LOWER EXTREMITY MUSCLE ACTIVITIES OF TRANS-FEMORAL AMPUTEES WHEN A SLIP OCCURS IN GAIT

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INTRODUCTION

Lower extremity muscle activities always play an important role of human locomotion and balance. In nowadays, surface electromyography (sEMG) is a major method to identify muscle activities. So that, many researchers have used sEMG to investigate the human balance strategies in slips and falls [1, 2]. In comparison with the healthy person, the trans-femoral amputee's ability to recover from slips is weakened obviously due to the absence of one leg. The purpose of this study is to investigate that the sEMG response of trans-femoral amputees when a slip occurs at the heel contact (HC) moment in gait.

METHODS

Six male unilateral trans-femoral amputees and five male healthy non-amputees participated in the current study. Each subject was required to walk at a self-selected comfortable pace along a 5 m plastic walkway, and to perform two walking trials on dry and oily conditions respectively. In oily condition, the motor oil (40#) was evenly applied across 2 m long in the middle of the walkway. A pair of parallel bars was used to protect the subjects against real falls.

The sEMG data were recorded using several bipolar surface electrodes (DE-2.1, Delsys Inc., Boston, MA, USA), which were placed on the skin overlying the muscle bellies of tibialis anterior (TA), gastrocnemius medialis (GM), rectus femoris (RF), biceps femoris (BF), gluteus maximus (GMA), gluteus medius (GME), erector spinae (ES), obliquus externus abdominis (OA) on both sides, unless the muscle was unavailable because of amputation. For analysis, the instantaneous power (IMP) was employed. Each IMP was then low-pass filtered and normalized to its own mean value. 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.

RESULTS AND DISCUSSION

When a slip occurred at HC moment for normal people, the power increase of TA, BF, GMA, GME and ES muscles on the anterior leg was observed obviously. All these muscles contracted to lock the ankle, knee, hip and waist joints. And then, if the body fell backward continuously, the power of RF and GMA muscles on the posterior leg increased significantly in order to support the falling body. Thus, it was demonstrated from the muscle activities that there were two steps to recover from a slip-and-fall event, "anti-slip" and "anti-fall", for healthy persons.

However, the muscle responses of trans-femoral amputees differentiated from that of non-amputees for the absence of their legs. When the anterior prosthetic limb encountered a slip at HC moment, which is mostly happened while the subjects walking on slippery surface, the absence of some body parts on the amputated side made the subject unable to sense the slip in time, so that, no timely anti-slip adjustment was implied soon enough. In these cases, slips usually induced complete falls. The function of the GMA muscle on the prosthetic side was mainly to "pull" back the sliding leg when fall had taken place, while the GMA muscle on the intact side contracted to support the falling trunk.

In other cases that the sound limb was anterior and encountered a slip at HC moment, the sliding limb could be locked and stabilized in time but the prosthetic limb was usually not competent for supporting the body. In this situation, the GMA muscle on the sound side cooperated with other muscles together to stabilize the sliding leg. If balance was regained rapidly, the process would continue. Nevertheless, if the adjustments on the sound side could not overcome the perturbation, the GMA muscle on the prosthetic side would act to support the falling trunk. Whether the prosthetic could do so, would depend on the function of the prosthesis. Therefore, the fall danger for amputees is much higher than non-amputees.

CONCLUSIONS

1) For normal persons, the anti-slip and anti-fall response strategies are employed in sequence to regain balance when a slip occurred. But for the absence of some muscles it is difficult for trans-femoral amputees to regain balance. 2) GMA muscles always made enormous contribution to balance control in the slip events, and it was much more obvious for the trans-femoral prosthesis users than for normal people. Moreover, the GMA muscle on the prosthetic limb acted as the compensation of the absent muscles. 3) The sEMG of GMA muscles were very sensitive to slips and could be used for slip detecting. The knowledge could be helpful for detecting the slip event and developing the device preventing the falls.

REFERENCES

1. Ferber R, et al.. Reactive balance adjustments to unexpected perturbations during human walking, *Gait and Posture* **16** (3), 238-248, 2002.
2. Marigold DS, et al.. Role of the unperturbed limb and arms in the reactive recovery response to an unexpected slip during locomotion, *Journal of Neurophysiology* **89**, 1727-1737, 2003.

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