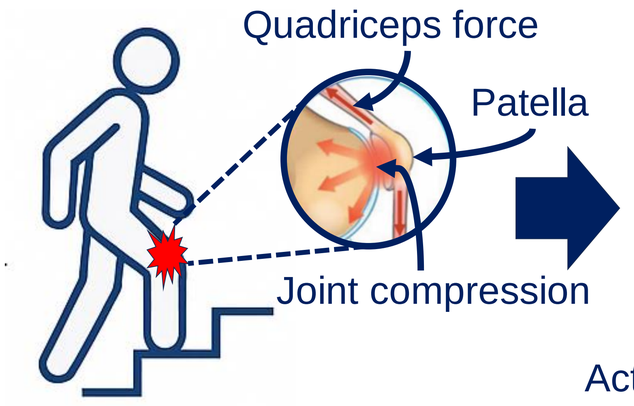
A Task-Agnostic Knee Exoskeleton for Reducing Osteoarthritis Pain Across Activities of Daily Life: A Pilot Study

Nikhil V. Divekar, Ernesto Hernandez Hinojosa*, Jiefu Zhang, and Robert D. Gregg*

*University of Michigan-Ann Arbor. *Authors contributed equally.*

Abstract



Painful high-torque tasks:
- ↑ Quadriceps force
- ↑ Joint compression



Backdrivable actuator + Task-agnostic controller = Adaptive quadriceps assistance



Less quadriceps activation (for challenging tasks)

62% Less pain

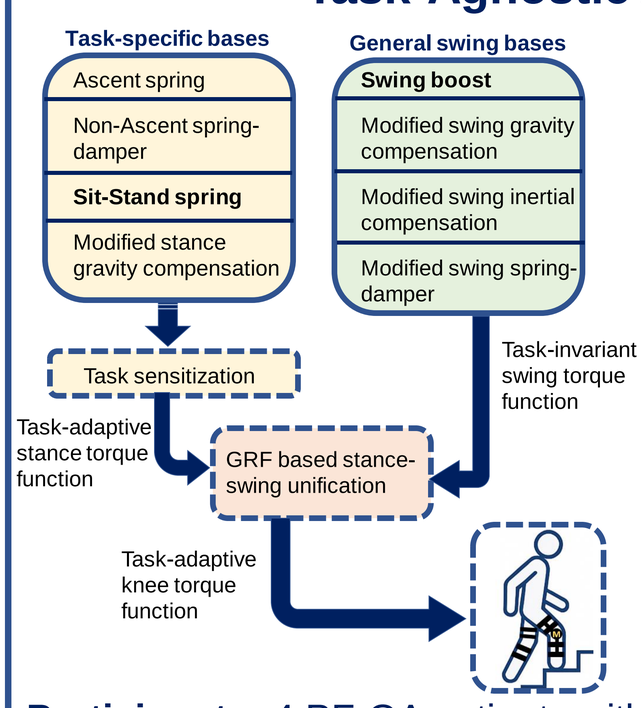
45% Less difficult

Introduction

- 4% of Adults suffer from patellofemoral osteoarthritis (PF-OA) pain during daily activities (e.g., stairs, sit-stand) due to high quadriceps forces [1–3].
- Spring-based unloaders cannot add or remove energy and bulky exoskeletons lack adaptability [6–8].
- Existing braces/unloaders fail to address muscle-force derived pain or support high-torque tasks [4,5].

Methods

Task-Agnostic Assistance



Adapted from [9] to support sit-stand (STS) transitions and swing-phase leg clearance.

- Reduced spring torque at small knee angles for sit - stand.
- Added thigh-angle-based "Swing boost" for flexion assistance.

Participants: 4 PF-OA patients with pain during stairs/walking.

Tasks: stair ascent (SA) stairs descent (SD), ramp ascent (RD), ramp descent (RD), STS-descent (STS-D), STS-ascent (STS-A), level walk (LW)

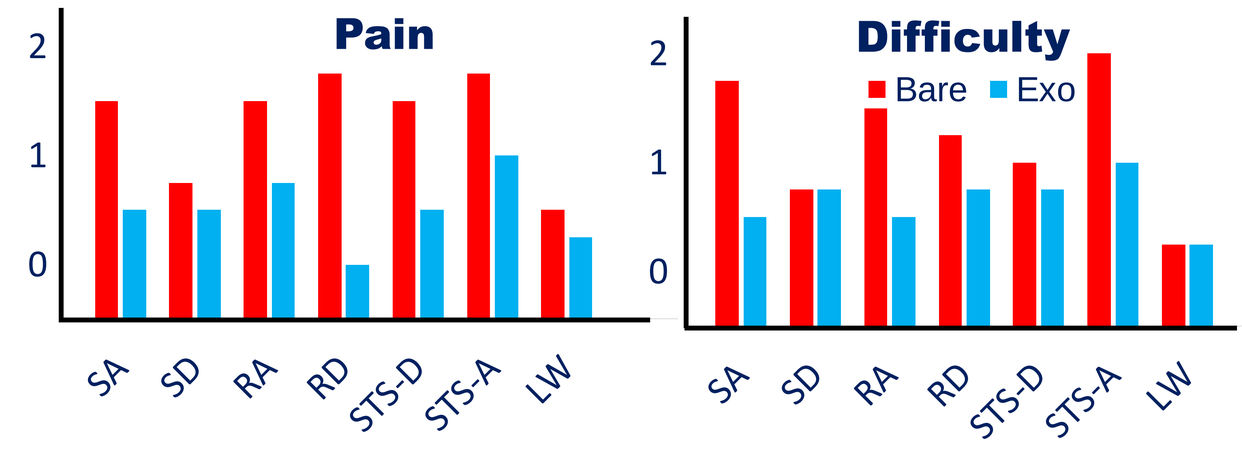
Metrics:
- Pain/Difficulty: WOMAC scale (0–4) post-trial.
  - "None", "Slight", "Moderate", "Very", and "Extremely".
- Quadriceps EMG: Vastus medialis/lateralis, rectus femoris (normalized to max activation).

[1] Murphy et al. (2008) | [2] Duncan et al. (2006) | [3] Heino Brechter & Salsich (2002) | [4] Fukutani et al. (2016) | [5] McGibbon et al. (2021) | [6] McGibbon et al. (2022) | [7] ROAM Press (2024) | [8] Budarick et al. (2019) | [9] Divekar et al.

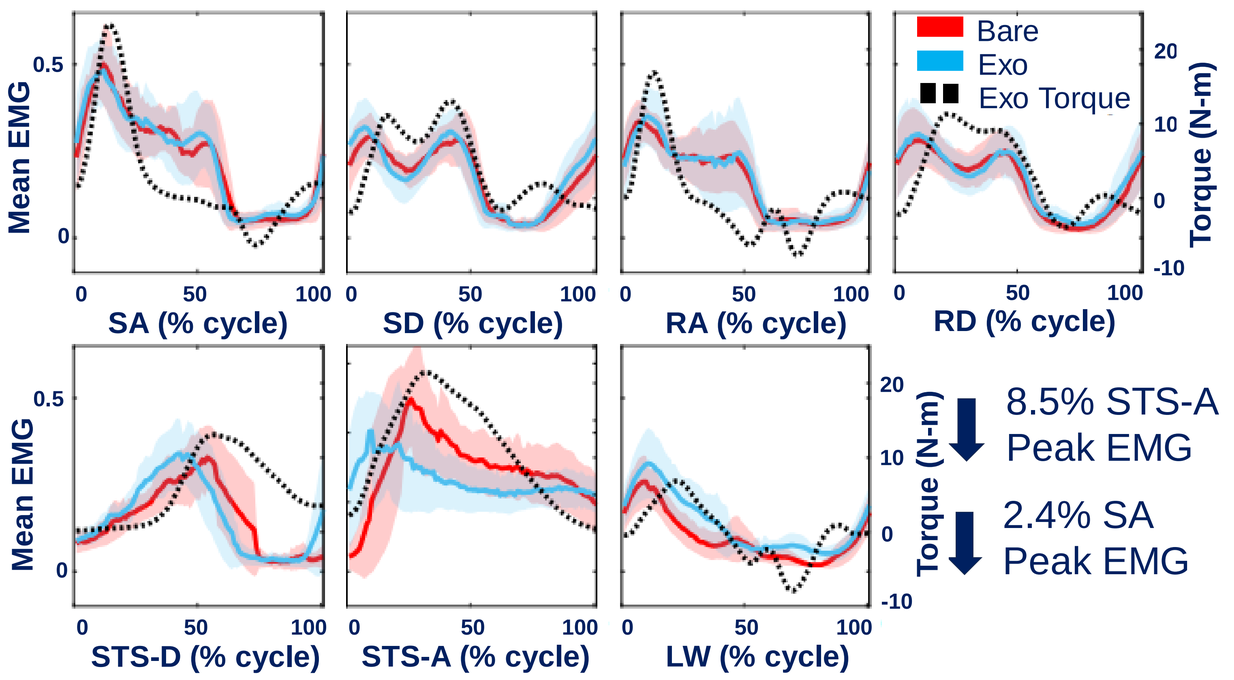
Results

Our knee exoskeleton reduced the average pain and difficulty across tasks and participants

- **Pain: 0.81 point reduction**
- **Difficulty: 0.57 point reduction**



Task-agnostic torque profiles align with quadriceps activation



8.5% STS-A Peak EMG

2.4% SA Peak EMG

Participant Variability:
- 2/4 participants showed overall average reductions in mean and peak EMG. Subject 4 showed increased mean EMG overall.

Conclusion

- Our backdrivable exoskeleton provided **acute pain relief** during demanding tasks like stair climbing and sit-to-stand transitions
- Offers key advantages over existing devices: **adaptive assistance** without restricting natural movement
- Potential to **break the inactivity cycle** and improve quality of life for knee OA patients
- Next steps: **larger clinical trials** to validate findings

Acknowledgements

This work was supported by the National Institute of Biomedical Imaging and Bioengineering of the NIH under Award Number R01EB031166. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.