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

Typical injury mechanism:

- 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]
- Exeter S2T2, [www.exeter-research.com/S2T2.html]
- Torque Wrench [Vachon, 2004]
- Testing apparatus [Villwock et al., 2009]
- Traction Measuring Device [BREG Inc., Ca, USA]
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

- 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.

Eils et al., 2004
Optimization – Foot and Ankle I

• New development of the foot and ankle model.

• Loading of metatarsal and forefoot.

• 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

- Reduced load (1.5xBW).
- Peak load at medial toe.
- Shift of plantar pressure to medial side in metatarsal area.
- Less loading of the heel.

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

- 6-comp load cell
- Bearing
- Linear bearing
- Pneumatic muscle
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 characterize artificial turf systems.
• Use data as input for biomechanical computer simulation models to gain insight into injury mechanisms.
• Further optimization of the TrakTester.
Thank you for your attention!
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