EXTERNAL LATERAL STABILIZATION REDUCES METABOLIC COST OF WALKING

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INTRODUCTION

Human walking appears to be laterally unstable (Kuo & Bauby, 1998). This requires active control involving muscle actions and thus, a metabolic cost. Our purpose was to quantify how much metabolic energy is associated with maintaining balance during walking. We hypothesized that providing external lateral stabilization would reduce the metabolic cost of walking.

We designed an apparatus to add external lateral stabilization for subjects walking on a treadmill. At zero step width, stabilization reduced metabolic cost by an average of 6%. We also found that stabilization reduced the preferred step width by an average of 41%.

METHODS

Ten healthy adults (6 male, 4 female) participated in the study after providing informed consent. Prior to the experimental trials, subjects practiced the experimental protocol. Subjects walked on a treadmill set to 1.25 m/s, both with and without external stabilization. We measured the subject’s preferred step frequency and step widths. During the experimental trials, we enforced step frequency using a metronome set to the previously determined preferred step frequency. We had the subjects follow lines marked on the treadmill belt to enforce various step widths, including zero step width and the subject’s stabilized and unstabilized preferred widths.

The external lateral stabilizer consisted of cords attached to the subject’s waist pulling elastically in both lateral directions (fig. 1).

Subjects wore a padded waist belt similar to that used with hip-supported backpacks. We attached lightweight nylon cord with adjustable straps to the sides of the belt extending laterally approximately 8 m. These ended in sections of elastic tubing approximately 0.5 m in length, anchored to the side walls. The apparatus exhibited an effective spring constant of 1700 N/m and an effective damping constant of 14 N·s/m. The relatively long side cords insured that any non-lateral forces exerted by the apparatus were negligible. Because the side cords prevent normal arm swinging, we had the subjects keep their arms crossed during all trials whether externally stabilized or not.

We measured net ground reaction forces and moments along 3 geometric axes as subjects walked on a force treadmill (Kram, et al., 1998). In-line force transducers on the

Figure 1: Lateral Stabilization Apparatus
(Color movie clips may be found at http://socrates.berkeley.edu/~hbbiomx1/mdonelan)
RESULTS AND DISCUSSION

At zero step width, average metabolic cost decreased by 6% (paired t-test: p = 0.036; fig. 2). We may infer that this reduction reflects the metabolic cost of zero step width stabilization. Active lateral stabilization may have a similar metabolic cost at normal step widths, because lateral instability does not vary greatly with step width (Kuo,1999).

Subjects selected a 41% smaller step width on average compared to walking without external stabilization (paired t-test: p = 0.0016; fig. 3). Wider step widths involve somewhat higher energy losses due to stance limb transition costs (Kuo, et al., 1999; Donelan, et al., 1999). It may be that subjects are trading off the stabilization cost of narrow walking against the higher stance limb transition costs of wide walking when they choose preferred step width. Another possible explanation for the smaller step widths may be that our subjects chose to walk with a gait that involves less lateral movement of the pelvis to avoid doing work against the stabilizer.

Because the external stabilizer allows walkers to maintain balance with less energy expenditure while maintaining a fairly normal gait, similar devices could be considered in clinical therapy situations involving patients having difficulty balancing, such as the elderly or those with inner ear disorders.

REFERENCES

Kuo AD (1999) Int. J. Robotics Res. 18: 917-930

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