ENHANCING AMPUTEE GAIT: COMBINING ACTIVE PROSTHESIS WITH A PROSTHETIC SOCKET FEATURING REAL TIME PNEUMATIC CONTROL

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Introduction

A novel transfemoral prosthetic socket has been developed to improve the comfort and stability of above-knee amputees. This socket is designed with two adaptive air bladders and a pneumatic controller to maintain consistent pressure and adapt to changes in residual limb volume, aiming to enhance gait efficiency when used with active prosthesis equipped with motorized joint control. Clinical trials (IRB [DSMC 2021-04-100-017]) indicated that real-time volume adjustments improved socket fit and enhanced biomechanical function during gait [1].

Methods

A participant (years: 57y, time since amputation: 3y) was fitted with reflective markers for the Plug-in Gait model and walked along a ten-meter pathway while wearing the pneumatic socket integrated with a 3.76 kg active prosthesis (robotic ankle-knee prosthesis). The socket includes air bladders, an air exhaust valve, an air pressure sensor, and a microcontroller, enabling real-time pressure adjustments to maintain consistent contact during movement. Kinematic data were collected using twelve infrared cameras (Vicon Motion Systems Ltd, UK) operating at a frame rate of 100 Hz [2,3].

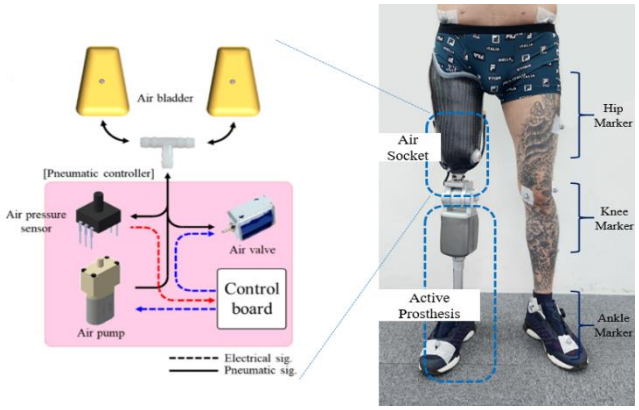

Figure 1: Experimental marker setup and conceptual diagram of pneumatic socket system.

Results

This study investigated the effects of pneumatic socket application in transfemoral amputees using active prostheses by comparing gait parameters under air-injected and non-injected conditions. When air was injected, gait velocity increased to 0.41 m/s, while gait time decreased to 1.56 seconds ($p<0.05$). Stride length improved from 548.94 mm to 631.16 mm, and step length increased from 279.93 mm to 324.20 mm, demonstrating statistically significant enhancements ($p<0.05$). These findings suggest that pneumatic sockets can effectively enhance gait efficiency and stability in transfemoral amputees.

Table 1: Gait parameter as gait cycle.

	Gait Velocity [m/s]	Gait Time [sec]	Cadence [step/min]	Stride Length [mm]	Step Length [mm]
No air	0.34 ± 0.02	1.65 ± 0.05	74 ± 4.17	548.94 ± 89.01	279.93 ± 39.26
Air	0.41 ± 0.03	1.56 ± 0.05	79 ± 4.96	631.16 ± 75.45	324.20 ± 39.99

Discussion and Conclusions

This study evaluated the impact of combining an active prosthesis with a pneumatic socket on the gait of transfemoral amputees. The findings demonstrated that the pneumatic socket significantly improved gait parameters. Specifically, step length and stride length showed substantial increases, which contributed to enhanced overall gait efficiency and reflected a positive progression toward normalized walking patterns. Notably, while active prostheses are inherently heavier due to the inclusion of motors and batteries, the pneumatic socket's adjustable pressure mechanism enhanced both comfort and stability. This innovation reduced concerns about the prosthesis detaching from the residual limb and ensured efficient gait performance even under the added weight of the active prosthesis. These findings suggest that pneumatic sockets are effective not only for passive prostheses but also for supporting the added demands of active prostheses, providing transfemoral amputees with improved gait performance and potential quality-of-life benefits.

Acknowledgments

This research was supported by the NK254H projects (Development of core mechanical technology implementing immersive extended reality for overcoming severe motor dysfunction) of the Korea Institute Machinery & Materials

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