Age-related differences in the maintenance of frontal plane dynamic stability while stepping to targets

Christopher P. Hurt, Mark D. Grabiner
Department of Kinesiology and Nutrition, University of Illinois at Chicago, Chicago, IL, USA
churt2@uic.edu, URL:http://www.uic.edu/ahs/biomechanics

Introduction
Laterally-directed steps are commonly utilized to circumvent an obstacle or to avoid an undesirable step location during gait. The increased lateral COM motion required to execute the step must then be arrested and reversed if the previous direction of travel (i.e. forward), as well as stability, is to be maintained. Previous research has suggested that older adults may be especially vulnerable to lateral instability [1, 2, 3]. Thus, relative to normal walking, maintaining control of the position and velocity of the COM with respect to the base of support (BOS) while performing a laterally-directed step could be particularly difficult for older adults. This may relate to the marked reductions in force generating capacity of the hip abductors-adductors [4], which are primarily responsible for controlling frontal plane COM motion during stance [5, 6].

The purpose of the present study was to investigate the age-related differences of subjects performing crossover (COS) and sidesteps (SS) to three different targeted step widths while walking. We hypothesized that older adults would generate a significantly smaller hip abductor moment compared to younger adults particularly at the longer step targets. Similarly, given the importance of the hip abductors in regulating dynamic stability, we hypothesized that older adults would be less dynamically stable while performing COS and SS than younger adults, particularly at the longer step targets for which the largest abduction moments would be expected.

Methods
Nineteen young adults (9 males, age: 22.9±3.1 years, height: 174.3±10.2 cm, mass: 71.7±13.0 kg) and eighteen older adults (9 males, age: 72.8± 5.2 years, height: 174.9± 8.6 cm, mass 78.0± 16.3 kg) volunteered to participate in this institutionally reviewed and approved study. All subjects were healthy and free from any musculoskeletal or neurological disorder that may have limited functional mobility.

Subjects walked along an eight meter carpeted walkway with demarcated lanes on the walkway surface (Figure 1). All laterally-directed step trials were executed with subjects’ dominant limb as the stepping limb to targets placed at three locations on a force plate. Subjects performed five SS trials at each distance followed by five COS trials at each distance. Subjects were instructed to walk at a speed that was comfortable to them.

Kinematics of the laterally-directed step were collected using a motion capture system (Motion Analysis, Santa Rosa, CA). The COM location for each subject was determined based on a ten segment model and regression equations [5].

Margin of stability (MOS) was utilized to quantify the instantaneous dynamic stability. The equation for MOS was as follows [6]:

\[ \text{MOS} = \frac{\text{BOS}_{\text{lat}} - x_{\text{COM}}}{\text{BOS}_{\text{lat}}} \]

\[ x_{\text{COM}} = \frac{\text{COM} + \frac{v_{\text{COM}}}{\sqrt{9.8/(1.34*\text{leg length})}}}{\text{BOS}_{\text{lat}}} \]

The average value for MOS was computed from heelstrike to contralateral toe-off of the laterally-directed step. Internal hip abduction moments were computed from the synchronized motion capture and force plate data using commercial software package (Orthotrak, Motion Analysis Corporation,}
Santa Rosa, CA). For all trials the initial peak of the bi-modal abduction moment was extracted from the continuous bi-modal curve.

We tested the hypothesis that the peak abduction hip moment of older adults would be significantly smaller than that of younger adults particularly at the longer step targets with a three-factor (step X target X age) ANOVA with repeated measures on the step and target terms.

To test the hypothesis that older adults would be less dynamically stable than younger adults, particularly at the longer step targets, we utilized a mixed three-factor (step X target X age) ANOVA with repeated measures on the target and step terms. Post hoc tests on the simple effects of significant interactions were performed if significant interactions were detected in the model. Significance was set at 0.05.

Results and Discussion

The general pattern of internal abduction hip moment generation between the stepping targets was similar across subjects for COS and SS (Figure 2). COS to the long targets resulted in the largest peak abduction moment while long SS resulted in the smallest peak abduction moment. A main effect of age was detected for the peak abduction moment (p<0.001). On average older adults generated a peak hip abduction moment that was 30% larger than younger adults across targeted COS and SS (Figure 3). COS resulted in greater abduction moment than a SS particularly at the long and medium step targets (p<0.001). Older adults were as stable or more-stable than younger adults (Figure 4) specifically for the long and medium steps (p<0.003). For both groups, the execution of a SS resulted in a larger MOS than the execution of a COS at all targeted distances (p<0.001).

Conclusion

Age-related differences existed in the performance of targeted laterally-directed steps. Surprisingly, peak hip abduction moments were larger in older adults. This may reflect greater muscular effort by older adults as an attempt to reduce the likelihood of becoming unstable. Contrary to findings related to platform-based disturbances [1,2,3], older adults were as stable or more-stable than younger adults. It is possible that the reactive nature of platform-based disturbances, compared to the proactive nature of voluntary stepping may explain the differences in these results.

References