ROLE OF MULTI-SENSORY INTEGRATION RELEVANT FOR BALANCE IN SLIP RECOVERY

Caitlin O'Connell, April Chambers, Arash Mahboobin, Rakié Cham

University of Pittsburgh, Pittsburgh, PA, USA
email: caitlino@pitt.edu, web: http://www.engineeringx.pitt.edu/hmbl/

INTRODUCTION

Falls are a leading cause of injury and death, particularly in the elderly, with over one-third of elderly adults experiencing a fall each year [1]. Stepping reactions are important for recovering and maintaining balance after gait perturbations such as slips and trips [2]. The purpose of this study is to determine if balance, specifically sensory integration abilities, play a role in stepping reactions to slips. It is predicted that deterioration in sensory integration abilities is related to delayed stepping reactions.

METHODS

Thirty-six subjects were recruited for participation in this balance and gait study and classified into two age groups: young (N=17, 8 females, age = 24.0 ± 3.2 years) and old (N=19, 9 females, age = 55.9 ± 4.6 years). Written informed consent approved by the University of Pittsburgh Institutional Review Board was obtained prior to participation. Exclusion criteria included orthopedic, neurological, pulmonary and cardiovascular abnormalities clinically hindering normal balance and gait.

For gait testing, participants walked along a vinyl tile pathway wearing a safety harness. Full body motion (120 Hz) and bilateral ground reaction forces (1080 Hz) were collected. EMG data were recorded from the trailing (swing) leg on the vastus lateralis (VL). Data was collected using a 8-channel Noraxon Telemyo EMG system sampled at 1080 Hz with a hardware bandpass filter (10-500 Hz).

Participants were instructed to walk at a comfortable self-selected pace. Several baseline (dry) trials were collected to ensure correct foot placement and consistency in gait. Then without participant's knowledge, a glycerol contaminant was placed on leading leg force platform. One trial, the unexpected slip (US), was collected with contaminant present. For the US, the start of the slip was defined as heel strike of the leading (slipping) leg. Slip severity is quantified by the peak slip severity (PSV) measured at the heel marker attached on the slipping foot shortly after heel strike onto the contaminated floor [3]. Slip hazardousness was classified into two categories: hazardous (PSV ≥1 m/s) and non-hazardous (PSV <1 m/s) [3].

EMG data was rectified and normalized using the average maximum value of the baseline gait cycles. EMG was not filtered to prevent smoothing of sudden onset of muscle activations. A custom algorithm was used to determine reactive muscle activation of the trailing leg [4]. Activation was calculated as the time when difference between slip and dry EMG signals exceeded 2 standard deviations of the difference during quiet period of gait. Only the VL was considered here due to its main contribution to a stepping reaction.

Standing balance testing consisted of sensory organization tests (SOT) using an Equitest posture platform (Neurocom, Inc). This platform is capable of providing rotations of the floor and/or the visual scene to allow sway-referencing of vision and/or proprioception [5]. Prior to testing, subjects donned a harness and instructed whether to keep eyes open or closed before beginning each trial. The SOT protocol consisted of six trials that were 20 seconds long, repeated twice (see Table 1 for trial descriptions). Only the second trial of each type was considered. The outcome variable of interested the mean velocity of anteroposterior (AP) sway.

The statistical analyses consisted of a regression model (α= 0.05) to determine the effect of age and sway mean velocity, as well as their interaction, on the activation of the VL after slip. The log transformation of the mean velocity was used in the statistical model in order to normalize the data. Analysis was conducted within each SOT trial type and hazardousness of slip.

Table 1: SOT trial descriptions including eye, vision and proprioception conditions.

Trial	Eyes	Vision	Proprioception
1	Open	Fixed	Fixed
2	Closed	--	Fixed
3	Open	Sway	Fixed
4	Open	Fixed	Sway
5	Closed	--	Sway
6	Open	Sway	Sway

RESULTS AND DISCUSSION

Mean sway velocity was significantly related to VL activation of hazardous slips for SOT condition 4 only. SOT condition 4 provides accurate visual information but unreliable proprioception. Thus, proprioception may be more important than vision in sensing a slip and triggering a stepping recovery response.

An increase in COP sway representing less balance stability correlated to faster muscle activations after slip (Figure 1). This is contrary to the hypothesis that poor balance will be associated with a delayed stepping reaction. A possible explanation for this trend is that individuals with poor balance are more cautious during gait, specifically when they encounter a perturbation such as a slip. Thus, they may interrupt swing phase of the trailing gait more quickly after slipping faster to prevent loss of stability. Alternatively, poor balance may correlate to more severe slips that require a faster reaction to recover balance [6]. The lack of relationship between muscle activation and balance for non-hazardous slips further supports this theory.

Interestingly, there was no age effect on VL activation, nor was there an interaction between age and sway mean velocity for SOT condition 4. This could be explained by the relative fitness and age of the subjects in the older group. The subjects did not have any comorbidities that typically affect balance performance and fall risk in the elderly.

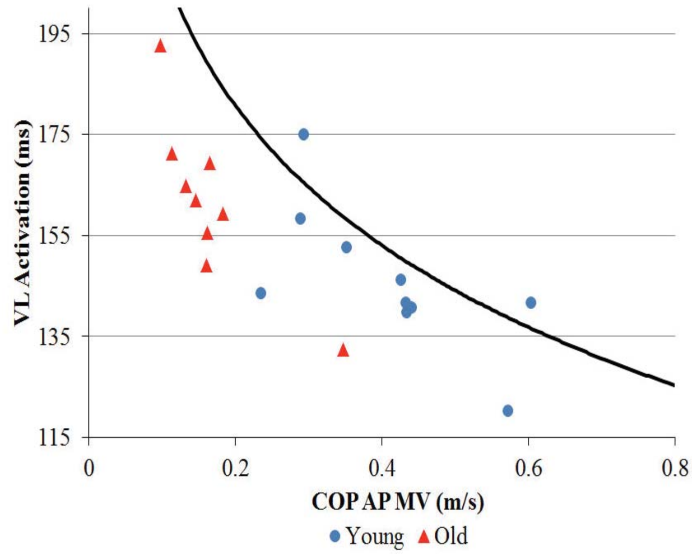

Figure 1: Relationship between reactive activation of the vastus lateralis muscle during hazardous slips and mean velocity of anteroposterior center of pressure sway during SOT condition 4.

CONCLUSIONS

The goal of this study was to determine the role that balance plays in slip recovery. The results suggest that proper integration of proprioception information is important in regaining balance after hazardous slips and that individuals with compromised balance may react more cautiously, and thus faster, to slips than those with normal balance.

REFERENCES

1. Rubenstein LZ. *Age Ageing,* **35**, ii37-ii41, 2006.
2. Bhatt T, et al. *Gait & Posture* **21**, 146-156, 2005.
3. Moyer BE, et al. *Ergonomics*, **49**, 329-343, 2006.
4. Chambers AJ, & Cham R. *Gait & Posture*, **25**, 565-572, 2007.
5. Nashner, LM, et al. J Neurosci, **5**, 117-124, 1982.
6. Wyszomierski, S. *U. of Pittsburgh (Master's Thesis)*, 2006

ACKNOWLEDGEMENTS

Funding provided by the National Institute of Occupational Safety and Health (R01 OH007592).