EMG-Informed Neuromusculoskeletal Model for Knee Joint Load Estimation with a Powered Knee Exoskeleton During Incline Walking

Bailey J. McLain[1], Dawit Lee[2], Inseung Kang[2], Aaron J. Young[1,2]

[1] Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology [2] Woodruff School of Mechanical Engineering, Georgia Institute of Technology

Introduction

Knee Joint Loading:

- Knee joint undergoes large mechanical loads during daily activities, especially during incline walking [1]
- Tibiofemoral contact force depends on net joint reaction force and muscle forces [2]
- High forces are potentially damaging to the knee joint [3]

Powered Exoskeleton Assistance: potential to reduce tibiofemoral forces by reducing the effort of the muscles [4]

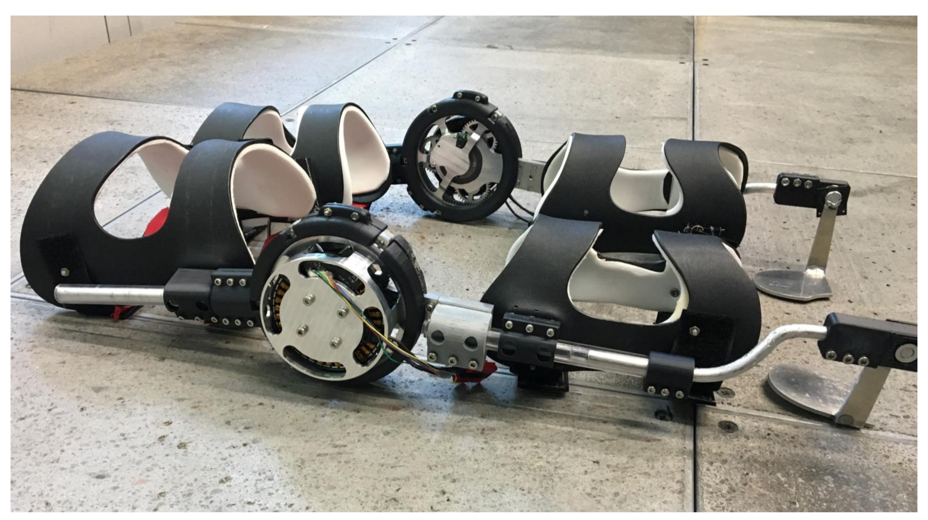

Figure 1. Robotic Bilateral Knee Exoskeleton used in this study

Musculoskeletal Modeling:

- Primary methods – static optimization, CMC, and EMG-informed [5,6]
- EMG-informed provides a more representative estimate by considering co-contraction and users actual muscle activation [5,7]

This study aimed to investigate the capability of assistance using a robotic bilateral knee exoskeleton to reduce the knee joint load in able bodied adults walking uphill using an EMG-informed model.

Hypothesis

Assistance provided at the knee joint during early stance will reduce the quadricep force required for walking and thus decrease the peak knee joint load during early stance phase compared to the unpowered condition

Methods

Experimental Protocol:

- 9 able bodied adults walking on treadmill walking at 15% gradient at 1.1 m/s
- Compared Biological Torque Controller (BT) to unpowered (UN) condition

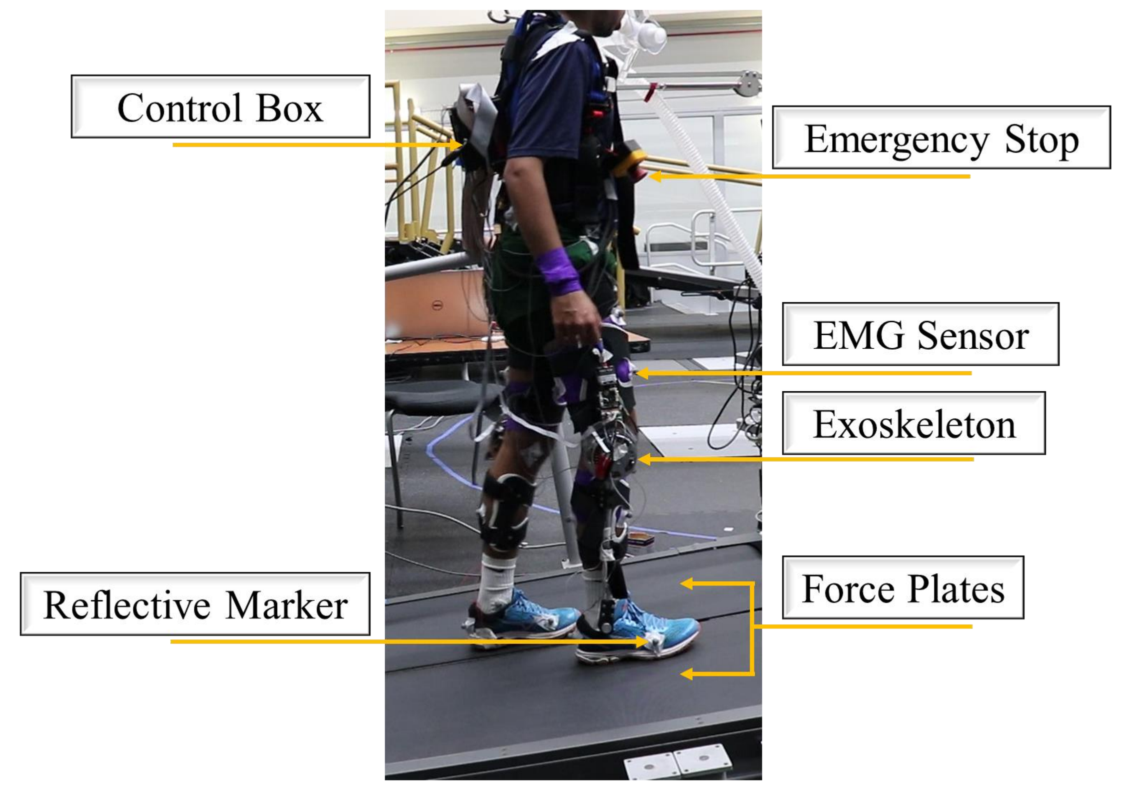

Figure 2. Experimental Setup

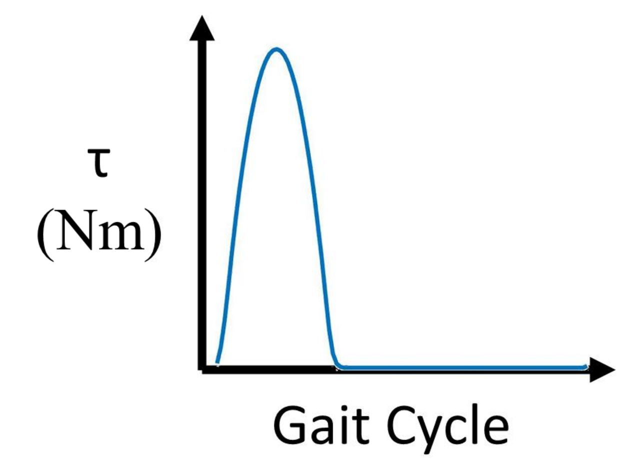

Figure 3. Assistance profile for BT. Extension torque provided 0-30% of gait cycle

EMG-Informed Neuromusculoskeletal Modeling to Estimate Joint Loads

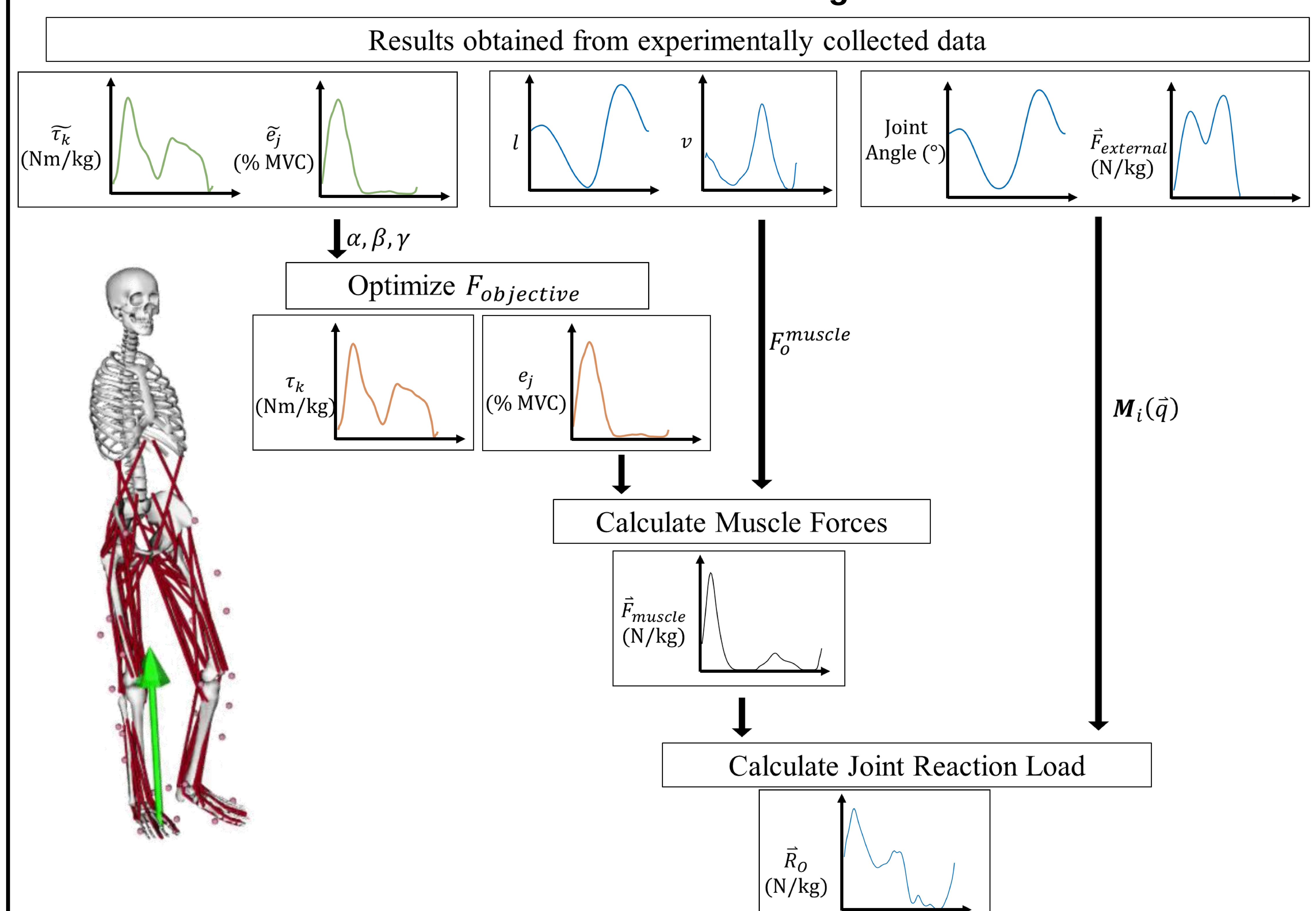

Figure 4. Data analysis detailed for musculoskeletal modeling

References

[1] I. Kutzner et al., (2010) *J Biomech* [2] S. M. Smith, et al.,(2008) *Gait & Posture* [3] N. Alexander et al, (2016) Gait & posture [4] D. Lee, et al., (2020) *IEEE TNSRE* [5] K. M. Steele, et al., (2012) Gait & Posture [6] C. Pizzolato et al., (2015) *J Biomech* [7] T. S. Buchanan, et al., (2004) *J Appl Biomech* [8] S. L. Delp et al., (2007) *IEEE TBME*

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Results

Average Tibiofemoral Compression Forces

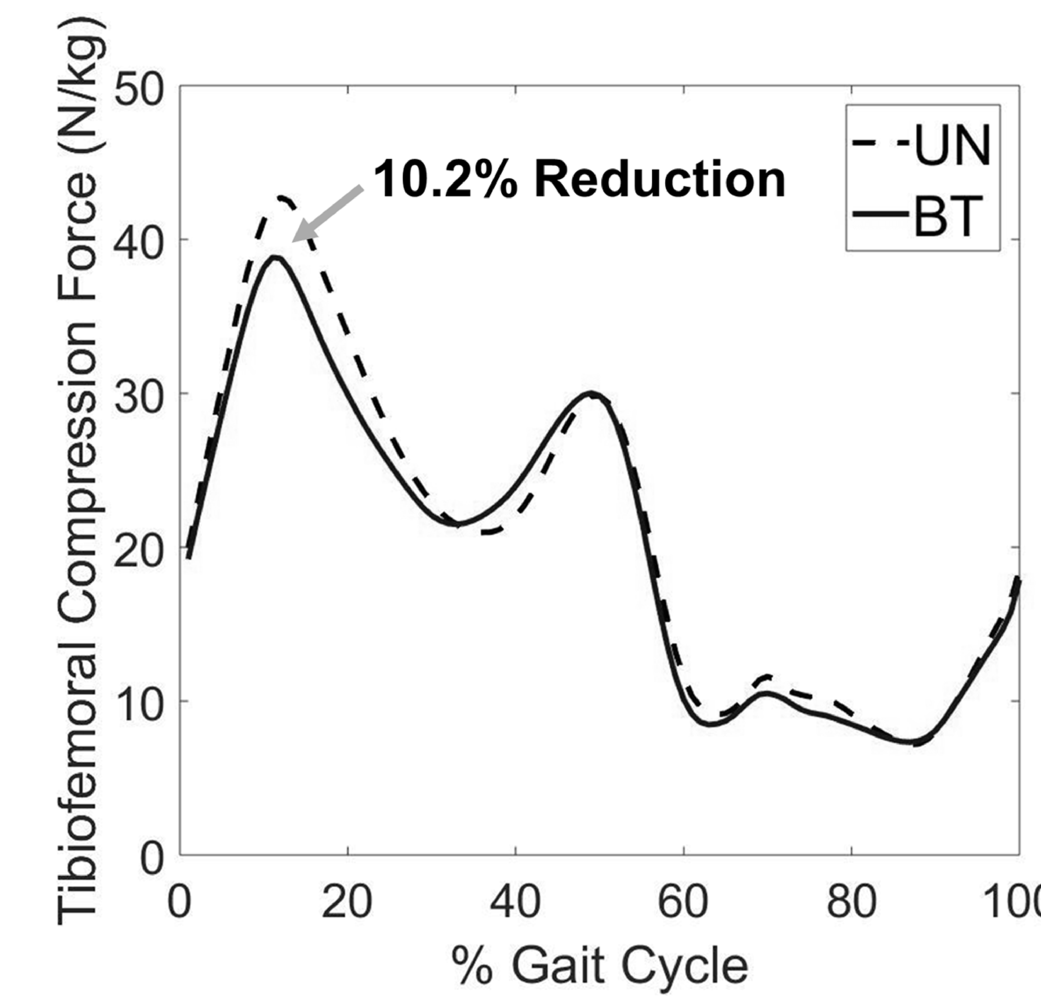

Figure 5. Assistance significantly reduced the peak tibiofemoral force

Average Vasti Muscle Forces

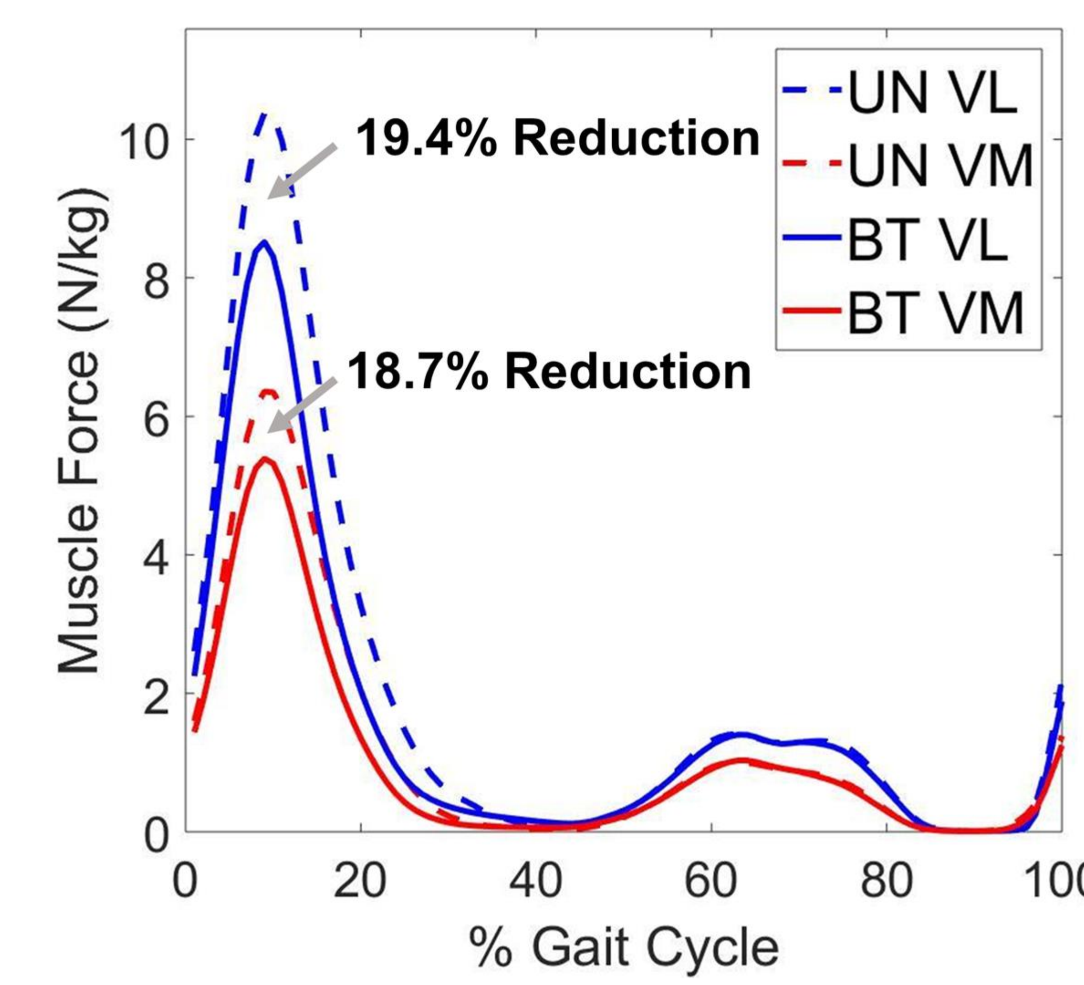

Figure 6. Assistance significantly reduced the peak muscle force for vastus lateralis (VL) and vastus medialis (VM)

Conclusion

Results confirm our primary hypothesis Exoskeleton assistance reduced the muscle force of the primary knee extensor muscles and reduced the knee joint load during the assistance phase.