CENTER OF MASS POSITION DURING REPEATED EXPOSURE TO FORWARD AND BACKWARD SLIPPING

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INTRODUCTION

Center of mass (COM) control is critical to the maintenance of balance when perturbed. In contrast to an exposure to an unexpected balance perturbation, i.e. a slip, proactive postural adjustments, e.g. repositioning of the COM, are made when the perturbation is anticipated in an attempt to increase stability and to reduce the likelihood of falling [4]. It is known that older adults are capable of increasing their stability through proactive postural adjustments to the COM state when repeatedly exposed to a slipping perturbation [6,7]. Other studies have also described COM adaptations in young adults to be impacted by both experience with and knowledge of a slip perturbation [4,5].

To date, potential associations between (healthy) aging and the ability to generate proactive postural adjustments when balance is challenged during a novel gait task has not yet been investigated. Successful balance maintenance during walking requires the ability to adjust postural responses to various environmental and task constraints. Changing the direction of locomotion is one way to vary task constraints and research supports that forward and backward walking are run from the same motor program [2,8]. This facilitates comparison between familiar (forward gait) and novel (backward gait) walking activities to describe abilities to generate postural responses when balance is challenged. The purpose of this study is to investigate differences in anticipatory postural strategies when repeatedly exposed to slipping perturbations between the two gait activities. Adaptations to whole body COM position with respect to the ankle of the slipping foot fifty milliseconds pre-slip will be compared for both young and older adults in an unexpected and when repeatedly exposed to the same slip perturbation.

METHODS AND PROCEDURES

Eleven young (22-35 years old) and eight healthy older (65-74 years old) subjects, screened for neurological and musculoskeletal abnormalities, were recruited for participation. Subjects were first asked to walk on known dry floors to retrieve baseline forward and backward gait characteristics. In each walking direction, presented in a random order, the slipping protocol included 2 conditions: (1) unexpected slip (subject unaware of the slippery condition and expecting a dry condition) (2) 5 repeated slips (subject aware of the slippery condition). Only the 1st and 5th repeated slips were included in this analysis. The slips were induced at foot contact with a glycerol solution. Whole body motion data were collected at 120 Hz. Segment masses and moments of inertia were determined as per deLeva [1]. Anterior-posterior (AP), medial-lateral (ML) and vertical COM position with respect to the ankle at foot contact were the dependent variables in a mixed model ANOVA with subject as a random effect; trial within direction (unexpected slip (UWS), repeated slip 1 (RWS1) and repeated slip 5 (RWS5)), age group (young/older), direction (forward/backward gait), and the interaction of these terms as fixed effects. Significance was set at $\alpha = .05$.

RESULTS

The ML-COM position was significantly correlated with the interaction of age and direction ($p<.005$, Figure 1a). A reduction in the ML distance between the ankle and the COM was observed in the backward direction for older adults. A significant age x trial within direction effect on AP-COM was also found ($p<.05$, Figure 1b). Specifically, older adults decreased the distance between their ankle and AP-COM position by 24% by the 5th repeated slip compared to only 3% in younger adults. Trial within direction played a significant role in the vertical positioning of the COM ($p<.001$) (Figure 1c). Posthoc results showed the vertical COM to be located more superiorly in repeated slips 1 and 5 compared to the unexpected slip. Young and older adults similarly changed the vertical location of their COM with respect to the ankle. Vertical COM position was different between directions independent of age. The vertical COM averaged across groups was 82.7 cm and 76.7 cm in the forward and backward directions, respectively.

DISCUSSION AND SUMMARY

Older adults differed from younger adults in that they moved their ML-COM closer to the body in the backward direction and continued to decrease AP-COM position with repeated exposure in both directions. This may be due to the precautionary gait (i.e., shorter step length and decreased foot-floor angle) in anticipation of the slippery condition [4, 6]. Further analysis is necessary to determine whether natural differences in walking posture (i.e., slightly leaning forward while walking backward) play a role in the significance found in vertical COM position between directions.

Older adults were affected by task novelty as well as repeated exposure to the perturbation. The results indicate that older adults adapt the AP-COM similarly regardless of direction continuously attempting to reach an optimal strategy with repeated exposure. However, older adults were impacted by task novelty in the ML-COM responses. This may indicate ML-COM stability to be a focal point of proactive postural adjustments to maintain balance when unfamiliar with the gait task.

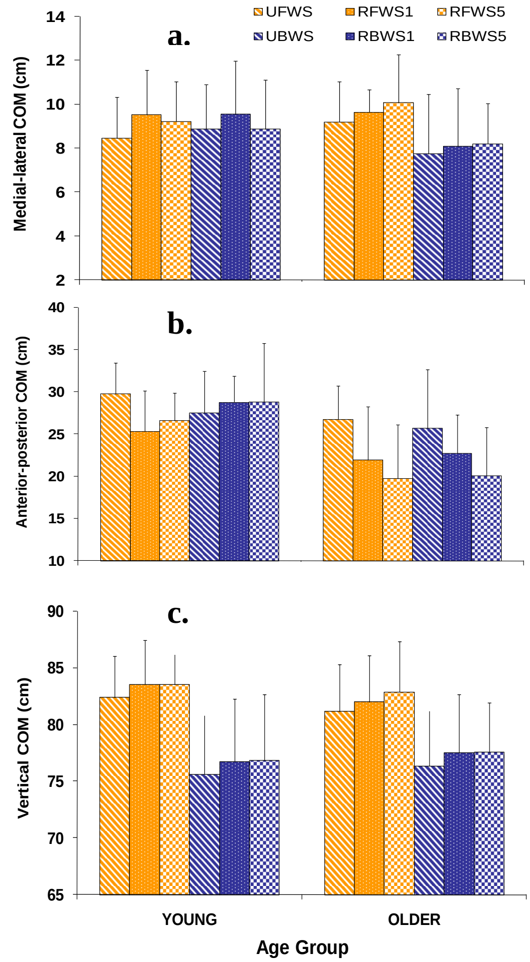

Figure 1. (a) Medial-lateral (b) anterior-posterior and (c) vertical COM position with respect to the ankle in young and older adults where orange indicates forward walking (F) and blue backward walking (B) trials. Trials within each direction are pictured with diagonal lines (U(F/B)WS - unexpected slip), dots (R(F/B)WS1 - repeated slip 1) and checkerboard (R(F/B)WS5 - repeated slip 5) patterns. Error bars represent standard deviations.

REFERENCES

1. deLeva P, *J Biomech* 29, 1223-30, 1996.
2. Duysens J, *J Neurophysioly* 76, 301-10, 1996.
3. Heiden TL, *Gait Posture* 24, 237-46, 2006.
4. Marigold DS, *J Neurophysiol* 88, 339-53, 2001.
5. Pai YC, et al. *Phys Ther* 87, 1478-91, 2007.
6. Pavol MJ, *J Gerontol Med Sci* 57A, M496-503, 2002.
7. Pavol MJ, *J Gerontol Med Sci* 59A, 484-502, 2004.
8. Winter DA, *J Mot Behav* 21, 291-305, 1989.

ACKNOWLEDGEMENTS

This study has been supported in part by F31 AG025684-03 NIH Ruth L. Kirschstein Award.