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Executive functioning, concern about falling and quadriceps strength mediate the relationship between impaired gait adaptability and fall risk in older people

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ABSTRACT

Background: Reduced ability to adapt gait, particularly under challenging conditions, may be an important reason why older adults have an increased risk of falling. This study aimed to identify cognitive, psychological and physical mediators of the relationship between impaired gait adaptability and fall risk in older adults.
Methods: Fifty healthy older adults (mean ± SD: 74 ± 7 years) were categorised as high or low fall risk, based on past falls and their performance in the Physiological Profile Assessment. High and low-risk groups were then compared in the gait adaptability test, i.e. an assessment of the ability to adapt gait in response to obstacles and stepping targets under single and dual task conditions. Quadriceps strength, concern about falling and executive function were also measured.
Results: The older adults who made errors on the gait adaptability test were 4.76 (95%CI = 1.08–20.91) times more likely to be at high risk of falling. Furthermore, each standard deviation reduction in gait speed while approaching the targets/obstacle increased the odds of being at high risk of falling approximately three fold: single task − OR = 3.10,95%CI = 1.43–6.73; dual task − 3.42,95%CI = 1.56–7.52. Executive functioning, concern about falling and quadriceps strength substantially mediated the relationship between the gait adaptability measures and fall risk status.
Conclusion: Impaired gait adaptability is associated with high risk of falls in older adults. Reduced executive function, increased concern about falling and weaker quadriceps strength contribute significantly to this relationship. Training gait adaptability directly, as well as addressing the above mediators through cognitive, behavioural and physical training may maximise fall prevention efficacy.

1. Introduction

Age-related declines in the ability to adapt gait, particularly under challenging conditions [1–8], may place older adults at increased risk of falling. For instance, a limited capacity to adapt gait when performing daily living activities such as avoiding obstacles, walking over uneven terrain or crossing a busy street might contribute to trips or slips; frequently reported causes of falls in older people [9].

Previous research has compared aspects of gait adaptability such as obstacle avoidance and target stepping accuracy between fallers and non-fallers [1,10–13]. Newstead et al. found that older adults who fell in the past year adopted a more conservative approach by making several small steps prior to stepping over a fixed obstacle compared to non-fallers [10]. Older adults who fell in the past year also demonstrated deteriorated postural adjustments during the pre-crossing phase of obstacle negotiation compared with those who did not fall [13]. Similarly, Chapman et al. reported that older adults who reported four or more fall risk factors, walked slower, with shorter step length and demonstrated less accurate and more variable foot placements than those who reported less than four fall risk factors in a walking task involving stepping targets [14]. More recently, Yamada et al. used an overground multi-target stepping task that required participants to step on assigned target colour squares while avoiding other coloured squares and found stepping and avoidance errors to be higher among older adults who fell

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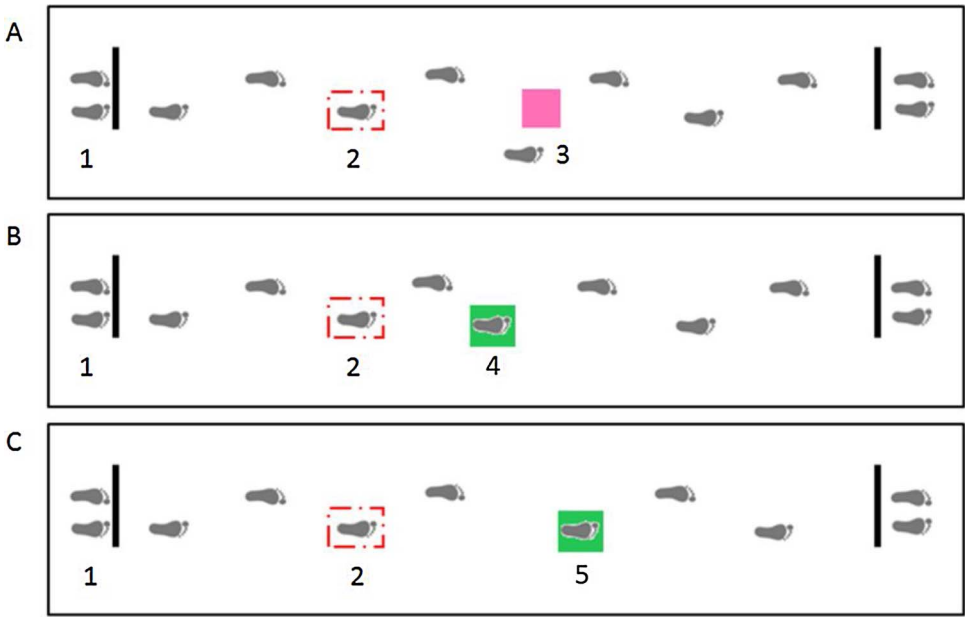

Fig. 1. Overhead view of the experimental setup including obstacle avoidance (A), short target (B) and long target (C) conditions. Distance to the obstacle/target was personalized for each individual. The starting position [1] was adjusted to align the obstacle [3] with the fifth foot landing location based on the average foot placement from the baseline walking trials. The stepping targets were projected in two locations − 24.5 cm anterior [4] and 24.5 cm posterior [5] to the obstacle position (centre to centre distance), and thus required a short or a long step length respectively. The projection system for the three stimulus consisted of three torches installed in the ceiling and connected to a control box. A force sensitive resistor (Sparkfun SEN-09376) placed underneath the participant's right shoe and connected to a wireless transmitter attached to the participant's ankle triggered the light projection on the third heel strike following gait initiation [2].

in the past year compared with those who did not fall [11,12].

In these studies, the obstacles and target panels were visible from trial commencement so participants were able to plan their stepping trajectories and therefore did not assess the ability to adapt gait in response to unforeseen changes while walking. In contrast, Weerdesteyn et al. devised a gait protocol involving the sudden-appearance of an obstacle on a treadmill and found that those who fell multiple times in the past six months struck more obstacles than their counterparts who did not fall or fell once only in this period [1]. Although these studies provide some insight into adaptive gait performance, no studies have compared gait adaptation strategies between fall risk groups during an over-ground walking task combining both precision steps and obstacle avoidance.

We recently devised a gait adaptability test (GAT) that assessed the ability to adapt gait in response to obstacles and targets appearing on the walkway two steps ahead of the individual [4], somewhat mimicking the cognitive load challenges required for walking in many daily life situations. We found that compared with their younger counterparts, older adults showed impaired gait adaptability (e.g. high prevalence of errors, reduced gait speed, short steps) [4] which was significantly associated with reduced sensorimotor and cognitive function [15].

The aim of this study was to investigate the relationship between gait adaptability performance and fall risk in older people and potential physical, cognitive and psychological mediating factors. Given that conduct of cognitive tasks adversely affects gait in older people [16], we also examined whether adding a concurrent task (counting backwards by 3s) assists in the discrimination of fall risk groups and whether mediating factors differed between the single and dual task conditions.

2. Methods

2.1. Participants

Participants were 50 adults (34 women) aged 65 years and older who were recruited from the NeuRA Healthy Research Volunteer Registry. All participants were living independently in the community and were cognitively capable of following all instructions. The participants were relatively healthy, with exclusion criteria including a physician diagnosed dementia, acute or terminal illness, progressive neurodegenerative diseases, major psychiatric illnesses, colour-blindness or visual impairments that could not be corrected, were unable to walk independently or had recently undergone surgery affecting mobility. The study was approved by the University of New South Wales Human Research Ethics Committee and participants provided written informed consent prior to participation.

2.2. Assessment of fall risk

Fall risk was assessed using four items of the Physiological Profile Assessment (PPA): visual contrast sensitivity, lower limb proprioception, postural sway when standing on a compliant surface with eyes open and simple hand reaction time [17]. The item quadriceps strength was omitted from the fall risk calculation to allow it to be entered as a possible mediator for fall risk in multivariate modelling as this measure has been identified as a determinant of gait speed [18]. The fall risk score generated from the above four items had very similar predictive accuracy (i.e. 75%) for multiple falls as the full 5-item model in the initial validation study [19]. The PPA fall risk is designated mild if the score is between 0 and 1, moderate between 1 and 2, and marked for scores > 2 [17]. Participants were also asked about any falls experienced in the past 12 months. A fall was defined as 'an unexpected event in which the participants come to rest on the ground, floor, or lower level' [20]. A reported history of multiple falls and/or having high physiological fall risk (PPA score = 1.5, top tertile) was used to classify participants into the high fall-risk group [21,22] with all other participants classified low risk. Including past falls in the fall risk classification broadened it beyond physical risk to also indirectly encompass behavioural and cognitive facets.

2.3. Gait adaptability test (GAT)

Initially, participants were required to walk at self-selected speed over a six-meter obstacle-free path (baseline condition). They were then instructed about the GAT and completed walking trials in four experimental conditions under single and dual task conditions: (i) avoid stepping on a pink stimulus appearing two steps ahead (obstacle avoidance); (ii) stepping onto a green stimulus appearing slightly short of two steps ahead (short target); (iii) stepping onto a green stimulus appearing slightly further than two steps ahead (long target); (iv) walking with no stimulus appearing on the pathway (walk-through) (Fig. 1 for more details). The concurrent cognitive task consisted of counting backwards by three, starting from a given two digit number that was randomly selected and provided to the participant just before