# Step to step variation in step width suggests a link to variations in trunk kinematics

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## INTRODUCTION

During human walking, maintenance of frontal plane balance requires that the body center of mass (COM) remain within the laterally-directed boundaries of the base of support (BOS) (MacKinnon & Winter 1993). Proper placement of the foot can be guided by active feedback processes (Kuo 1999). Therefore, given the mass of the trunk and its capacity to act as a inverted pendulum having its axis at the hip, control of balance may rely upon the ability to temporally and spatially coordinate lateral placement of the foot on the ground with trunk states during gait. For this reason, we would expect to observe an association between trunk kinematics and foot placement, as measured by step width (SW).

Sensing of trunk states relies on information from the visual, vestibular and/or somatosensory systems. As humans age, the fidelity of sensory information from these systems decreases (Kuo 2007). Age related differences may also be compounded by a decreased ability of older adults to execute motor commands (Barry et al. 2005). Reliance on degraded signals and/or execution of motor commands would be expected to result in a loss of control accuracy and/or precision.

In this study we tested the hypothesis that step-to-step variations in step width are associated with step-to-step variations in preceding trunk states. We also tested the hypothesis that the association between step-to-step variations in step width and preceding trunk states would differ between young and older adults.

## METHODS AND PROCEDURES

Twelve healthy young adults (6 males 6 females, age 25± 3.3 years) and eleven healthy older adults (4 males 7 females, age 61±5.6 years) participated. Each subject walked on a motorized treadmill at a self-selected speed for 10 min. Kinematics were captured using an eight camera motion capture system.

SW and the frontal plane position $(y)$ and acceleration $(\ddot{y})$ of the trunk COM were identified using custom software. SW was calculated as the difference between successive left to right foot centroids. The COM of the trunk segment was estimated from the positions of the shoulder and pelvis markers. Values for $y$ and $\ddot{y}$ were taken at the when frontal plane lateral velocity was zero. This instant represents the point when the COM begins to “fall towards” from the stance foot, and may set the initial conditions that influence step width adjustment.

*Statistics:*
The relationship between trunk kinematics and SW for the aggregate datasets of each group was quantified using stepwise linear regression. The regression coefficients $\beta_1$ and $\beta_2$were statistically examined for between-group differences.

## RESULT

Step to step variations in $y$ and $\ddot{y}$ explained over half of the shared variance with SW. SW appeared to be more sensitive to changes in trunk position, evidenced by a larger standardized coefficient for position than acceleration of the trunk COM (Table 1). In addition, position of the trunk COM accounted for 43% (of 55%) and 60% (of 63%) of the shared variance for young and older adults respectively. The regression equations were not parallel. The beta coefficients for position and acceleration of the trunk COM of the young and older adults were significantly different ($p<0.05$).

| | Young | Old |
|---|---|---|
| Position | 1.03± 0.018<br>(.568) | 1.29 ± 0.040<br>(.690) |
| Accleration | 0.082±0.02<br>(.359) | 0.040±0.02<br>(.201) |

Table 1.Unstandardized Beta coefficients for position and acceleration of trunk COM ± standard error. Beta coefficients are given in the parentheses**.**

## DISCUSSION

Insofar as step to step variations in step width were strongly and significantly associated with step to step variations in position and acceleration of the trunk COM we accepted the first hypothesis. Frontal plane balance during walking is primarily maintained through step to step adjustment in SW. The present results suggest that SW is a function of the sensing of and responses to trunk states during the swing phase.

Given that the between-group differences for the trunk state beta coefficients were significant we accepted the second hypothesis of an age-related effect. In the regression model more of the explained variance in step width was accounted for in older adults than younger adults. Because balance control in older adults is subject to increased sensor and processor noise (Kuo 2007) we reject the possibility that older adults may have a more robust control system than younger adults.

The degradation of sensory input may play a weaker role in the relationship between trunk states and step widths than other age-related physiological changes. For example older adults exhibit increased joint stiffness due to less compliant soft tissue. Older adults also demonstrate increased trunk roll stiffness (Allum 2002), which reduces the motion of the trunk relative to the pelvis and considerably decreases frontal plane postural stability.

Coupled translations of the trunk, pelvis and lower extremity in the frontal plane due to reduced lumbosacral and hip joint stiffness could account for the larger observed $R^2$ of the older adults. It would be of value, therefore, to develop a method to parse out the effects of active control and passive motion that may be reflected in the overall relationship.

## SUMMARY

To our knowledge, this is the first study to link step to step variations in SW to step-to-step variation in trunk position and acceleration. This relationship was different in the young and old.

## REFERENCES

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