HOW DO OLDER PEOPLE RESPOND TO A PERTURBATION DURING WALKING?

Kirstie Rowlands, Siobhan Strike and Raymond Lee
Department of Life Sciences, Roehampton University, London SW15 4JD, UK; email: s.strike@roehampton.ac.uk

SUMMARY
The purpose of this research was to measure the inter-stride trunk acceleration variability while walking at different treadmill velocities and to determine the response to an imposed perturbation in the form of a sudden acceleration at different treadmill velocities for older people. There was a gradual decrease in inter-stride variability as walking speed increased up to the point of natural (self-chosen) walking speed, and then the variability increased again. In response to the perturbation the correlation coefficient followed a similar pattern. The results of this study suggest that the risk of fall may be least when a person is walking at their optimal speed, and any perturbation at this speed will produce the least disruption.

INTRODUCTION
Falling is a major health concern for older people [1] with one in three over 65 year olds experiencing a fall each year [2]. A successful recovery from a disturbance while walking can be crucial in stopping a person from falling over. Determining how the body responds to a sudden change in momentum can develop our understanding of strategies that may result in a successful or unsuccessful recovery.

Inertial sensors are used to analyse gait variables such as speed, step length and variability and body instability. The inter-stride trunk variability has been shown to differentiate between fit and frail older people, with frail older people demonstrating higher vertical and lower mediolateral variability compared to fit people [3]. Inter-stride trunk variability at different speeds of walking and the variability and transition time back to steady state walking in response to a perturbation may be important in determining if a person is likely to fall.

Therefore, the inter-stride trunk acceleration variability while walking at different treadmill velocities and the inter-stride variability during the response to an imposed perturbation in the form of a sudden acceleration at different treadmill velocities for older people was determined. The time taken to return to a steady-state walking pattern was also determined.

METHODS
Fourteen participants (9 male, 5 female; 59.1± 3.35 years) walked on a treadmill while wearing a safety harness. A three-dimensional accelerometer (MSR 145B, CiK Solutions, Haid-und-Neu-Str. 7, Karlsruhe, Germany) was attached to the participants using wig-tape on the lower part of their back (S1). The accelerometer contained a data logger which collected samples at 10Hz. Following a warm-up which was used to determine self-selected walking pace, the treadmill was programmed to start at 0.5 x self-selected walking pace, increase to self-selected walking pace, then 1.5, 2 x and finally to 2.5 x self-selected walking pace. The steady state intervals varied between 15 and 25 seconds so that the acceleration could not be anticipated. The acceleration of the treadmill was 0.5m.s\(^{-2}\). Signal processing was performed in Matlab. The acceleration in the vertical and medio-lateral directions was filtered using a low pass Butterworth filter (5Hz). The collected data were divided into two phases, the steady state of walking on the treadmill at a given velocity and the transition from one walking speed to the higher one, as defined by the treadmill programme.

To determine the inter-stride trunk variability an unbiased autocorrelation coefficient was obtained by correlating overlapping parts of an acceleration time series - in this case 100 data points from the middle of each steady state phase. Perfect correlation would return an r-value of 1 and indicates a perfect replication of each stride with the neighbouring strides. A wholly different signal will return an r-value of 0. This method has been used in previous research [3]

The sudden unexpected transition from one speed to a higher one represented a perturbation to the walking activities. The response of the body to this perturbation was assessed by cross correlation of two sections of the data - 100 samples of the previous steady state data and 100 samples associate with the initiation of the disruption. To ensure the immediate reaction to the increased velocity was captured, 50 samples prior to and 50 samples after the disruption were used. The time taken to respond to the perturbation was determined as the difference between the point at which the perturbation occurred, determined by the treadmill to the point where the participant had returned to steady state, defined by the vertical acceleration returning to within 1 SD of the RMS acceleration for the following steady state.

Repeated measures ANOVA was employed to determine if there was a difference in inter-stride variability between each steady state, between each transition and between the time to respond to the perturbation. Post hoc tests, using the Bonferroni adjustment, determined where the differences occurred.

RESULTS AND DISCUSSION
There was no statistical difference in inter-stride variability between different walking speeds. However, the pattern of
inter-stride variability during steady state showed an inverted U shape (Table 1). The most variable velocity was the slowest, 0.5 x self-selected walking speed (r=0.402), followed by the fastest velocity (r=0.561). The least variability was evident at 1.5 x self-selected walking pace (r=0.631). This reduced variability near to self-selected walking pace indicates a more consistent trunk acceleration at comfortable walking speed. The increased variability at slow and fast paces may indicate a more adaptable walking pattern at the extremes of comfort (4).

For the transition phases, the correlation coefficient increased during the first three transitions (Table 1). There was a significant difference in the inter-stride variability between the response from 0.5 x to 1 x self-selected walking speed and the response between 1.5-2 x self-selected walking speeds (p=0.001). The decrease in variability as the speed increases could be due to a less variable response and the decrease in the steady-state variability in the phase before.

The time taken to return to the steady state walking pattern decreased as the velocity increased. The transition time from 0.5 x self-selected walking speed was significantly slower than all the other times (p=0.001) In the transition from 0.5 x self-selected walking speed to steady state walking took 1.62s to return to a steady-state walking pattern while in the transition from 2 x self-selected walking to 2.5 x self-selected walking it took 0.84s.

**CONCLUSIONS**

Inter-stride variability for these healthy older people walking on a treadmill was not significantly different when walking at steady state speeds which ranged from slow to fast. The transition from slow to self-selected walking speed was different to the transition to other speeds. The results imply that the risk of fall may be the least when a person is walking at its optimal speed, and any perturbation at this speed will produce the least disruption. Future studies should examine a sudden decrease in speed.

**REFERENCES**

4. Jordan, K et al., *Gait and Posture*. **26**:128-134. 2007

### Table 1: Inter-stride trunk acceleration variability (r-value) for steady state walking and the transition phase and transition time (s)

* indicates significant difference. Perfect stride replication (no variability) will return an r-value of 1.

<table>
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<tr>
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<th>Inter-stride trunk acceleration variability in steady-state walking (r-value)</th>
<th>Inter-stride trunk acceleration variability in the transition phase walking (r-value)</th>
<th>Time taken to return to steady state walking pattern (s)</th>
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