Required coefficient of friction during walking in individuals with unilateral transfemoral amputation

Shunta Kobayashi[1], Kai Kobayashi[1], Takeshi Hara[1], Ryouta Morishima[1], Chien-Chi Chang[2], Hiroaki Hobara[3]
[1]Graduate School of Advanced Engineering, Tokyo University of Science, Tokyo, Japan
[2]Department of Industrial Engineering & Engineering Management, National Tsing Hua University, Hsinchu, Taiwan
[3]Faculty of Advanced Engineering, Tokyo University of Science, Tokyo, Japan

Email: 8321047@ed.tus.ac.jp

Summary

This study examined the differences in slipping risk between the prosthetic and intact limbs during walking in individuals with unilateral transfemoral amputation. The findings indicate that the intact limb is exposed to an elevated risk of mediolateral slipping, possibly as a compensatory mechanism to address the functional limitations associated with the prosthetic limb.

Introduction

Individuals with unilateral transfemoral amputation are at a heightened risk of falls during daily activities, with slipping being a major contributing factor [1]. Many studies assess slip risk by measuring the required coefficient of friction (RCOF), which represents the minimum friction needed at the shoe-floor interface to prevent slipping. However, these studies primarily focus on healthy individuals and provide little to no insight into how the RCOF differs between prosthetic and intact limbs in the amputee population. In distinction from these studies, the current study examines the RCOF of prosthetic and intact limbs across a wide range of walking speeds in individuals with unilateral transfemoral amputation.

Methods

A total of 30 individuals with unilateral transfemoral amputation (7 females and 23 males, classified at K-3 or K-4 functional levels) were recruited for this study. Participants were instructed to walk at eight predetermined speeds, ranging from 2.0 to 5.5 km/h, on a split-belt instrumented treadmill (FTMH-1244WA, Tec Gihan, Kyoto, Japan), where ground reaction forces (GRFs) were measured. The RCOF was calculated as the ratio of the mediolateral (RCOFx: Fx/Fz) and anteroposterior GRF (RCOFy: Fy/Fz) components to the vertical GRF, respectively. A higher RCOF indicates an increased frictional demand at the shoe-floor interface, thereby elevating the risk of slipping. Conversely, a lower RCOF reflects reduced frictional demand, suggesting a diminished risk of slip incidents. In this study, the maximum RCOF during the first half of the stance phase was extracted, excluding the initial 50 ms following heel strike [2]. Data normality was assessed using the Shapiro-Wilk test. For normally distributed data, two-way repeated measures ANOVA followed by post-hoc comparisons was applied. The Friedman and Wilcoxon signed-rank tests were utilized for non-normally distributed data. Statistical significance was defined as $p < 0.05$.

Results and Discussion

When walking speed ranged from 3.0 to 4.0 km/h, significant differences were observed in RCOFx between the prosthetic and intact limbs (Figure 1-A). No significant differences in RCOFy (Figure 1-B) were found across all walking speeds. These findings appear to echo the results of a previous study, which showed that individuals with unilateral transfemoral amputation exhibit dynamic instability during walking in the mediolateral direction [3]. These results suggest that the intact limb may be exposed to a higher risk of mediolateral slipping than the prosthetic limb due to compensatory strategy or the functional limitations of the prosthetic limb.

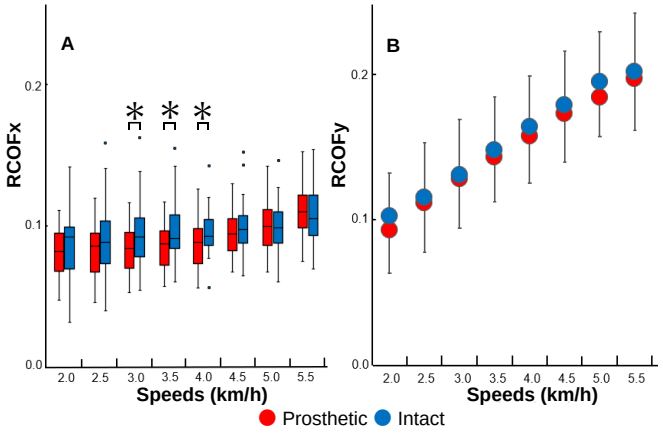

Figure 1: Whisker-Box plots and mean (and error bars) plots of RCOFx (A) and RCOFy (B) at eight speeds. Plots falling outside the whiskers were identified as outliers. An asterisk (*) indicates a significant difference between two limbs.

Conclusions

The results of the present study suggest that the intact limb exhibits a higher risk in mediolateral slipping than prosthetic limb around at a preferred walking speed in individuals with unilateral transfemoral amputation.

Acknowledgments

We appreciate all subjects who participated in the study.

References

[1] Noah et al. *J Prosth Orth*, **4**: 387-392, 2017
[2] Rakie at al. *Gait Posture*, **15**: 159-171, 2002
[3] Ichimura at al. *Scientific report*, **12**: 17501, 2022