Incremental Socket Size Adjustments during Ambulation: Effects on Residual Limb Fluid Volume

J Sanders PhD, B Larsen MS, J McLean, J Brzostowski, C Gurrey, B Hafner PhD, J Garbini PhD, P Hinrichs MS, K Allyn LCPO
Bioengineering, Mechanical Engineering, and Rehabilitation Medicine Departments, University of Washington, Seattle, Washington

INTRODUCTION

Limb volume fluctuations are perceived by people with limb loss as the most important issue when using their prosthesis (Legro 1999). Some transtibial prosthesis users, especially those without co-morbidities, gain fluid volume during ambulation (Sanders 2014). The purpose of this investigation was to determine if incrementally increasing volume of adjustable sockets during ambulation caused fluid volumes to increase and stay elevated as the prosthesis user continued walking.

METHOD

Participants: People with transtibial amputation were included if they had their amputation at least 18 months prior and were using a well-fitting definitive prosthesis. IRB approval and informed consent were obtained before any study procedures were initiated.

Procedures: A duplicate of each participant's regular socket was fabricated as an adjustable socket using a cabled panel system. The design was similar to the Click Medical REVOfit socket except that an instrumented motor mounted beneath the socket was used to adjust and measure cable length. Movable panels with closed-cell foam pads affixed to their inside surfaces were located anterior medially, anterior proximally, and along the posterior midline. Participants walked on a treadmill wearing a safety harness, while a researcher made small adjustments to socket size. Participants rated socket fit after each adjustment using the Socket Comfort Score. Limb fluid volume was continuously monitored using a bioimpedance analysis system (Sanders 2015).

Data Analysis: Collected cable length data was converted to percent socket volume change using as a reference socket volume with the insides of the panel pads flush with the surrounding socket. Limb fluid volume was expressed in percent relative to fluid volume at the outset of socket adjustment.

RESULTS

Twelve individuals with transtibial amputation participated in this study. Ten were male. Mean time since amputation was 21.3 (±15.3) years, and mean age was 49 (±14) years.

Participants preferred socket sizes in the linear part of the fluid volume vs. socket size curve (Fig. 1). In this region, participants changed fluid volume in proportion to socket size. Slopes in the linear region averaged 2.7 (±0.7) percent limb fluid change per percent socket volume change.

Participants tended to slowly change fluid volume after an adjustment was completed (Fig. 2). The rate of fluid volume change after a socket enlargement was significantly greater than that after a socket reduction (p=0.04).

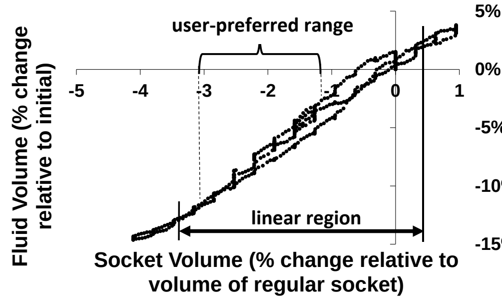

Fig. 1. Example fluid volume-socket volume plot. Data collected while adjustments were being made.

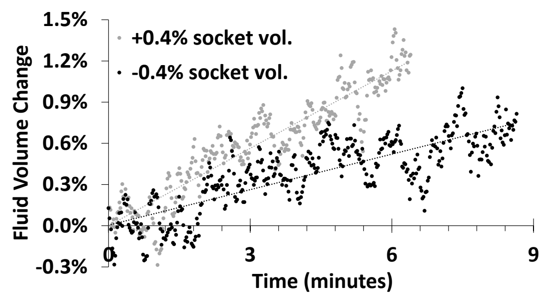

Fig. 2. Example of fluid volume change right after socket adjustment. Socket volume changes relative to the participant's regular socket.

DISCUSSION

Across participants there is a relatively narrow range of fluid volume-socket volume slopes during socket adjustment. Changes in limb blood volume, may be responsible for the observed behavior.

The greater rate of fluid volume gain after enlarging a socket compared with after reducing it may result from changes in fluid transport across vessel walls – arterial-to-interstitial fluid drive increased relative to interstitial-to-venous fluid drive.

CONCLUSION

To minimize limb fluid volume loss, socket size should be adjusted to the high end of the linear section of the fluid volume-socket volume curve.

CLINICAL APPLICATIONS

Findings are relevant both towards effective clinical use of adjustable socket systems and the engineering design of automatically adjusting sockets.

REFERENCES

Legro MW. J. Rehabil. Res. Dev. 36, 155-163, 1999.
Sanders, JE. J. Rehabil. Res. Dev. 51, 201-212, 2014.
Sanders, JE. IEEE Trans. Biomed. Engi. 63, 1760-70, 2015.

American Academy of Orthotists & Prosthetists
44th Academy Annual Meeting &
Scientific Symposium
February 14 – 17, 2018