



# Effects of walking speed on gait stability and interlimb coordination in younger and older adults



Tal Krasovsky<sup>a,c</sup>, Anouk Lamontagne<sup>a,c</sup>, Anatol G. Feldman<sup>b,c</sup>, Mindy F. Levin<sup>a,c,\*</sup>

<sup>a</sup> School of Physical and Occupational Therapy, McGill University, Montreal, Quebec, Canada

<sup>b</sup> Department of Physiology, Université de Montréal, Montreal, Quebec, Canada

<sup>c</sup> Centre for Interdisciplinary Research in Rehabilitation, Montreal, Quebec, Canada

## ARTICLE INFO

### Article history:

Received 22 February 2013

Received in revised form 12 June 2013

Accepted 9 August 2013

### Keywords:

Perturbation

Central pattern generators

Locomotion

Aging

## ABSTRACT

Many falls in older adults occur during walking following trips. Following a trip, older adults take longer than younger adults to recover steady-state walking. Although faster gait speed may improve interlimb coordination, it may also increase fall risk in older adults. We hypothesized that older adults would take longer than younger adults to recover from an unexpected perturbation during gait especially when walking faster.

Twelve younger ( $26.3 \pm 4.4$  years) and 12 older adults ( $68.5 \pm 3.4$  years) walked at comfortable, faster and slower speeds when movement of the dominant leg was unexpectedly arrested for 250 ms at 20% swing length. Gait stability was evaluated using the short- and longer-term response to perturbation.

In both groups, walking faster diminished the occurrence of elevation and increased that of leg lowering. Older adults took longer than younger adults to recover steady-state walking at all speeds ( $3.36 \pm 0.11$  vs.  $2.89 \pm 0.08$  strides) but longer-term recovery of gait stability was not related to gait speed. Arm-leg and inter-arm coordination improved with increasing gait speed in both groups, but older adults had weaker inter-leg coupling following perturbation at all speeds.

Although both younger and older adults used speed appropriate responses immediately following perturbation, longer duration of recovery of steady-state walking in older adults may increase fall risk in uncontrolled situations, regardless of gait speed. Recovery from perturbation when walking faster was associated with better interlimb coordination, but not with better gait stability. This indicates that interlimb coordination and gait stability may be distinct features of locomotion.

© 2013 Elsevier B.V. All rights reserved.

## 1. Introduction

A leading cause of injury in older adults is falling, causing a heavy burden on the health-care system. Most falls in older adults occur when walking, specifically following a trip [1]. Avoidance of falling is related to gait stability, defined as the ability to maintain functional locomotion despite disturbances [2]. When walking faster, responses to unexpected perturbations need to be performed within shorter timeframes, which can increase fall risk especially among older adults [3]. Longer recovery times toward steady-state walking patterns following a perturbation may reveal lower stability properties of the unperturbed gait pattern in the absence of a fall [4].

Young healthy adults use different response strategies following a trip to prevent falling. Immediate lowering of the perturbed leg

(lowering strategy) allows a faster transition to a double-support phase. While this may be safer in the short-term [5], this strategy also requires a rapid transition of the non-perturbed leg from stance to swing, which is relatively energy-demanding [6,7] and associated with longer recovery times toward a steady-state walking pattern [8]. An alternative strategy (elevation) is to stabilize the body on the non-perturbed leg and complete the perturbed step with minimal disturbance. This strategy requires early muscle recruitment on the non-perturbed leg [9] and allows faster recovery of the steady-state walking pattern [8]. A third strategy (combined) is a combination of lowering and elevation [7]. Changing gait speed affects the available response time and may also affect strategy selection. Younger and older adults use similar leg strategies when gait speed is constrained by a treadmill [10] and when walking at their comfortable speed [8]. However, due to limitations in the magnitude and rate of muscle recruitment in older adults [9], walking faster may be associated with an increased occurrence of leg lowering, as well as a longer period of recovery toward a steady-state walking pattern.

Recovery from a trip involves the re-establishment of a coordinated gait rhythm in all four limbs [8,11]. Generally,

\* Corresponding author at: School of Physical and Occupational Therapy, 3654 Promenade Sir William Osler, Montreal, Quebec, Canada H3G 1Y5.

Tel.: +1 514 398 3994; fax: +1 514 398 6360.

E-mail address: [mindy.levin@mcgill.ca](mailto:mindy.levin@mcgill.ca) (M.F. Levin).

**Table 1**Anthropometric and kinematic data for young ( $N=12$ ) and older ( $N=12$ ) adults.

|                   | Young ( $N=12$ ) |                  |                 | Older ( $N=12$ ) |                  |                  |
|-------------------|------------------|------------------|-----------------|------------------|------------------|------------------|
| Age (years)       | 26.3 $\pm$ 4.4   |                  |                 | 68.5 $\pm$ 3.4   |                  |                  |
| Gender (M/F)      | 7 M/5 F          |                  |                 | 8 M/4 F          |                  |                  |
| Height (cm)       | 172.7 $\pm$ 8.5  |                  |                 | 166.5 $\pm$ 10.0 |                  |                  |
| Weight (kg)       | 71.7 $\pm$ 8.5   |                  |                 | 70.0 $\pm$ 13.6  |                  |                  |
|                   | Slower           | Comfortable      | Faster          | Slower           | Comfortable      | Faster           |
| Gait speed (m/s)  | 0.77 $\pm$ 0.06  | 1.05 $\pm$ 0.06  | 1.33 $\pm$ 0.1  | 0.79 $\pm$ 0.11  | 1.10 $\pm$ 0.14  | 1.30 $\pm$ 0.20  |
| Swing length (cm) | 61.81 $\pm$ 4.16 | 65.52 $\pm$ 4.32 | 68.94 $\pm$ 6.1 | 62.18 $\pm$ 6.15 | 65.55 $\pm$ 4.85 | 65.47 $\pm$ 6.99 |
| Swing time (s)    | 0.52 $\pm$ 0.02  | 0.44 $\pm$ 0.02  | 0.39 $\pm$ 0.01 | 0.52 $\pm$ 0.04  | 0.43 $\pm$ 0.02  | 0.38 $\pm$ 0.02  |

temporal coupling between movements of different limbs is weaker in older compared to younger adults [12,13], possibly due to altered processing of afferent information and/or cognitive decline [12]. These factors may also affect older adults' ability to coordinate the response to a unilateral gait perturbation [8]. Increasing gait speed improves interlimb coupling in healthy adults [14], as well as in individuals with central nervous system damage, such as cerebral palsy [15] and stroke [4]. Recovery of interlimb coordination may be more challenging for older adults given the limited response time available at faster speeds.

We evaluated the effects of gait speed on recovery of the steady-state walking pattern following a leg perturbation in younger and older adults. We hypothesized that (1) in the short-term, faster walking would involve more leg lowering responses; and in the longer-term, faster walking would result in better interlimb coordination, but longer recovery times toward a steady-state walking pattern; and (2) older adults were expected to take longer than younger adults to restore steady-state walking patterns, especially when walking faster.

## 2. Methods

### 2.1. Participants

Twelve younger and 12 older adults were recruited (Table 1). Subjects were excluded if they had any orthopedic, vestibular or neurological disorders affecting gait or documented cognitive decline. All subjects signed informed consent forms approved by the local ethics committee.

### 2.2. Experimental procedure

The experimental procedure has been described in detail elsewhere [8]. Subjects walked on a self-paced treadmill while wearing a safety harness that did not restrict trunk motion (Fig. 1A). Safety switches could stop the treadmill if needed. Comfortable gait speed was set once the subject habituated to treadmill walking. Thirty-six 40 s trials were performed in which subjects walked at one of three speeds: comfortable, 20% faster or 20% slower (12 trials each), paced by a digital metronome. Order of speed conditions was fully randomized. The dominant leg, determined as the leg preferred for kicking, was perturbed 1–2 times per trial (~20 perturbations in total for each speed) by clamping a wooden rod attached to an ankle cuff. An identical rod was attached to the non-dominant leg to equalize sensation. Rods were equipped with transducers measuring perturbation force. Leg arrests of 250 ms duration occurred at early swing (~20% of swing length based on mean swing length of 3 unperturbed strides) using a custom-built microcontroller. To prevent anticipation, 3–4 non-perturbed “catch” trials were randomly interspersed throughout all trials. Markers were placed on body landmarks, specifically on both heels (calcanei) and hands (dorsum of 2nd metacarpals). Movement kinematics were recorded at 120 samples/s using a 12-camera motion analysis

system (Vicon, Oxford, UK) and filtered using a 6th order Butterworth filter (dual-pass, cutoff 10 Hz).

### 2.3. Data analysis

Spatiotemporal gait parameters were calculated from heel marker positions. Indices of gait stability were described in the short (1–2 steps) and longer (>2 steps) term. The short-term response was divided according to three leg strategies (Fig. 1B). In the longer term, an index of recovery of double-support time [4,8] was used to estimate return to steady-state walking. Due to possible asymmetry in double-support times, baseline double-support times during unperturbed gait (the time between foot contact and subsequent toe-off of the other leg) were computed separately for each side and averaged across the 3 pre-perturbed strides. The double-support recovery index was defined as the number of gait cycles taken until recovery of baseline values on both sides (plus or minus 10%).

To quantify the residual effect of the perturbation, phase shifts were calculated using timing of gait events in the arms and legs before and after perturbation [11]. The sagittal plane position of each limb in 3 pre-perturbed cycles was projected forward and the minimal time between the actual and projected event (foot contact or arm direction reversal) was divided by the pre-perturbed cycle period and multiplied by 360°. A negative value (phase advance; up to  $-180^\circ$ ) indicated that the gait event occurred prior to its unperturbed occurrence and a positive value (phase delay; up to  $180^\circ$ ) denoted a delayed occurrence of the event.

Temporal interlimb coupling following perturbation was computed using absolute phase shift differences between limb pairs: arm–leg on perturbed and non-perturbed sides, arm–arm and leg–leg pairs. Values ranged from  $0^\circ$ , indicating full restoration of the pre-perturbed coordination pattern, to plus/minus  $180^\circ$ , indicating no coupling and a full shift in the coordination pattern.

### 2.4. Statistical analysis

Student's *t*-tests compared subject characteristics between groups. Repeated measures ANOVAs tested the effect of group and speed condition on baseline spatiotemporal walking characteristics, perturbation force, and short- and long-term indices of gait stability and interlimb coordination. Levels of significance in post hoc tests were adjusted using a Bonferroni correction. A circular two-way ANOVA (Harrison–Kanji test) was implemented [16] in Matlab 6.5 (Mathworks, Inc., Natick, MA, USA) for phase shifts. All tests except circular procedures were done using SPSS (version 17.0). Initial significance was  $P < 0.05$ .

## 3. Results

Younger and older subjects did not differ in height, weight or gait speed (Table 1). Younger and older adults walked 27% and 28% slower in the slower speed condition and 27% and 18% faster in the faster speed condition respectively compared to their comfortable

Download English Version:

<https://daneshyari.com/en/article/6207049>

Download Persian Version:

<https://daneshyari.com/article/6207049>

[Daneshyari.com](https://daneshyari.com)