METABOLIC COSTS AND WALKING SYMMETRY OF TRANS-TIBIAL AMPUTEES ARE INFLUENCED BY PROSTHETIC MASS DISTRIBUTION

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INTRODUCTION

Unilateral, trans-tibial amputees expend 20% to 30% more metabolic energy than non-amputees walking at the same speed (Gailey et al., 1994). Reasons for these higher costs are not fully understood. The use of lighter weight prostheses is thought to reduce walking metabolic cost, but empirical results have been equivocal. For example, Lehmann et al. (1998) increased prosthesis mass of trans-tibial amputees from approximately 40% to 70% of intact leg mass without significantly altering cost. Gait asymmetries are also common in unilateral amputees. Asymmetrical walking patterns have been thought to contribute to increased joint loading of the intact leg, which may lead to early degenerative joint disease (Royer and Wasilewski, 2006).

Based on the effects different inertia configurations had on the half-period of oscillation of a simple pendulum, we altered prosthetic leg inertia with the intent of increasing, decreasing or not changing swing time of the prosthetic leg. We hypothesized that adding mass proximally to the prosthetic leg (i.e., near the thigh center of mass) would improve walking symmetry and reduce metabolic costs during walking.

METHODS

Six unilateral, trans-tibial amputees (age: 47±16 yrs, mass: 104±10 kg, height: 175±8 cm) participated in this study. All were fully ambulatory, used energy storing prostheses, and maintained some degree of physical activity in their vocational or daily activities.

Inertial properties of each participant's prosthesis were measured using oscillation and reaction board techniques. Seven load conditions were studied (2 loads x 3 positions) plus an unloaded baseline condition (NL). 100% and 50% of the estimated mass difference between the intact and prosthetic legs were added at each of the following load positions: a) near the prosthetic ankle, b) near the prosthesis center of mass, and c) near the prosthetic leg's thigh center of mass. Participants walked at their measured preferred velocity for all walking conditions. Temporal and metabolic data were measured while participants completed 10 min treadmill walking trials under each load condition. In a separate session, kinematic data were measured while participants walked overground under the same load conditions.

Symmetry indices (SI) were computed for stance time, swing time, and knee and thigh angular positions and velocities to determine the effects of the loading configurations on walking symmetry:

$$SI = \frac{(P - I)}{0.5 * (P + I)} * 100$$

where P and I refer to prosthetic and intact legs. Nine planned contrasts were used to statistically identify significant ($p < 0.05$) effects due to the different load configurations.

RESULTS AND DISCUSSION

Metabolic cost increased significantly compared to NL regardless of load position (Figure 1). Cost increased to a greater extent for more distally positioned loads. Our results do not support previous findings (Selles et al., 2004a) of a reduced muscular cost for proximally positioned masses. Adding mass distally to the prosthetic leg also increased stance and swing time asymmetries. However, adding mass to the prosthesis COM or thigh COM had little or no effect on temporal asymmetries (Figure 1). Increased stance time asymmetries were due primarily to increased stance time of the intact leg, whereas increased swing time asymmetries were due primarily to increased swing time of the prosthetic leg. Temporal walking symmetry did not improve with any of the load configurations. Thigh kinematics of the prosthetic leg exhibited the greatest effects due to load, which was consistent with previous findings (Selles et al., 2004b). Specifically, thigh angular velocity of the prosthetic leg was reduced by adding mass; distally positioned loads had the greatest effect on thigh angular velocity.

SUMMARY/CONCLUSIONS

Adding mass proximally to the prosthetic leg did not improve walking symmetry or reduce metabolic cost during walking. It appears that the use of lightweight prostheses minimize metabolic costs and walking asymmetries.

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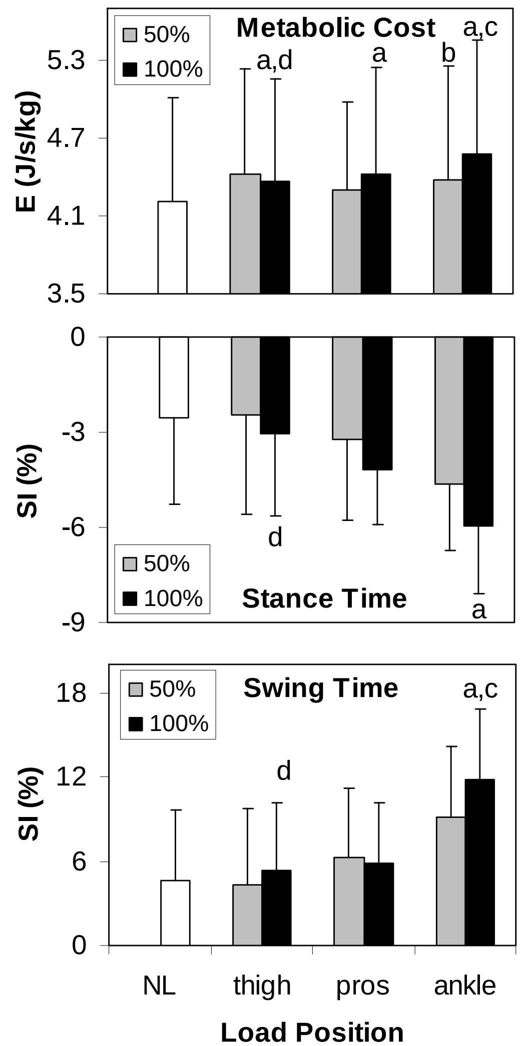

Figure 1: Load effects on metabolic cost, stance time symmetry, and swing time symmetry (means ± SD).

a – NL vs 100% mass for load position

b – 50% vs 100% mass for load position

c – 100% ankle vs 100% pros

d – 100% ankle vs 100%