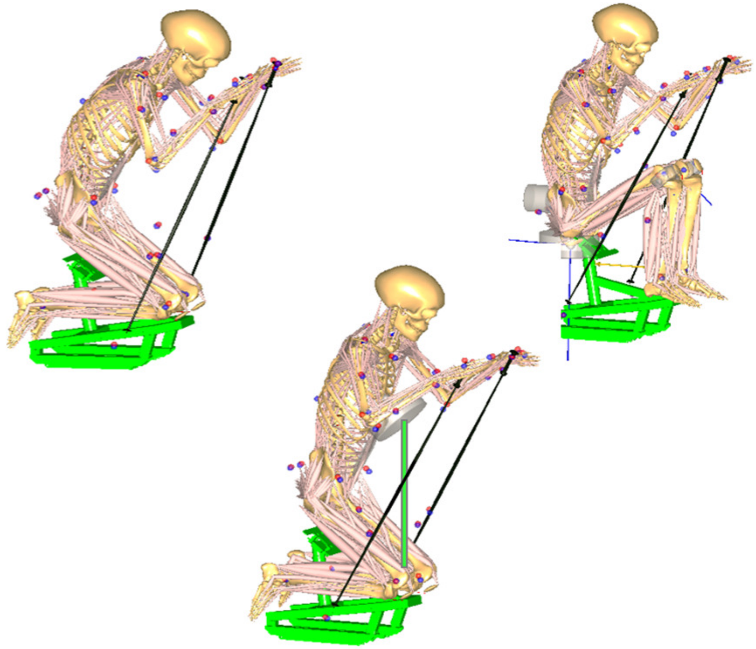
MUSCULOSKELETAL SIMULATIONS IN CROSS-COUNTRY SIT-SKIING



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2018-09-27

PhD thesis: http://www.diva-portal.org/smash/get/diva2:1181248/FULLTEXT01.pdf

Lund Ohlsson, Marie, Jonas Danvind, and L. Joakim Holmberg. "Shoulder and Lower Back Joint Reaction Forces in Seated Double Poling." *Journal of applied biomechanics* (2018): 1-27.

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Background

Classification in parasports

- Classification provides a structure for competition and is performed to ensure that an athlete's impairment is relevant to sport performance and that all athletes compete equitably.
  (IPC Classification code, 2007)
- Classification has a large impact on creating fair competitions and therefore it is important that classification groups athletes into different classes depending on how their impairment affects their sport performance
  (Tweedy, Beckman, & Connick, 2014; Tweedy & Vanlandewijck, 2011).

Musculoskeletal simulations can answer where in the body muscle work is performed and thereby increase understanding of how impairment impact sports performance

Background

Lower back pain and injuries

- High prevalence in able-bodied cross-country skiing

  (Bahr et al., 2004), (Bergstrøm et al., 2004)

- General risk factors

  Sitting (Andersson et al., 1975)

  High peak anterior shear force, high compression over time

  (Norman et al., 1998)

  Spinal flexion results in high shear force

  (McGill et al., 2000)

Background

Lower back pain (LBP) and injuries

- High prevalence in able-bodied cross-country skiing

  (Bahr et al., 2004), (Bergstrøm et al., 2004)

- Hypothesized risk in Cross-Country sit-skiing
  - Sitting
  - High ROM in spine flexion- extension
  - Many repetitions (~600 hours training yearly)
- Injury rates in Cross-Country sit-skiing ?

Background

Shoulder pain and injuries

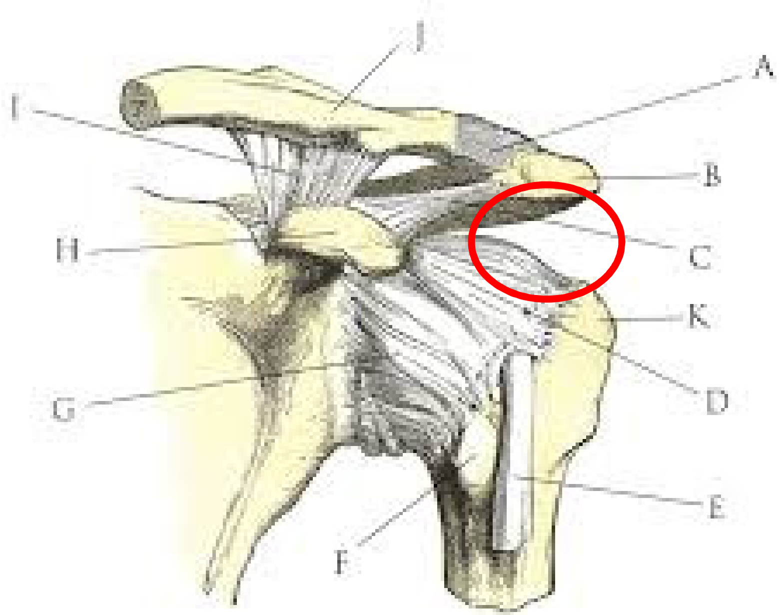
Is a large risk for people using wheel-chair

Sub-acromion impingement syndrome common

(Bayley et al., 1987)

A crouched sitting posture, with backward tilt of pelvis and flexion of the spine can increase the risk of sub- acromion impingement

(Samuelsson et al., 2004)



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Background

Comparative study – two different sitting positions

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Comparative study – two different sitting positions

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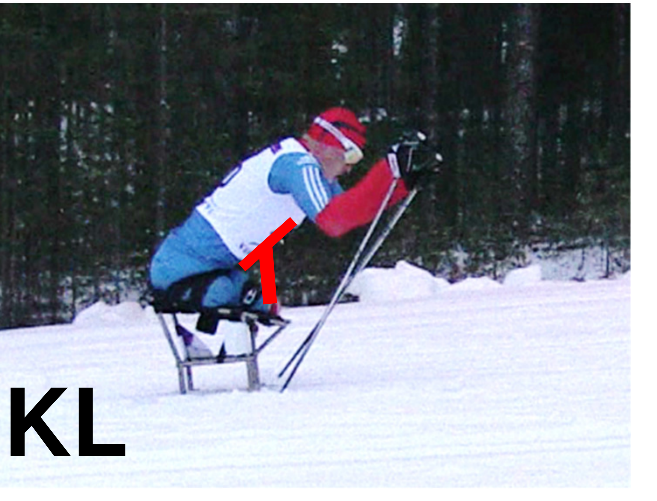
Comparative study – two different sitting positions

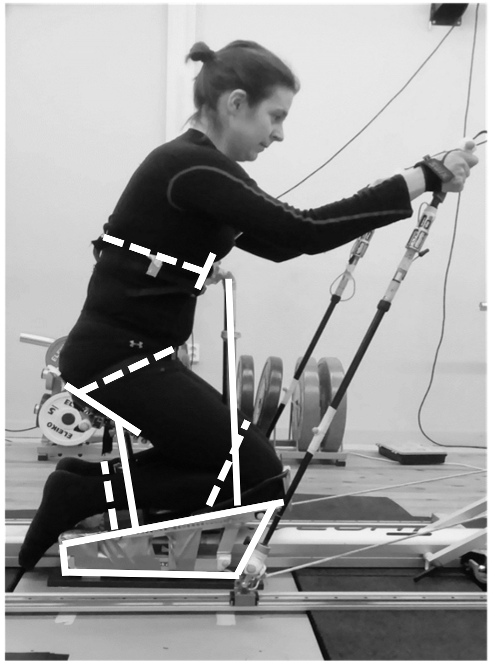
Aims

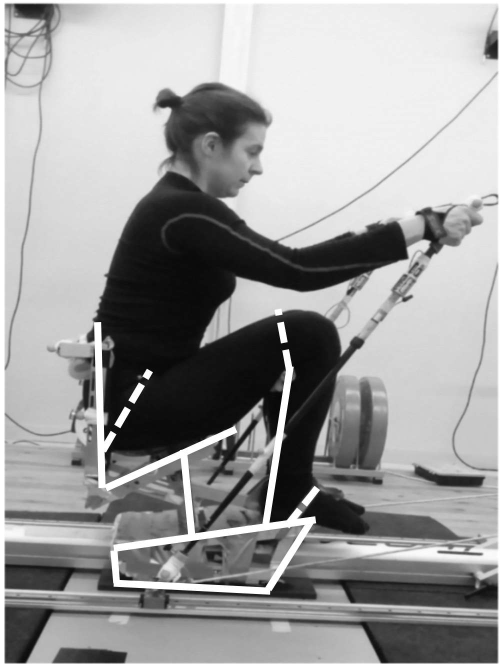
- Explore the difference between sitting position KH and KL
  - Performance
  - Spinal flexion
  - Muscular power
  - Joint reactions in the lumbar spine
  - Joint reaction in the shoulder



Methods

Data collection





5 able-bodied female participants
national class cross-country skiers
(62.6±8.1kg,1.67±0.05m)

Ergometer

Submaximal incremental test (4-7 x 3min)

37W : [B-La^{-}] ~4mmol/l

Maximal time-trial 3 min (MAX)

4 cycles analysed

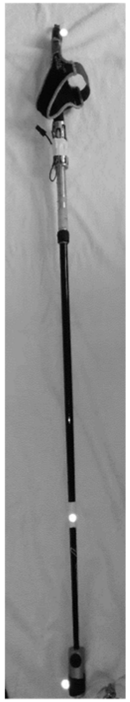
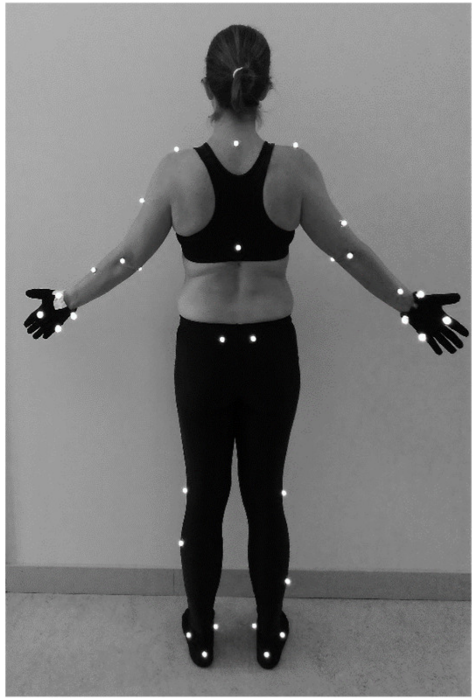
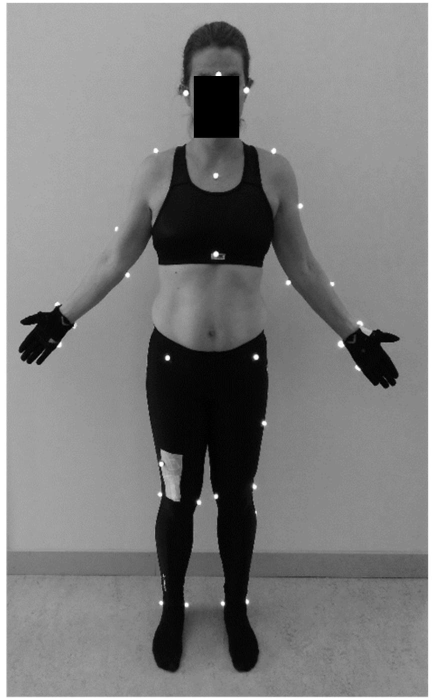
Methods

Musculoskeletal simulations using the Anybody Modelling System

- Inverse dynamics
  kinematic data (Qualisys AB, Sweden) and
  pole forces (Biovision, Wehrheim, Germany)

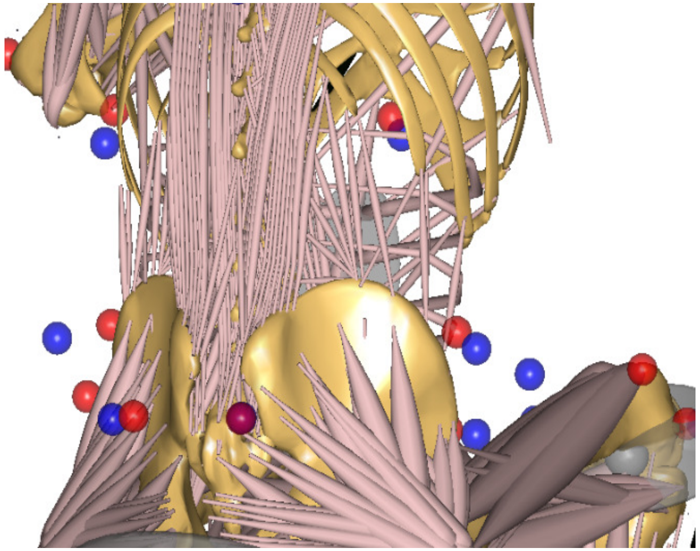
  ➡

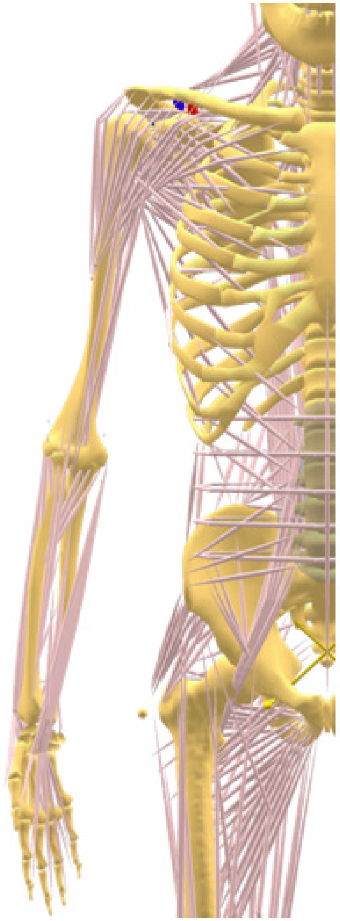
  muscle forces and joint reactions

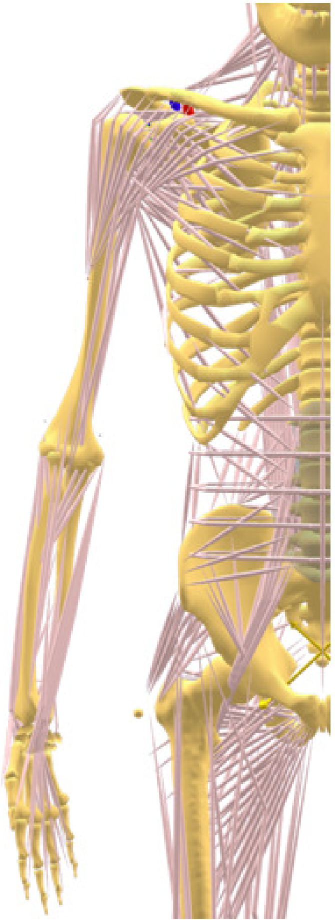
Modelling

- Full body model
  (AnyBody Managed Model Repository v.1.6.3, www.anybodytech.com)
- Scaling LengthMassFat
- Simple force muscle model
- Lumbar spine, 5 vertebrae, spherical joints
  (De Zee et al., 2007)
- Lumbar spine rhythm
- Validation of lumbar spine forces
  (Bassini et al. 2017)
- The glenohumeral joint (shoulder) forces
  (Carbes S. Anyscript Wiki. 2011.)



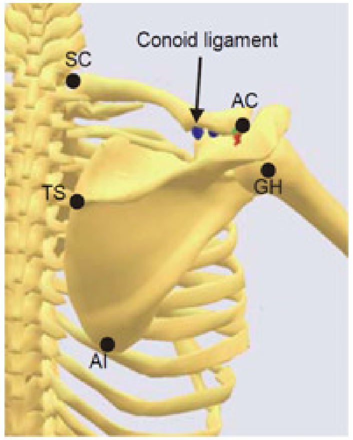


Shoulder

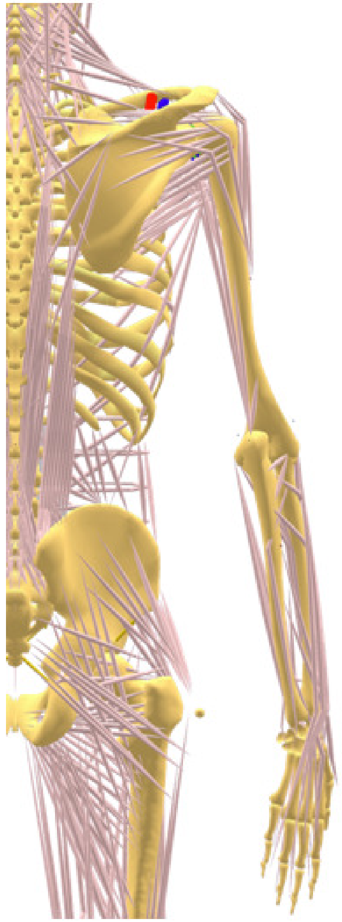


- 118 muscle fascicles on each side
- Wrapping of muscles by contact mechanics
- Contact criterion in the GH joint

Veeger et al. 1991: J. Biomech. 24, 615-29
Van der Helm 1994: J. Biomech. 27, 551-69
Veeger et al. 1997: J. Biomech. 30, 647-52



AC Spherical joint
GH Spherical joint
SC Spherical joint
TS Scapula thoracic gliding plane, ellipsoid
AI Scapula thoracic gliding plane, ellipsoid

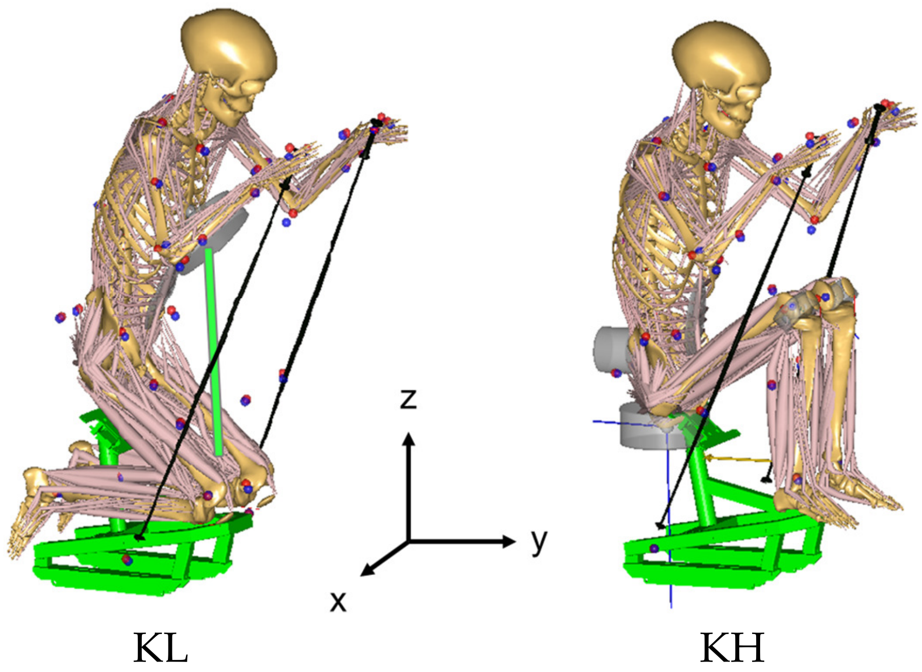


Modelling and simulation

- Connection body model and sit-ski
  - Hard constraints (no motion allowed)
  - Soft contraints (motion allowed, grey cylinders)

- Muscle recruitment criteria

$$G(f_m) = \sum_{i=1}^{n_m} \left(f_{m,i}\right)^5$$



Muscular power

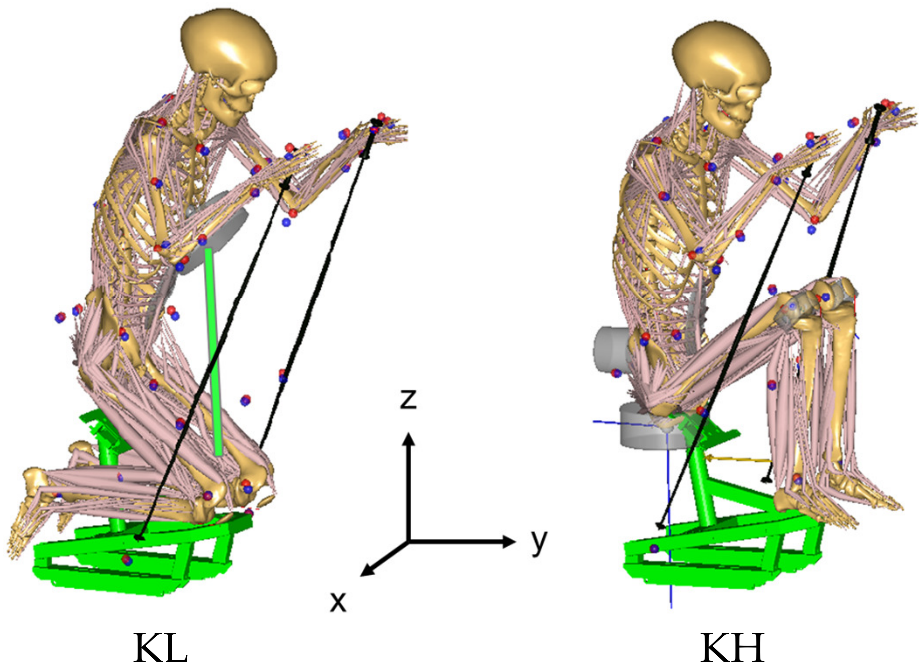
- Muscular metabolic power

$$\mathrm{mMP_i} = \begin{cases} f_i \cdot v_i/1.25 & \text{if } v_i > 0 \\ -f_i \cdot v_i/0.25 & \text{if } v_i < 0 \end{cases}$$

v_i is the contraction velocity

$$\mathrm{mMP_{tot}} = \frac{\sum_{i=1}^{n} \int_0^{Cycle\ time} \mathrm{mMP_i}\, dt}{Cycle\ time}$$

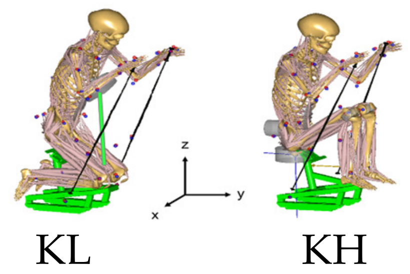
n is the number of muscles



Results

KH - larger performance (mean power output in MAX / body weight)

KL: 0.77±0.08 W/kg KH:1.00±0.14 W/kg $p < 0.01$



Results – Kinematics, Kinetics

Knees high (KH):

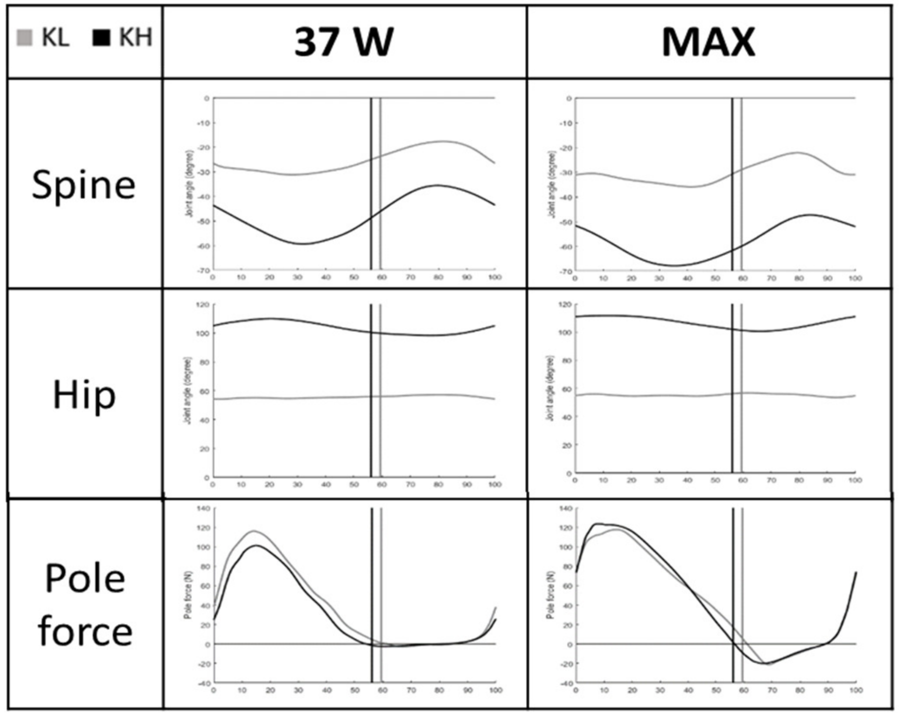
Larger ROM and flexion of spine

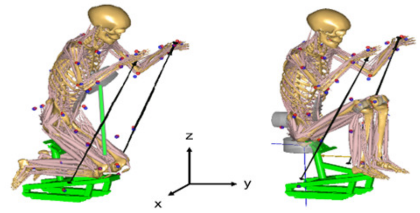
Larger ROM and flexion of hip

Axial pole forces

smaller peak in 37W

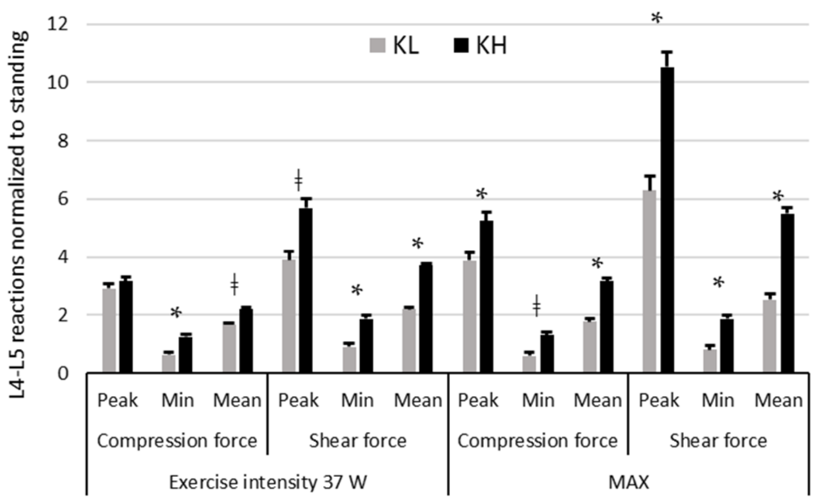
no difference in MAX





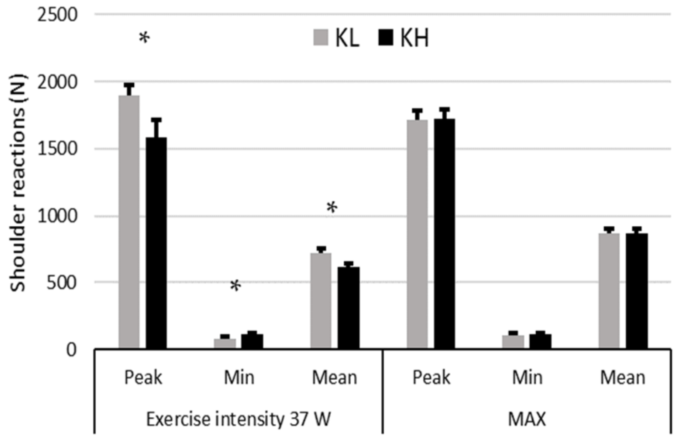
Results

Lumbar joint reaction forces

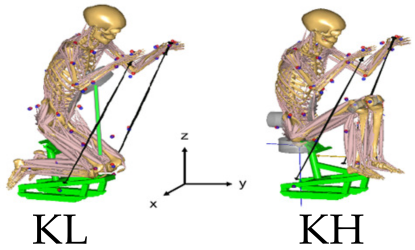


Significant difference marked (*) and tendency of difference (0.05 ≤ p < 0.10) marked (ǂ). Error bars shows standard deviation.

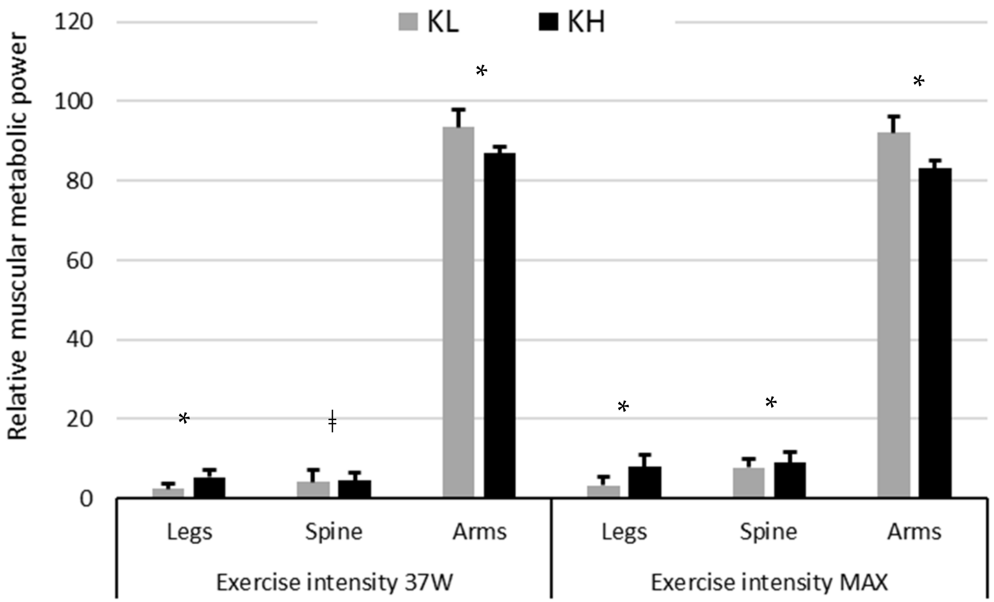
Shoulder joint reaction forces



MAX Power output KL 48W, KH 63W



Results- Muscular metabolic power



Significant difference marked (*) and tendency of difference ($0.05 \leq p < 0.10$) marked (ǂ). Error bars shows standard deviation.

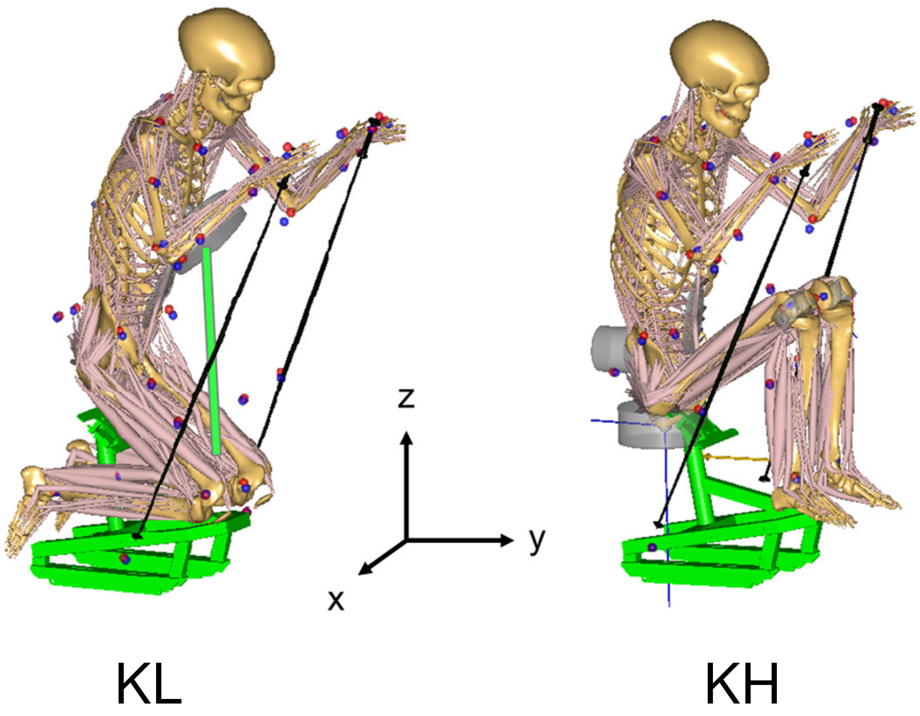
Summing up

KH

- Higher performance

- larger spinal flexion
- higher L4-L5 shear force
- higher L4-L5 compression force

- Relatively larger involvement of hips-legs and spine muscles



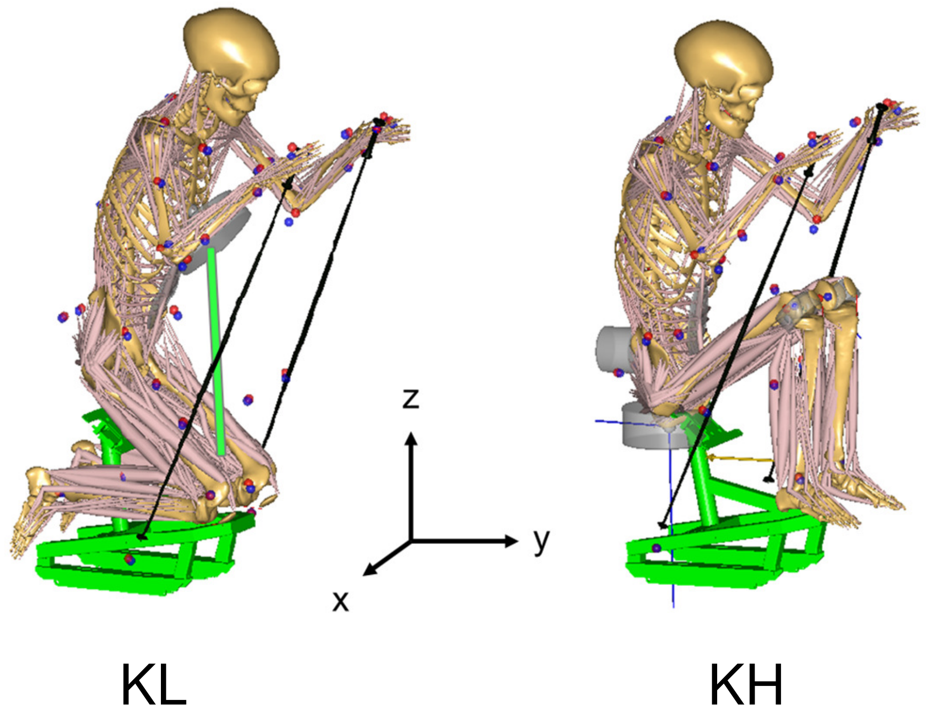
Summing up

KL

- Larger shoulder joint reactions
- Lower performance
- Larger arm muscle power

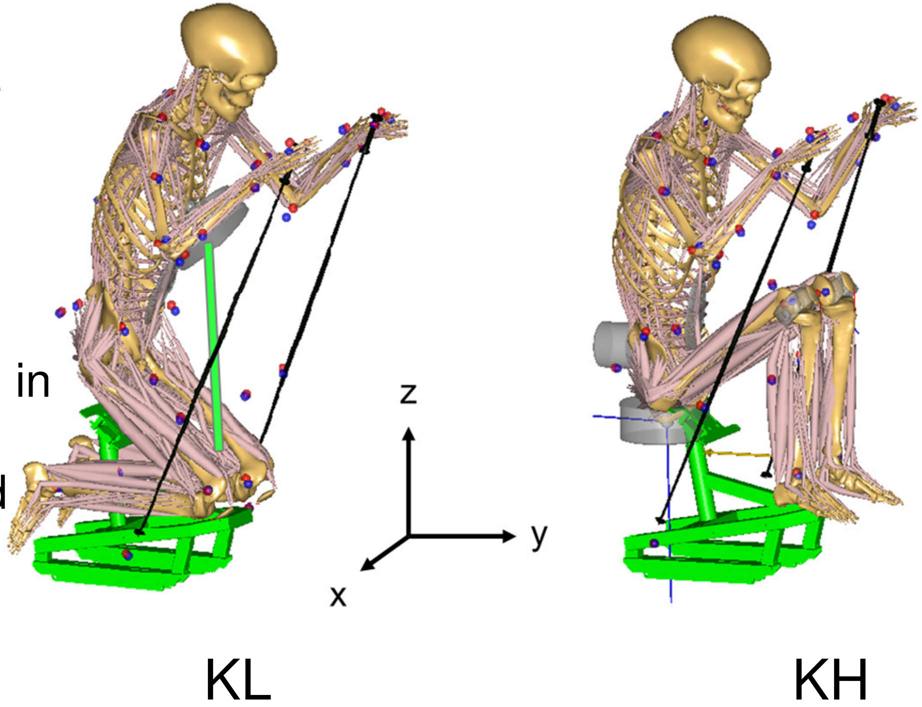
Limitations:

- able-bodied participants
- low number of participants



Conclusion

- KH with larger flexion of spine might indicate higher risk of lower back pain/injury
- Larger shoulder reactions when shoulder muscle power was larger (KL)
- Most muscle metabolic power was produced in the arms for both positions
  - KH was relatively more driven by spine and hip-leg muscles
    (useful for classification development?)



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Thank you!

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