Relationships between the Transfemoral Socket Interface Pressure and EMG of Residual Limb during Gait

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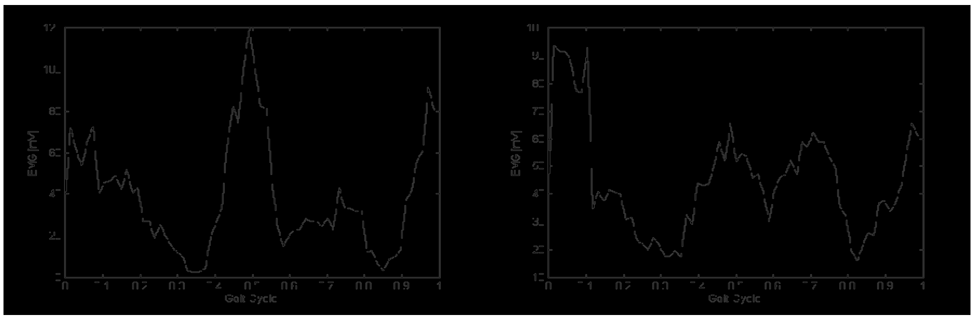
Introduction: For transfemoral amputees, the biomechanical interaction between the stump and the prosthetic socket during the stance and swing phases of gait is critically important to achieve normal-like ambulation. It is widely accepted that an abnormal socket interface pressure (IP) distribution and behavior cause pathology in the stump, which directly affects gait of amputees. Therefore, many investigators have studied static and dynamic socket pressure behaviors. The results of the investigations suggested that the pressure changes during gait of transfemoral amputees are closely related to the prosthetic alignment, the socket shape, and the stump size[1]. It is suggested that the temporal changes of hip moment during ambulation also affect the socket pressure distributions of transfemoral amputees[2], since knee flexor and extensor muscle activities are essential for normal gait. In addition, it can be postulated that the residual muscles in the stump of transfemoral amputees are still active. As a result, the residual muscle activities could affect to the socket IP characteristics. However, relationships between the residual muscle activities and the socket pressure have not been well understood. Also, the behavior of knee flexor and extensor during gait of transfemoral amputees is not studied. The purpose of this study is to investigate the relationships between the residual muscle activities and the socket pressure characteristics during amputee gait with transfemoral prostheses.

Statement of Clinical Significance: The knowledge of the transfemoral socket IP generation and EMG behavior during gait of transfemoral amputees could improve the transfemoral socket design concept and eventually help them to achieve a close normal-like gait.

Methodology: In this study, an intelligent swing phase controlled 4-bar pneumatic knee transfemoral prosthetic system (BK Meditech, Korea) and a quadrilateral suction socket based on brims (Otto bock, Germany) were utilized. To measure EMG of residual muscles in the stump, specially designed sockets that the EMG electrodes could be instrumented between the skin and inner wall of the socket, were fabricated based on the individual muscle anatomy of subjects. Two unilateral transfemoral amputees fitted with the knee prosthesis, a fixed ankle, an energy storing foot, and the quadrilateral suction socket, participated in gait experiments (VICON, UK) with measuring socket IP near at the EMG electrodes (Novel, Germany). The prosthetic knee, foot, ankle, and socket were developed by Korea Orthopedic and Rehabilitation Engineering Center (KOREC). The subjects had no prior stump pain and disorder. Before the tests, the subjects were instructed and trained for close-to-normal ambulation for 4 weeks with the prostheses. The prosthetic system including the socket was carefully aligned based on individuality of each subject to make sure for close-to-normal walking before experiments. Data acquisition was performed in a manner that captured one complete, gait cycle with a gait speed of 1.14 m/s. Minimums of five gait trials for each subject for the statistical analysis were performed as a rate of 60 frames per second. The pressure measurements were synchronized to the gait experiments. Also, the EMG electrodes were placed on the rectus femoris (RF) and biceps femoris (BF) that are the knee extensor and flexor, respectively. The EMG was measured as a sampling rate of 1200 Hz and processed using the adaptive filter algorithm[3]. Pearson correlation method (Minitab, USA) was applied to understand the relationship between the EMG amplitude of residual muscles, and the measured socket IP changes.

Results: Figure 1 shows the temporal changes of EMG of residual muscles in stump for the subjects during gait. For all events in gait cycle such as IC, FF, MS, PS, TO, and TS, the IP values of the RF and BF were significantly correlated with the EMG behavior for both subjects ($P < 0.05$). For the RF, Pearson correlation coefficients were 0.92 and 0.86 for subjects 1 and 2, respectively. For the BF, the coefficients for each subject were 0.72, and 0.61, respectively.



(a) (b)

Figure 1. Transfemoral amputees' residual muscle activities (the vertical axis is EMG in microvolts, mV) of the BF and RF plotted as a function of the gait cycle (a) EMG of the BF; and (b) EMG of the RF.

Discussion: As seen in Figure 1, the activities of residual muscles in transfemoral stump are different from those of normal person. For the BF, EMG behavior of subjects shows an abnormal second burst near 50% of gait cycle, which cannot be observed in the normal gait. However, the residual muscle activity at the beginning period of gait is still existed. This means that the BF in the transfemoral stump is still working as the assistant for the hip extensor. However, it can be known that the function as decelerator for the swing leg at the terminal swing phase is lost. For the RF of transfemoral amputees, the activity still can be observed as seen in the normal gait. Particularly, the activities just after toe-off (about 50 to 60% of gait cycle), which is assisting the hip flexion to pull swing limb forward, is existed. Therefore, it can be understood that the residual muscles in the transfemoral stump are active to assist the gait of transfemoral amputee's gait. Based on the test results, it was suggested that the residual muscle activities, the RF and BF, of amputee's stump is an important factor affecting socket IP changes during walk.

References:

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