Volume Changes of Adjustable Sockets

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INTRODUCTION

Adjustable sockets allow prosthesis users to conveniently change their socket size to improve fit and comfort. Though adjustable sockets are commercially available (WIRED 2012, Hein 2015), the volume changes that they achieve are unknown. The purpose of this study was to develop a means to quantify volume changes of cabled-panel sockets, and to measure ranges of socket volumes preferred by trans-tibial prosthesis users.

METHOD

Participants: People with trans-tibial limb loss were included if their amputation was at least 18 months prior and they regularly used a definitive prosthesis that fit properly as deemed by the research prosthetist.

Procedures: After informed consent was obtained, a duplicate of the participant's regular socket was fabricated. The socket was modified to include three adjustable panels (anterior laterally, anterior medially, and along the posterior midline) and a cable, configured similar to the REVOfit system (Click Medical). Unlike the REVOfit system, an instrumented motor positioned at the base of the socket was used to adjust and measure cable length, i.e. socket size. The participant walked on a treadmill at a self-selected walking speed wearing a support harness while the researcher adjusted cable length in 4.75 mm increments. The cable length range over which the participant felt the socket was usable and the socket size the user most preferred were identified.

Data Analysis: Collected cable length data were converted to socket volumes using a geometric model (Figure 1).

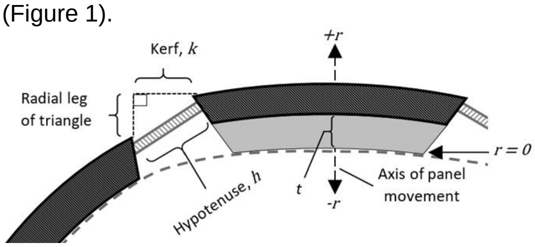

Figure 1. Computational model. *k* is the gap width.

At the neutral position: $h_0 = \sqrt{t^2 + k^2}$. By distributing the cable evenly among the 3 panels: $h = h_0 + c/(n_g * n_p)$ where n_g is the number of gaps spanned by the cable per panel (4) and n_p is the total number of panels (3). Further, $r = \sqrt{h^2 - k^2} - t$. The volume change for each of the 3 rectangular panels (height p_H and length p_L) is $v = r * p_H * p_L$

$$= \left(\sqrt{(h_0 + c/(n_g * n_p))^2 - k^2} - t\right) * p_H * p_L$$.

To calculate percent volume change, the volumes for the 3 panels are summed, then divided by total socket volume below the patellar tendon (from socket CAD file).

RESULTS

Ten individuals with trans-tibial limb loss participated in this study, 9 males, and 1 female. All had their amputation as a result of trauma. Mean age was 49 (SD 14) years.

Socket volumes usable to participants relative to the neutral position (foam pad flush with surrounding socket) ranged from a mean low -3.0% (±1.1%) to a mean high of 2.4% (±1.2%). The mean preferred volume was -1.1% (±1.1%). User-preferred settings were in the lower half of the usable volume range for 9 of the 10 participants (Figure 2).

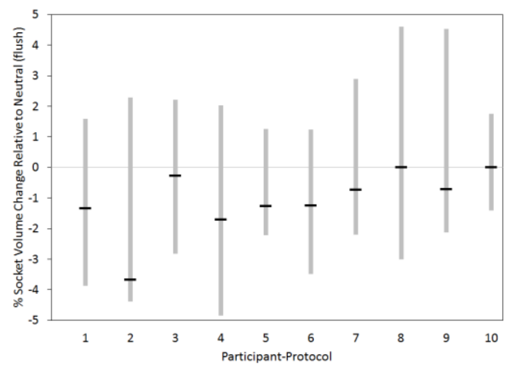

Figure 2. Results from participant testing. Tolerated socket volume range (gray); user-selected optimum (black).

DISCUSSION

The -3.0% to 2.4% range relative to neutral reflects addition of a 2-ply cotton sock to removal of a 1-ply cotton sock (Sanders 2012). Participants preferred relatively tight sockets during this short-term protocol.

CONCLUSION

The 3-ply range (+2-ply to -1-ply) is consistent with clinical objectives for socket fit.

CLINICAL APPLICATIONS

Cabled-panel adjustable sockets allowed users to accomplish their preferred socket size range. Users preferred relatively tight socket sizes. The long-term impact of using tight socket sizes should be considered for investigation.

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