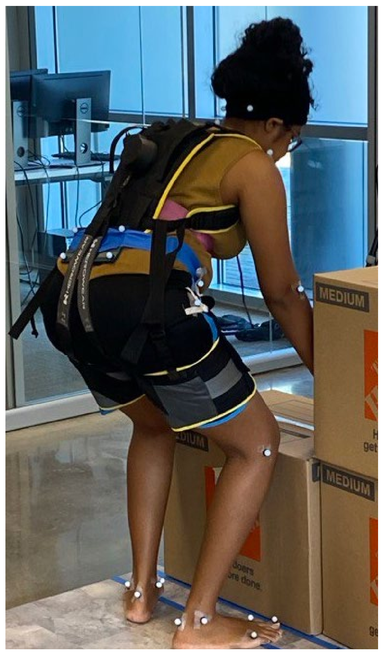
Effects of Prolonged Back-support Exoskeleton Use on Trunk Kinematics During Repetitive Lifting and Lowering

Mehdi Shayan, Duleepa Subasinghe, Jessica Aviles, Divya Srinivasan
Departments of Bioengineering and Industrial Engineering, Clemson University, Clemson, SC, USA

Introduction and Objective

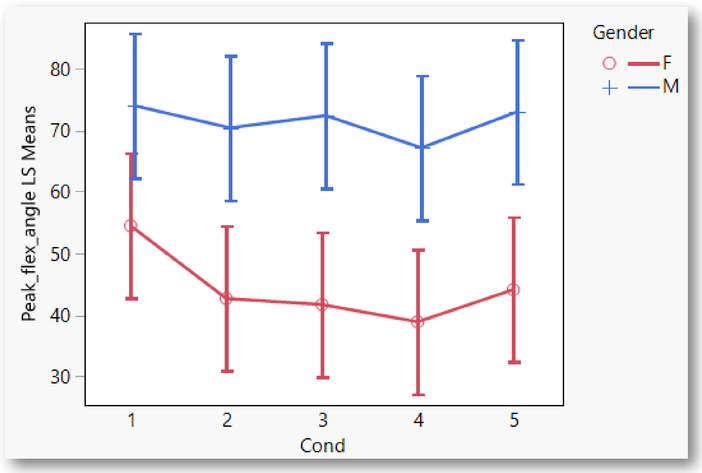
- **Prior research:** back-support exoskeletons (EXO) can reduce muscle activity and strain during manual material handling (MMH) tasks [1].
- May also cause changes in movement patterns [2].
- Small changes in trunk angles while bending could significantly affect muscle activity levels, and excessive trunk flexion by itself has been shown to be a risk factor for developing musculoskeletal disorders (MSD) [3].
- **Aims:** Investigate (1) the impact of a soft passive EXO on trunk kinematics during repetitive lifting/lowering tasks, (2) whether such changes represent an initial reaction or persist over time.
- **Hypothesis:** EXO use affects trunk kinematics immediately, and some changes persist over time, leading to potential ergonomic benefits.



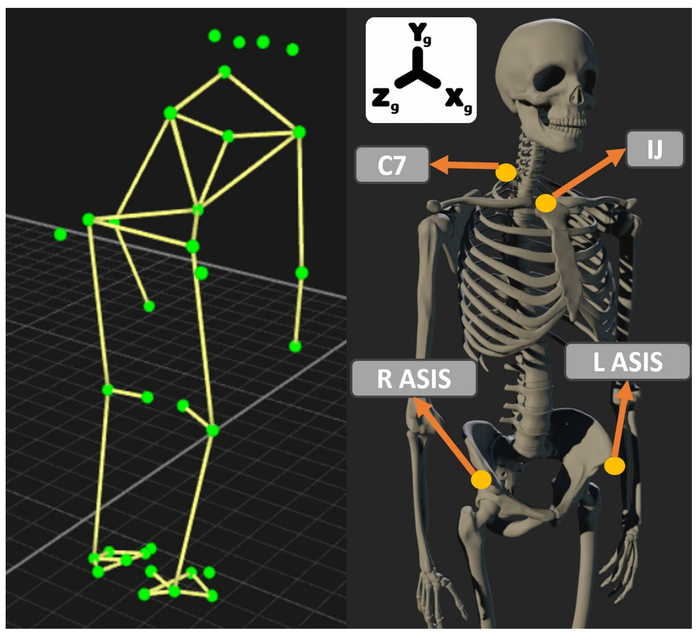
Participant wearing HeroWear Apex exosuit

Results

- Significant reduction in PeakFlex, ROM, peakFlexVel, peakExtVel with EXO use ($p < 0.0001$).
- Persistent kinematic changes throughout 90-minute EXO exposure.
- **Gender-specific effects:** Females showed greater reduction compared to males.
- Females showed ~21% change in peak flexion angle from noEXO to EXO1, while males showed a ~2% change.



Cond 1 and 5: noEXO
Cond 2, 3, and 4: Beginning, middle, and end of EXO



Anatomical landmarks used to define the trunk segment

Methods

- **Participants:** 8 gender-balanced, aged 18-31, no EXO experience or MSD history.
- **Procedure:** A-B-A protocol → noEXO, EXO, noEXO
- **Assessments:** Trunk kinematics measured using Qualisys marker-based MoCap system, analyzed via two-way repeated measures ANOVA.
- **Outcome Measures:** Means and cycle-to-cycle standard deviation (SD) of
  - Peak trunk flexion/extension angles
  - Trunk range of motion (ROM)
  - Peak trunk flexion/extension angular velocity
  - Time to reach peak trunk flexion angle (normalized to task duration).

References

[1] Kermavnar et al. (2021), Ergonomics
[2] Schwartz et al. (2023), Int. J. Environ. Res. Public Health 20
[3] M. Gorsic et al. (2022), J Biomech 126 (110620)

Conclusion

- EXO use significantly alters trunk kinematics, with sustained ergonomic benefits. Given gender differences in strength and the fact that we made the assistance level uniform across all users, the female participants may have perceived more resistance when bending (due to the elastic bands).
- Highlights the potential of EXOs in reducing biomechanical load on the lumbar spine during MMH tasks, mitigating the high physical demands experienced during dynamic lifting tasks.
- Further exploration is needed to understand and enhance EXO use within workplace health and safety protocols.

Reach out via email at *ashayan@clemson.edu* or visit *MehdiShayan.com*