THE EFFECTS OF AGING ON THE METABOLIC COST OF SUPPORTING BODY WEIGHT DURING WALKING

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INTRODUCTION

Elderly adults consume more metabolic energy for walking than young adults across a range of speeds (1), yet the reason for the greater metabolic cost is unclear. During walking, the muscles of the body consume metabolic energy to generate force to support body weight. Previous walking studies that have measured changes in metabolic cost in response to simulated reduced gravity have shown that the cost of generating muscle force to support body weight accounts for as much as 28-33% of the total metabolic cost of walking (2, 3).

Changes in lower limb posture during the stance phase of walking directly affect the cost of generating muscle force to support body weight. Changes in limb posture affect muscle forces by altering the mechanical advantage for muscle force production (4). For example, by increasing flexion at the hip, knee and ankle joints by approximately 20% during walking, the mechanical advantage of the stance limb muscles decrease and the metabolic cost of walking increases by nearly two-fold (5).

Prior research has shown that elderly adults tend to walk with greater anterior tilt of the pelvis and greater flexion at the hip, knee and ankle joints (6, 7). These increases in flexion of the lower limb joints during the stance phase likely increase the metabolic energy consumed by the active stance limb muscles due to a reduction in their mechanical advantage. In this study, we examined how force generation to support body weight contributes to the cost of walking in young and elderly adults. It is hypothesized that body weight support incurs a substantially greater metabolic cost in elderly adults than young adults.

METHODS

Twelve healthy young (26 ± 4 yrs, mean ± SD) and twelve healthy elderly (75 ± 4 yrs) adults walked on a motorized treadmill at an intermediate speed of 1.3 m s⁻¹ at four levels of body weight support (0%, 25%, 50%, and 75% of body weight). Prior to the walking trials, subjects performed a standing resting metabolic rate trial. Each trial lasted seven minutes followed by five minutes rest. For each trial, we determined net metabolic cost and lower limb kinematics.

We provided weight support by applying a nearly constant upward force to the pelvis and torso near the center of mass using a custom built harness and elastic pulley system (Figure 1) as described by Griffin et al. (8).

Figure 1: Weight support apparatus (adapted from Grabowski et al. 2005).

Metabolic cost was determined using indirect calorimetry (9) during minutes 4-6 of each treadmill trial. We calculated net metabolic cost by subtracting standing metabolic power from gross metabolic power and dividing by body mass.
We determined bilateral hip, knee and ankle joint kinematics for a 20-second period during the last two minutes of each trial using a 100 Hz 6-camera digital motion capture system (Vicon, Centennial, CO, USA). Sagittal plane joint angles were determined for the stance phase of each leg and averaged for ten strides of each walking trial.

RESULTS AND DISCUSSION

Weight support reduced the rate of metabolic energy consumption to a greater extent in elderly subjects compared to young subjects (P<0.0001; Fig. 2). Without weight support, elderly subjects consumed metabolic energy 15% faster per kilogram of body mass (W kg\(^{-1}\)) than young subjects (P<0.0001; Table 1). As weight support increased, metabolic energy consumption decreased in both young and elderly adults (P<0.0001).

![Figure 2: Net Metabolic Power as a function of Weight Support. Asterisk indicates significant differences from normal walking (P<0.05).](image)

Weight support decreased metabolic energy consumption more in elderly adults compared to young adults (P<0.0001). Across the range of weight support, metabolic energy consumption decreased an average 50% (SD 7) in older adults, whereas metabolic energy consumption only decreased by an average 31% (SD 8) in young adults.

Although elderly subjects used a faster step frequency and spent a shorter portion of the gait cycle in single limb support compared to young subjects, our kinematic analysis revealed that elderly subjects only tended to use a more flexed lower limb posture during the stance phase of walking compared to young adults (Table 1).

CONCLUSION

The results of our study support the hypothesis that elderly adults have a greater cost of generating force to support body weight compared to young adults. Moreover, our results suggest body weight support comprises as much as 50% of the net metabolic cost of walking in elderly adults. Thus, the high metabolic cost of walking in elderly adults is likely due in part to a greater metabolic cost of generating muscle force for supporting body weight.

REFERENCES


<table>
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<tr>
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<th>Net Metabolic Cost (Watts/kg)</th>
<th>Step Frequency (Hz)</th>
<th>Ankle Dorsiflexion (degrees)</th>
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<td>Young</td>
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