ADVANCED AGE AND THE MECHANICS OF UPHILL WALKING: A JOINT-LEVEL, INVERSE DYNAMIC ANALYSIS

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INTRODUCTION

The biomechanical demands of uphill walking can be challenging for community-dwelling old adults. We recently quantified how advanced age (65+ yrs) brings diminished ground reaction forces (GRFs), mechanical work, and leg muscle recruitment during both level and uphill walking [e.g., 1-3]. While these measures have been valuable and informative, they offer only indirect insight into the muscular limitations of old adults walking uphill. In this study we compared the kinetics (moments and powers) of old and young adults at each leg joint to more precisely identify biomechanical factors that may lead to impaired uphill walking ability with age.

One of the most pervasive biomechanical consequences of advanced age is a reduction in ankle joint kinetics. During level walking, for example, even healthy and active old adults generate 17 to 29% less ankle power compared to young adults [1-3]. Reduced ankle joint kinetics in old adults are compensated for by an increase in hip extensor moments and power generation during early stance [e.g., 1] and/or an increase in hip flexor moments and power generation during push-off [e.g., 2]. Uphill walking places increased demands on the leg muscles of old adults that could exacerbate age-related changes in leg joint kinetics.

In this study, we quantified sagittal plane ankle, knee, and hip joint moments and powers in healthy old and young adults during level and uphill walking. We hypothesized that: 1) old adults would exhibit smaller peak ankle joint kinetics and larger peak hip joint kinetics than young adults during both level and uphill walking and 2) these age-related differences in ankle and hip joint kinetics would be greatest during uphill vs. level walking.

METHODS

We analyzed the walking patterns of 10 old adults (mean ± SD, age: 72 ± 5 yrs) and 8 young adults (age: 27 ± 5 yrs) walking at 1.25 m/s on a dual-belt, force-measuring treadmill at four grades (0°, +3°, +6°, +9°). We placed 15 retro-reflective markers on each subject’s skin/shoes corresponding to the following anatomical landmarks: anterior superior iliac spines, sacrum, greater trochanters, lateral femoral condyles, tibial tuberosities, lateral malleoli, posterior calcanei, and lateral fifth metatarsal heads. An 8-camera motion analysis system (Motion Analysis Corp, Santa Rosa, CA) captured the three-dimensional marker positions at 100 Hz in synchrony with the GRF data.

We used the analysis methods described by Vaughan et al. [4] to calculate the sagittal plane ankle, knee, and hip joint kinematics and kinetics for each subject over 15 consecutive strides. In a secondary analysis, we integrated the joint power curves with respect to time to calculate the net positive work performed by muscles crossing the ankle, knee, and hip joints. An analysis of variance (ANOVA) for repeated measures tested for significant main effects of and interactions between age and grade with a p<0.05 criterion.

RESULTS AND DISCUSSION

As hypothesized, old adults walked with smaller peak ankle joint kinetics (e.g., power generation: -18% at +9°) and larger peak hip joint kinetics (e.g., power generation: +119% at +9°) than young adults, most evident during the late stance phase of both level and uphill conditions (Fig. 1). In partial support of our second hypothesis, the age-related reduction in peak ankle joint moments was greater during uphill (-0.41 Nm/kg) vs. level (-0.30 Nm/kg) walking. Indeed, a significant interaction revealed that only young adults increased their peak ankle
extensor moments during uphill vs. level walking (p=0.003).

Old adults performed 317% (level) and 119% (uphill) more trailing leg positive double support work than young adults using muscles crossing the hip (p=0.012). However, this was not enough to compensate for the reduced contribution from muscles crossing the trailing leg knee and ankle joints. Thus, old adults tended to perform 20% (level) and 16% (uphill) less total double support trailing leg positive joint work than young adults (p=0.051).

In addition to their more vigorous hip joint kinetics during push-off, old adults further compensated for reduced propulsive ankle function by performing two to three times more positive work per step than young adults during single support via muscles crossing the stance leg knee joint (Fig. 2). In contrast, old adults performed 75% (level) and 71% (uphill) less single support positive work per step using muscles crossing the hip (p<0.001).

**CONCLUSIONS**

Old adults exhibit reduced trailing leg propulsive function during uphill walking largely because they generate significantly less ankle power than young adults during push-off. Old adults compensate for reduced ankle power by: 1) generating greater hip power than young adults during push-off to initiate leg swing and 2) performing greater positive work during single support via muscles acting across the knee (i.e., quadriceps). In our opinion, interventions to preserve the uphill walking ability of old adults should focus on the source of their walking impairments rather than observed compensations. Thus, our findings indicate that maintaining ankle power generation and trailing leg propulsive function with age should be the primary focus of “prehabilitation” strategies for old adults.

**REFERENCES**


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