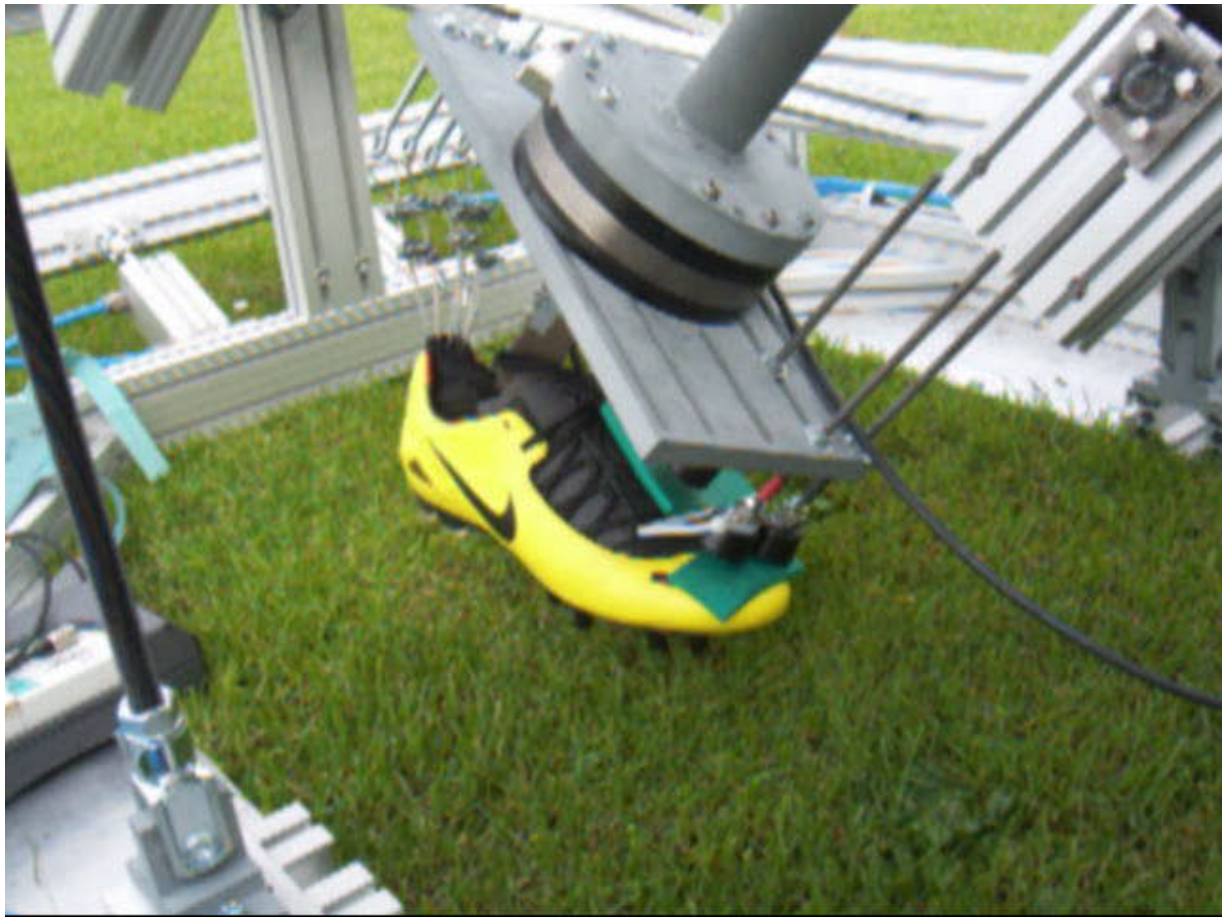
Rotation angle: 10° - 13°
(depending on applied air pressure)

TrakTester details – plantar pressure

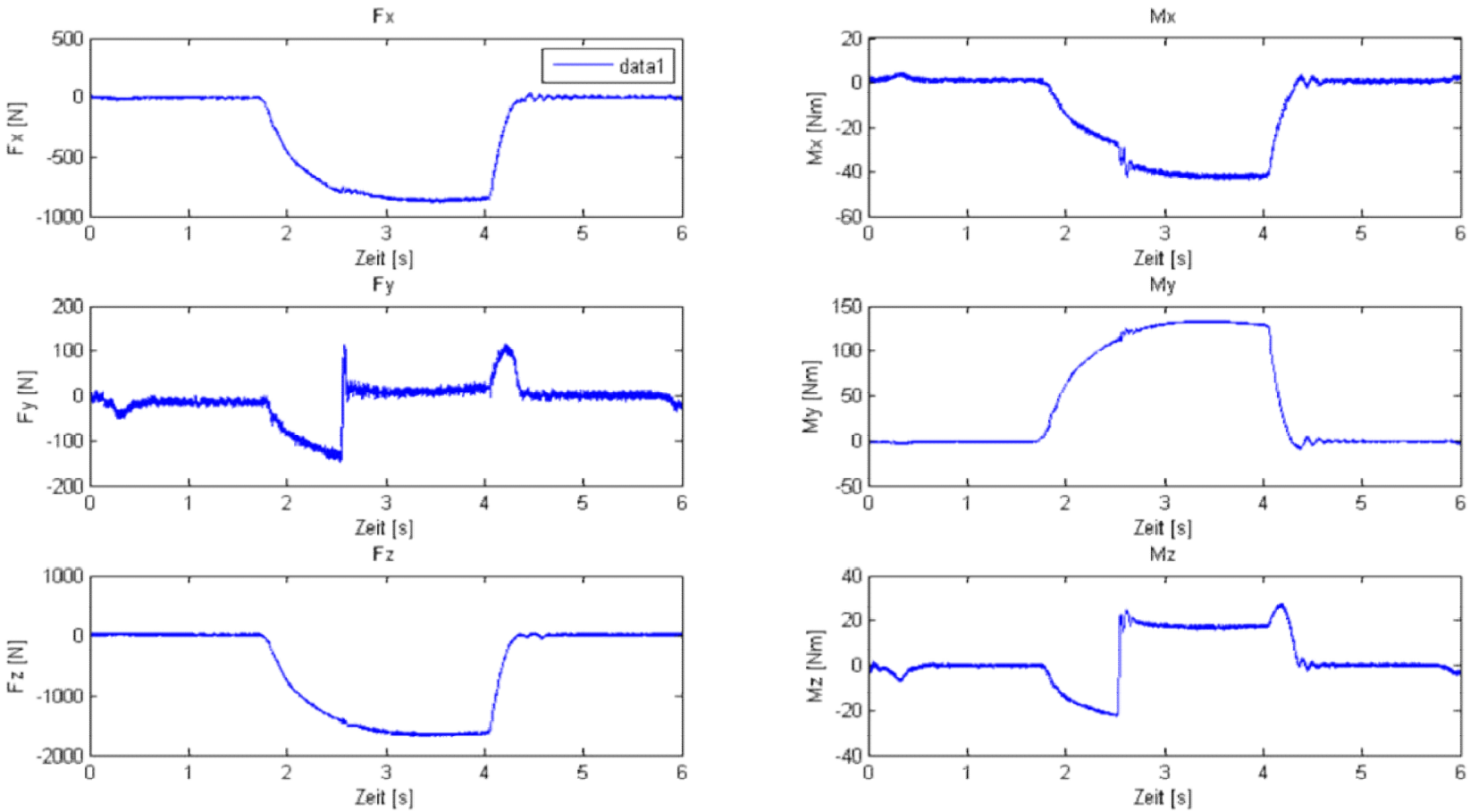
Tensioning of plantar tendons to load the forefoot

Optional (small) plungers for punctual external force application

Proceeding of a measurement



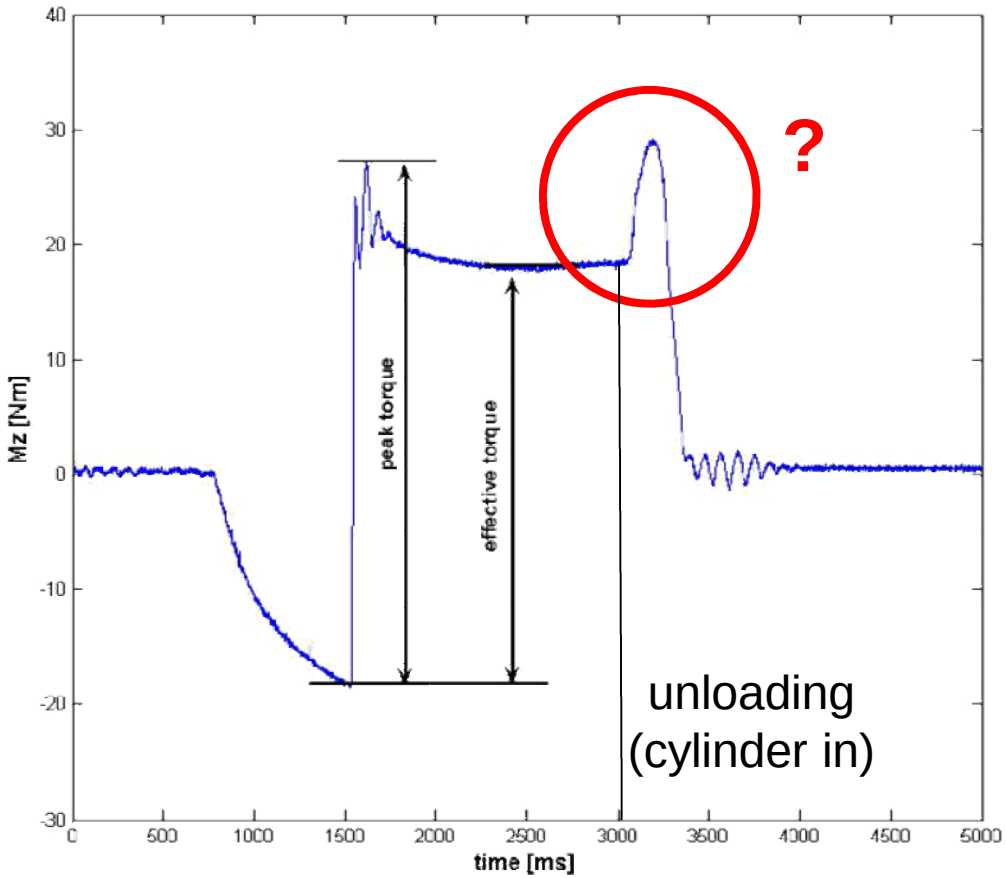
Measurement results - Example



Measurement results – Example Mz

- Tibial torque.
- Peak torque:
  initial breakaway of shoe
  (dynamic traction)
- Effective torque:
  amount of traction
  generated by shoe
  (static traction)
- What happens exactly
  during unloading of shoe?

⇒ Still a lot of work to do!



Discussion

- Reproduction of game relevant situations is possible.
- Varus / Valgus position and flexion of the lower leg.
- Plantar pressure distribution influences the measurement values considerably.
- Still no muscle forces implemented.
- A mechanical test device is not capable to represent the interaction between player and surface exactly.
- Further improvement of the TrakTester is necessary.
- Understanding and correct interpretation of the measurement data requires a lot of additional work.

How do we proceed?

- Systematic measurement series to investigate the influence of individual parameter.
- Detailed data analysis of all force/torque components.
- Develop meaningful parameter to describe shoe-surface interaction.
- Use of the TrakTester to charaterize artificial turf systems.
- Use data as input for biomechanical computersimulation models to gain insight into injury mechanisms.
- Further optimization of the TrakTester.

Thank you for your attention!

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