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Manipulating walking path configuration influences gait variability and six-minute walk test outcomes in older and younger adults

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ABSTRACT

This study determined whether manipulations to walking path configuration influenced six-minute walk test (6MWT) outcomes and assessed how gait variability changes over the duration of the 6MWT in different walking path configurations. Healthy older (ODR) and younger (YNG) ($n = 24$) adults completed familiarisation trials and five randomly ordered experimental trials of the 6MWT with walking configurations of; 5, 10 and 15 m straight lines, a 6 m by 3 m rectangle (RECT), and a figure of eight (FIG8). Six-minute walk distance (6MWD) and walking speed ($m.s^{-1}$) were recorded for all trials and the stride count recorded for experimental trials. Reflective markers were attached to the sacrum and feet with kinematic data recorded at 100 Hz by a nine-camera motion capture system for 5 m, 15 m and FIG8 trials, in order to calculate variability in stride and step length, stride width, stride and step time and double limb support time. Walking speeds and 6MWD were greatest in the 15 m and FIG8 experimental trials in both groups ($p < 0.01$). Step length and stride width variability were consistent over the 6MWT duration but greater in the 5 m trial vs. the 15 m and FIG8 trials ($p < 0.05$). Stride and step time and double limb support time variability all reduced between 10 and 30 strides ($p < 0.01$). Stride and step time variability were greater in the 5 m vs. 15 m and FIG8 trials ($p < 0.01$). Increasing uninterrupted gait and walking path length results in improved 6MWT outcomes and decreased gait variability in older and younger adults.

1. Introduction

The six-minute walk test (6MWT) measures the distance achieved in a continuous six-minute walking bout and is a global indicator of functional capacity [1]. Due to its simplicity and close relation to activities of daily living, the 6MWT has been used to represent functional capacity in chronic obstructive pulmonary disease and total knee arthroplasty patients and older individuals [1–3]. Conversely, measures of gait variability are more specific indicators of the neural control of gait [4] and have been used to discriminate between older fallers and non-fallers and to predict older adults at risk of falling, a major health hazard in this population [5,6].

Although the 6MWT distance achieved (6MWD) and gait variability have clear utility in characterising function and predicting falls risk, respectively, non-adherence to the American Thoracic Society (ATS) 6MWT guidelines, result in adaptations to the walking path set-up or configuration, rest periods, turning strategy, familiarisation and encouragement provided [1,7,8]. Adaptation to walking path configuration has been suggested to impact upon 6MWD due to the effects of turning and gait speed strategy adopted [9–11]. Adaptation to walking path configuration has also been shown to influence gait variability, with repeated single walking path trials displaying increased variability vs. continuous walking trials [12], perhaps due to the variability in the acceleration vs. steady-state phase of walking gait [13]. In order to ameliorate these issues, continuous overground walking path protocols, such as the 'figure of eight', have been proposed [14]. Currently, there is no agreement on the minimum number of gait cycles to recommend for reliable gait variability assessment, indicating that gait variability is also affected by the stride count and/or duration of a walking trial [13–15].

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Both the functional capacity and gait variability of older adults have been assessed using continuous walking protocols [6,12,16]. However, results need to be interpreted with caution, considering the walking path configuration and trial duration employed.

Given that information regarding gait variability and 6MWD may inform clinical diagnostic processes, understanding the influence of differing 6MWT walking path configurations and trial duration on these measures is vital to enhance the homogeneity and interpretation of information from local testing protocols. Therefore, the aim of this study was two-fold: (i) to determine if manipulations to walking path configuration influences 6MWT outcomes in older and younger individuals; (ii) to assess how gait variability changes over the duration of an extended period of walking (6MWT in this instance) in different walking path configuration manipulations in older and younger individuals. It was hypothesised that (1) 6MWT outcomes would be improved in walking path configurations with increased straight line walking distance and reduced turning requirements in both older and younger individuals. It was also hypothesised that (2) gait variability would exhibit an interaction effect, where walking path configurations with increased straight line walking distance and reduced turning requirements would have decreased variability in conjunction with reductions in variability across the 6MWT duration and that this effect would be present in both older and younger individuals.

2. Methods

2.1. Participants

A consecutive sample of both older (ODR) and younger (YNG) individuals were recruited to form two groups of $n = 12$. All participants in the ODR (3♂9♀, aged 70.2 ± 3.4 years, height 1.62 ± 0.07 m and mass 77.4 ± 10.5 kg) and YNG groups (12♂, aged 21.9 ± 1.3 years, height 1.79 ± 0.07 m and mass 76.1 ± 6.5 kg) provided written informed consent to participate in the study, which was approved by the Nottingham Trent University Human Research Ethics Committee.

In order to recruit healthy older participants whose physical function would not be adversely affected by their health or lifestyle, prospective participants for the ODR group were included if they: 1) were community living adults aged between 60 and 75 years of age; 2) displayed a good health status as established by a health screen; 3) were able to walk, pain free, for a period of 6 minutes without the use of a walking aid; 4) had good (corrected) vision and 5) partook in physical activity at least once a week for 30 minutes. These individuals were excluded if they: 1) had experienced an unintentional fall in the previous 12 months; 2) were current smokers; 3) were currently taking ≥5 prescribed medications.

For the YNG group, prospective participants were included if they: 1) were adults aged between 18 and 30 years of age and 2) displayed good health status as established by a health screen and were excluded if they: 1) had a current neuromuscular and/or musculoskeletal injury; 2) had a current medical condition that may affect gait and/or balance and 3) were current smokers.

2.2. Experimental design

Participants completed two trials of the standard 6MWT along a 30 m straight walking path according to the standardised ATS guidelines, which also acted as familiarisation trials [1], followed by five experimental trials of the 6MWT, where the walking path configuration was manipulated (Fig. 1A). The five experimental walking path configurations were; five (5 m); ten (10 m); and fifteen metre (15 m) straight lines with 180 degree turns; a six metre by three metre rectangle (RECT) with 90 degree turns; and a continuous figure of eight walking path (FIG8) with two intersecting straight line sections of 10 m (Fig. 1B). The ordering of experimental trials was randomised using a random number generator.

2.3. Experimental protocol

Participants attended data collection sessions wearing comfortable clothing and flat, everyday walking shoes. As foot kinematic measures offer a viable assessment of gait variability [17], participants were fitted with 14 mm reflective markers bilaterally at 1st and 5th distal metatarsal heads, 2nd proximal metatarsal head, calcaneus, distal aspect of the foot, as well as a single marker on the sacrum during the 5 m, 15 m and FIG8 experimental trials. These experimental trials were selected in order to assess the effects of straight line walking path distance and continuous vs. repeated straight gait with turns, on gait variability. Participants started each trial by standing at the start of each walking path and were free to self-select a turning direction. Standardised instruction and demonstration at the start of the 6MWT, as well as verbal encouragement at one minute intervals, were provided according to the ATS guidelines [1].

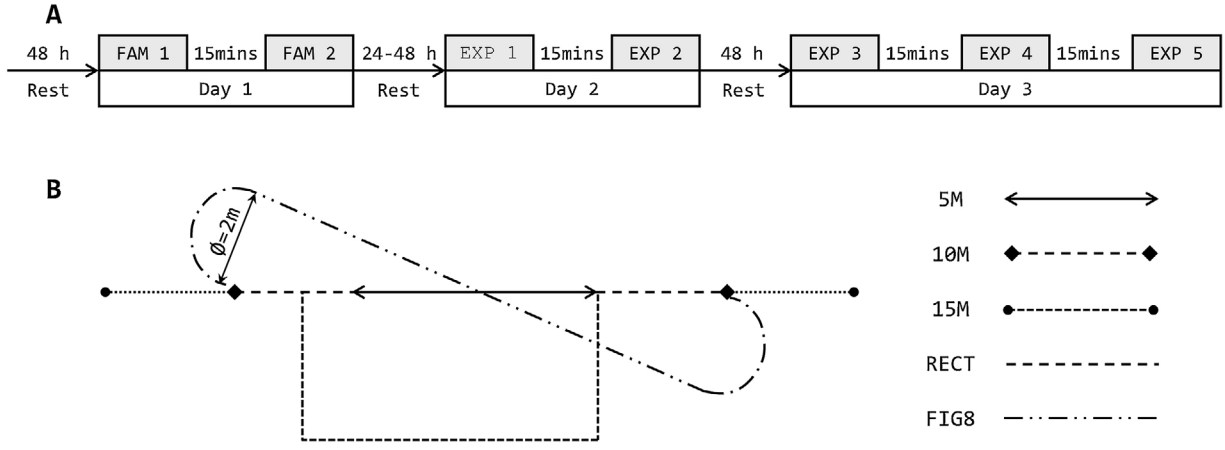

Fig. 1. Schematic representations of the experimental design with the two familiarisation trials conducted on day 1, the remaining five experimental trials being spread over two separate days (A) and the different walking path configurations which were completed in a randomised order by each participant (B).