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The effect of prolonged level and uphill walking on the postural control of older adults

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ABSTRACT

Prolonged walking could alter postural control leading to an increased risk of falls in older adults. The aim of this study was to determine the effect of level and uphill prolonged walking on the postural control of older adults. Sixteen participants (64 ± 5 years) attended 3 visits. Postural control was assessed during quiet standing and the limits of stability immediately pre, post and post 15 min rest a period of 30 min walking on level and uphill (5.25%) gradients on separate visits. Each 30 min walk was divided into 3 10 min blocks, the limits of stability were measured between each block. Postural sway elliptical area (PRE: 1.38 ± 0.22 cm^2, POST: 2.35 ± 0.50 cm^2, p = .01), medio-lateral (PRE: 1.33 ± 0.03, POST: 1.40 ± 0.03, p = .01) and anterio-posterior detrended fluctuation analysis alpha exponent (PRE: 1.43 ± 0.02, POST: 1.46 ± 0.02, p = .04) increased following walking. Medio-lateral alpha exponent decreased between post and post 15 min' rest (POST: 1.40 ± 0.03, POST15: 1.36 ± 0.03, p = .03). Forward limits of stability decreased between the second walking interval and post 15 min' rest (Interval 2: 28.1 ± 1.6%, POST15: 25.6 ± 1.6%, p = .01) and left limits of stability increased from pre-post 15 min' rest (PRE: 27.7 ± 1.2%, POST15: 29.4 ± 1.1%, p = .01). The neuromuscular alterations caused by prolonged walking decreased the anti-persistence of postural sway and altered the limits of stability in older adults. However, 15 min' rest was insufficient to return postural control to pre-exercise levels.

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1. Introduction

Postural control of older adults is associated with neuromuscular function, falls and functional ability (Ko and Newell, 2016; Kurz et al., 2013; Orr, 2010; Shaffer and Harrison, 2007). An acute reduction in neuromuscular function increases fall risk (Morrison et al., 2016). Fatigue acutely impairs muscle force output, and increases synaptic time delays, motor variability and proprioceptive inaccuracies, resulting in a disturbance to the postural control system (Davidson et al., 2011; Paillard, 2012; Singh and Latash, 2011; Vuillerme and Boisgontier, 2008).

Walking is a common daily activity for older adults that can lead to fatigue (Morrison et al., 2016). Short duration (up to 15 min) high intensity walking increases postural sway in older adults during single and double leg stance (Donath et al., 2015a, 2013; Morrison et al., 2016). This suggests the fatiguing exercises acutely altered proprioceptive and vestibular function (Paillard, 2012) and muscle activation patterns (Ortega and Farley, 2015; Paillard, 2012). However, the studies observing postural sway differences (Donath et al., 2015a, 2013; Morrison et al., 2016) have used high intensity exercise over short durations (<15 min) which is not typical of activity performed by older adults. During longer duration (up to 30 min) exercise, younger adults demonstrate an initial decrease in performance of postural control tasks after commencing exercise, however as exercise duration increased, performance of postural control tasks either remained constant or returned towards baseline (Simoneau et al., 2006; Thomas et al., 2013). However, it is currently unclear if the postural control of older adults can adapt during longer duration exercise, as is seen in younger adults.

In addition to the walking duration, the gradient of the surface could impact the muscle activation and the fatigue and postural control change experienced by the older adult. Older adults have increased muscle activation when walking uphill compared to younger adults (Franz and Kram, 2013; Hortobagyi et al., 2011; Ortega and Farley, 2015). Greater muscle activation could therefore cause uphill walking to have greater effects on postural control than level walking. Furthermore, the neuromuscular alterations associated with fatigue and uphill walking (Franz and Kram, 2013) may alter the postural control dynamics of older adults. More persistent postural sway dynamics, a strategy associated

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with fewer and less frequent postural adjustments (Borg and Laxåback, 2010), can increase the risk of falls in older adults (Kurz et al., 2013) because the postural control system is less versatile and able to adapt to perturbations or changing environmental conditions (Ko and Newell, 2016; Seigle et al., 2009). However, the effect of walking on the postural sway dynamics of older adults is unknown.

The aim of the present study was to investigate the effect of level and uphill walking at a moderate intensity on postural control measured during quiet standing and the limits of stability (LOS) and walking muscle activation. Additionally, this study aimed to investigate the effect of exercise duration on the LOS. It was hypothesised that level and uphill walking would increase quiet standing postural sway while decreasing sway anti-persistence the LOS. It was further hypothesised that uphill walking would have a greater effect on postural control and walking muscle activation than level walking.

2. Method

2.1. Participants

Sixteen older adults (n-female: 6, n-male: 10, age: 64 ± 5 years, height: 1.73 ± 0.14 m, mass: 76.8 ± 12.7 kg, level self-selected walking speed 1.22 ± 0.19 m/s) participated in the study. A priori power calculation revealed a sample size of 16 participants was required based on an effect size of f = 0.56 for pre-post walking changes in postural control variables (Donath et al., 2013), a desired power of 80% and alpha = 0.05. Participants were excluded if they suffered from neurological conditions, visual impairment, or lower limb injuries. The study received ethical approval from the University ethics committee and all participants were made aware of the nature of the study and their right to withdraw at any time, before providing written informed consent. All aspects of the study were conducted in accordance with the Declaration of Helsinki.

2.2. Procedures

Participants attended 3 laboratory visits. During the first visit participants were familiarised with postural control tasks and treadmill walking. The exercise intensity for visits 2 and 3 was also determined during visit 1 as 105% of the average heart rate (HR) during 5 min at self-selected walking speed (SSW) on 0% gradient. Pilot data collection established that this intensity was deemed to be moderate intensity (Mazzeo and Tanaka, 2001) and the 5.25% gradient was suitable to complete the 30 min protocol.

In the second and third visits, participants performed quiet standing, LOS and 1 min of SSW on 0% gradient immediately before (PRE) and after (POST) 30 min of treadmill walking at the predetermined exercise intensity on either 0% or 5.25% gradient (Fig. 1). A period of 30 min walking was selected as it reflects the duration and intensity of physical activity, to be performed 3–5 days per week, recommended to older adults to maintain a healthy lifestyle (NHS, 2017). The order of 0% and 5.25% conditions was randomised and counterbalanced. Quiet standing and LOS tests were repeated after 15 min of rest following completion of POST measurements (POST15).

The 30 min walk was divided into 3 blocks of 10 min. After the first (walking interval 1) and second (walking interval 2) block the LOS test was repeated. Only measurement of the LOS was performed in walking interval 1 and 2 to minimise the time between walking blocks and reduce the time for recovery during the balance tests. Walking speed was increased during the first 10 min block until the target HR was reached and then speed was fixed for the remainder of the 30 min walk. Heart rate and rate of perceived exertion (RPE) were recorded in alternate minutes and expired air was collected for the final 2 min of each 10 min block using a Douglas bag for the calculation of oxygen consumption (VO_2).

Electromyographic (EMG) activity of the dominant leg Rectus Femoris (RF), Vastus Medialis (VM), Biceps Femoris (BF), Tibialis Anterior (TA), Gastrocnemius Medialis (GM) and Soleus (SOL) was recorded during alternate minutes of each walking block and during PRE and POST SSW. Bipolar Ag/AgCl electrodes were placed with a 2 cm inter-electrode distance according to the SENIAM guidelines (Hermens et al., 1999). Prior to placement of electrodes each site was shaved and cleaned with an alcohol wipe. All EMG signals were recorded at 1000 Hz, amplified (gain ×1000) and A/D converted using 6 wireless transmitters (BTS FREEEMG 300, BTS Bioengineering, Milan, Italy) and software (EMGAnalyzer, BTS Bioengineering, Milan, Italy). A footswitch was placed under the heel of the dominant leg, and recorded synchronously with EMG signals at 1000 Hz, to allow the detection of heel strike gait events.

Postural control during quiet standing and LOS tests were assessed with participants stood barefoot in a comfortable position on a force plate (Kistler Instruments Ltd, Winterthur, Switzerland) with eyes open. The foot position of each participant was marked on a clear covering placed over the surface of the force plate to ensure the same position was adopted for each trial and visit, as foot placement can alter the calculated postural sway parameters (Chiari et al., 2002). Participants performed 5 trials of 60 s quiet standing at PRE, POST, POST15 measurements while the movements of the centre of pressure (COP) were recorded at 48 Hz using Bioware software (Kistler Instruments Ltd, Winterthur, Switzerland).

Participants performed the LOS task at PRE, between walking blocks 1 and 2 (walking interval 1), between walking blocks 2 and 3 (walking interval 2), POST and POST15. Three trials 30 s trials were performed in the forward, right and left directions at each time point. The backward direction was not included to reduce the risk of falling. Each 30 s trial was divided into 3 phases, in

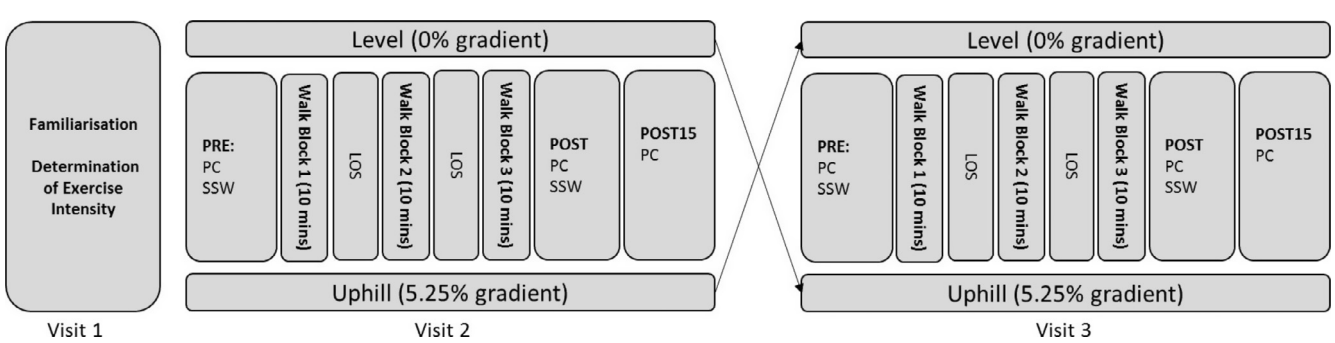

Fig. 1. Overall study design. SSW: self-selected speed walking, PC: postural control assessments including quiet standing and limits of stability, LOS: limits of stability test

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