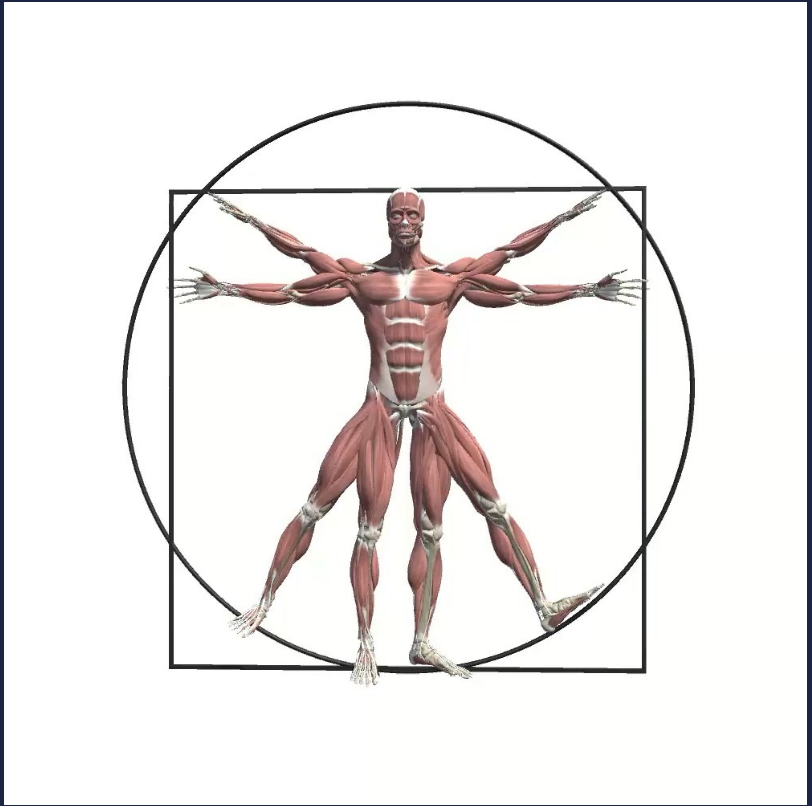
Evaluation of the load on bicycle delivery services using the 3D-musculoskeletal computermodel „Myonardo“



Mag. Norbert Lechner
Manchester, September 10th 2025

predimo
prediction of movement

WWU
MÜNSTER

AUVA

Arise of bicycle delivery services

History:

- Since 80ths part of cityscapes, especially big cities

  (NY, London, San Francisco, etc)

- Own style (fixed gear, clothing, bags, etc)

- Mainly documents and small objects

Today:

- Food deliveries
- With a rapid increase during pandemic

Advantages: environment, fast accessibility despite city traffic

Risks for bicycle delivery workers

- 409 commuting accidents in 2018
- Increase by a factor of 4 from 2019 to 2020
- A doubling from of accidents 2021 compared to 2020
- Self employment → „no“ insurance
- No sufficient training
- Pressure (especially food delivery)
- Weight of the transport box up to 19kg

Previous and current assessment of cycling biomechanics

- 2D and 3D video analysis (Ericson, & Nisell, 1987)
- Electromyography (EMG) (Ericson et al., 1987)
- Powermeters (instrumented bike parts, i.e. pedals, seatpole, handlebars) (Ericson, & Nisell, 1987)
- Instrumented prostheses (Rohlmann et al., 2014; Damm et al., 2017)

→ Good estimation of muscle forces and joint loads, but high expenses, demand for preparation, or invasive

New approach to assess muscle forces and joint loads

Computed MyoGraphy

3D-Muscle-Skeleton-Computer-Model „Myonardo

Scaled and validated

35 bones, 21 joints, 682 muscles

exact measurements of muscle activities and forces

with examined immersive dynamics

Research questions

1. What are the loads acting on the riders‘ joints during cycling?

2. How do different positions affect the riders‘ joint loads?

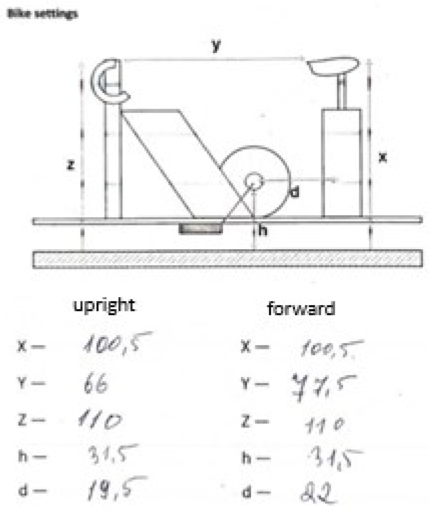
3. How different external loads in the backpack affect the riders‘ joint loads?

4. How large are the joint loads compared to standing, walking and squat lifting?

Methods

Participants and tasks

- 20 male subjects (184.6 ± 7.1 cm, 79.8 ± 10.9 kg, 27.86 ± 8.18 years old)
    - Healthy
    - No experience in bike delivery
- 2 cycling positions
    - Cycling upright (94.5 ± 2.2 deg)
    - Cycling bent forward (76.6 ± 2.3 deg)
- 3 reference tasks
    - Standing
    - Walking
    - Squat lifting
- 4 weight conditions
    - 0 – 5 – 10 – 15 kg



Bike positions

bent forward

upright

Data acquisition

- Stationary bike (Retül, Louisville, CO)
  - Fitted to match the positions for each subject
- Xsens Awinda IMU system (Movella, Enschede)
  - 17 IMUs attached to body segments
  - 1 IMU attached to backpack
- External forces
  - Handle bar forces
  - Pedal forces
  - Bike seat forces
  - Backpack was modeled as prop object

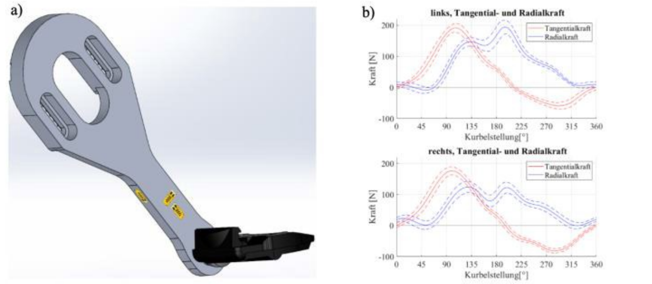


Abbildung 0.1: a) 3D-Modell der Fahrradkurbel mit Sensorik zum Detektieren der Biegung und der Druck-Zug-Dehnung; b) Exemplarische Messwertdarstellung der Tangential- und Radialkraft vom linken und rechten Kurbelmesssystem

Röttger, 2021

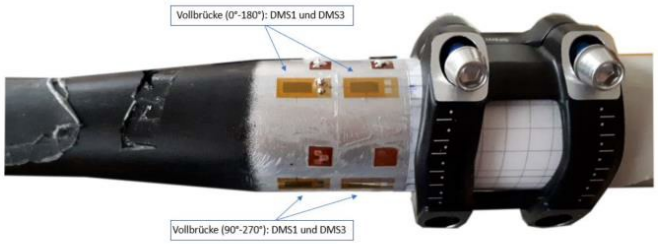
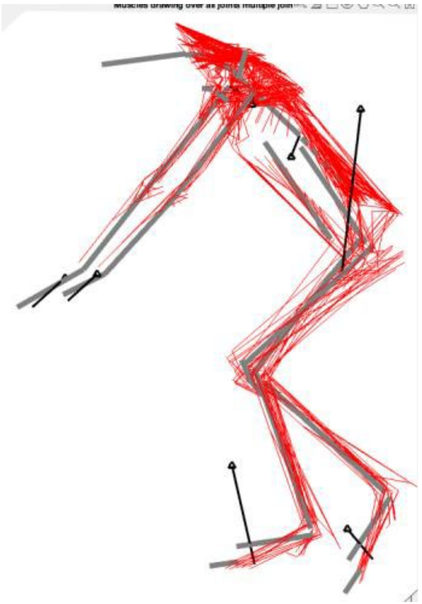


Abbildung 7.5: Bearbeitete Lenkerseite mit installierten DMS; Abgebildet sind die DMS 1 und 3 der beiden um 90° versetzten Messbrücken

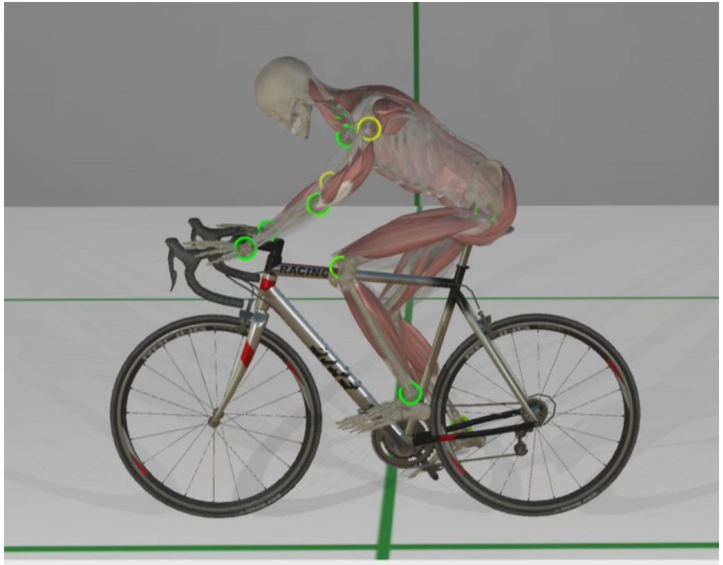
Polinski, 2022

Computed MyoGraphy using Myonardo®



- Musculoskeletal model Myonardo (v.7.5.9, Predimo GmbH, Münster, Germany)
- 28 rigid body segments and 692 muscle-tendon-units (Wagner et al., 2023)
- Scaled relative to the subject's body mass and height
- Net joint torques computed based on measured segment kinematics external forces
- Calculation of total joint force for each joint as the sum of the external forces and the muscle forces

Computed MyoGraphy using Myonardo®



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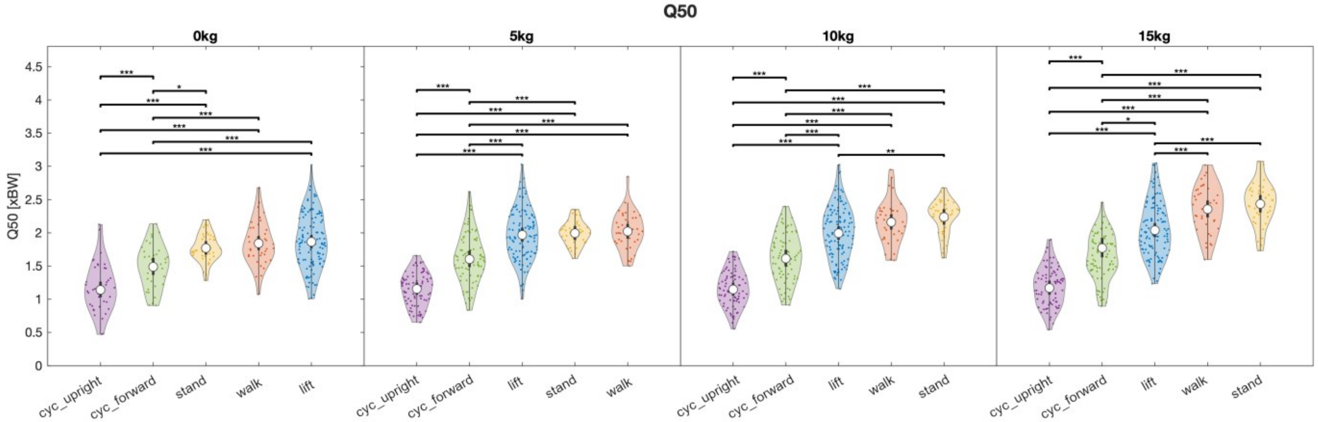
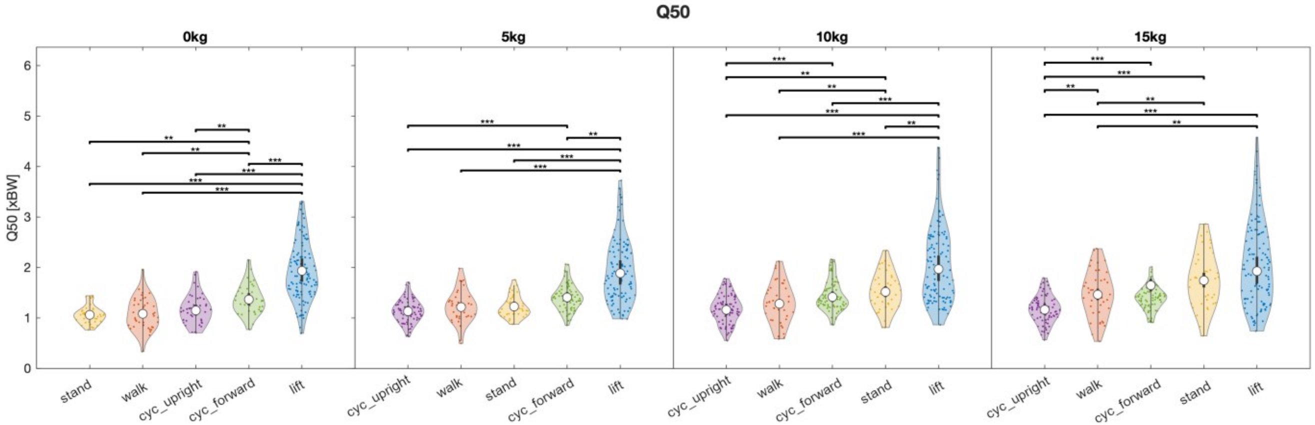
Results

Hip & Knee

Hip



Knee



Discussion and Conclusion

Summarized findings

- Biking in a forward bent position always leads to higher median forces than biking in an upright position
- Biking in a forward bent position mostly leads to highest median forces in the upper body joints than reference tasks (except lifting with no and low weight at L5/S1
- Highest median forces were found at L5/S1 joint (up to 6xBW)
- Lower extremities are less prone to additional weight and cycling tasks

Conclusion

- The results indicate a recommendation towards cycling in an upright position compared to forward bent position

- Additional weight can lead to high loads, especially in the lower back region

- Limitations of the study
  - Forces were only analysed during steady state cycling, sub-tasks like getting on or off the bike were not evaluated (yet)
  - Wattage of cycling was not recorded or fixed, subjects could choose their preferred speed

Next steps

- Analysis and interpretation of
  - Remaining joints (i.e. ankle, elbow)
  - Shear forces and peak forces
  - Forces during sub-tasks (e.g. getting on/off the bike)

- Comparison between computermyography and conventional biomechanical assessment

- Derive measures to improve occupational safety and health of bike delivery riders

Literature

Ericson, M. O., & Nisell, R. (1987). Patellofemoral joint forces during ergometric cycling. *Physical therapy*, *67*(9), 1365-1369.

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Thank you very much for your attention!

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