Muscle activation pattern to distinguish balance recovery from falls at loss of balance

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Purpose Falls are a major cause of death in older adults, and prevention is important (Berry & Miller, 2008). Since successful recovery of balance in the event of a fall is largely attributed to contraction of muscles (Qu et al., 2012; Weerdesteyn et al., 2008), unique muscle activation patterns may exist to differentiate balance recovery from falls, and such information should help develop fall prevention strategies to reduce the frequency of falls. We conducted falling experiments to examine muscle activation patterns during a backward fall versus balance recovery. **Method** Seventeen young individuals (9 males, 8 females) participated. Subjects stood on a board attached to a linear motor which translates backward to cause loss of balance. The level of perturbation differs, and all subjects resulted in a backward fall and balance recovery. To minimize learning effects and anticipatory postural control, the order of perturbation severity was randomized. During trials, muscle activation was recorded with electrodes placed on the belly of rectus abdominis (RA), quadriceps (Quad), and tibialis anterior (TA) muscles, bilaterally (Ultium EMG, Noraxon Inc., Scottsdale, AZ, USA). Kinematics of falling were also recorded with a motion capture system (Vicon Motion Systems, Oxford, UK). Outcome variables included the onset, time to peak, and percent of reference voluntary contraction (%RVC) of muscles in the same side of the first backward step. All analyses were done with a customized Matlab routine (MathWorks, Natick, MA, USA). Two-way repeated measures ANOVA was used to test if the outcome variables were associated with group (2 levels, fall vs balance recovery) and muscles (3 levels). **Results and Discussion** ANOVA indicated that the onset and time to peak were not associated with group ($p > 0.223$). However, %RVC was associated with group ($F = 7.092$, $p = 0.017$), and the %RVC was 17.5% greater in balance recovery than falls (67% versus 57%) (Table 1). This suggests that the extent of the level of muscle activation is important to determine successful balance recovery at the time of loss of balance. ANOVA also suggested that all outcome variables were associated with muscle ($p < 0.039$), and the onset and time to peak were greatest in RA and followed by Quad and TA. However, %RVC was least in RA and followed by Quad and TA. This indicates the progressive recruitment of muscles in order of distal to proximal, and large to small activation level. Our results should inform the development of fall prevention strategies (exercise program, exoskeleton gear) for older adults to increase the extent of TA, Quad, RA muscles contraction. These novel fall prevention strategies may help reduce fall injury than existing fall prevention strategies, especially for older adults than younger adults.

References

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Table 1. Average values of outcome variables with standard deviation shown in parenthesis.

	Fall			Balance recovery			p value		
	TA	Quad	RA	TA	Quad	RA	Group	Muscle	Group X Muscle
Onset (ms)	74 (30)	83 (29)	126 (34)	74 (26)	88 (31)	124 (32)	0.47	0.0005*	0.433
Time to peak (ms)	156 (34)	160 (28)	173 (30)	162 (31)	167 (32)	181 (23)	0.223	0.039*	0.964
% RVC (%)	79 (15)	48 (26)	46 (29)	82 (19)	68 (31)	51 (31)	0.017*	0.0005*	0.126