EFFECTS OF GENDER ON SINGLE-STEP RECOVERY FROM INDUCED POSTERIOR AND LATERAL FALLS

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INTRODUCTION

Falls are a significant source of serious injury and death among the elderly population, with hip fractures leading to considerable numbers of cases involving fall-related morbidity and mortality. The mechanics of trips and stumbles in the anterior direction have been extensively studied by the author and by other groups, but fewer studies have attempted to examine the ability of people to regain balance when falls are induced in the lateral and posterior directions. Falls to the side or rear have been shown to occur after perturbations to people walking with a slower gait, while people walking more quickly will have a tendency to fall in a forward direction [1,2]. Falling and landing to the side or to the rear are likely to lead to increased loading to the hip and a higher risk of fracture at that joint.

Prior work by the author [3,4] indicated that young males and young females were well matched in their ability to regain balance after an induced forward fall. Maximum angles, step lengths, and step velocities all showed negligible gender-related differences among the young subjects. It was also found, however, that significant differences existed in the lower-extremity joint torques used during the single-step recoveries. The current study was performed, therefore, to see if similar gender-related trends exist in the maximum recoverable perturbations and body segment kinematics of healthy young males and females when regaining balance from experimentally-induced lateral and posterior falls. The results of this study provide baseline measures for further age-based comparisons with an older subject population.

METHODS

Two groups of healthy young subjects were used for this study. Both the young males (mean age 24.3 years, N=17) and young females (mean age 22.6 years, N=21) were recruited from among University students at Virginia Tech. All subjects were screened to ensure the absence of neurological, otological, or musculoskeletal impairments, and all test procedures were approved by Virginia Tech's IRB. Because of the necessary positioning of test equipment, all subjects were required to be right-handed and right-footed. Height, weight, and lower-extremity anthropometry were measured for each subject.

A horizontal cable attached to a padded pelvic belt supported the subjects while leaning. This belt was used to suspend subjects in lateral and posterior leans of predetermined magnitudes, which were described in terms of the percent of body weight supported by the belt. Lean angles corresponding to each supported body weight were calculated with a one-link rigid model of the subjects' bodies [5]. All subjects wore a full-body safety harness connected with multiple cables to an overhead track, and the lengths of these cables were adjusted so that the subjects could not contact the floor in the event of a failure to regain balance. Floor reaction data were measured with two six-degree of freedom force platforms located under the subjects' feet (AMTI, Watertown, MA). Kinematic data were recorded using an Optotrak® optoelectronic motion analysis system (Northern Digital, Waterloo, Ontario), with infrared-emitting diodes placed over palpable bony structures on the subjects' upper and lower extremities. Data were collected at 100 Hz starting 500 ms before subjects were released from each suspended lean.

Falls were induced by releasing the support cable after a random time delay. Subjects were instructed to attempt to regain balance by taking a single step with the right foot. Each subject was allowed three practice trials before data collection began. In the first set of recorded trials, the subject attempted to recover balance following releases at each of three small lean-control cable loads. The small leans were presented in sets of three fixed and randomized trial blocks for a total of nine recoveries. In the second set of trials, the weight supported by the lean-control cable was successively increased in increments of three percent of body weight in order to determine the maximum lean angle from which the subject could successfully regain balance with a single step. Testing was terminated if the subject failed twice at any given percentage of supported body weight (by taking multiple steps or relying on the safety harness for support) or if further trials were refused.

RESULTS AND DISCUSSION

Young males (YM) were able to achieve single step-balance recoveries from significantly larger posterior ($p<0.04$) and lateral ($p=0.01$) lean magnitudes than were young females (YF). Table 1 shows the maximum lean magnitudes for anterior [3], posterior, and lateral leans, expressed in terms of both percent body weight (%BW) and angular measure from vertical (deg). Some gender-related differences were noted in the maximum step lengths and step velocities that subjects used when achieving their single-step balance recoveries as well.

	YM	YF	p
Anterior %BW [3]	41.8 ± 5.7	38.3 ± 4.3	0.14
Posterior %BW	22.0 ±5.1	18.4 ± 5.2	0.039
Lateral %BW	17.6 ± 7.8	11.8 ± 3.7	0.01
Anterior (deg) [3]	32.5 ± 4.49	30.7 ± 2.83	0.31
Posterior (deg)	26.2 ± 7.9	25.3 ± 8.0	0.71
Lateral (deg)	21.8 ± 11.7	15.2 ± 6.4	0.047

Table 1. Maximum leans from which single-step recovery was possible

It was noted that the difference in maximum recoverable lean magnitude was significant for lateral and posterior leans if those magnitudes were measured in terms of the percent of body weight supported by the lean cable, but not if the leans were converted to a whole-body straight line lean angle. A comparison of body lean and weight supported by the cable before release is shown for posterior leans in Figure 1.

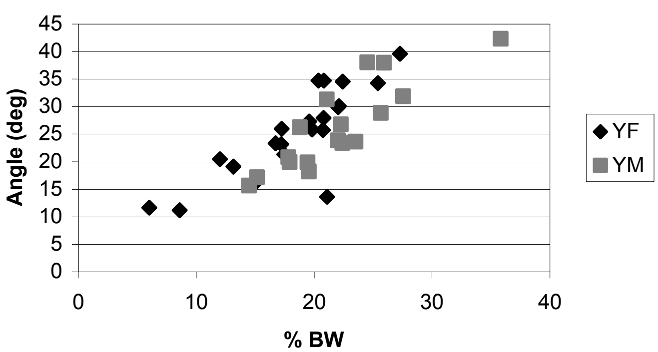

Figure 1. Comparison of lean cable load and corresponding whole-body lean angle for posterior trials

Note that many of the male subjects needed a smaller lean angle to achieve a given supported body weight. It is possible that this effect arises from most males having a proportionally greater upper body mass than most females.

The fact that females had to be suspended from generally larger perturbation angles to achieve the same lean magnitude, as measured by percent of supported body weight, might have also affected psychosocial aspects of this fall recovery test. In trials where the subject fell and had to rely on the harness to maintain upright posture, there was one YF posterior and one YF lateral, as compared to falls in two YM posterior and five YM lateral. Two YF asked to stop the posterior tests before they had failed to regain balance with a single step, along with one YF who asked to stop the lateral trials. No YM subjects asked to stop the trials before failing twice at any lean magnitude for either posterior or lateral leans.

CONCLUSIONS

The results of this study indicate that there may be underlying gender-related factors affecting balance recovery from rearward and sideways perturbations in balance, even among young adults. It is undeniably challenging, however, to separate the effects of actual physiological differences from the confounding factors of training and psychological fear of falling. While efforts were made to recruit subjects with similar moderate levels of physical activity, it was noted that several of the young male subjects who performed particularly well on these balance recovery tasks were avid downhill skiers or skaters, so they presumably had more experience in proprioception and control of body motions with their centers of gravity displaced to the side or rear. Nevertheless, the results of this study do provide the necessary baseline measures for further comparison with a healthy elderly cohort of subjects in order to examine age-related differences for this type of balance recovery task. Given the differences already found by the author and by other investigators in tasks related to anterior balance perturbations, it is expected that similar age-related differences would be found for posterior and lateral tasks in conjunction with the underlying gender effects found in the young.

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