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Effect of varying step geometry on biomechanical risk factors of falls during stair descent: a pilot study in healthy young and older adults

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INTRODUCTION

In Canada, stair-related falls remain persistently high, leading to hospitalization, admission to a long-term care home and even death in those at greater risk of injury. As emphasized by ergonomics-based research, one strategy by which to reduce stair injuries is through improved stair design [1, 2]. To date, research has focused on understanding how certain biomechanical measures, such as toe clearance, are influenced by changes in step rise and run in healthy young adults [3]. However, there is still debate regarding the optimal step geometry design to minimize falls during stair ambulation. This results in difficulty guiding safe stair design to minimize falls risk. Thus, more research is needed to provide further insight to user behaviour and subsequent risk of falls on stairs of varying geometry. The current pilot work aims to address knowledge gaps regarding safe stair design by providing a more comprehensive biomechanical assessment of user behaviour during stair descent on steps of varying dimensions.

METHODS

Pilot data was collected from 3 healthy young adults and 3 healthy older adults as they ascended and descended 3 sets of custom built stairs. Each staircase had a fixed riser height (7 inch rise, 7.5 inch rise, 8 inch rise). Subjects performed two trials on each set of stairs. The length of the tread run varied randomly from 8 inches to 14 inches, in 1-inch increments for each riser height (Figure 1). Therefore a total of 21 conditions were tested (7 run lengths x 3 riser heights). For this pilot work, results are reported for the 7 inch and 8 inch staircases during descent only.

Minimum run length   Maximum run length

Figure 1. Custom-built staircases, highlighting the minimum (left) and maximum (right) run lengths used for testing. Note. A handrail (not shown in the picture) was present for all testing. However, subjects were instructed to ascend/descend without the handrail.

Three-dimensional biomechanical data were acquired during the task using 3 optoelectric camera banks (Phoenix Technologies Inc., Burnaby, BC) placed in front of the staircases. Four infrared emitting diodes (IREDs) were secured on the subject's shoe (bilaterally) to quantify measures of foot trajectory, foot angles and foot-to-step clearance. The markers were placed such that they tracked the foot as an assumed rigid segment. A probe instrumented with IRED markers at a known distance from the tip permitted identification of the midpoint of the heel and toe relative to the cluster of tracking markers. Whole body motion was also tracked throughout the task with IRED markers secured anteriorly on the subject's torso at the sacral level of S2, providing a proxy measures of whole-body centre of mass. A single IRED secured at the thoracic level of T12 provided a measure of upper trunk motion. Therefore, for each condition, measures of whole-body and segmental control were identified. Finally, markers were secured on the step edges to track the staircases in the global coordinate reference frame. All motion data were sampled at 60Hz, filtered using a second-order, low pass Butterworth filter (cut-off frequency 6 Hz) and processed using Visual 3D (C-Motion, Inc.). The protocol was approved by the Institute's research ethics boards and all subjects provided informed consent prior to participation in the study.

Because of the small sample size, statistical analyses were not possible. Therefore, only preliminary results are reported. Ongoing data collection will provide a larger sample size.

RESULTS AND DISCUSSION

Foot-to-step clearance

Figure 2 illustrates the clearance of the heel with respect to the step edge during steady state stair descent. As indicated by the data, there is a gradual trend to increased clearance of the foot relative to the step edge with increasing run lengths, irrespective of a change in riser height. Although difficult to ascertain with the limited number of subjects, older adults do not appear to increase foot clearance on the larger run lengths, as is seen in the younger group. This may be a maladaptive strategy adopted by the older group to position a greater portion of their foot on the step at the possible risk of contact with the step edge, despite the increased run length permitted.

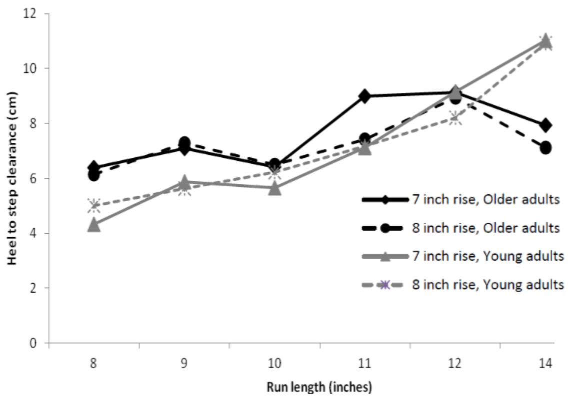

Figure 2. Heel-to-step clearance at foot contact during steady state stair descent.

Whole body and segmental control

Figure 3 illustrates whole body centre of mass and upper body position in the sagittal plane during stair descent. As demonstrated by the data, all subjects position their upper body behind the step at foot contact during steady state stair descent, despite the varied step geometry conditions.

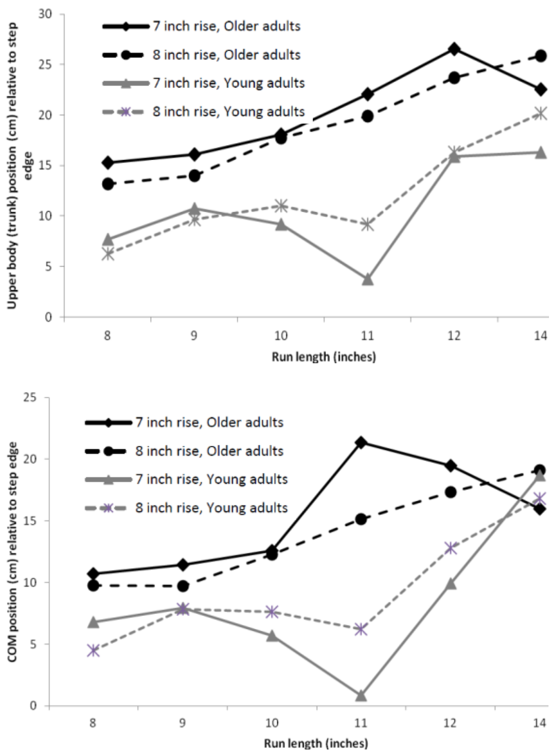

Figure 3. Position relative to the step edge of the upper body (top) and whole body COM (bottom) at foot contact during steady state stair descent. Zero degrees represents position aligned with step edge. Positive values indicate segment positioned behind the step. Negative values indicate position in front of step.

However, as the run length increases, both older and younger adults appear to maintain their COM and trunk position further away from the anterior limits of their base of support. Riser height appears to have less effect on dynamic postural control during stair descent than run length. Of note, it appears as though the older adults maintain a general position of their upper body and COM further away from the step edge compared to young adults.

At foot contact inability to control momentum generated by forward pitching motion of the upper body and/or whole body centre of mass places an individual at greater risk of falling during stair descent. Ability to increase distance between anterior base of support and upper body/COM, as evidenced by increasing the run length, provides individuals with a more biomechanically stable posture at the critical point when body weight is being transferred to the anteriorly placed foot. In the young adults, the riskier behaviour paired with greater speed of descent may place them at an even greater risk of falls particularly as the step run length is reduced.

CONCLUSIONS

The current pilot study provides a descriptive evaluation of biomechanical risk factors of falls during stair descent in healthy young and older adults and the effect of varying step geometry. Such empirical evidence highlight the increased risk related to reduced run lengths in both young and older adults, which appear to impact foot clearance and COM position to a greater extent than riser height. More data is required to provide recommendations. However, safer stair standards should be considered to minimize the risk of falls given the relatively huge personal and societal costs of injuries on stairs.

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REFERENCES

1. Roys MS,. *Appl Ergon.* 32(2):135-139, 2001
2. Wright M, Roys M., *Contemporary Ergonomics*. 632-637, 2008
3. Wright M, Roys M., *Contemporary Ergonomics.* 469-474, 2005