Human Movement Science 59 (2018) 30–36

Contents lists available at ScienceDirect

Human Movement Science

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

Full Length Article

Dynamic balance control during stair negotiation for older adults and people with Parkinson disease

Zachary J. Conway[a,*], Tim Blackmore[a,b], Peter A. Silburn[c], Michael H. Cole[a,*]

[a] Australian Catholic University, School of Exercise Science, Brisbane, Queensland, Australia
[b] University of Portsmouth, Department of Sport & Exercise Science, Hampshire, United Kingdom
[c] Asia-Pacific Centre for Neuromodulation, Queensland Brain Institute, The University of Queensland, Brisbane, Queensland, Australia

ARTICLE INFO

Keywords:
Gait
Balance
Harmonic ratio

ABSTRACT

It is well understood that stability during ambulation is reliant upon appropriate control of the trunk segment, but research shows that the rhythmicity of this segment is significantly reduced for people with Parkinson's disease (PD). Given the increased risk associated with stair ambulation, this study investigated whether people with PD demonstrate poorer trunk control during stair ambulation compared with age-matched controls. Trunk accelerations were recorded for twelve PD patients and age-matched controls during stair ascent and descent. Accelerations were used to derive measures of harmonic ratios and root mean square (RMS) acceleration to provide insight into the rhythmicity and amplitude of segmental motion. Compared with what is typically seen during level-ground walking, gait rhythmicity during stair negotiation was markedly reduced for older adults and people with PD. Furthermore, both groups exhibited significantly poorer trunk movements during stair descent compared to stair ascent, suggesting that both populations may face a greater risk of falling during this task. As stair negotiation is a common activity of daily life, the increased risk associated with this task should be considered when working with populations that have an increased risk of falling.

1. Introduction

Pertinent to one's independence, stair ambulation has been rated by older adults as one of the most challenging activities of daily life (Williamson & Fried, 1996), with more than half of stair-related falls occurring during descent (Startzell, Owens, Mulfinger, & Cavanagh, 2000). Research involving older adults suggests stair ambulation places a greater emphasis on lower limb muscle strength (Karamanidis & Arampatzis, 2011), which exposes the known strength deficits of some populations (Conway, Silburn, Blackmore, & Cole, 2017). Subsequently it is known that older adults are at a greater risk of falling, in particular during stair descent, compared to younger adults due to a reduced ability to control their centre of mass (Bosse et al., 2012).

Due to their symptoms of postural instability, people with Parkinson's disease (PD) face a greater risk of falls (de Lau & Breteler, 2006; Michel, Benninger, Dietz, & van Hedel, 2009) that ultimately contributes to the increased incidence of falls and fall-related consequences in this population (Bloem, van Vugt, & Beckley, 2001). Traditionally, clinicians and researchers have assessed a patient's risk of falling during tasks, such as stair climbing, using established clinical assessments (e.g. the Stair Climb Test) that either rate the patient's performance using a Likert scale or assess the time taken for the individual to ascend or descend a flight of stairs. However, while such clinical assessments may provide insight into whether or not a patient is capable of performing such tasks, they

* Corresponding authors at: School of Exercise Science, Australian Catholic University, P.O. Box 456, Virginia, Queensland 4014, Australia.
E-mail addresses: zachary.conway@acu.edu.au (Z.J. Conway), michael.cole@acu.edu.au (M.H. Cole).

https://doi.org/10.1016/j.humov.2018.03.012
Received 7 December 2017; Received in revised form 12 March 2018; Accepted 22 March 2018

are potentially limited in their capacity to determine whether the patient can perform the task safely. For example, the instability that is evident in people with PD is believed to be caused, at least in part, by an increase in trunk rigidity, which impairs one's capacity to make appropriate postural adjustments (Adkin, Bloem, & Allum, 2005). This increase in trunk stiffness restricts the spinal segments from moving independently and reduces their spine's capacity to attenuate movement-related forces (Kavanagh, Barrett, & Morrison, 2004). During stair walking, these individuals exhibit a greater trunk roll angle than healthy older adults and this excessive movement has been linked with an increased risk of falls (Adkin et al., 2005). Given this relationship between trunk movements and overall dynamic stability during stair negotiation, it appears that assessments of the amplitude and/or rhythmicity of trunk motion may provide further insight into deficits in gait rhythmicity for PD populations (Cole, Naughton, & Silburn, 2017; Cole, Silburn, Wood, & Kerr, 2011; Cole, Silburn, Wood, Worringham, & Kerr, 2010; Cole, Sweeney, Conway, Blackmore, & Silburn, 2017; Latt, Menz, Fung, & Lord, 2009).

The harmonic ratio (HR) is a commonly used measure of walking stability in people with PD (Hubble, Naughton, Silburn, & Cole, 2015) and requires the placement of one or more accelerometers on the head, trunk or pelvis (Cole et al., 2014; Latt, Menz, Fung, & Lord, 2008; Latt et al., 2009). The HR provides a ratio of the in-phase to out-of-phase accelerations and, hence, offers a measure of movement rhythmicity (or symmetry) that gives insight into segmental control along each axis of movement (i.e. anterior-posterior (AP), medial–lateral (ML), vertical (VT)) (Bellanca, Lowry, Vanswearingen, Brach, & Redfern, 2013). During unconstrained walking, people with PD demonstrate significantly less rhythmic trunk movements in the AP and ML directions compared with age-matched controls, which authors have argued is indicative of impaired dynamic stability in these individuals (Lowry, Smiley-Oyen, Carrel, & Kerr, 2009). However, while these studies provide evidence of the utility of the HR for assessing impaired dynamic stability in people with PD, its previous use has been limited to assessments of walking on level and predictable surfaces, while more challenging tasks have been largely overlooked.

While it can be argued that only 2% of the falls experienced by people with PD occur on stairs (Ashburn, Stack, Ballinger, Fazakarley, & Fitton, 2008), the greater risk of serious injury and fatality that is associated with these incidents (Manning, 1983) indicates that they must not be overlooked. Despite the apparent risk associated with stair ambulation for people with PD, there is a paucity of research examining the performance of this task in this population. Given the importance of trunk control for the maintenance of dynamic stability during walking, this study sought to contrast the rhythmicity of trunk movements during stair ascent and stair descent for both older adults and people with PD. It was hypothesised that gait rhythmicity would be reduced during stair descent compared to ascent, and that people with PD would exhibit lower trunk HRs in the AP, ML and VT directions.

2. Methods

2.1. Study population

Two groups of 12 participants (Table 1) comprising; i) people with idiopathic PD; and ii) age- and gender-matched healthy controls were recruited. Participants with PD were recruited from a neurology clinic and were confirmed to have PD based on the United Kingdom Brain Bank Criteria (Hughes, Daniel, Kilford, & Lees, 1992) by their treating neurologist. Controls were randomly-recruited from a pre-existing database and from the wider community of staff at the University. To be eligible, participants were required to be; i) independently living; ii) able to ambulate without assistance; iii) without dementia based on the Standardized Mini-Mental State Examination (total score $\geq$ 24); iv) free of clinically-diagnosed visual or musculoskeletal problems; v) free of medical conditions (other than PD) that would adversely affect their balance (e.g. vestibular disorders); and vi) receiving no non-pharmacological therapies (e.g. deep brain stimulation). An a priori sample size calculation based on ML trunk HRs indicated a minimum of 11 participants was required per group to detect differences between the two study cohorts (Effect size = 1.25, Power = 0.8, $p = 0.05$) (Lowry et al., 2009). The study was approved by the University's Human Research Ethics Committee (approval #2014 345Q) and all participants provided written informed consent.

2.2. Clinical assessment

Participants completed assessments of cognitive function (Standardized Mini-Mental State Examination (SMMSE)), quality of life (8-item Short-Form questionnaire (SF-8)) and balance confidence (6-item Activities-specific Balance Confidence scale (ABC-6)). PD participants also completed a PD-specific 8-item quality of life scale (PDQ-8), while disease stage and symptom severity were established by an experienced movement disorders scientist using the Movement Disorders Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS), the Hoehn & Yahr stage score, the Schwab & England Activities of Daily Living scale and the New Freezing of Gait (*N*-FOG) questionnaire. Where applicable, participants were assessed approximately 1 hour following their anti-parkinsonian medication to ensure they were optimally-medicated.

2.3. Movement assessment

For the stair ascent trials, participants started 5-metres away from an instrumented laboratory staircase comprising three steps (19 cm riser, 30 cm tread) designed to comply with national building regulations. Although it could be argued that ascending or descending a 3-step staircase may be different to negotiating a longer flight of stairs, the conditions adopted in this study were comparable to previous biomechanical research (Adkin, Frank, & Jog, 2003; Bosse et al., 2012; Reeves, Spanjaard, Mohagheghi, Baltzopoulos, & Maganaris, 2008). When instructed, participants began walking, ascended each step in a foot-over-foot pattern and