Reducing Tibiofemoral Joint Force During Downhill Walking Using Various Passive Exosuits: A Pilot Study

Alireza Nasirzadeh[1], WooIhl Kim[1], Jaeha Young[1], Jeongho Choo[1], **Giuk Lee**[1,2]
[1] School of Mechanical Engineering, Chung–Ang University, Seoul, South Korea.
[2] HUROTICS Inc., Seoul, South Korea.
Email: giuklee@cau.ac.kr

Summary

Downhill walking increases tibiofemoral joint loading, elevating the risk of mechanical stress-related injuries. This pilot study investigates the impact of different passive exosuit configurations on tibiofemoral joint contact force. Three participants completed downhill walking trials under normal and six exosuit conditions. The stance-phase average of the biological component of the tibiofemoral joint resultant force was estimated. The condition connecting the trunk to the posterior thigh showed the greatest joint force reduction. These findings highlight the potential of passive exosuits to reduce tibiofemoral joint force.

Introduction

Downhill walking imposes significant mechanical loads on the tibiofemoral joint, increasing the risk of joint injuries and degeneration. Passive exosuits may help mitigate these forces by assisting movement and reducing joint loading. This pilot study examines the effectiveness of different passive exosuits in reducing tibiofemoral joint force during downhill walking.

Methods

Three young males completed seven 1-minute downhill walking trials in a randomized order on a force plate treadmill set at –15° inclination (speed: 1.25 m/s). Trials included normal walking and 6 exosuit conditions. The exosuit consisted of a trunk component, adjustable passive elastic bands (exobands), and thigh/shank components, as shown in Fig 1. Full–body motion capture data was collected using the Plug-in Gait marker set, with three extra markers on the exoband to identify its origin, insertion, and path. The force in the exoband was measured with an embedded load cell.

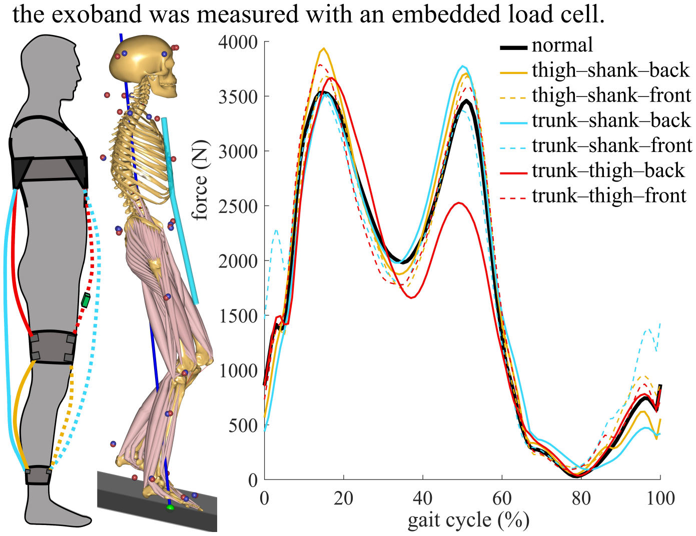

Figure 1. Left: Exosuit conditions connecting the trunk, thigh, and shank. Center: musculoskeletal model. Right: biological component of the tibiofemoral joint resultant force.

Five consecutive gait cycles from each trial were modeled using the AnyBody Modelling System. The exoband was incorporated into the model using markers and load cell data. Each model was scaled and run with and without the exoband to estimate the biological component of the joint contact force, as described elsewhere [1]. Finally, the average tibiofemoral joint force during the stance phase was calculated.

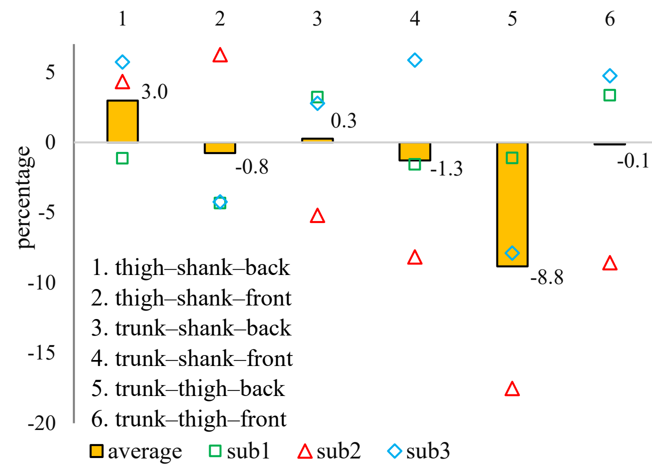

Figure 2. Percentage difference in the average stance-phase tibiofemoral joint force across all conditions relative to normal.

Results and Discussion

The effect of different exosuit configurations on tibiofemoral joint resultant force is shown in Fig 1. On average, the trunk–thigh–back condition resulted in the greatest force reduction (−8.8%), followed by trunk–shank–front (−1.3%) and thigh–shank–front (−0.8%) (Fig 2). The trunk–thigh–front condition had a minimal effect (−0.1%), while the trunk–shank–back configuration showed a negligible increase (+0.3%). In contrast, the thigh–shank–back condition resulted in the largest increase in joint force (+3.0%), suggesting it may not effectively offload the tibiofemoral joint. Individual responses varied, with some participants showing force reductions and others experiencing increased loading in certain conditions.

Conclusions

These findings suggest that passive exosuits have the potential to reduce the resultant tibiofemoral joint force effectively, potentially alleviating joint stress. The exosuit configuration connecting the trunk to the posterior thigh resulted in the greatest reduction in the tibiofemoral joint force. Future research should examine larger sample sizes and investigate whether optimizing band tension or placement can further reduce tibiofemoral joint contact force.

References

[1] Nasirzadeh A et al. (2024). *ISBS Proc. Arch.*, **42(1)**: 105.