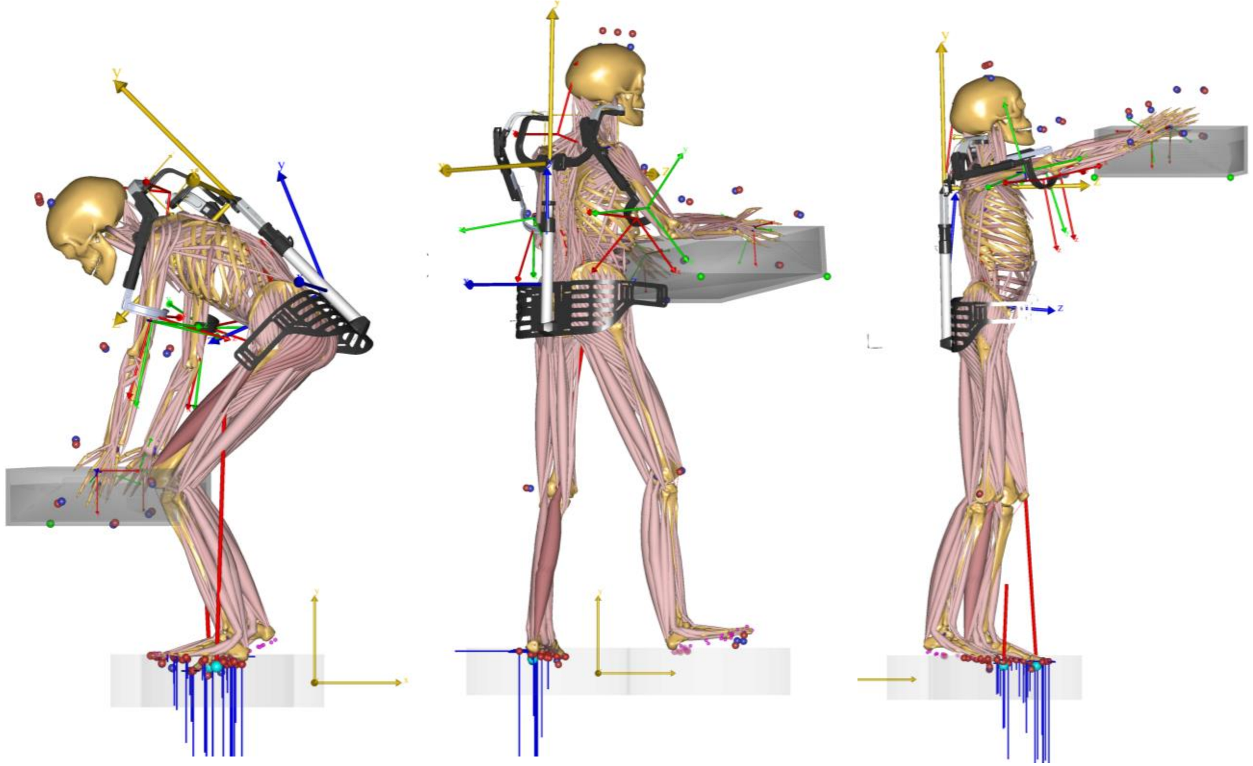
The webcast will begin shortly…

Biomechanical investigation of a passive upper extremity exoskeleton for manual material handling - A computational parameter study

January 12th , 2021



Outline

- General introduction to the AnyBody Modeling System
- Presentation by Bo Eitel Seiferheld
  - *Biomechanical investigation of a passive upper extremity exoskeleton for manual material handling - A computational parameter study*
- Question and answer session

Presenter:
Bo Eitel Seiferheld,
M.Sc. Sports Technology,
Aalborg University, Denmark

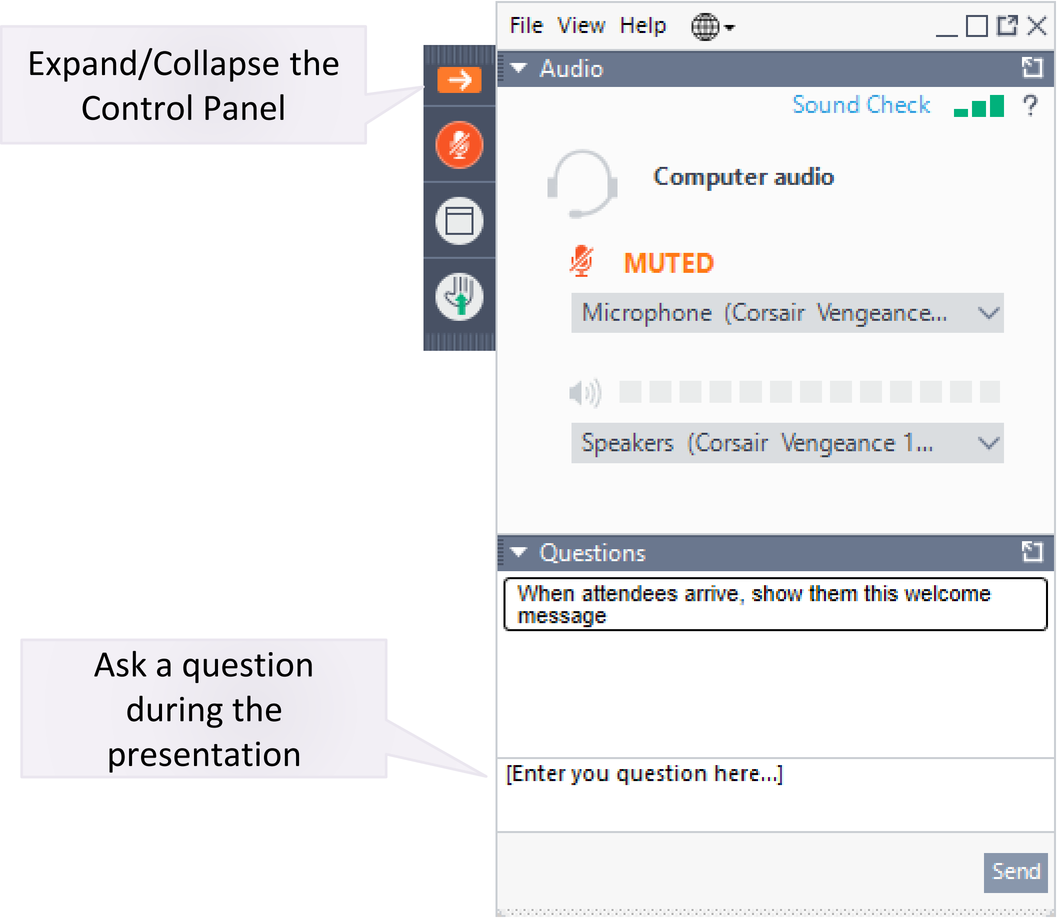
Host:
Kristoffer Iversen
R&D Engineer
AnyBody Technology

Control Panel

The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.



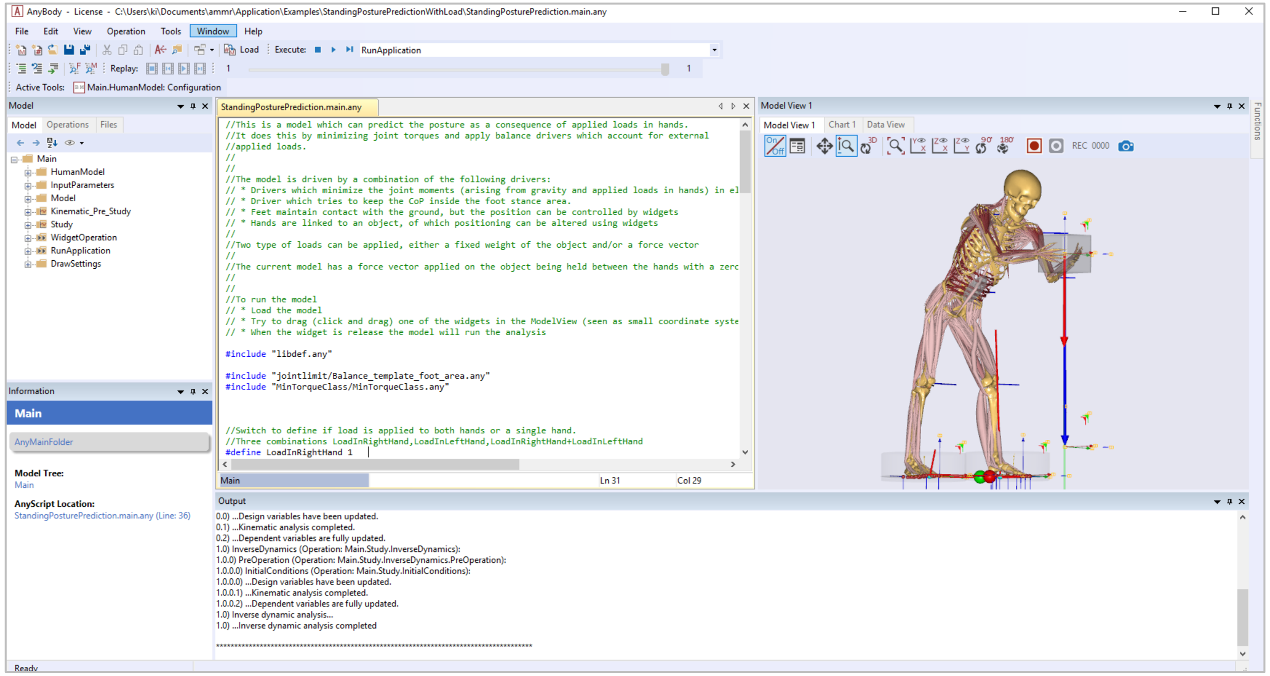
ANYBODY TECHNOLOGY

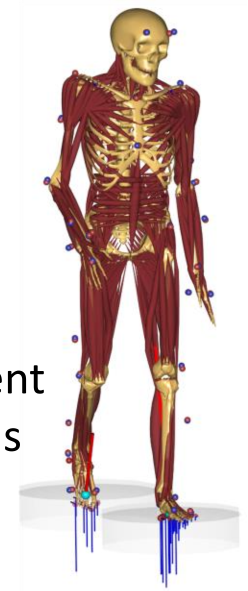
Musculoskeletal Simulation

Motion Data
Kinematics and Forces

ANYBODY
Modeling System

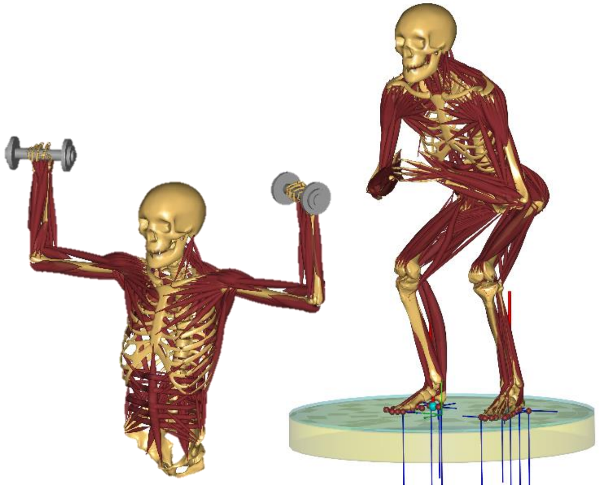
Body Loads
- Joint moments
- Muscle forces
- Joint reaction forces





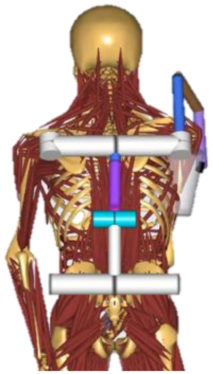
Movement Analysis

Product optimization design

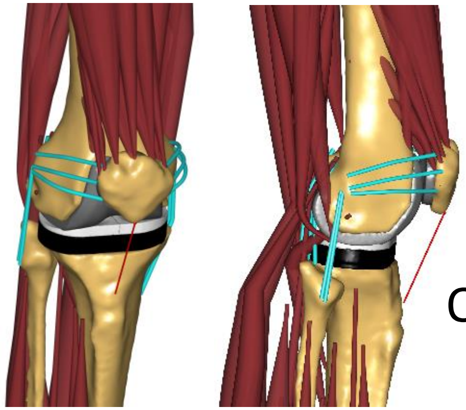


Sports

ANYBODY Modeling System

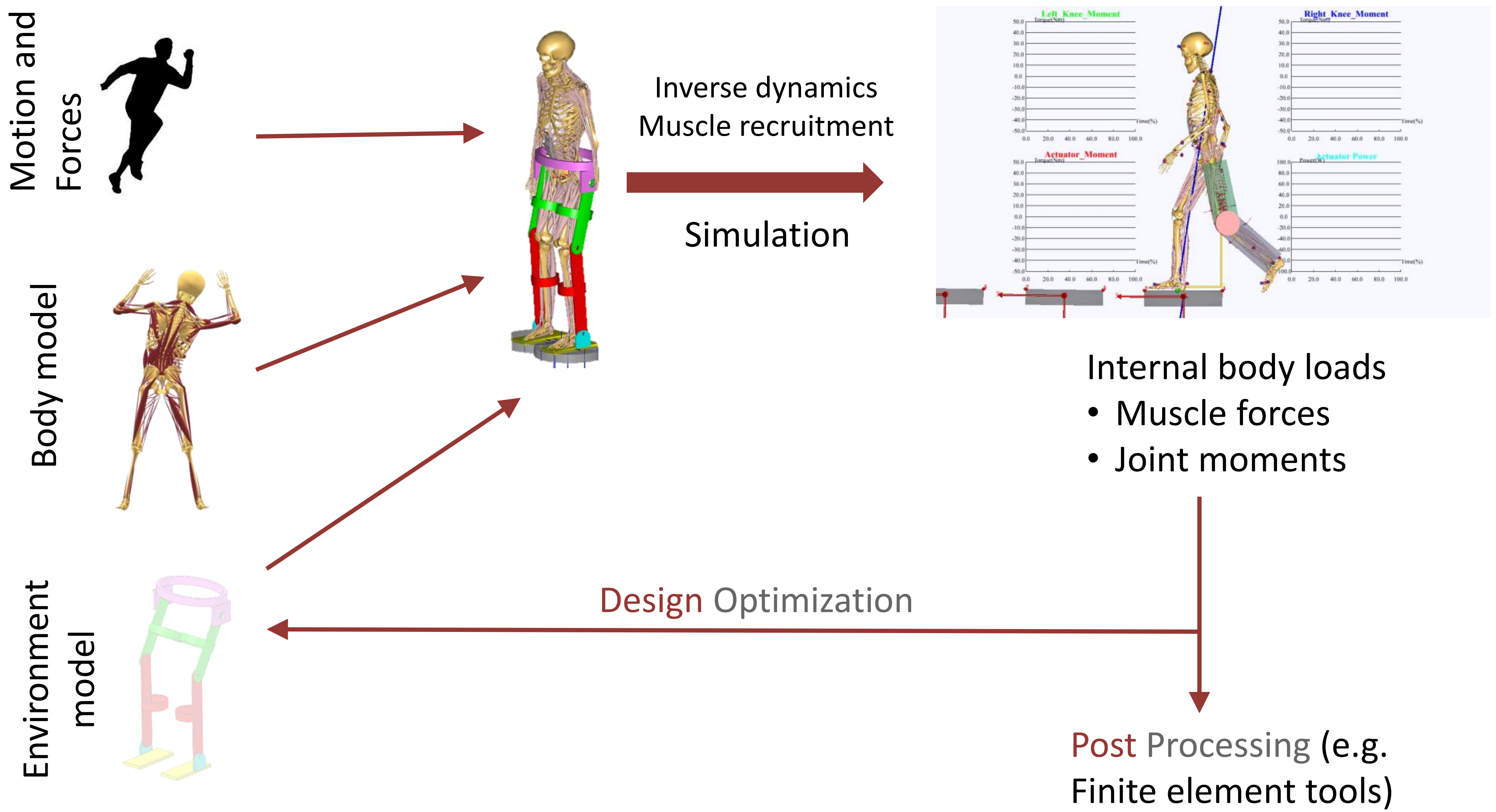



Assistive Devices



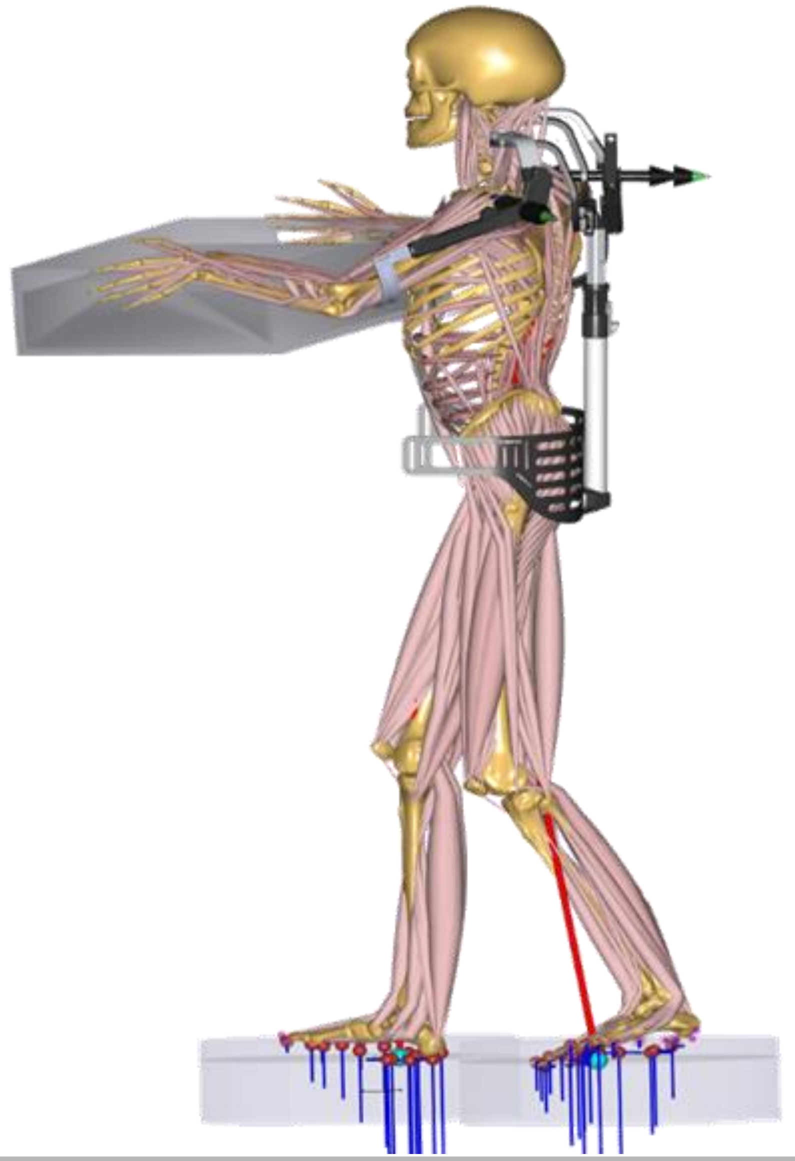
Orthopedics and rehab

AnyBody Modelling System



Biomechanical investigation of a passive upper extremity exoskeleton for manual material handling - A computational parameter study

Presented by Bo Eitel Seiferheld



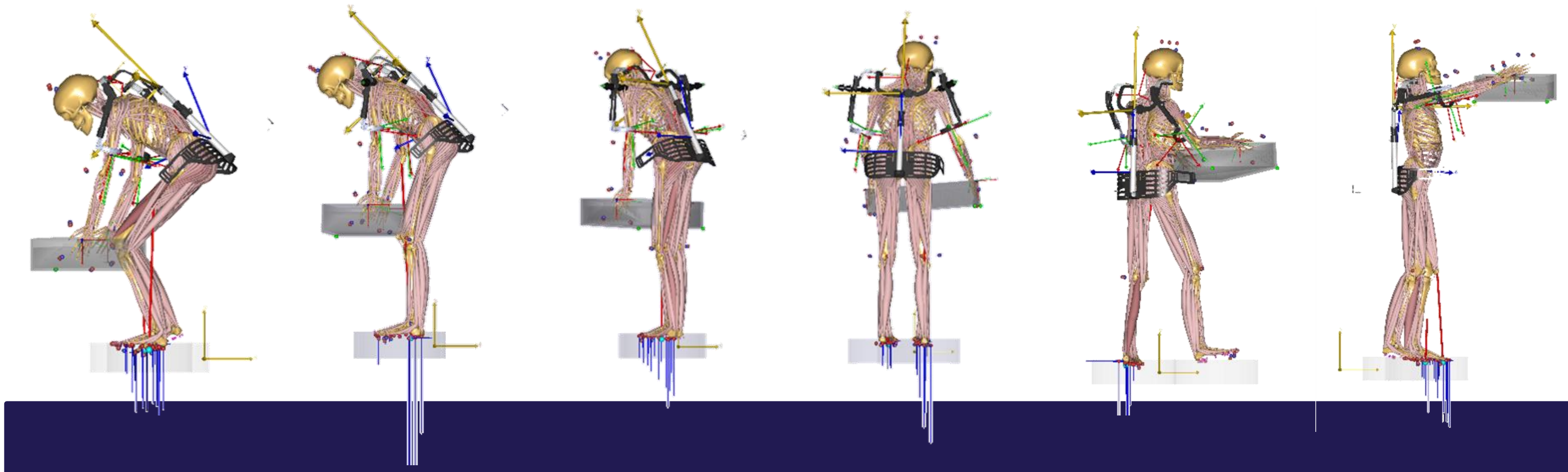
Biomechanical investigation of a passive upper extremity exoskeleton for manual material handling – A computational parameter study

Bo E. Seiferheld[1], Jeppe Frost[1], Mathias Krog[1], Sebastian Skals[1,2], Michael S. Andersen[3]

[1]Department of Health Science and Technology, Aalborg University, Denmark

[2]National Research Centre for the Working Environment, Copenhagen East, Denmark

[3]Department of Materials and Production, Aalborg University, Denmark



Work-related musculoskeletal disorders

Strong evidence for the association between work-related musculoskeletal disorders (WMSDs) and manual material handling (MMH) tasks[1]

Especially[2,3]

- Repetitive motions
- Awkward postures
- High forces

Highly prevalant in the supermarket sector[4]

- Approximatly 40% grocery workers suffer from shoulder and/or lower back disorders and pain

Exoskeletons – The new ergonomic tool?

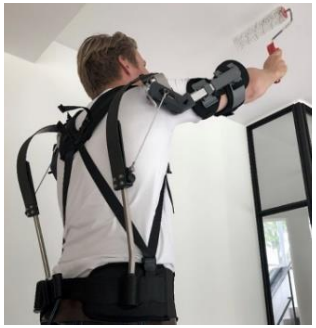
MATE

Levitate airframe

ShoulderX

PAEXO

EksoWorks Vest



Skelex 360-XFR

EXHAUSS Stronger

Robo-mate

Steadicam Fawcett Exoskeletal vest

How is it related?

Pros

- Reduced shoulder flexor muscle activity and increased endurance[5-16].

- Reduced spinal loading[17]

- Increased productivity[11,12]

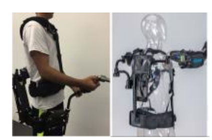
Cons

- Altered kinematics[14,15]

- Additional muscle activity[9,13]

- Increased spinal loading[7,13,17]

- Increased error[7,13]



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AIM:

WE WANTED TO DESIGN A METHOD TO EVALUATE THE BIOMECHANICAL RISK FACTORS ASSOCIATED WITH USING AN EXOSKELETON BASED ON INERTIAL MOTION CAPTURE DATA OF MMH PERFORMED IN TWO SUPERMARKETS.

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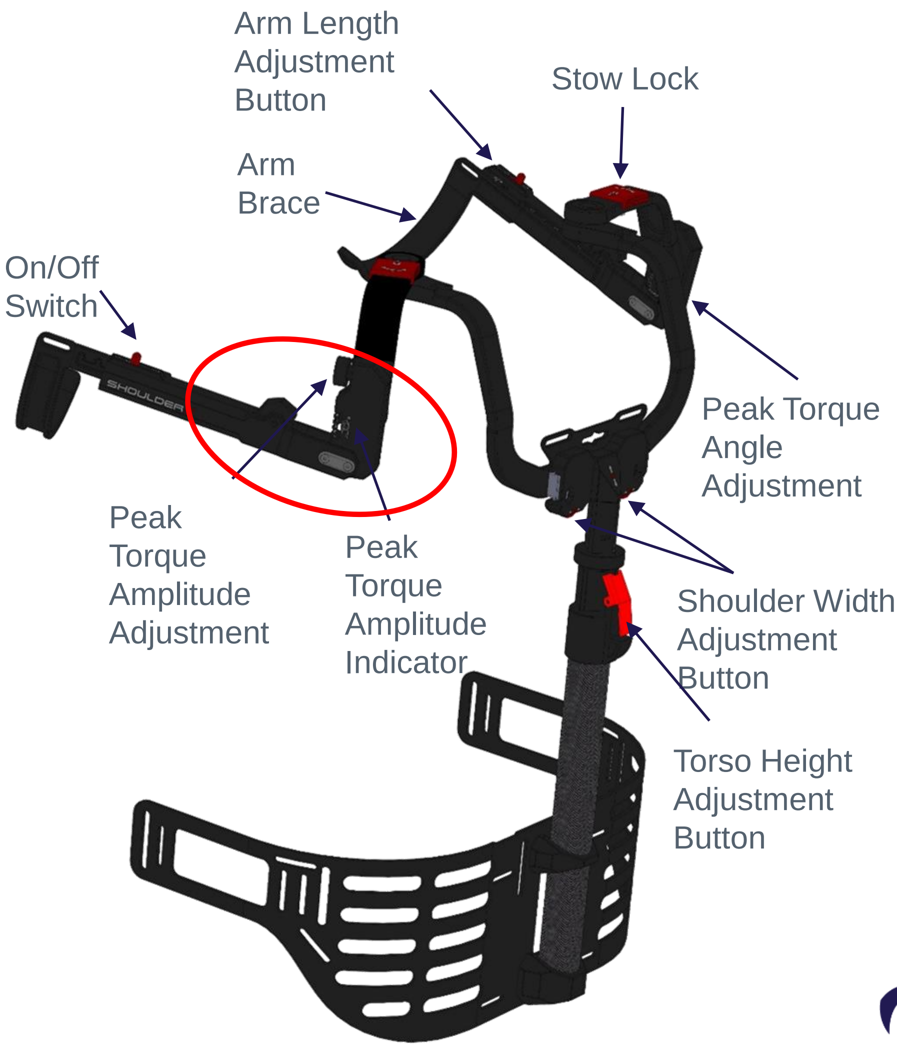
Experimental procedures

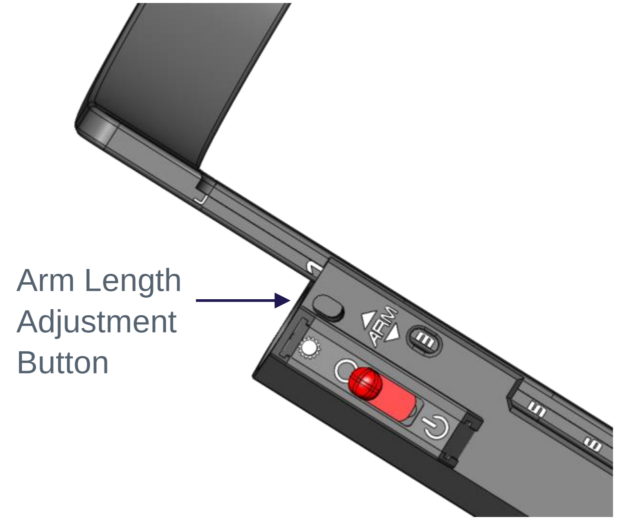
- This study was a part of a larger project aimed at determining the biomechanical loads, muscular demands and working postures during MMH in the Danish supermarket sector.

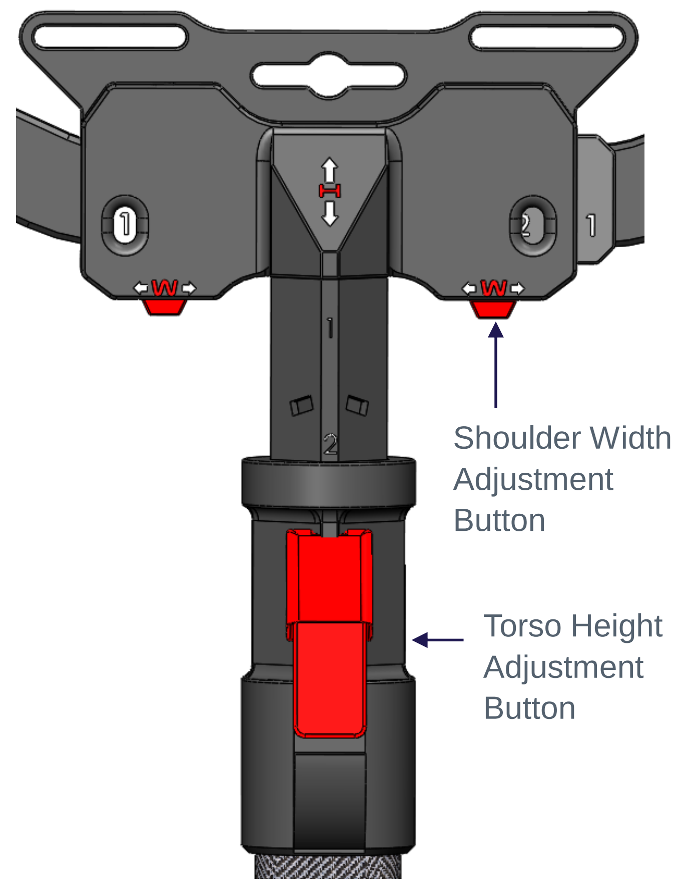
See previous webcast (https://www.youtube.com/watch?v=Xk1_YgXgVgg&t=667s&ab_channel=AnyBodyTechnology) or journal paper[18] for more information.

ShoulderX from SuitX

ShoulderX from SuitX







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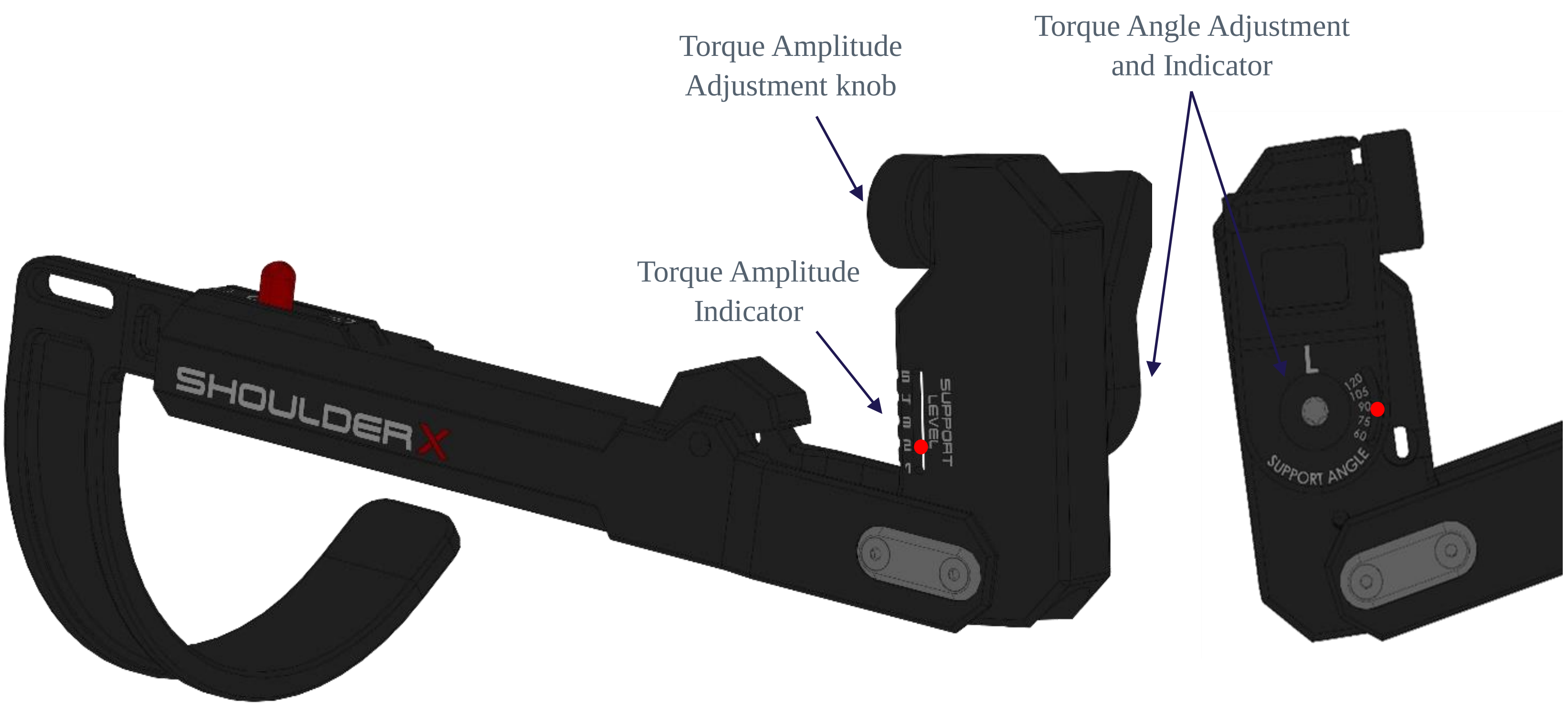
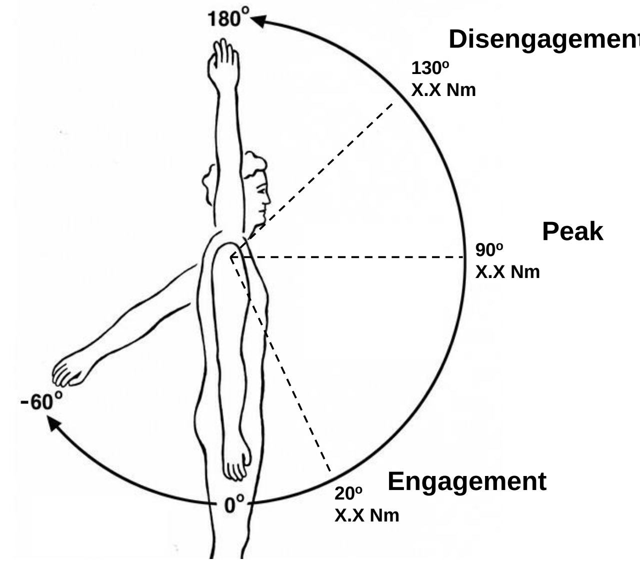
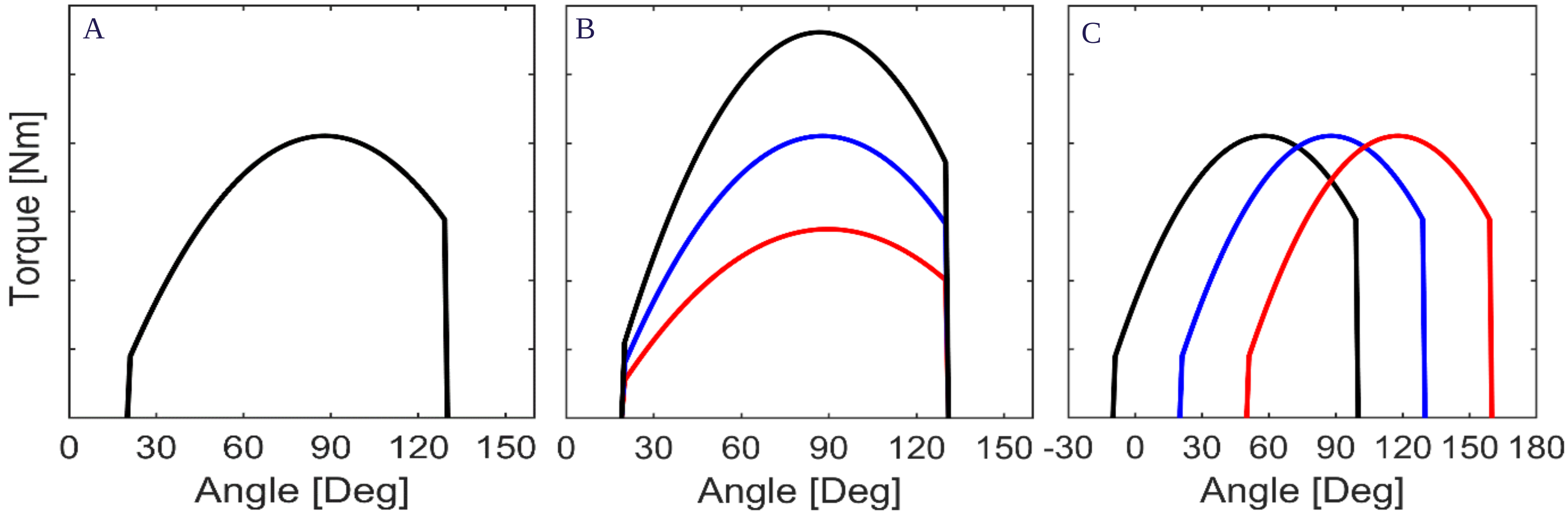
Torque profiles



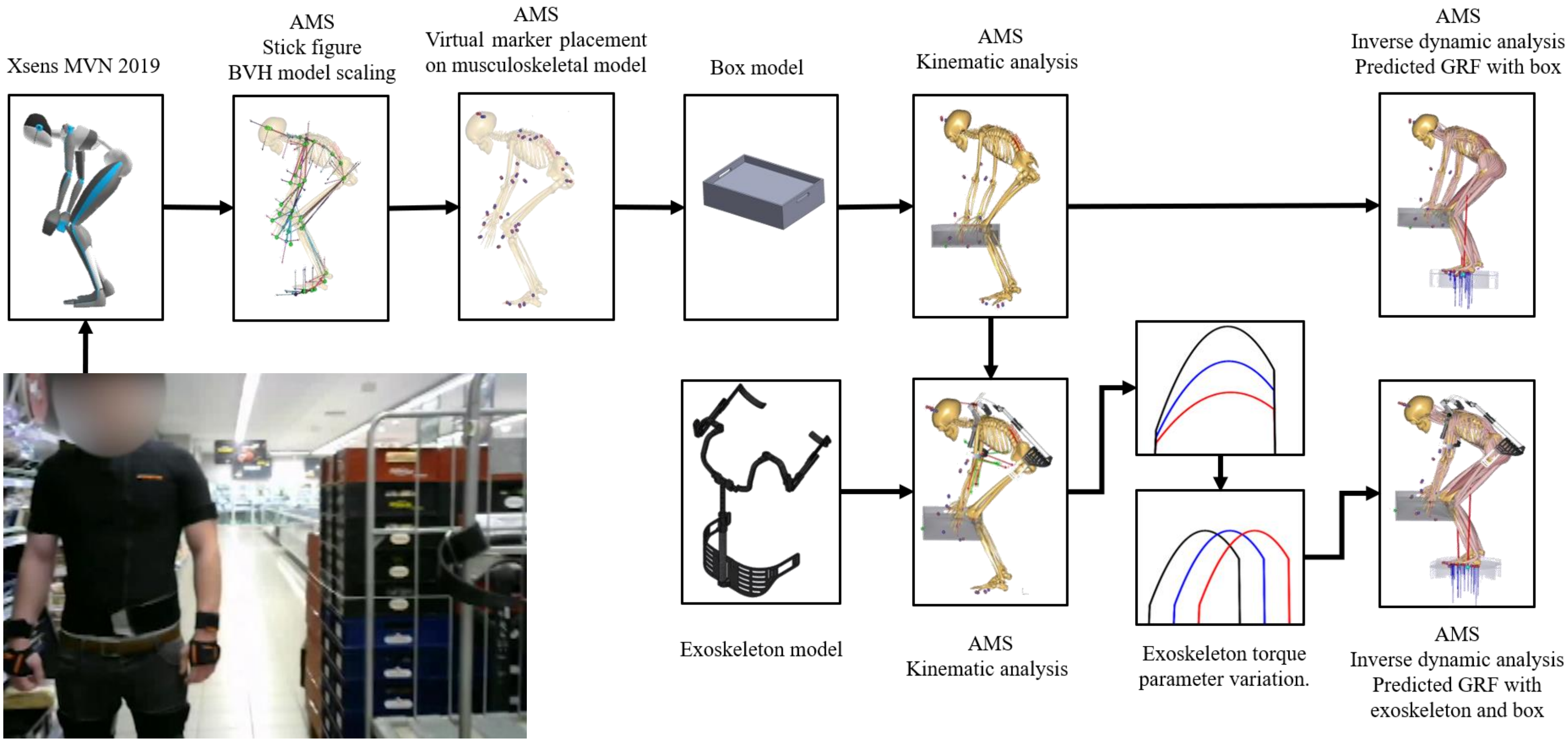
Torque profiles





Additional information can be found here[19]

Experimental procedures



- 15 full-time employees
- Two-handed lift.
- 7.9 kg rye bread.
- Starting position of 15 cm
- End position at shelf height approx. 145.5 cm.

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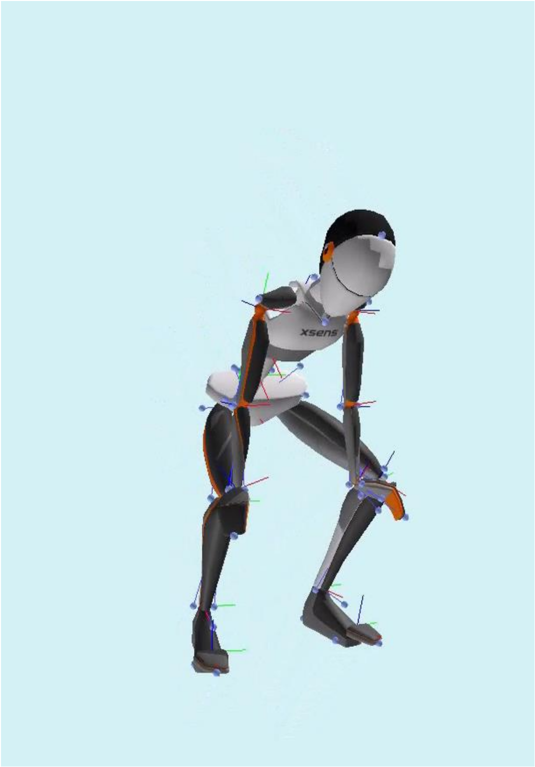
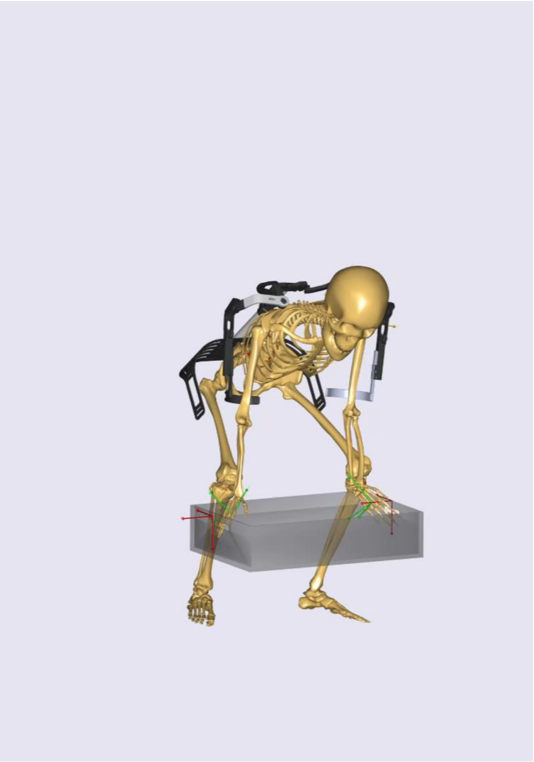
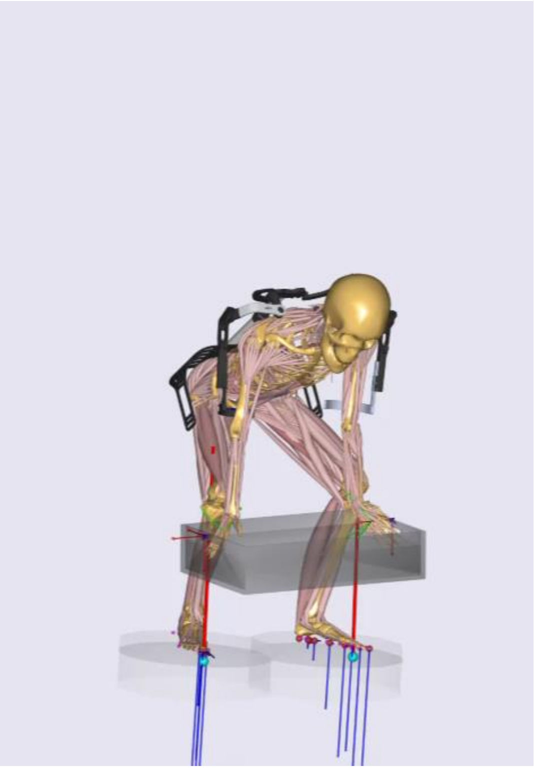
Additional information about used methods:
Virtual marker tracking method[20]
Least-square difference between kinematic models[21]
Ground reaction forces and moments prediction method[22]

Experimental procedures

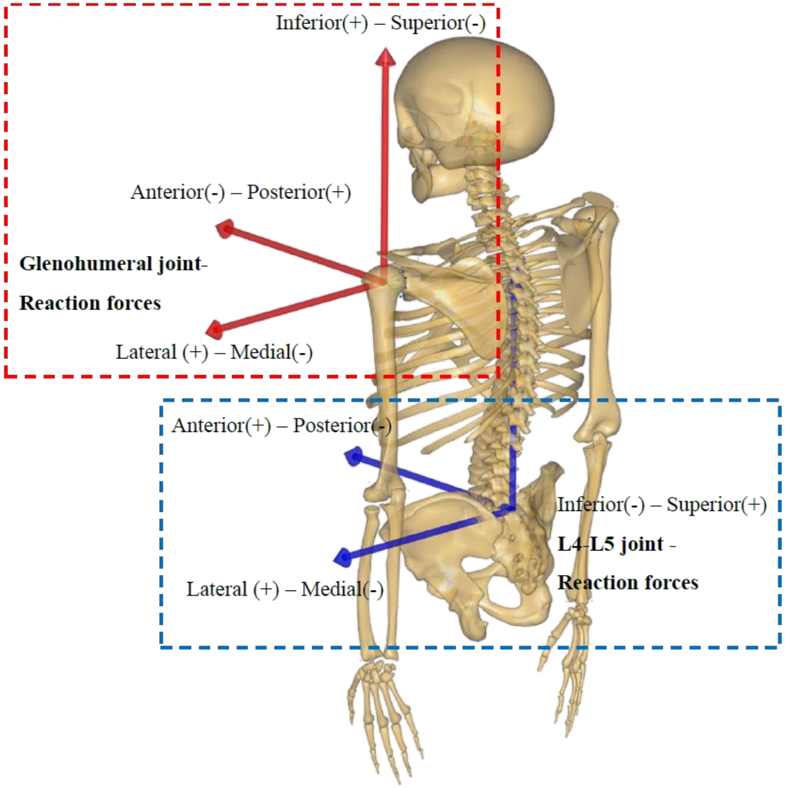






Data

- Torque profile variation - 27 settings
  - 5x5 exoskeleton settings
  - 1 With exoskeleton but no support
  - 1 No exoskeleton
- Extracted
  - Joint reaction forces
    - L4-L5
    - Glenohumeral joint
  - Muscle forces
    - Deltoideus
    - Upper Trapezius
    - Latissimus Dorsi
    - …
- Impulse $(\%BW \cdot s)$ and Peak forces $(\%BW)$



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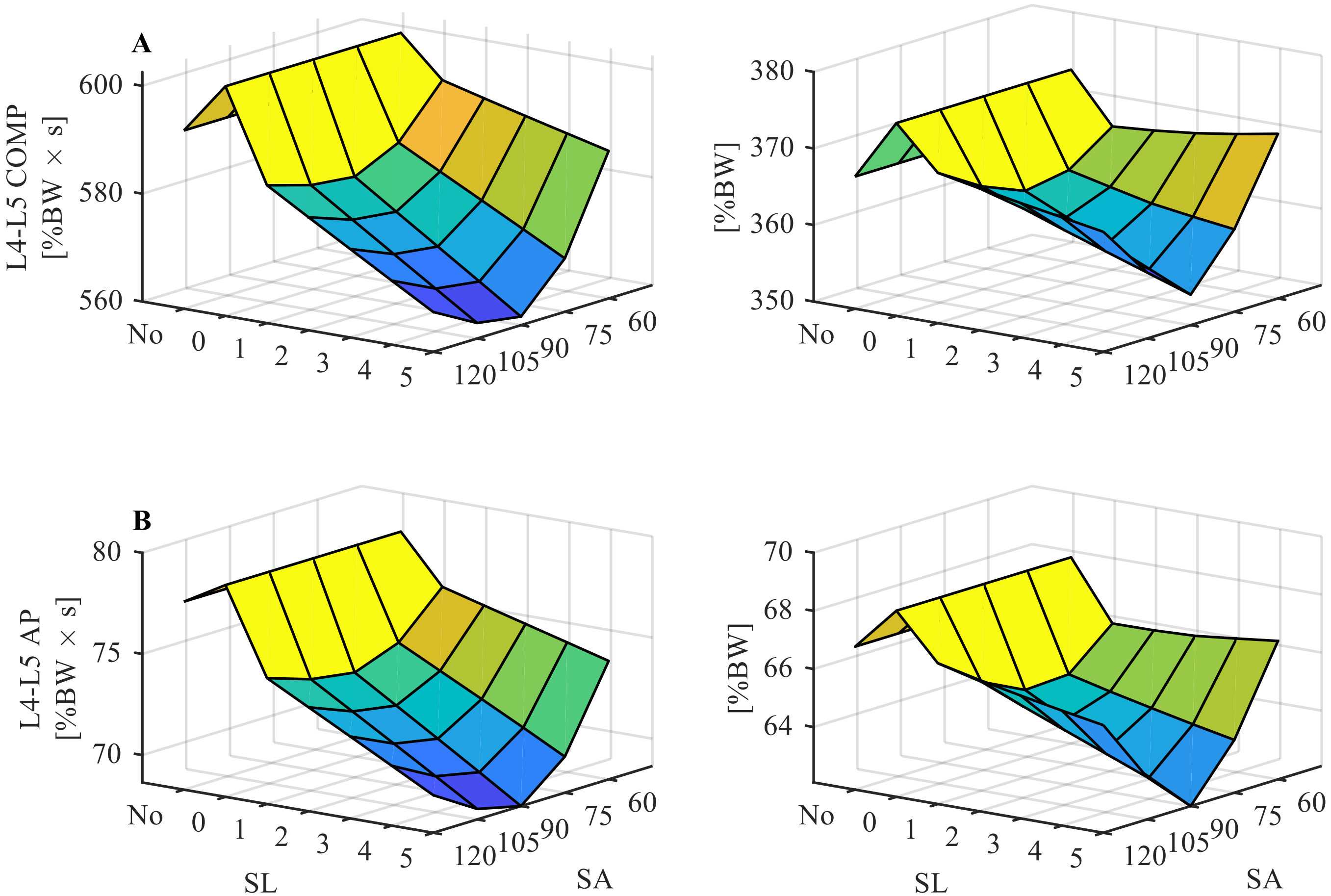
L4-L5



SL (support level) refers to the different torque outputs with (No: no exoskeleton, 0: exoskeleton with no torque, 1-5: lowest to highest torque output on the device.

SA (peak support angle) refers to the different peak support angles and their corresponding engagement and disengagement angles.

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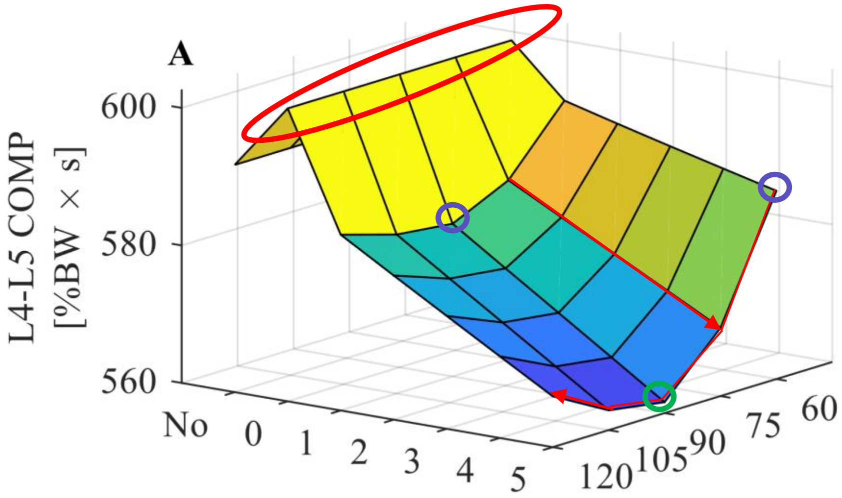
L4-L5



- Increased loadings, no support
- Regulating settings
- Best setting (90°, 5)

Recommendations

- 3400N Compression[5]
- 700N Shear[6]
  - Average subject (74.1 kg).
  - Without exoskeleton: maximum peak at 367%BW (≈2670N) and 67%BW (≈490N).
  - Best exoskeleton setting: maximum peak at 354%BW (≈2575N) and 62%BW (≈450N).

- Expands beyond worker safety and wellbeing

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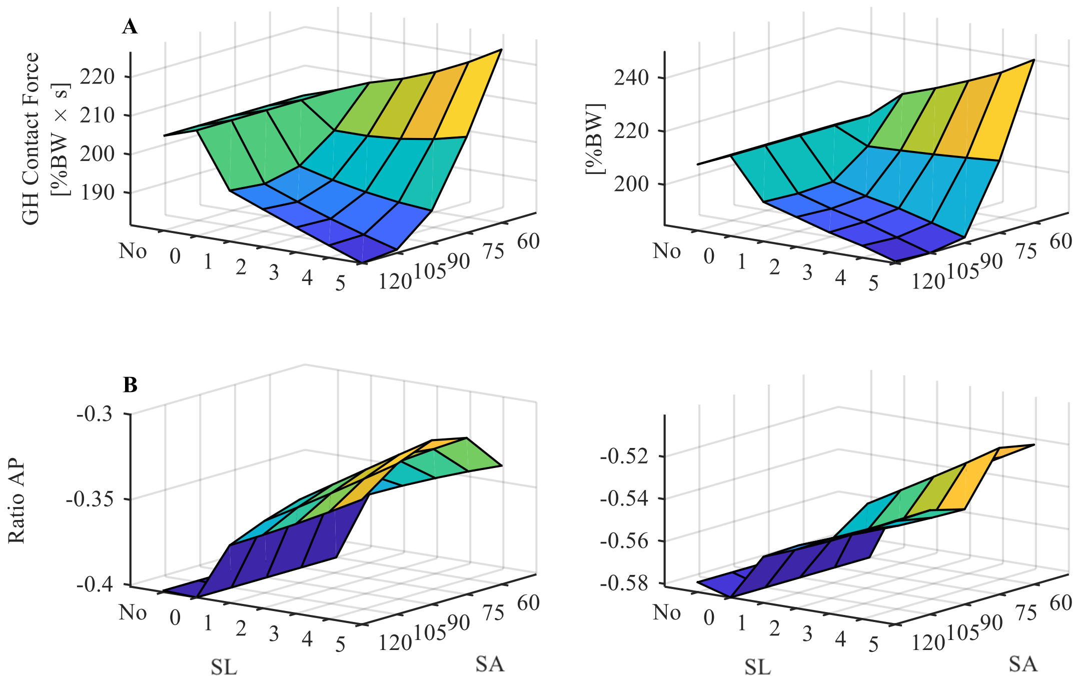
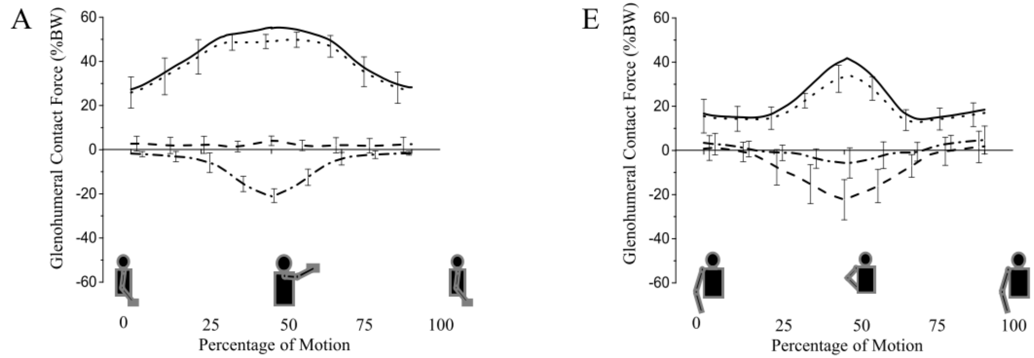
Glenohumeral joint



Glenohumeral joint



Activity	Force components & resultant F (%BW)			
	F_x	F_y	F_z	F
Lifting 1.4 kg coffeepot, straight arm	38	−91	31	103
Putting 2.5 kg into shelf,	20	−64	17	69

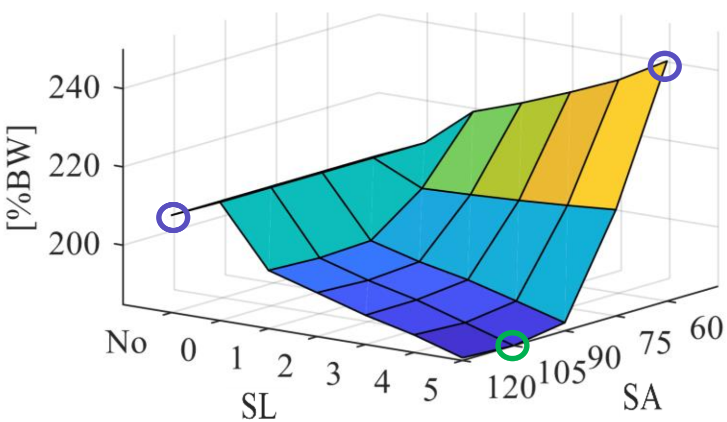
More information see paper[25,26]

- Resultant forces
  - 209%BW without exo
  - 246%BW with worst settings
  - 184%BW best setting
  - Two-three times daily activity[25,26]

  - Our vs. Anglin et al. (2000)[27]
    - 5 kg box shoulder, 10 kg suitcase laterally
  - High glenohumeral forces

	Box		Suitcase	
Average CF (× BW) (all trials and subjects)		1.8	2.4	

More information see paper[27]



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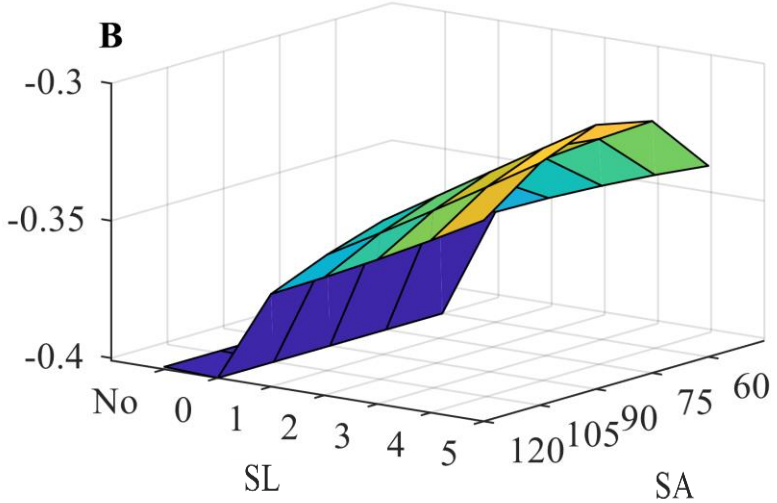
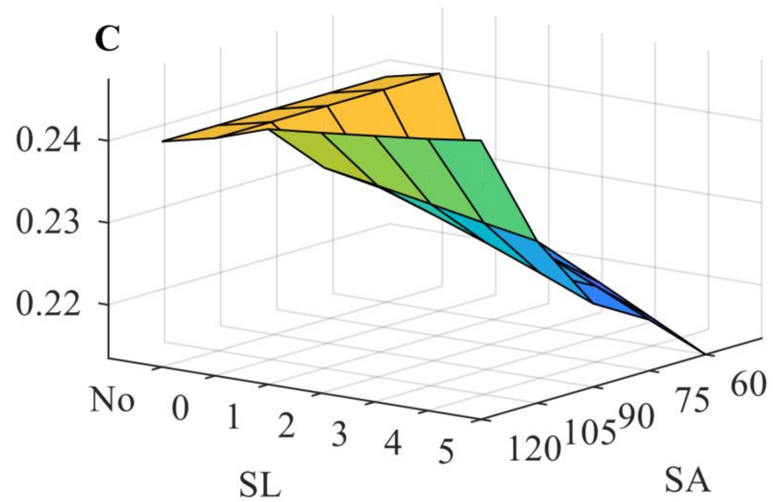
Glenohumeral ratios

- Resultant force leads to information loss, ratio help predict risk of injuries[25]
- Where reduced compression forces and increased shear forces are indicative of instability[28]

Ratio of glenohumeral compression force to anterioposterior shear force



Ratio of glenohumeral compression force to superoinferior shear force



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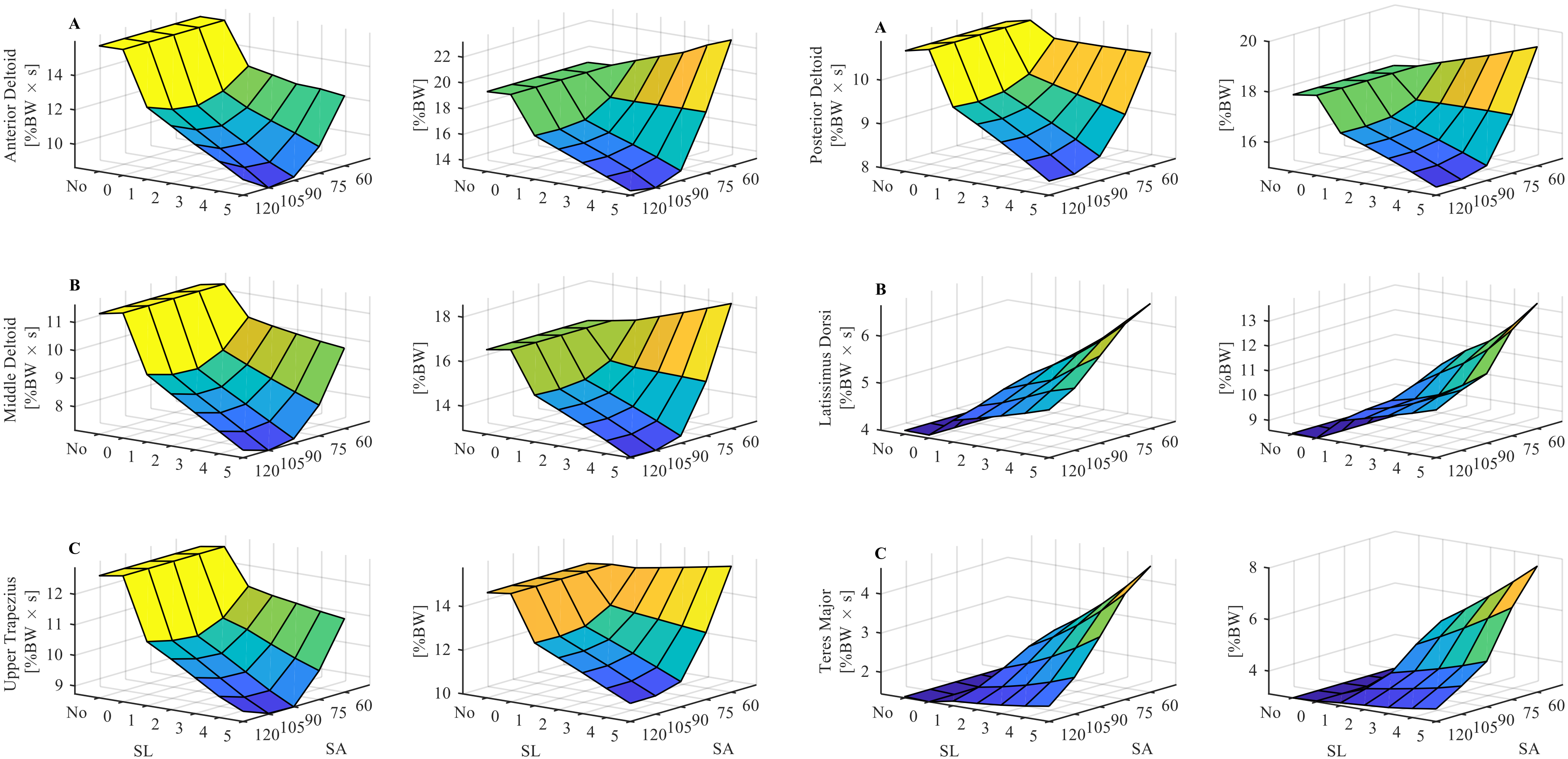
Muscle forces



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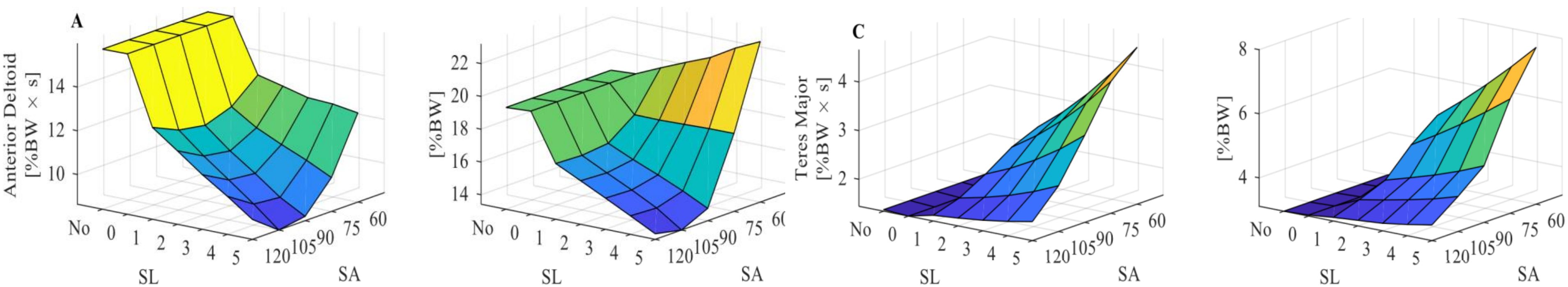
Muscle forces

- Increasing torque amplitude at appropriate angles

- Relative changes were up to 45% reduction
  - Similar findings in literature for peak and median muscle activity with the ShoulderX[5] and Levitate Airframe[6-7,10]

- Consequently, higher torque amplitude provoked additional force generation in latissimus dorsi and teres major.
  - However, very small changes as demonstrated previously[5]



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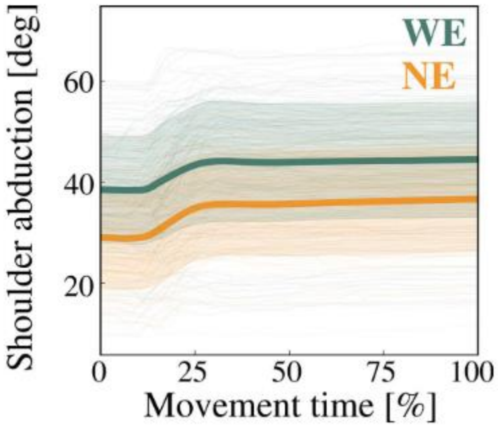
Limitations

- Measurement errors from IMU-based motion capture
  - However, satisfying agreement[29]
- Virtual marker tracking errors[21]

- Box and exoskeleton kinematics
- Potentially altered kinematics[14-15]

- Correct modelling of the contacts elements (human-box, human-exoskeleton).



Study with the PAEXO[15]

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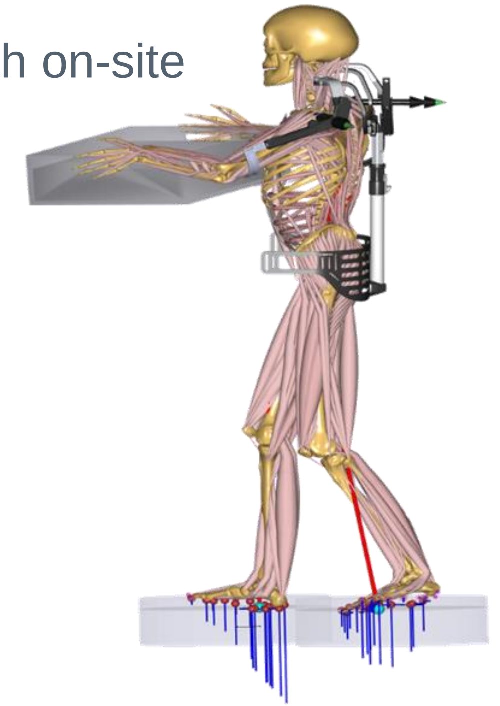
Summary

- Spinal and shoulder loads were reduced with the ShoulderX exoskeleton.
- Muscle force were reduced for agonist muscles.
- Additional antagonist muscle force.
- Optimal exoskeleton setting.
  - Detrimental to the protective effect of the device.

- Demonstration of musculoskeletal modelling in tandem with on-site kinematic data.



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Brief introduction to ERGOTA

- Who are we?
  - Brand new start-up company
  - Burning passion to improve working conditions
  - Prevent musculoskeletal disorders and pain

- What do we do?
  - We perform ergonomic risk-assessments
    1. Problematics
    2. Load risks and injury occurrence
    3. Alleviate strain to retain workers

Follow us on LinkedIn: ERGOTA
Contact: info@ergota.dk

ERGOTA
We ensure a healthy life at work

References

[1]Mayer, J., Kraus, T., & Ochsmann, E. (2012). Longitudinal evidence for the association between work-related physical exposures and neck and/or shoulder complaints: a systematic review. *International Archives of Occupational and Environmental Health*, *85*(6), 587–603. https://doi.org/10.1007/s00420-011-0701-0

[2]Griffith, L. E., Shannon, H. S., Wells, R. P., Walter, S. D., Cole, D. C., Côté, P., … Langlois, L. E. (2012). Individual participant data meta-analysis of mechanical workplace risk factors and low back pain. *American Journal of Public Health*, *102*(2), 309–318. https://doi.org/10.2105/AJPH.2011.300343

[3]van Rijn, R. M., Huisstede, B. M., Koes, B. W., & Burdorf, A. (2010). Associations between work-related factors and specific disorders of the shoulder – a systematic review of the literature. *Scandinavian Journal of Work, Environment & Health*, *36*(3), 189–201. https://doi.org/10.5271/sjweh.2895

[4]Anton, D., & Weeks, D. L. (2016). Prevalence of work-related musculoskeletal symptoms among grocery workers. *International Journal of Industrial Ergonomics*, *54*, 139–145. https://doi.org/10.1016/j.ergon.2016.05.006

[5]Van Engelhoven, L., Poon, N., Kazerooni, H., Rempel, D., Barr, A., Harris-Adamson, C., 2019. Experimental Evaluation of a Shoulder-Support Exoskeleton for Overhead Work: Influences of Peak Torque Amplitude, Task, and Tool Mass. IISE Trans. Occup. Ergon. Hum. Factors 7, 1–14. https://doi.org/10.1080/24725838.2019.1637799

[6]Kim, S., Nussbaum, M.A., Mokhlespour Esfahani, M.I., Alemi, M.M., Alabdulkarim, S., Rashedi, E., 2018. Assessing the influence of a passive, upper extremity exoskeletal vest for tasks requiring arm elevation: Part I – "Expected" effects on discomfort, shoulder muscle activity, and work task performance. Appl. Ergon. 70, 315–322. https://doi.org/10.1016/j.apergo.2018.02.025

[7]Alabdulkarim, S., Kim, S., Nussbaum, M.A., 2019. Effects of exoskeleton design and precision requirements on physical demands and quality in a simulated overhead drilling task. Appl. Ergon. 80, 136–145. https://doi.org/10.1016/j.apergo.2019.05.014

[8]Huysamen, K., Bosch, T., de Looze, M., Stadler, K.S., Graf, E., O'Sullivan, L.W., 2018. Evaluation of a passive exoskeleton for static upper limb activities. Appl. Ergon. 70, 148–155. https://doi.org/10.1016/j.apergo.2018.02.009

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References

[9]Rashedi, E., Kim, S., Nussbaum, M.A., Agnew, M.J., 2014. Ergonomic evaluation of a wearable assistive device for overhead work. Ergonomics 57, 1864–1874. https://doi.org/10.1080/00140139.2014.952682

[10]Gillette, J.C., Stephenson, M.L., 2019. Electromyographic Assessment of a Shoulder Support Exoskeleton During on-Site Job Tasks. IISE Trans. Occup. Ergon. Hum. Factors 7, 1–9. https://doi.org/10.1080/24725838.2019.1665596

[11]Moyon, A., Poirson, E., Petiot, J.F., 2018. Experimental study of the physical impact of a passive exoskeleton on manual sanding operations. Procedia CIRP 70, 284–289. https://doi.org/10.1016/j.procir.2018.04.028

[12]Spada, S., Ghibaudo, L., Gilotta, S., Gastaldi, L., Cavatorta, M.P., 2018. Analysis of Exoskeleton Introduction in Industrial Reality: Main Issues and EAWS Risk Assessment. pp. 236–244. https://doi.org/10.1007/978-3-319-60825-9_26

[13]Weston, E.B., Alizadeh, M., Knapik, G.G., Wang, X., Marras, W.S., 2018. Biomechanical evaluation of exoskeleton use on loading of the lumbar spine. Appl. Ergon. 68, 101–108. https://doi.org/10.1016/j.apergo.2017.11.006

[14]Theurel, J., Desbrosses, K., Roux, T., Savescu, A., 2018. Physiological consequences of using an upper limb exoskeleton during manual handling tasks. Appl. Ergon. 67, 211–217. https://doi.org/10.1016/j.apergo.2017.10.008

[15]Maurice, P., Ivaldi, S., Babic, J., Camernik, J., Gorjan, D., Schirrmeister, B., Bornmann, J., Tagliapietra, L., Latella, C., Pucci, D., Fritzsche, L., 2020. Objective and Subjective Effects of a Passive Exoskeleton on Overhead Work. IEEE Trans. Neural Syst. Rehabil. Eng. 28, 152–164. https://doi.org/10.1109/tnsre.2019.2945368

[16]Pacifico, I.; Scano, A.; Guanziroli, E.; Moise, M.; Morelli, L.; Chiavenna, A.; Romo, D.; Spada, S.; Colombina, G.; Molteni, F.; et al. An Experimental Evaluation of the Proto-MATE: A Novel Ergonomic Upper-Limb Exoskeleton to Reduce Workers' Physical Strain. IEEE Robot. Autom. Mag. 2020, 27, 54–65.

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References

[17]Kim, S., Nussbaum, M.A., Mokhlespour Esfahani, M.I., Alemi, M.M., Jia, B., Rashedi, E., 2018. Assessing the influence of a passive, upper extremity exoskeletal vest for tasks requiring arm elevation: Part II – “Unexpected” effects on shoulder motion, balance, and spine loading. Appl. Ergon. 70, 323–330. https://doi.org/10.1016/j.apergo.2018.02.024

[18]Skals, S., Bláfoss, R., Andersen, M.S., de Zee, M., Andersen, L.L., 2021. Manual material handling in the supermarket sector. Part 1: Joint angles and muscle activity of trapezius descendens and erector spinae longissimus. Appl. Ergon. 92, 103340. https://doi.org/10.1016/j.apergo.2020.103340

[19]Van Engelhoven, L., Kazerooni, H., 2019. Design and Intended Use of a Passive Actuation Strategy for a Shoulder Supporting Exoskeleton. 2019 Wearable Robot. Assoc. Conf. WearRAcon 2019 7–12. https://doi.org/10.1109/WEARRACON.2019.8719402

[20]Karatsidis, A., Jung, M., Schepers, H.M., Bellusci, G., de Zee, M., Veltink, P.H., Andersen, M.S., 2019. Musculoskeletal model-based inverse dynamic analysis under ambulatory conditions using inertial motion capture. Med. Eng. Phys. 65, 68–77. https://doi.org/10.1016/j.medengphy.2018.12.021

[21]Andersen, M.S., Damsgaard, M., Rasmussen, J., 2009. Kinematic analysis of over-determinate biomechanical systems. Comput. Methods Biomech. Biomed. Engin. 12, 371–384. https://doi.org/10.1080/10255840802459412

[22]Fluit, R., Andersen, M.S., Kolk, S., Verdonschot, N., Koopman, H.F.J.M., 2014. Prediction of ground reaction forces and moments during various activities of daily living. J. Biomech. 47, 2321–2329. https://doi.org/10.1016/j.jbiomech.2014.04.030

[23]Waters, T. R., Putz-Anderson, V., Garg, A., & Fine, L. J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics*, *36*(7), 749–776. https://doi.org/10.1080/00140139308967940

[24]Gallagher, S., & Marras, W. S. (2012). Tolerance of the lumbar spine to shear: A review and recommended exposure limits. *Clinical Biomechanics*, *27*(10), 973–978. https://doi.org/10.1016/j.clinbiomech.2012.08.009

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References

[25]Klemt, C., Prinold, J.A., Morgans, S., Smith, S.H.L., Nolte, D., Reilly, P., Bull, A.M.J., 2018. Analysis of shoulder compressive and shear forces during functional activities of daily life. Clin. Biomech. 54, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

[26]Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., Westerhoff, P., 2007. In vivo glenohumeral contact forces—Measurements in the first patient 7 months postoperatively. J. Biomech. 40, 2139–2149. https://doi.org/10.1016/j.jbiomech.2006.10.037

[27]Anglin, C., Wyss, U.P., Pichora, D.R., 2000. Glenohumeral contact forces. Proc. Inst. Mech. Eng. Part H J. Eng. Med. 214, 637–644. https://doi.org/10.1243/0954411001535660

[28]Vidt, M.E., Santago, A.C., Marsh, A.P., Hegedus, E.J., Tuohy, C.J., Poehling, G.G., Freehill, M.T., Miller, M.E., Saul, K.R., 2018. Modeling a rotator cuff tear: Individualized shoulder muscle forces influence glenohumeral joint contact force predictions. Clin. Biomech. 60, 20–29. https://doi.org/10.1016/j.clinbiomech.2018.10.004

[29]Larsen, F.G., Svenningsen, F.P., Andersen, M.S., de Zee, M., Skals, S., 2020. Estimation of Spinal Loading During Manual Materials Handling Using Inertial Motion Capture. Ann. Biomed. Eng. 48, 805–821. https://doi.org/10.1007/s10439-019-02409-8

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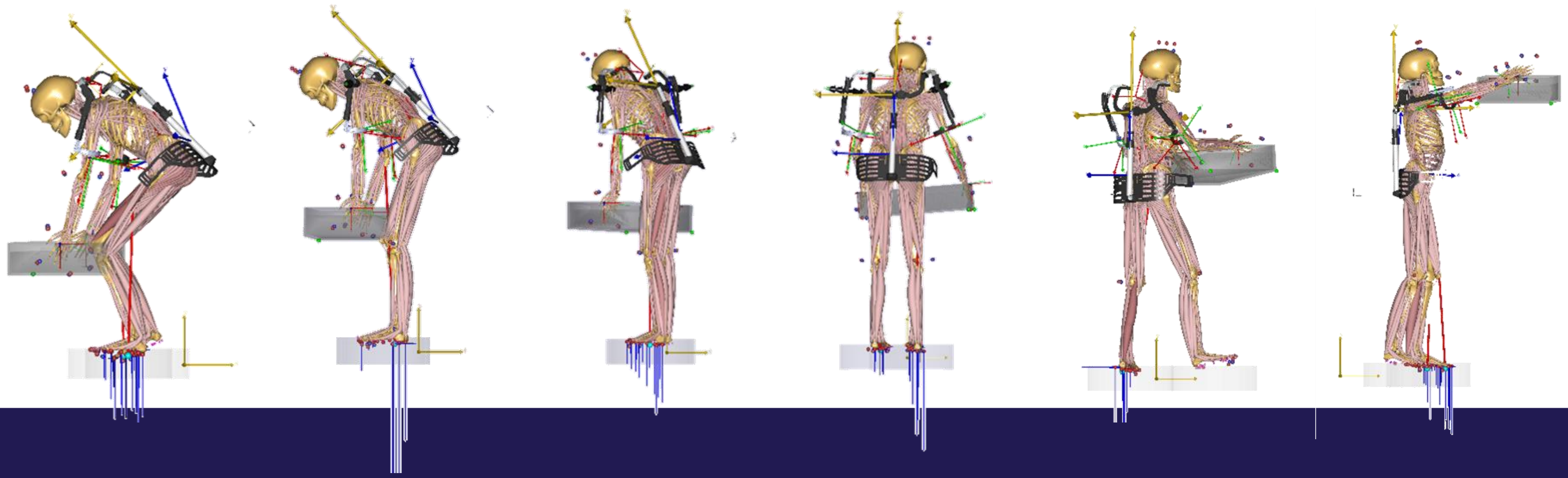
Bo E. Seiferheld
bo@seiferheld.dk



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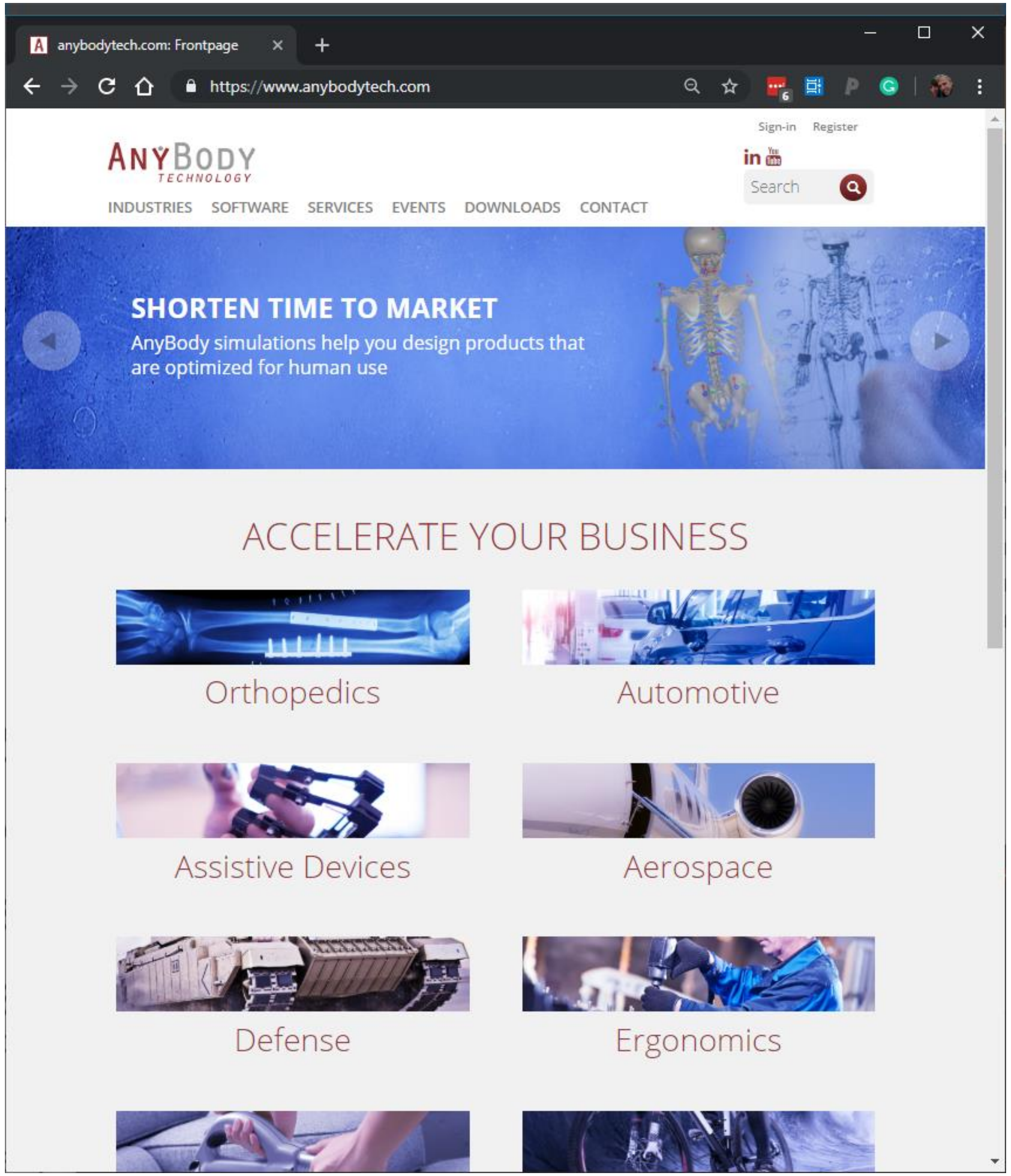

Time for questions: