Athletic training affects the homogeneity of muscle and tendon adaptation during adolescence

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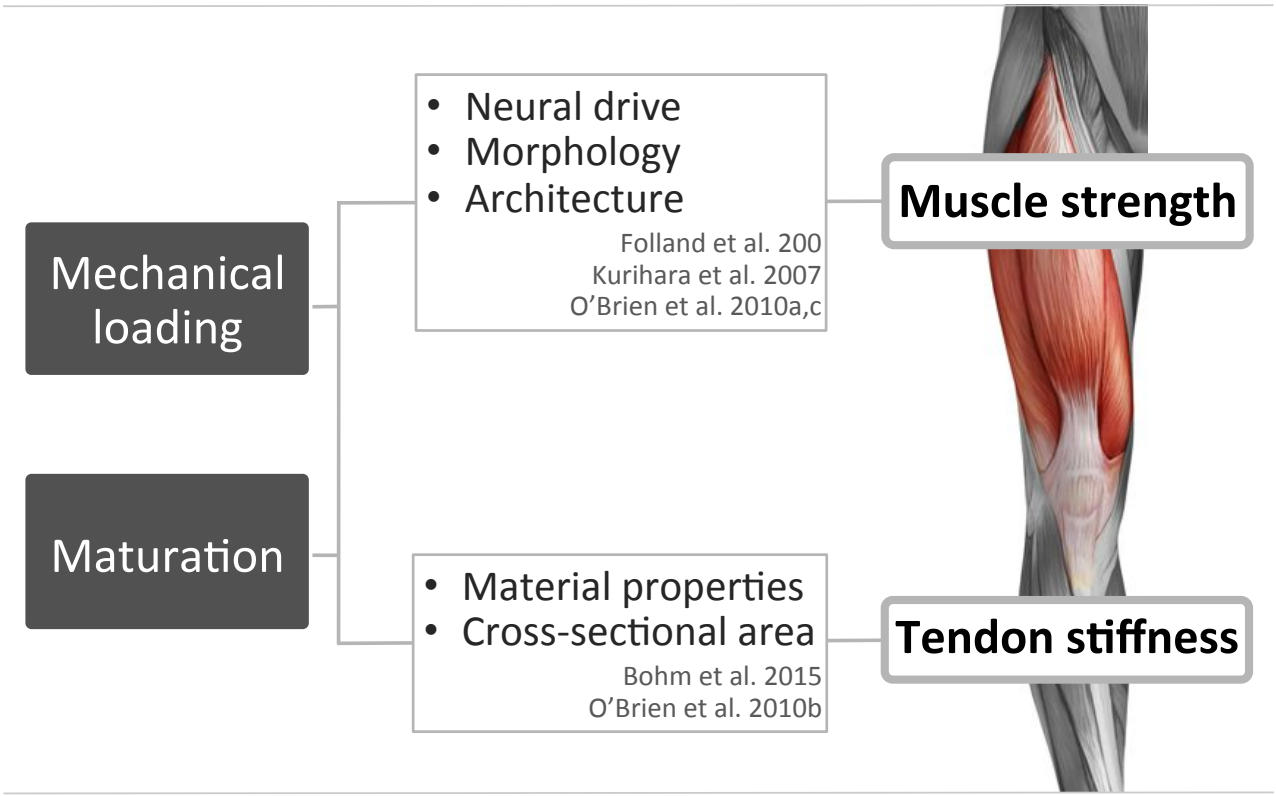
Introduction

Muscle-tendon unit of adolescent athletes



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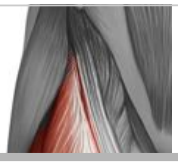
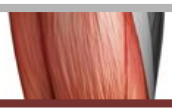


Muscle strength



Increased risk of imbalance

Tendon stiffness

Mechanical loading

Maturation

Different time course and effective mechanical stimuli
Kubo et al. 2011
Arampatzis et al. 2010

Episodes of increased demand
Neugebauer et al. 2010

Introduction
Imbalances and risk of injury

- Evidence of imbalanced adaptation in adolescent volleyball athletes
  ➔ increased stress (& tendentially strain)
  Mersmann et al. 2014, 2015
- Association between tendon stress, strain and overuse
  Arya & Kulig 2010; Child et al. 2010; Couppé et al. 2013

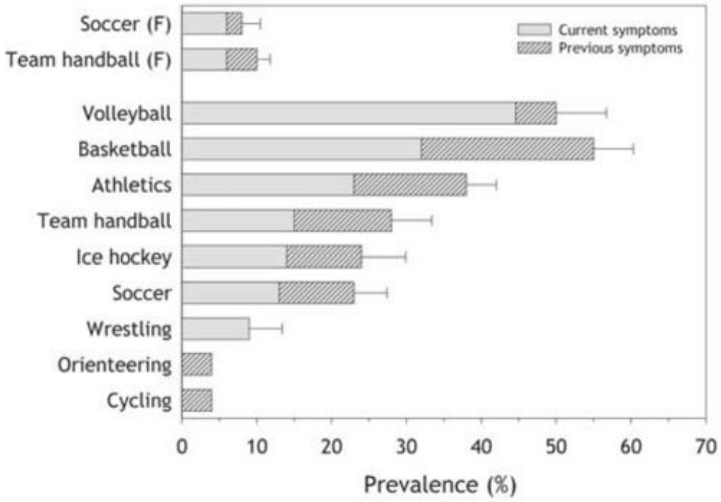


Fig.: Prevalence of tendinopathies in 613 athletes of different sports
Lian et al. 2005

Introduction
Aim

The purpose of the present study was...

- to provide detailed information about the **time-course** of **muscle** and **tendon adaptation** during **adolescence**
- investigate the **effect** of **training** on the **uniformity** of muscle and tendon development

Hypotheses

Non-uniform development of muscle and tendon
→ Episodes of **increased tendon strain** in **athletes**

Methods
Participants & experimental design

Adolescent athletes

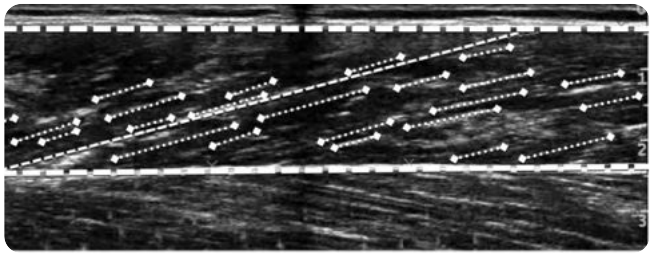
- 7 m, 5 f
- 16 ± 1 years; 187 ± 7 cm; 73 ± 10 kg
- Junior national team
  ~ 3h strength, ~ 4h athletic &
  ~ 9h ball training per week

Control group

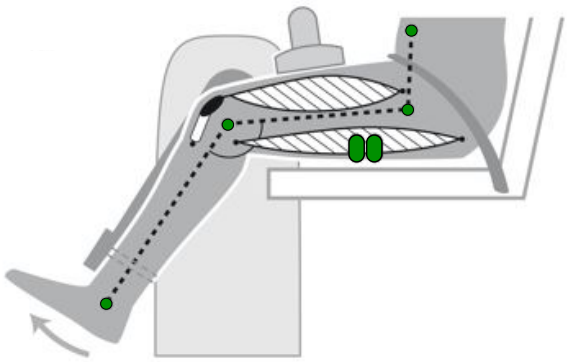
- 3 m, 5 f
- 16 ± 1 years; 169 ± 9 m; 57 ± 9 kg
- Sportive activity < 2x / week

Methods
Muscle properties

- **Morphology & architecture**
  Muscle thickness, pennation angle
  - Inactive muscle
  - 60° knee angle



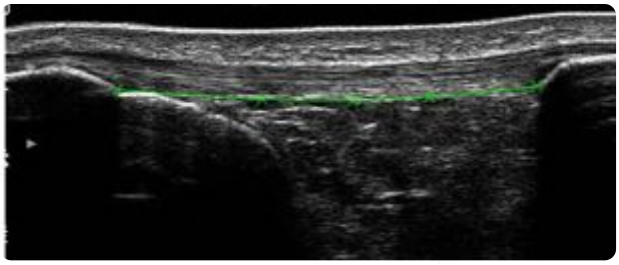
- **Muscle strength**
  Knee extension moments
  - Axis misalignments
    Arampatzis et al. 2004
  - Moments due to gravity
    Arampatzis et al. 2004
  - Coactivation
    Mademli et al. 2004

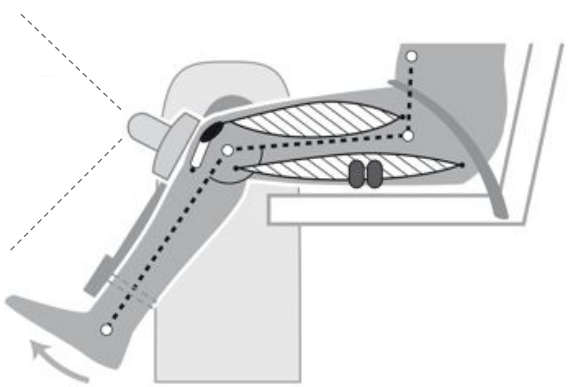


Methods
Tendon properties

- **Mechanical properties**
  Tendon stiffness, maximum strain
  - 5 trials isometric ramp contractions
    Schulze et al. 2012
  - Force elongation relationship

- **Moment arm**
  for calculating tendon force
  - Athletes: MRI segmentation
    Churchill et al. 1998; Herzog & Read 1993
  - Controls: Prediction using anthropometric data





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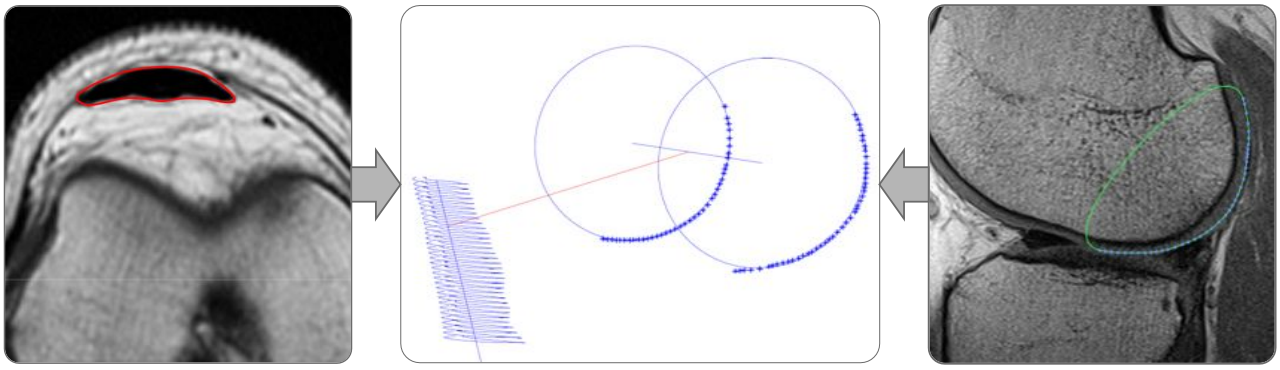
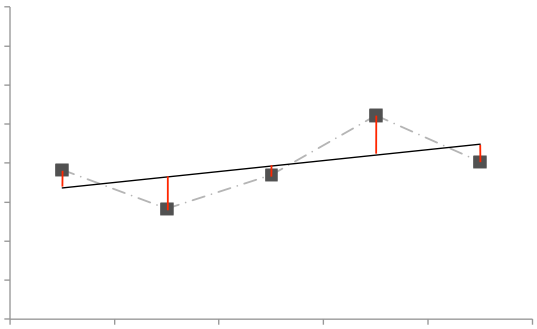


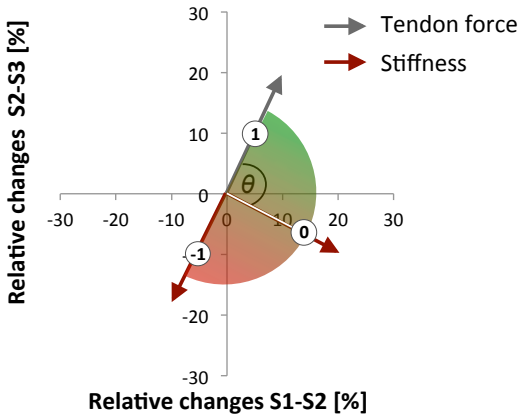
Methods
Data analysis

- **Time-dependent changes and group differences**
  Linear mixed model (LMM)

- **Fluctuations over time**
  Absolute residuals to LMM fit
  - *Welch's t-test* for between-group comparison

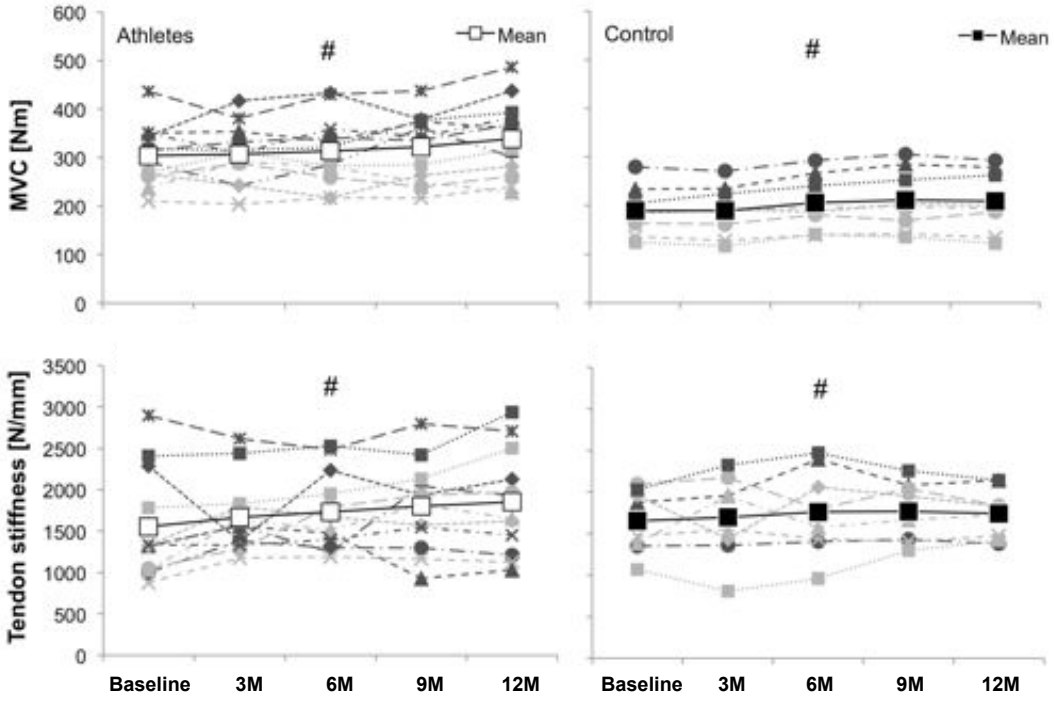


- **Association & uniformity of muscle-tendon adaptation**
  LMM & Cosine similarity
  - Association: LMM prediction of tendon stiffness by tendon force
  - Uniformity: Cosine similarity of relative changes



Results

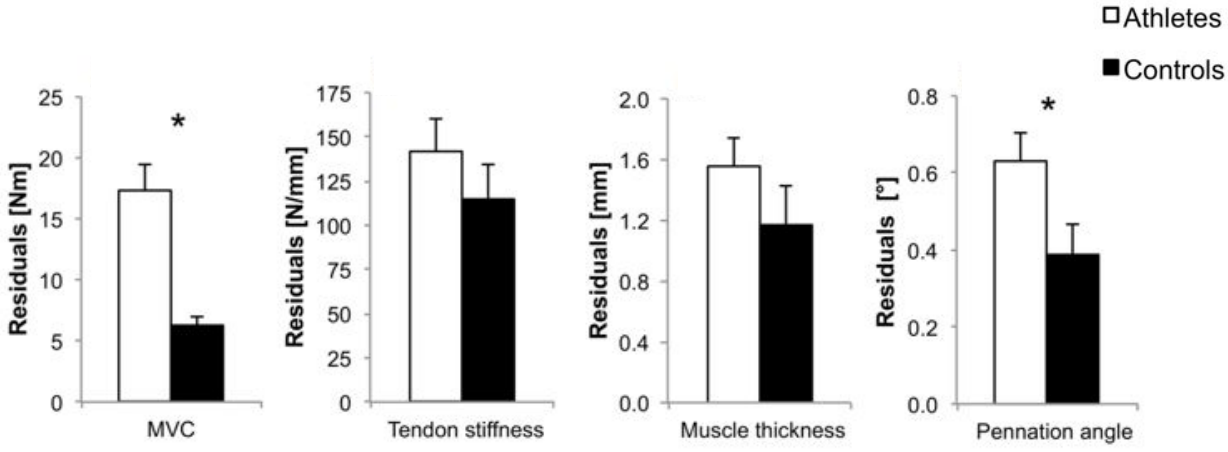
Muscle strength & tendon stiffness over time



sign. change over time

Results

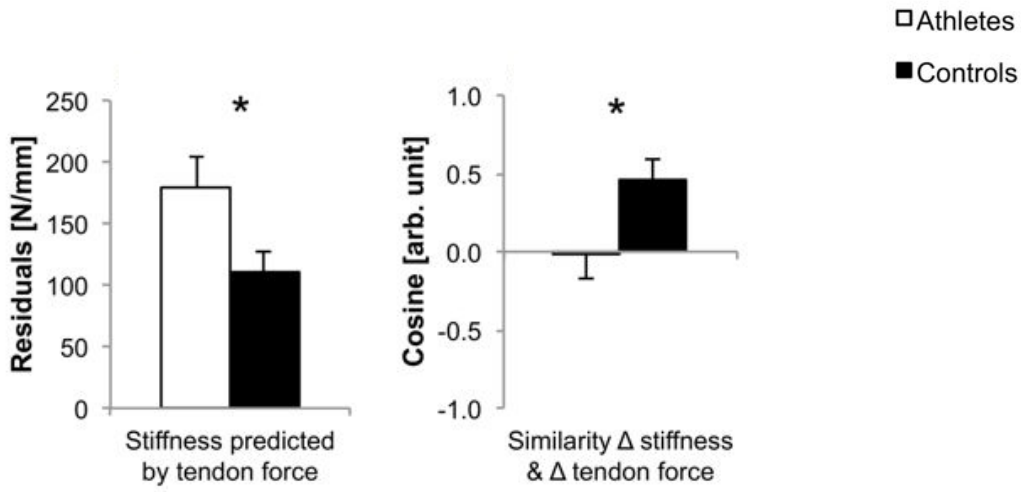
Fluctuations of strength, architecture and stiffness



* sign. difference between groups

- Athletes demonstrated greater fluctuations of strength and pennation angle
- Pennation angle and thickness predicted MVC ($R^2 \geq 0.94$)

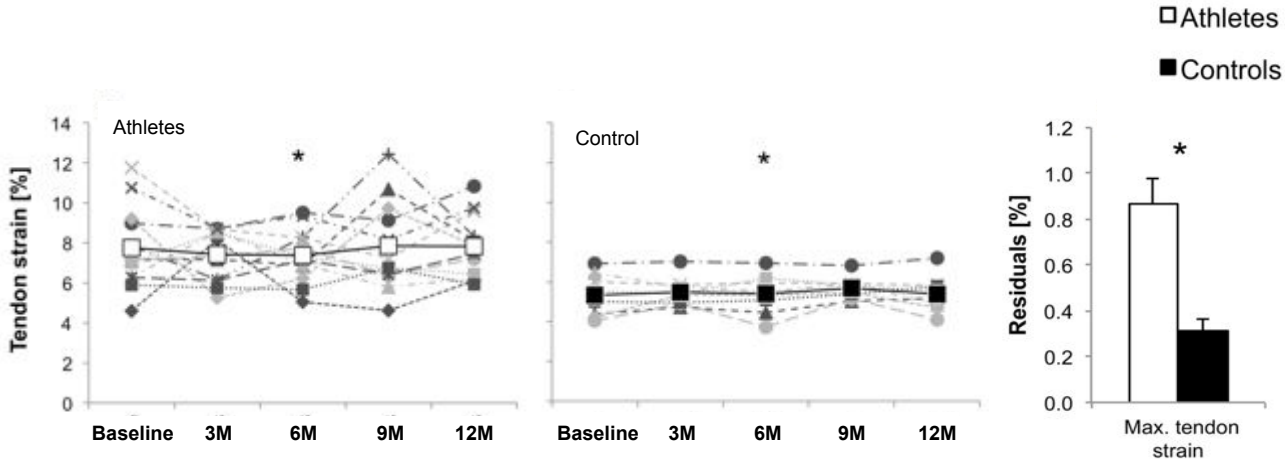
Results
Uniformity of tendon force and stiffness



* sign. difference between groups

- Athletes demonstrated greater less uniformity of muscle and tendon adaptation

Results
Consequences for tendon strain



* sign. difference between groups

- Athletes demonstrated greater average maximum strain and fluctuations of strain

Discussion
Non-uniform adaptation of muscle and tendon

- **Athletes** demonstrate **greater fluctuations of strength** over time
  - Seasonal variations of mechanical loading Koutedakis 1995

- … and **less uniformity** of muscle and tendon adaptation.
  - Plyometric loading profile effective for muscle but not tendon adaptation Kubo et al. 2007, Bohm et al. 2014

- This results in a **greater** mechanical **demand** on the **tendon**
  - Potential contribution to predisposition for tendon overuse injury
    Arya & Kulig 2010, Child et al. 2010

Discussion
Non-uniform adaptation of muscle and tendon

- **Athletes** demonstrate **greater fluctuations of strength** over time
  - Seasonal variations of mechanical loading Koutedakis 1995

- **Injury prevention: Facilitation of tendon adaptation**
  ≥ 85 % MVC contractions, ~ 3 s contraction duration ; n
  Arampatzis et al. 2007, 2010; Bohm et al. 2014

- This results in a **greater** chronic **demand** on the **tendon**
  - Potential contribution to predisposition for tendon overuse injury
    Arya & Kulig 2010, Child et al. 2010

Thank you
for your attention!

Sebastian Bohm

Arno Schroll

Robert Marzilger

Adamantios Arampatzis

3rd International Autumn School on Movement Science

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