

STEPPING OVER AN OBSTACLE CHALLENGES DYNAMIC STABILITY IN THE ELDERLY ADULTS

Li-Shan Chou¹, Kenton R. Kaufman¹, Robert H. Brey²

¹Orthopedic Biomechanics Laboratory, Department of Orthopedic Surgery

²Vestibular/Balance Laboratory, Department of Otorhinolaryngology

Mayo Clinic, Rochester, MN 55905

Email: chou.lishan@mayo.edu

INTRODUCTION

Falling to the side has been found to be an important risk factor for hip fracture (Greenspan et al., 1998). Imbalance and tripping over obstacles during gait were reported as two of the most common causes of falls in the elderly (Tinetti et al., 1989). Imbalance of the whole body during obstacle crossing may cause inappropriate movement of the lower extremities or misplacement of the swing foot, which will consequently lead to a foot-obstacle contact and result in a fall. Greater motion of body segments will result in greater excursion of the whole body's center of mass (COM). Furthermore, the greater swing time required for the limb when stepping over a higher obstacle also implies a longer duration of single stance for the supporting limb. It is, therefore, reasonable to expect that maintaining dynamic balance of the whole body during obstacle crossing is a more challenging task than during unobstructed level walking.

In a recent study (Kaya et al., 1998) demonstrated that excessive lateral momentum of the whole body during gait was observed in the elderly with bilateral vestibular hypofunction. However, there is a lack of knowledge about how dynamic stability of the whole body is maintained during balance-challenging ambulatory tasks, such as obstacle crossing. The purpose of this study was to investigate the effect of obstacle height on the motion of the COM

while negotiating obstacles in different subject groups.

METHODS

Eighteen subjects, including six healthy young adults (mean age, 30.2 years), six healthy elderly adults (mean age, 70 years) and six elderly patients with imbalance (mean age, 75.7 years), were recruited for this study. Gait analysis was performed on each subject during unobstructed level walking and when stepping over an obstacle of height corresponding to 2.5%, 5%, 10%, or 15% of the subject's height. All trials were conducted at a comfortable self-selected walking speed while barefoot. The order of obstacle height was randomly selected.

A 13-link biomechanical model of the human body was used to compute the kinematics of the whole body's COM. The 3-D trajectory of the whole body's COM was computed from the weighted sum of the COM from each body segment. The linear velocities of the whole body's COM were computed using the GCVSPL algorithm (Woltring, 1986). Effects of the subject group and the obstacle height on the gait parameters were assessed with a two-way ANOVA with repeated measures.

RESULTS

Total displacement of the COM in all three orthogonal directions increased linearly ($p \leq 0.036$) with obstacle height. Significant

group differences were found in both the anterior/posterior (A/P) and medial/lateral (M/L) directions ($p=0.021$ and 0.05 , respectively). All subject groups maintained a similar magnitude of M/L displacement of the COM during unobstructed walking. However, when stepping over higher obstacles, the elderly demonstrated greater M/L displacements of the COM than the young adults. Elderly patients demonstrated the greatest M/L displacement of the COM during the crossing stride (Figure 1).

Peak forward velocities of the COM of all subjects decreased linearly ($p<0.001$) as obstacle height increased. Significant group differences were identified for the peak forward velocity of the COM ($p=0.025$). Peak M/L velocities of the COM increased linearly ($p=0.002$) as obstacle height increased (Figure 2). Although no significant group differences were found in peak M/L velocities of the COM, elderly patients demonstrated the greatest M/L velocity during all of the testing conditions. Both peak upward and downward velocities of the COM increased linearly ($p<0.001$) with obstacle height. No significant group differences were identified for the maximum upward and downward velocities of the COM.

DISCUSSION AND SUMMARY

Investigating the effect of obstacle height on the motion of the COM while negotiating obstacles in different groups of subjects will enhance our understanding of the increasing incidence of falls with aging and provide recommendations for the development of strategies aimed at reducing falls.

The results of this investigation have shown that elderly patients with imbalance demonstrated the largest and fastest movement of the COM in the M/L direction when stepping over an obstacle. This may

explain the propensity to fall sideways in the elderly population, which has been shown to be the most likely cause of hip fractures (Hayes et al., 1996; Greenspan, 1998).

REFERENCES

- Greenspan SL et al. (1998) *Am J. Med* **104**:539-45.
 Hayes WC et al. (1996) *Bone* **18**:77S-86S.
 Kaya, BK et al. (1998) *J. of Gerontology* **53A**: M126-134.
 Tinetti ME et al. (1989) *N Engl J Med* **302**: 1055-1059.
 Woltring, HJ (1986) *Adv Eng Software* **8**: 104-113

ACKNOWLEDGMENTS

Supported by NIH grants (HD07447 & AG05770) and the Mayo Foundation.

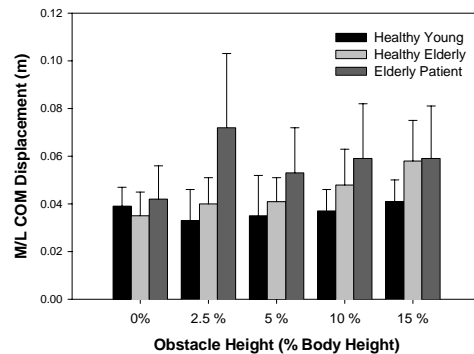


Figure 1. M/L COM displacements

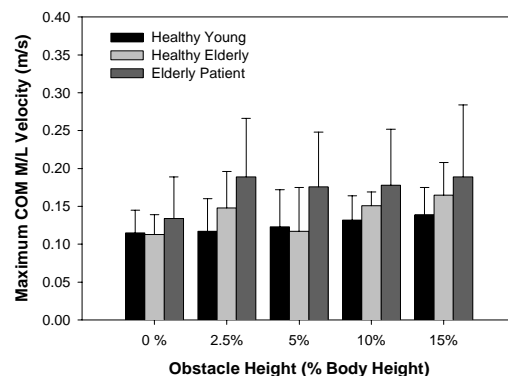


Figure 2. Maximum M/L COM velocities