INVESTIGATION ON SLIP DANGER TO TRANS-FEMORAL PROSTHESIS USER DURING LEVEL WALKING

[1]Jin Dewen, [1]Yang Jiankun, [1]Wang Rencheng, [1]Zhang Jichuan, [1]Ji Linhong,[2]Fang Xin, [2]Zhou Dawei
[1]Division of Intelligent and Biomechanical System, State Key Laboratory of Tribology, Tsinghua University, Beijing (100084), PR China email: jdw-om@tsinghua.edu.cn
[2]China Center of Orthopedic Technology (CHICOT), Beijing (101601), PR China

INTRODUCTION

Slip-related falls have become a major cause of serious injuries, so that more and more researchers dedicate to this field. Grönqvist et al. [1] have indicated that the moment of heel contact is most dangerous for slip occurrence in a gait cycle. Cham et al. [2] have quantified the changes in gait biomechanics when people anticipate slippery environments. Buczek et al. [3] have suggested that the peak required coefficient of friction ($RCOF_{peak}$) can be used to predict slip potentials in gait activities. However, little work has been carried out on the slip events of trans-femoral amputees. The aim of this study is to investigate the slips happening to trans-femoral amputees during level walking on normal and slippery path via the gait analysis.

METHODS

Six male unilateral trans-femoral amputees and ten non-amputees participated in the current study. All of the amputated subjects were active and able to walk independently in daily life. In the experiment, the subjects were required to walk at a self-selected comfortable pace on the dry surface along a 5 m plastic walkway. Then five amputees and five non-amputees were required to walk on the oily surface. Two force plates (OR6-7, AMTI, MA), which were placed in the walkway, were employed to record the ground reaction forces (GRF). At the same time, the Qualysis Motion Capture System (Qualisys Medical AB, Sweden) were employed to record the kinematics data of each trail at 200 Hz synchronously.

The $RCOF_{peak}$ and the contribution ratio of Fx to the RCOF (R_{Fx}) were calculated using the following equations:

$$RCOF_{peak} = \left| \frac{\sqrt{F_x^{\,2} + F_y^{\,2}}}{F_z} \right| \qquad R_{Fx} = \frac{F_x^{\,2}}{F_x^{\,2} + F_y^{\,2}}$$

Where *Fz* represents the force in vertical direction; *Fy* represents the force in forward direction; *Fx* represents the force in lateral direction. A one way analysis of variance (ANOVA) was performed on $RCOF_{peak}$ and R_{Fx}, respectively. Only values of $P < 0.05$ were considered significant.

RESULTS AND DISCUSSION

The values of $RCOF_{peak}$ and R_{Fx} are listed in Table 1 and Table 2. It is indicated from the comparison between the trans-femoral amputees and non-amputees that the $RCOF_{peak}$ and R_{Fx} of amputees were significantly greater than that of non-amputees. And the comparison between sound side and prosthetic side shows that the value of R_{Fx} of prosthetic side is much higher than that of sound side while the R_{Fx} of sound side is close to that of non-amputees.

Table 1: The comparison between the trans-femoral amputees and non-amputees

	$RCOF_{peak}$	R_{Fx}
Amputees	0.220 ± 0.071	0.183 ± 0.150
Non-amputees	0.165 ± 0.025	0.052 ± 0.059
P-value	0.007	0.008

Table 2: The comparison between the sound and prosthetic sides of trans-femoral amputees

	$RCOF_{peak}$	R_{Fx}
Sound Side	0.231 ± 0.094	0.071 ± 0.016
Prosthetic Side	0.209 ± 0.054	0.295 ± 0.137
P-value	0.707	0.017

The results come from the differences of ground reaction forces. The forces in lateral direction of prosthetic side Fx are much greater than that of sound side and both Fx and Fy of sound side are greater than that of non-amputees.

The kinematic data also show the rationality of the results. When the subjects walking on the dry surface, there were obvious lateral swings in amputees' gait pattern. In the slip events the slip direction was completely different between prosthetic side and non-amputees including sound side. When the sound side of amputees or the non-amputees encountered slips, the foot slid mainly in the forward direction while that when slips occurred to the prosthetic side the foot slid mainly sideways.

CONCLUSIONS

1) The large value of peak required coefficient of friction indicates that the trans-femoral amputees face a greater slip danger than normal people during level walking. 2) Swing in the lateral direction of amputees' gait pattern is the main cause of the increase of peak required coefficient of friction. 3) Sideway slip is the peculiar character of the prosthetic side of trans-femoral prosthesis user.

REFERENCES

1. Grönqvist R, et al. An apparatus and a method for determining the slip resistance of shoes and floors by simulation of human foot motions, *Ergonomics* **32** 979-995, 1989.
2. Cham R, et al. Changes in gait when anticipating slippery floors, *Gait and Posture* **15** 159-171, 2002.
3. Buczek FL, et al. High-resolution force plate analysis of utilized slip resistance in human walking. *Journal of Testing and Evaluation* **24** 353-358, 1996.

ACKNOWLEDGEMENTS

Supports: NSFC (No. 30170242) and NHTRD (863) (No. 2001AA320601)