EFFECTS OF AGE AND LOSS OF BALANCE DIRECTION ON THE KINEMATICS OF THE THRESHOLD OF BALANCE RECOVERY

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INTRODUCTION

It is only recently that studies have focused on postural perturbations at the threshold of balance recovery, i.e., postural perturbations large enough that balance recovery is not always possible and a fall can occur. The knowledge at the threshold of balance recovery is thus very limited. Moreover the effects of age and loss of balance direction on the threshold of balance recovery have not been quantified, despite evidence of their importance during small and medium postural perturbations (Hsiao, Robinovitch, 2001; Maki et al., 1996). Understanding the effects of age and loss of balance direction are particularly important given that case controlled studies have shown that sideways falls, compared to other fall directions, increase hip fracture risk (Greenspan et al., 1998; Hayes et al., 1993; Nevitt, Cummings, 1993). Therefore, the purpose of this study was to quantify the effects of age and loss of balance direction on the kinematics of the threshold of balance recovery.

METHODS

Balance recovery following sudden release from an initial lean was performed by ten healthy younger adults (21.8±3.7yrs) and ten healthy older adults (66.1±2.4yrs) with an equal number of males and females in each group. The maximum lean angle that these healthy adults could be released from and still recover balance using a single step was determined for i) forward, ii) dominant side, iii) non-dominant side and iv) backward leans. The lean angle was sequentially increased until the subjects failed twice at a given angle and the lean directions were randomly ordered. Initial lean angles, reaction times, weight transfer times, step times, step lengths and step velocities were measured using force platforms (AMTI, Newton, MA) and a motion measurement system (Optotrak, NDI, Waterloo, ON). Two-way analyses of variance with repeated measures were used to determine the effects of age and lean direction.

RESULTS AND DISCUSSION

Both age ($p<0.001$) and lean direction ($p<0.001$) significantly affected the maximum lean angles that healthy adults could be released from and still recover balance using a single step (Figure and Table). There was also a significant interaction between age and lean direction ($p=0.027$). Moreover, at the maximum lean angles, age and lean direction also significantly affected several of the other kinematics variables (Table).

At lean angles larger than their maximum, participants failed to recover balance. Younger adults were more likely to sustain harness failures than stepping failures in all lean directions. However, older adults were more likely to sustain stepping failures than harness failures in all lean directions.

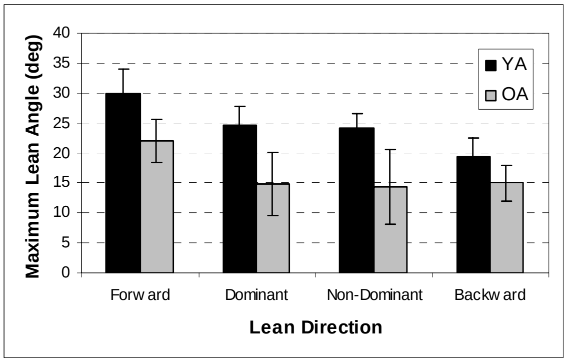

Figure: Effects of age (p<0.001) and lean direction (p<0.001) on the maximum lean angle that younger (YA) and older (OA) adults could be released from and still recover balance.

Finally, crossover steps were rare. At lean angles smaller than their maximums, only one younger male and two older females used crossover steps. However, at the maximum lean angles, only one older female used crossover steps.

CONCLUSIONS

Results have shown that lean direction significantly affects the postural disturbance younger and older adults could sustain. Moreover, the age-related reduction in maximum lean angles is more important for dominant (40%) and non-dominant (41%) leans than for forward (26%) or backward (23%) leans. It is thus conceivable that different mechanisms could be responsible for balance recovery in different directions.

At lean angles larger than their maximum, older adults were more likely to take multiple steps. However, crossover steps, typically seen during small and medium postural perturbations (Hsiao and Robinovitch, 2001; Maki et al., 1996), were only rarely seen at the threshold of balance recovery.

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Table: Effects of age and lean direction on kinematics variables

Lean Direction	Age	Max Lean Angle (deg) *** ††† ‡	Reaction Time (s) †††	Weight Transfer Time (s) *** †††	Step Time (s)	Step Length (m) ** †††	Mean Step Velocity (m/s) ** †††	Maximum Step Velocity (m/s) * ††† ‡‡‡
Forward	**OA**	22.1±3.5	0.065±0.008	0.196±0.024	0.212±0.025	0.836±0.068	3.99±0.65	5.57±0.83
	YA	29.9±4.1	0.068±0.015	0.128±0.026	0.197±0.019	0.961±0.078	4.90±0.65	6.97±1.09
Dominant	**OA**	14.8±5.2	0.088±0.011	0.185±0.057	0.223±0.091	0.557±0.122	2.79±0.98	3.86±1.19
	YA	24.7±3.1	0.084±0.009	0.141±0.052	0.206±0.041	0.758±0.122	3.75±0.52	4.96±0.61
Non-Dominant	**OA**	14.3±6.2	0.090±0.010	0.165±0.023	0.219±0.071	0.606±0.096	2.92±0.70	3.92±0.82
	YA	24.1±2.4	0.083±0.010	0.133±0.028	0.204±0.026	0.737±0.091	3.65±0.43	4.79±0.52
Backward	**OA**	15.0±2.9	0.097±0.015	0.108±0.030	0.248±0.029	0.654±0.126	2.69±0.69	4.04±0.80
	YA	19.4±3.1	0.085±0.010	0.083±0.013	0.221±0.029	0.778±0.127	3.54±0.42	5.05±0.73

* p<0.05, ** p<0.01, *** p<0.001 for age: Younger Adults (YA), Older Adults (OA).
† p<0.05, †† p<0.01, ††† p<0.001 for lean direction.
‡ p<0.05, ‡‡ p<0.01, ‡‡‡ p<0.001 for age * lean direction.