Biomechanical studies on the finger flexor tendon pulley system – Stringing the bow

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Anatomy: Pulley System

- 4 anular fibroosseous pulleys (A1, A2, A4, A5)
- 1 anular pulley inserting on the palmar plate (A3)
- 3 cruciform pulleys (C1, C2, and C3)
Anatomy: Pulley System

- FDP runs through the pulleys A2, A3, and A4
- FDS only runs through the pulleys A2 and A3
  => The A4 pulley is not loaded by the FDS tendon.
Anatomy: Pulley System
Histology: Pulley System

The inner layer has multiple folds and creases.

Hyaluronic acid
Crimping and Hanging Fingerposition
\[ F_P = 2 \times TT \times \cos\left(\frac{\beta}{2}\right) \]

\( \beta \) is a function of:
- \( \alpha \) (PIP-angle)
- Position of the pulley

Roloff, Schöffl et al. J Biomech 2005

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Concentric vs. Eccentric Motion

- Concentric Motion consists of Flexing of the finger = closing the hand.
- Eccentric Motion consists of Extending the previously flexed finger = opening the hand.
- Eccentric Movements are always stronger than concentric Movements as a consequence of the allignment of the muscle fibres.
The Importance of the Eccentric Motion

- Birds and Bats show a Tendon locking mechanism leading to a high strength deficit enabling them to hang effortlessly on their closed fingers.
Importance of the Eccentric Motion

- Same histology in humans?
- Possible pathomechanism for pulley ruptures: „opening of the hand“ when tired or when losing a foothold.
Material and Methods of Anatomic Study

FDS/FDP:\nHanging = 1:1
Crimp grip = 1:2

\[1 \text{ Vigouroux et al., Journal of Biomechanics 40, 2007}\]
\[2 \text{ Schweizer et al., Journal of Biomechanics 36, 2003}\]
Measuring of the Forces acting underneath the pulley System

Specifically designed force transducers:
- 1 finger with transducer under A2 pulley
- 1 finger with transducer under A2 and A4 pulley
Results: Forces acting underneath the pulleys

Schöffl et al., J Sports Tech., 2009
Discussion: Forces acting on the pulleys

- Measured forces about half as high as calculated ones from the model.
  - Measuring technique faulty?
  - Model incorrect?
- The data showed the same tendency
- More research needed for better understanding of these forces
- However first measuring technique for measuring forces in such confined spaces.
Results: Hanging vs. Crimp Grip Position during Concentric Movement

Schöffl et al. 1, J. of Biomechanics, 2009
Results: Hanging vs. Crimp Grip Position during Concentric Movement

The forces acting on the pulleys at the moment of rupture are higher on the pulleys for crimp but comparable for FDP and fingertip.

The distance between pulleys at the moment of rupture is lower for cimp grip (pulleys approach each-other).

Schöffl et al. 1, J. of Biomechanics, 2009
Discussion: Hanging vs. Crimp Grip Position

- A pulley rupture was rare in the hanging finger position as a consequence of lower forces acting on the pulleys.
Discussion: Hanging vs. Crimp Grip Position

- A pulley rupture was rare in the hanging finger position as a consequence of lower forces acting on the pulleys.
- No A4 pulley rupture in the hanging finger position because of the lesser influence of FDS.
However, the forces at the first event were comparable. Thus the fact that the pulleys approach each other in the crimp grip is a protective factor for other injuries.
Discussion: Hanging vs. Crimp Grip Position

Slopers are better than Crimps
Results: Concentric vs. Eccentric Motion

Schöffl et al. 1, J. of Biomechanics, 2009
Results: Concentric vs. Eccentric Motion

At the moment of pulley rupture comparable forces on the pulleys but lower in FDP and fingertip = Less force needed for pulley rupture in eccentric movement.

Schöffl et al. 1, J. of Biomechanics, 2009
Discussion: Concentric vs. Eccentric Motion

- Ruptures occurred at far lower forces for the Eccentric Motion => Friction underneath the pulleys also relevant in humans
Discussion: Concentric vs. Eccentric Motion

- Ruptures occurred at far lower forces for the Eccentric Motion. Friction underneath the pulleys is also relevant in humans.
- A2 rupture was more common in the Eccentric Motion. This reflects the injuries we observe.
Discussion: Concentric vs. Eccentric Motion

- Ruptures occurred at far lower forces for the Eccentric Motion => Friction underneath the pulleys also relevant in humans
- A2 rupture was more common in the Eccentric Motion. This reflects the injuries we observe.
- Beware with difficult moves when being tired!
Thank you for your attention