EFFECT OF VACUUM SOCKET SUSPENSION ON UNILATERAL TRANS-TIBIAL AMPUTEE GAIT

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INTRODUCTION

Elevated vacuum socket suspensions are used by amputees to secure lower-limb prostheses to the residual limb via externally applied vacuum. This suspension system has been shown to improve gait symmetry (Board et al., 2001), reduce pistoning (Klute et al., 2011) and improve proprioception (Stevens and Liston, 2007).

The aim of the present research was to investigate the effect of vacuum levels on various gait metrics including temporal, kinematic, and kinetic parameters as well as ground reaction forces. Socket comfort was also assessed.

METHOD

Subjects: seven male unilateral trans-tibial amputee subjects: mean (±SD) age of 51.0±13.7 years, height of 182.4±5.6 cm; five male control subjects: mean (±SD) age of 27.0±3.3 years, height of 178.6±1.9 cm, body mass of 76.5±12.4 kg

Apparatus: retroreflective markers, ten Vicon MXf40 cameras, four AMTI OR-6 force plates, Vicon Nexus software, vacuum pump device and pressure measurement system; questionnaire

Procedures: markers were attached bilaterally to subjects using a standard protocol (Davis, 1991). Amputees walked at a controlled speed, 1.3 m/s, at five randomized vacuum levels from 0-20 inches Hg. Controls also walked at the controlled speed.

Data Analysis: data were filtered, normalized, and summarized; repeated measures analysis of variance was used to determine differences between limbs and vacuum levels for various parameters

RESULTS

Socket comfort improved with increasing vacuum ($p<0.01$, Figure 1). Peak knee adduction moment (KAM) values increase with vacuum ($p<0.05$, Figure 2) but remained below control values. Ground reaction forces were not significantly affected by vacuum level ($p>0.05$). Intact limbs had greater values than residual limbs for several temporal parameters.

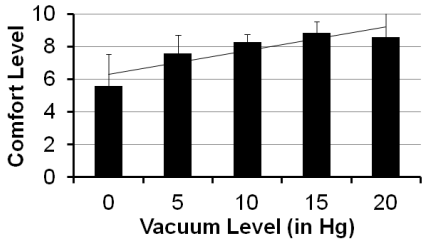

Figure 1. Socket comfort level by vacuum level

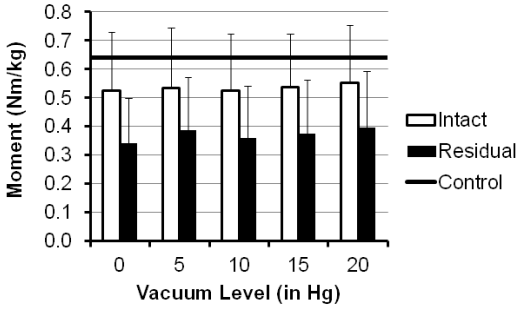

Figure 2. Maximum knee adduction moment by vacuum level for residual and intact limbs

DISCUSSION

Socket comfort improved with increasing vacuum levels. Peak KAM values indicate that knee loads shift medially with increasing vacuum. Increased KAM has been associated with increased severity of osteoarthritis (OA) in the knee joint (Sharma et al., 1998). However, the increase in KAM with higher vacuum still results in lower KAM than for control subjects walking with similar walking speed, stride length and stride time. For amputees the knee loads shift toward the medial compartment of the knee from the lateral as vacuum increases. The knee load is more medial for the intact limb than the residual limb.

CONCLUSION

There is improved socket comfort at higher levels of vacuum, and more normal peak KAM. Peak KAM for both amputee limbs remains lower than for the control subjects even at the highest vacuum level evaluated.

CLINICAL APPLICATIONS

Lower vacuum levels result in poorer socket comfort and in peak KAM values which are further from the normal values than at higher vacuum levels. Amputees should select the most comfortable vacuum levels and clinicians should encourage the use of higher vacuum levels if comfort remains good.

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