On the biomechanical relationship between external hip, knee and ankle joint moments and the internal knee compressive forces

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Motivation – Knee Osteoarthritis (KOA)

- Inflammation
- Stiffness
- Pain

- >9.5 million EU KOA patients (Peat G. et al, 2001)
- Multi-factoral disease
  - Genetic
  - Previous ligament ruptures
  - Overloading

Non-invasive treatments of KOA

- Skin surface displacement
- MCL may be too stiff
- Shifts load but not reducing

Modified picture from (Pollo et al. 2002)
Investigate how internal knee joint loads depend on external moments
Hypothesis: Joint loads depend as much on muscle contraction as on KAM
Method

10 healthy subjects, 3 gait trials each (self-selected speed)
• Recorded with marker-based motion capture
• Measured ground reaction force

Skals et. al, 2016
Method

Apply external joint moments to simulate a brace *in-silico*

- **40%** compensation of muscle work $\rightarrow$ Reducing joint load

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- **40%** compensating muscle work → Reducing joint load
Method

Example of knee flex-ext
Results – Total compression load

40% Muscle Compensation

Shaded area: ± 1 SD

<table>
<thead>
<tr>
<th>Normal</th>
<th>Hip Fle-Ext</th>
<th>Knee Fle-Ext</th>
<th>Ankle Plant-Dors</th>
</tr>
</thead>
</table>

Total Compressive Load [%BW]

% of Gait Cycle

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Method – Combined load cases

Hip+Knee  Hip+Ankle  Knee+Ankle  Hip+Knee+Ankle
Results – Total compression load

40% Muscle Compensation

Shaded area: ± 1 SD

Total Compressive Load [%BW]

% of Gait Cycle

No Ext, Hip+Knee, Hip+Ankle, Knee+Ankle, Hip+Knee+Ankle

Lateral, Medial

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Results – Medial condyle load

Shaded area: ± 1 SD

On the biomechanical relationship between external hip, knee and ankle joint moments and the internal knee compressive forces
Results – Lateral condyle load

Shaded area: ± 1 SD

Lateral Load [%BW]

% of Gait Cycle

No Ext
Hip+Knee
Hip+Ankle
Knee+Ankle
Hip+Knee+Ankle
Knee Var-Val

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Discussion and Conclusion

• Useful information for brace development

• Muscle contraction $\rightarrow$ Joint compressive force
  – First peak: Knee and hip compensation
  – Second peak: Ankle compensation

• The external moment activation is a big challenge
  – Combine two moments

• Take home message:
  Muscle compensation might be a more efficient approach for joint load reduction
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