Gait & Posture 46 (2016) 35–41

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Age-related changes in gait adaptability in response to unpredictable obstacles and stepping targets

Maria Joana D. Caetano [a,b], Stephen R. Lord [a,b], Daniel Schoene [a,c], Paulo H.S. Pelicioni [a,d], Daina L. Sturnieks [a,e], Jasmine C. Menant [a,b,*]

[a] Neuroscience Research Australia, University of New South Wales, Sydney, Australia
[b] School of Public Health & Community Medicine, University of New South Wales, Sydney, Australia
[c] Institute for Biomedicine of Aging, Friedrich-Alexander-University Erlangen-Nuremberg, Nuremberg, Germany
[d] UNESP Univ Estadual Paulista, Instituto de Biociências de Rio Claro, Departamento de Educação Física, Posture and Gait Studies Laboratory, Rio Claro, Brazil
[e] School of Medical Sciences, University of New South Wales, Sydney, Australia

ARTICLE INFO

Article history:
Received 18 June 2015
Received in revised form 28 January 2016
Accepted 3 February 2016

Keywords:
Gait adaptability
Obstacle avoidance
Stepping accuracy
Ageing
Aged

ABSTRACT

Background: A large proportion of falls in older people occur when walking. Limitations in gait adaptability might contribute to tripping; a frequently reported cause of falls in this group.
Objective: To evaluate age-related changes in gait adaptability in response to obstacles or stepping targets presented at short notice, i.e.: approximately two steps ahead.
Methods: Fifty older adults (aged 74 ± 7 years; 34 females) and 21 young adults (aged 26 ± 4 years; 12 females) completed 3 usual gait speed (baseline) trials. They then completed the following randomly presented gait adaptability trials: obstacle avoidance, short stepping target, long stepping target and no target/obstacle (3 trials of each).
Results: Compared with the young, the older adults slowed significantly in no target/obstacle trials compared with the baseline trials. They took more steps and spent more time in double support while approaching the obstacle and stepping targets, demonstrated poorer stepping accuracy and made more stepping errors (failed to hit the stepping targets/avoid the obstacle). The older adults also reduced velocity of the two preceding steps and shortened the previous step in the long stepping target condition and in the obstacle avoidance condition.
Conclusion: Compared with their younger counterparts, the older adults exhibited a more conservative adaptation strategy characterised by slow, short and multiple steps with longer time in double support. Even so, they demonstrated poorer stepping accuracy and made more stepping errors. This reduced gait adaptability may place older adults at increased risk of falling when negotiating unexpected hazards.

1. Introduction

The ability to adjust gait is crucial when performing daily living activities such as crossing a busy street or avoiding obstacles. In older age, limited sensorimotor and cognitive functions [1] may lead to poor gait adaptability which might contribute to tripping; a frequently reported cause of falls in this group [2].

Obstacle negotiation tests have previously been used to measure gait adaptability performance. Compared with young, older adults initiate adjustments in step length and step time one or two steps earlier when approaching a fixed obstacle [3] and display shorter step lengths, slower gait speed and smaller obstacle-heel distance when crossing an obstacle [4]. In addition, gait protocols involving the sudden-appearance of an obstacle on a treadmill reveal that older adults have longer avoidance reaction times, larger toe clearances [5] and lower obstacle avoidance success rates compared with young adults [5,6]. Adaptive gait experiments have also found that compared with young, older adults were less accurate when stepping on targets [7] and made slower stepping adjustments to visual target moving to unpredictable locations [8].

More recent research has used stepping paradigms including an inhibitory component [6,9,10] that may reflect the cognitive load challenges required for walking in many daily life situations. Yamada et al. [10] used an overground multi-target stepping task which required participants to step on squares with an assigned colour while avoiding other coloured squares and demonstrated

* Corresponding author at: Neuroscience Research Australia, Barker Street, Randwick, NSW 2031, Australia. Tel.: +61 2 9399 1267; fax: +61 2 9399 1005.
E-mail address: j.menant@neura.edu.au (J.C. Menant).

http://dx.doi.org/10.1016/j.gaitpost.2016.02.003
0966-6362/

that stepping failures were associated with an increased risk of falling. However, the target panels were present at all times so participants were able to pre-plan their stepping trajectories. This limits the ability to draw conclusions about an individual's ability to adapt gait in response to changes in the pathway. Response inhibition has also been incorporated in a treadmill stepping test [6,9] requiring precision steps and avoidance of obstacles. This research showed that shorter available response time contributes to increased stepping failures [9] with the largest failure rates occurring when participants had to perform a secondary inhibitory task [6]. Although these studies provide good insights into adaptive gait failures, no studies have investigated gait adaptation strategies during an over-ground walking task combining both precision steps and obstacle avoidance.

We, therefore, devised an overground walking task that assessed the ability to adapt gait in response to obstacles and targets appearing on the walkway two steps ahead of the individual. Walk-through trials in which no stimulus appeared (catch trials) were included as a way to estimate the extent of the effects of expectation of a gait perturbation. Our aim was to compare the gait adaptability strategies of young and older adults when performing this task. We hypothesised that compared with young, older adults would (a) make more mistakes and demonstrate lower accuracy in negotiating the targets/obstacle, and/or (b) use a more cautious/conservative strategy when approaching the targets/obstacle.

Table 1
Anthropometric, physiological and neuropsychological characteristics of young and older groups.

Variables	Younger adults Mean ± SD, $n = 21$	Older adults Mean ± SD, $n = 50$
Age (years)	26 ± 4	74 ± 7
Number of women	12	34
Body mass (kg)	72.0 ± 17.2	71.1 ± 15.4
Body height (cm)	170.7 ± 10.2	165.4 ± 10.7
Leg length (cm)	88.8 ± 6.1	90.6 ± 5.8
Edge contrast sensitivity (dB)[a]	24.3 ± 2.1	20.5 ± 3.0[g]
PPA fall risk score[b]	−0.6 ± 0.8	1.2 ± 1.0[g]
TMT score (s)[c]	33.6 ± 15.1	55.3 ± 39.7[g]
MoCA score[d]	N/A	26.3 ± 2.6
Icon-FES score[e]	N/A	45.2 ± 13.5
Previous falls (%)[f]	N/A	34

[a] Melbourne Edge Test, score range 0–26, low scores indicated impaired performance.
[b] Physiological Performance Assessment, includes measures of vision (contrast sensitivity), hand reaction time, postural sway, proprioception and leg muscle strength (PPA fall risk is designated mild if the score is between 0 and 1, moderate between 1 and 2, and marked for scores >2).
[c] Trail Making Test, time difference between part B and part A, high scores indicated impaired performance.
[d] Montreal Cognitive Assessment, scores ≥26 indicate intact cognition.
[e] Iconographical-Fall Efficacy Scale, indicating low-moderate concern of falling.
[f] Percentage of participants that reported falling once or more in the previous 12 months.
[g] Significantly different between young and older groups ($p < 0.05$).

2. Methods

2.1. Participants

Fifty older adults aged 65 years and older and twenty-one young adults took part in this study. Anthropometric, neuropsychological and physiological function scores for the young and older groups are presented in Table 1. Older participants were recruited from Neuroscience Research Australia's (NeuRA) volunteer database. Younger participants were NeuRA employees or university students. All participants were living independently in the community and were able to walk 20 m without assistance and cognitively capable to follow all instructions. Exclusion criteria were: insufficient English language skills, colour-blindness; neurological, musculoskeletal or cardiovascular impairment affecting the assessments. The study was approved by the University of New South Wales Human Research Ethics Committee and participants provided informed consent prior to participation.

2.2. Protocol

Participants attended NeuRA on one occasion where they performed a brief neuropsychological [11,12] and physiological assessment [13] as well as the gait adaptability test. Older participants were also asked about any falls suffered in the past year and their concern about falling [14].

2.3. Gait adaptability test

Initially, participants were required to walk at self-selected speed over a 6 m obstacle-free path (baseline-walking condition). They were then instructed about the gait adaptability test and completed walking trials in four experimental conditions: (i) avoid stepping on a pink stimulus positioned two steps ahead (obstacle avoidance); (ii) stepping onto a green stimulus positioned slightly short of two steps ahead (short target); (iii) stepping onto a green stimulus positioned slightly further than two steps ahead (long target); (iv) walking with no stimulus appearing on the pathway (walk-through). Walk-through trials were included to encourage participants to walk naturally [15–17]. The main difference between the baseline-walking and walk-through conditions was probability of stimulus appearance (75% for the walk-through condition and 0% for baseline). Trials were presented in a completely randomised order. Participants performed three trials per condition and at least one practice trial per experimental condition before data acquisition or until the experimenter was certain that the task was understood.

The target/obstacle consisted of a coloured light stimulus projected on a 215 mm × 215 mm area on the walkway presented on the third heel strike following gait initiation and positioned at two-step ahead of the participant at the time of presentation (Fig. 1). The target/obstacle size and shape was chosen to ensure that (a) the targets/obstacles were long enough (approximately a third of step length) so that participants would have to adjust their stepping pattern in the anterior–posterior plane and (b) not too long or wide so that participants would be unable to step over or around them. Participants were instructed to step in the middle of the targets and to avoid stepping on the obstacle, being free to use any avoidance strategy.

For the purpose of comparing stepping strategies, the step that hit or avoided the stimulus was named "target/obstacle step" and the preceding step was named "previous step". Outcome measures were: (i) number of incorrect responses to the stimulus (stepping on an obstacle or missing a target), (ii) number of steps taken to approach the target/obstacle (during interval between the appearance of the stimulus and the target/obstacle step), (iii) stepping accuracy for target conditions (distance between the centre of the target and the centre of the foot) and for the obstacle condition (the smallest distance between the edge of the foot and the edge of the obstacle), and (iv) step length, step velocity and the percentage of the gait cycle spent in double support (double-support time) during baseline (average of 4th and 5th steps) and experimental conditions (for target/obstacle and previous steps). An electronic walkway (GAITRite® mat, v4.0, 2010 CIR Systems, USA) recorded the temporal and spatial gait parameters. Position coordinates of the foot and target/obstacle obtained from the electronic walkway were used to determine incorrect responses and to calculate stepping accuracy.