Kinetic analysis of metatarsophalangeal joints during level and stair walking

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Summary

This study investigated the kinetics of metatarsophalangeal (MTP) joints during level walking and stair ascent (SA)/stair descent (SD) walking. Our results show that level walking exhibited greater maximum plantarflexion moment and negative power of the MTP joint compared to stair walking. These results suggest that during level walking, the MTP joints play a more significant role in propulsion and energy absorption.

Introduction

The MTP joints are synovial joints between the proximal end of phalanges and metatarsals. The MTP joints support 20~33% of the ankle plantarflexion moment in push-off and double support phase during level walking [1]. Also, the MTP joints store energy to move body mass forward during level walking [2]. However, there were no studies on the kinetics of the MTP joints during stair walking.

Therefore, this study aimed to investigate the kinetics of the MTP joint in the sagittal plane during SA/SD walking and compare them with during level walking.

Methods

Fifteen healthy male subjects without lower extremity injuries participated in this study. Twelve retro-reflective markers were placed to calculate the MTP joint motion on the following locations on each foot. The kinematic and kinetic data were obtained using a motion capture system and force/pressure plate. The experimental five-step staircase was designed with a pressure plate and force plate embedded on the third floor. Subjects were instructed to perform level, SA, and SD walking. The pressure plate and force plate were synchronized using the center of pressure (Figure 1). A registration equation is based on the root mean squared error and the MTP joint axis is defined as a line of the first metatarsal head coordinates projected to the force plate plane (Figure 1).

Kruskal-Wallis t-test was performed to compare the maximum MTP joint plantarflexion moment and absorption power among the walking conditions, and then Bonferroni post hoc t-test was performed at a significance level of 0.05.

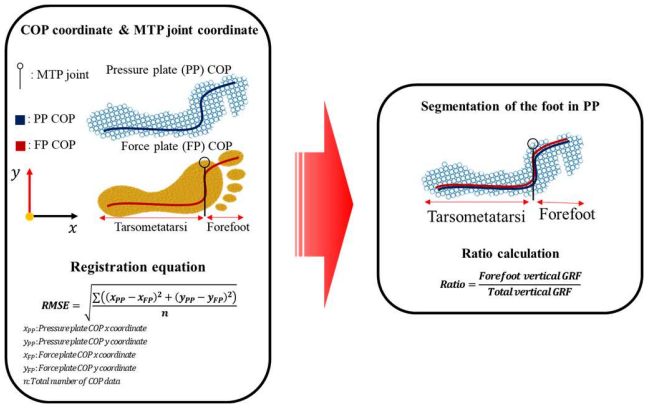

Figure 1: Segmentation of foot in pressure plate and ratio calculation.

Results and Discussion

The maximum plantarflexion moment of the MTP joint was smallest during SA walking ($p<0.05$ and $p<0.05$, respectively; Table 1). Also, the maximum absorption power of the MTP joint was smallest during SA walking ($p<0.05$ and $p<0.05$, respectively; Table 1). During SA walking, the maximum forefoot force was lower than level walking [3]. To calculate the plantarflexion moment of the MTP joint, it is essential to obtain both the forefoot force and the moment arm associated with the MTP joint [2]. This may lead to a reduction in both the maximum plantarflexion moment of the MTP joint and the negative power during SA walking.

Conclusions

As the maximum MTP joint moment and negative power during level walking were not different from or greater than those during SA and SD walking, the MTP joints in level walking appear to be more involved in propulsion and energy absorption.

Acknowledgments

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References

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Table 1: Kinetics of metatarsophalangeal joint during level and stair ascent/stair descent walking (mean±SD)

	Level	Stair ascent	Stair descent
Max. MTP joint plantarflexion moment (% Nm/(BW*L))	41.41±24.73	4.38±3.78[a]	28.27±21.04[b]
Max. MTP joint absorption power (% W/(BW*L))	3.87±2.52	0.05±0.08[a]	0.79±0.93[a,b]

MTP: metatarsophalangeal
[a] $p<.05$, significant difference compared to level walking; [b] $p<.05$, significant difference compared to stair ascent walking