Ground Reaction Force Analysis of Hip-Flexion Gait Exercise with Increasing Speed

Tanner A. Thorsen[1], Nuno Oliveira[1]
[1]Biomechanics Laboratory, The School of Kinesiology and Nutrition, The University of Southern Mississippi, Hattiesburg, MS, USA
Email: tanner.thorsen@usm.edu

Summary

Ground reaction force (GRF) profiles of increased hip flexion gait (HFgait) were compared across increasing movement velocities. Peak GRF increased with velocity, however, vertical GRF impulse did not. HFgait may be a valid exercise modality wherewith cardiovascular demand can be increased without excessive load added further up the kinetic chain.

Introduction

HFgait is an exercise modality where individuals walk on a treadmill and increase intensity (metabolic cost) by increasing hip flexion [1]. HFgait is an open chain movement that involves the whole body and promotes coordination between the body segments involving many degrees of freedom and has demonstrated reduced tibial acceleration [2]. Thus, HFgait may be a valid exercise alternative for where joint loading is of paramount concern (e.g., osteoarthritis). Although the metabolic cost and kinematic behavior of this activity has been investigated, the kinetic properties associated with this exercise modality have yet to be investigated.

Understanding GRF during HFgait, especially with increasing movement velocity will highlight biomechanical characteristics of this modality and inform the exercise prescription of HFgait as an alternative exercise modality.

Methods

Twelve healthy individuals (6M, 6F; age 29.3 ± 9.8 years; height 171.1 ± 0.1 cm; body mass 68.7 ± 13.3 kg) completed HFgait trials on a tandem belt instrumented treadmill at three speeds, 1.34, 1.07 and 0.81 m/s while simultaneous kinematic (240 Hz) and kinetic data were recorded (1200 Hz).

During HFgait, participants used a biofeedback system that uses markerless motion tracking for hip flexion angle calculations [2]. This system displays the real-time hip flexion angle and the target peak hip flexion angle while participants walk on the treadmill. This ensured that participants maintained a consistent peak hip flexion angle during the test.

Peak three-dimensional GRF were determined from consecutive steps at each speed. The vertical GRF impulse was also calculated during the stance phase of each step. A one-way ANOVA was used to assess differences in GRF across speeds, and, within a given speed, a dependent samples t-test assessed differences between 1st and 2nd peak vertical GRF.

Results and Discussion

Peak lateral, posterior, and 1st peak vertical GRF were increased during HFgait at 1.34 m/s compared to HFgait at 0.81 m/s (Table 1). This is likely a direct consequence of increased movement velocity. In addition, 2nd peak vertical GRF was significantly lower than 1st peak vertical GRF at all three speeds (all p <.001). Vertical GRF impulse was also greater at 1.34 m/s than 0.81 m/s (Table 1).

These results suggest HFgait may be a valid exercise modality with cardiovascular demand comparable to running but promotes GRF similar to walking. Significant reductions in 2nd peak vertical GRF likely play a role in consistent vertical GRF impulse across speeds, which suggests a favorable environment for increasing cardiovascular demand while mitigating load further up the kinetic chain (e.g., tibiofemoral joint compressive forces).

Conclusions

Peak GRF during HFgait increase with speed, as expected, however, vertical GRF impulse did not. This supports HFgait as a sound modality for patient populations where joint loading is of primary concern.

Acknowledgments

The current study has been supported by the American Heart Association (grant 23AIREA1055000).

References

[1] Oliveira et al. (2023). *Eur. J. Appl. Physiol..*, **123**: 2157-2165.
[2] Oliveira et al. (2024). *P J. Sports Eng. Tech.*, **238**: 296-301.

Table 1: Peak three-dimensional GRF (% body weight) and vertical GRF impulse (%BW/s) during HFgait at three different speeds.

	1.34 m/s	1.07 m/s	0.81 m/s	p
Lateral GRF	0.04 ± 0.02	0.03 ± 0.02	0.02 ± 0.01$^{\alpha}$	**0.030**
Medial GRF	-0.11 ± 0.03	-0.12 ± 0.03	-0.10 ± 0.03	0.406
Anterior GRF	0.31 ± 0.12	0.30 ± 0.10	0.25 ± 0.08	0.257
Posterior GRF	-0.33 ± 0.08	-0.29 ± 0.06	-0.23 ± 0.06$^{\alpha}$	**0.003**
Vertical - 1st Peak	1.60 ± 0.19	1.45 ± 0.17	1.27 ± 0.09$^{\alpha\beta}$	**<.001**
Vertical - 2nd Peak	1.04 ± 0.15$^{\#}$	1.09 ± 0.11$^{\#}$	1.11 ± 0.11$^{\#}$	0.409
Vertical GRF Impulse	0.66 ± 0.12	0.68 ± 0.16	0.81 ± 0.12$^{\alpha}$	**0.043**

$^{\alpha}$ significantly different from 1.34 m/s. $^{\beta}$significantly different from 1.07 m/s.
$^{\#}$ Significantly lower than Vertical - 1st Peak GRF