THE EFFECT OF ADDED PROSTHETIC MASS ON PHYSIOLOGIC RESPONSES AND STRIDE TIME DURING MULTIPLE SPEEDS OF WALKING IN PERSONS WITH UNILATERAL TRANSTIBIAL AMPUTATION

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INTRODUCTION

Increased energy cost and decreased gait efficiency of walking has been a concern for persons with lower extremity amputation. In walking, there appears to be a particular combination of stride length, stride time and speed at which energy expenditure per unit distance is minimized (Zarrugh, M.Y. 1974). Studies on transtibial prosthesis mass revealed controversial findings. It was suggested that there was no need to further decrease the prosthesis mass; on the contrary, heavier prosthesis may result in better gait symmetry (Lehmann, J.F. 1998; Selles, R.W. 1999). However, matching prosthesis moment of inertia to 100% of the intact leg resulted in increased energy cost and decreased gait symmetry (Mattes, S.J. 2000).

Both mass and mass distribution affect moment of inertia. The critical level of added mass has not been fully examined in multiple speeds of walking. Thus, the purpose of this study was to examine the effect of added prosthetic mass on several physiologic responses as well as stride time while walking at multiple speeds in persons with transtibial amputation.

METHODS

Eight male subjects (age: 36 ± 15 years (mean ± S.D); height 1.75 ± 0.06m; weight: 81.71 ± 9.64 kg; prosthesis mass: 1.68 ± 0.27kg) with unilateral traumatic transtibial amputation wearing the same type of prosthesis participated in this study. Subjects were considered in the high to very high activity level according to the Day activity scale 33.3 ± 6.8 (Day, H. 1981).

Mass of stump was simulated with an appropriately sized water bag. Three levels of added masses were 60%, 80% and 100% of estimated intact shank and foot mass (Winter, D. 1990). The average amounts of added mass for the three levels of mass were 0.3 ± 0.26kg, 1.31 ± 0.34 kg and 2.31 ± 0.45kg respectively. The center of gravity (CG) of each prosthesis was measured using a force plate. The mean CG of baseline prostheses was 55% of shank length from knee. Pliable lead strips were used as the material for the added mass and taped to the CG of each prosthesis. Subjects had at least three hours acclimation to each added mass condition.

For each added mass condition (randomly assigned), a multiple speed treadmill walking test was performed. The test involved four minutes of resting data collection, followed by five incremental speeds (2.0, 2.5, 3.0, 3.5, 4.0 mph) of four minute continuous walking stages, followed by an appropriate cool down period. A metabolic cart (Medgraphics MN), interfaced with a telemetry ECG system, was used for data collection of oxygen
consumption and heart rate. An instrumented treadmill (Gaitway, Kistler Ins. NY) was used for collection of stride time. Relative exercise intensity was defined as the percentage of age predicted maximal heart rate (% APMHR). Gait efficiency was defined as the oxygen consumption per distance traveled (ml/kg/m).

RESULTS AND DISCUSSION

Two-way (mass x speed) repeated measures analysis of variance was used for data analysis on oxygen consumption, gait efficiency, % APMHR and stride time. There was no effect of interaction. There was no significant difference in oxygen consumption and gait efficiency for the three mass levels across the five speeds studied.

Surprisingly, added mass up to 100% of prosthetic mass did not significantly increase energy cost. One possible reason might be that the proximal loading in current study results in less change in the moment of inertia compared to previous studies (Mattes, S.J. 2000). Furthermore, the mean 100% added mass value in current study was about 2.8% of body mass. Our subjects were considered high to highly active, which might explain their ability to adjust to this load without extra burden on the cardiovascular system.

There was significant difference in %APMHR (p = 0.013) and stride time (p=0.0126) for the three mass levels. Follow up t tests showed that significant increases in stride time occurred between the 60% and 100% (p=0.0098), and the 60% and 80% (p=0.0008) mass condition. The change of stride time with added mass reflected the immediate adaptation of gait to the change of moment of inertia of lower extremity. However, this change in moment of inertia does not reflect in any changes of the metabolic demand.

SUMMARY

The results showed adding mass at the center of gravity of prosthesis, up to 100% mass of intact limb, did not increase energy cost across five speeds of walking. Further study on the complete temporal-spatial parameters of gait might give us insight as to the impact of proximally added mass on gait symmetry. Stride time did change with the added mass. The relationship between stride time and its preferred resonant period needs further study in order to understand energy minimization in person with transtibial amputation.

REFERENCES


ACKNOWLEDGEMENTS

This work was supported in part by Ottobuck Inc.