

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

Authors: Zachary J. Conway¹, Tim Blackmore^{1, 2}, Peter A. Silburn³, Michael H. Cole^{1*}

Affiliations: 1. Australian Catholic University, School of Exercise Science, Brisbane, Queensland, AUSTRALIA
2. University of Portsmouth, Department of Sport & Exercise Science, Hampshire, UNITED KINGDOM
3. Asia-Pacific Centre for Neuromodulation, Queensland Brain Institute, The University of Queensland, Brisbane, Queensland, AUSTRALIA

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Correspondence*:	Mr Zachary J. Conway	Dr Michael H. Cole
	School of Exercise Science	School of Exercise Science
	Australian Catholic University	Australian Catholic University
	P.O. Box 456	P.O. Box 456
	Virginia, Queensland, 4014	Virginia, Queensland, 4014
	AUSTRALIA	AUSTRALIA

Email Address: zachary.conway@acu.edu.au michael.cole@acu.edu.au

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Abstract

It is well understood that stability during ambulation is reliant upon appropriate control of the trunk segments, but research shows that the rhythmicity of these segments 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 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, 2016; 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 ambulate without assistance; iii) without dementia based on the Standardized Mini-Mental State

Examination (total score ≥ 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 continued along the 1.7-metre long landing. Following a 30-second rest period, participants traversed the landing, descended the staircase in a foot-over-foot pattern and returned to the starting position. Participants performed the stair ascent and descent trials at a self-selected pace until they had completed three trials with the left foot hitting the first step and three trials with the right foot hitting the first step (total of 6 trials). To prevent participants from specifically aiming to reach the first step with a particular foot (otherwise known as ‘targeting’), participants were unaware of the requirement to achieve three trials with each foot. As such, participants were instructed as to which foot to initiate walking from the starting position to avoid them repeatedly reaching the first step with the same foot. For the participants’ safety, handrails were situated bilaterally around the staircase and the upper landing. However, they were instructed only to use the handrails if they felt unsteady or if they needed to regain their balance to prevent a fall. Only those trials that were completed without the use of the handrails were included in the analyses.

During the movement tasks, trunk accelerations were assessed at 120 Hz using an inertial measurement unit (IMU) (W: 3.8 x H: 5.3 x D: 2.1 cm, 30 grams) that featured a tri-axial

accelerometer, gyroscope and magnetometer (XSens Technologies, Netherlands). Given there is little consensus regarding the best site from which to assess gait-related trunk accelerations, the IMU was secured directly to the skin overlying the 12th thoracic vertebra, as accelerations recorded from this spinal level have been shown to have excellent concurrent validity (Cole et al., 2014). Additionally, to quantify walking speed, reflective markers were firmly affixed over specific anatomical landmarks on the feet, knees and pelvis and bilaterally over the mid-thigh and mid-shank via securely-fastened rigid bodies. During the tasks, three-dimensional marker trajectories were captured at 120 Hz by a 12-camera motion analysis system and the Vicon Nexus software (Version 2.1.1, Vicon Nexus, Vicon, UK).

2.4 Data Analysis

The time-series acceleration data for each trial (6 stair ascents; 6 stair descents) were truncated to include only the two gait cycles completed on the stairs (i.e. 12 gait cycles total for each participant during each walking task). Data for these gait cycles were then mathematically transformed using previously-described trigonometric procedures to separate gravitational acceleration (which has a constant value of -9.81 m/s^2 or 1 g) from the movement-related accelerations (Kavanagh et al., 2004) and low-pass filtered using a fourth-order Butterworth filter with a cut-off frequency of 30 Hz. The filtered accelerations were subsequently analysed in the frequency domain using the well-established Fourier series technique (Oppenheim & Willsky, 1997) with the fundamental frequency of the signal derived from stride duration (Smidt, Arora, & Johnston, 1971). Using the first 20 harmonic coefficients (Kavanagh et al., 2004), HRs were calculated for the trunk by dividing the sum of in-phase harmonics by the sum of out-of-phase harmonics (Bellanca et al., 2013). Within a stride, higher HRs represented more in-phase

harmonics relative to out-of-phase harmonics and, hence were considered to represent greater movement symmetry and dynamic stability (Bellanca et al., 2013). To provide insight into the amount of trunk movement occurring during the dynamic tasks, the root mean square (RMS) amplitude of the AP, ML and VT accelerations (m/s^2) was also calculated for each gait cycle (Latt et al., 2009). All processing and analyses of the acceleration data were performed using a custom MATLAB program (v7.13, The MathWorks, USA).

To facilitate calculation of walking speed (metres/second) and cadence (steps/min), marker locations were processed using Vicon Nexus and the trajectories were low-pass filtered using a fourth-order Butterworth filter with a cut-off frequency of 6 Hz. As walking speed during stair ambulation comprises both horizontal and vertical components, the anterior-posterior and vertical displacements of the markers on the pelvis were used with Pythagoras' theorem to calculate the diagonal displacement and, subsequently, the velocity of these markers. Cadence was calculated as the elapsed time between consecutive foot contacts on the first and second step divided by 60 to yield step frequency per minute. The calculation of cadence was considered to be important, as research suggests that the HR may only be an appropriate measure for walking patterns with cadences above 60 steps/min (Bellanca et al., 2013).

2.5 Statistical Analysis

Univariate analysis of variance (ANOVA) examined group differences in the continuous demographic variables (e.g. age), while the Chi-square test assessed differences in the frequencies of categorical variables (e.g. gender). To ensure the assumptions of parametric statistics were met, the Shapiro-Wilk test assessed normality, while equality of variance was

assessed using the Levene's test statistic. If underpinning assumptions were violated, the non-parametric Kruskal-Wallis Test was used to compare continuous demographic variables. To take advantage of the repeated trials, linear mixed models (LMM) with one fixed (Group: 2 levels) and two repeated (Trial: 6 levels; Condition: 2 levels) factors were used to examine differences in HRs and RMS accelerations. Unlike repeated measures ANOVA, LMMs can accommodate an uneven number of observations for different participants and, hence was considered to offer more flexibility (Barton & Peat, 2014). To determine the potential influence of differences in walking speed on the accelerometer-based outcomes, the LMM analyses were conducted both with and without walking speed entered as a covariate. Furthermore, to determine whether symptom severity (MDS-UPDRS) and/or balance confidence (ABC scale) were predictive of an individual's trunk rhythmicity during stair negotiation, linear regression analyses were also performed. All statistical procedures were conducted using the Statistical Package for the Social Sciences (SPSS) (v22, SPSS Inc., USA) and the level of significance was set at $p < 0.05$.

3. Results

The results indicated the PD and control groups did not differ with respect to age, height, mass, body mass index, previous falls history, SMMSE or psychological factors influencing their quality of life (Table 1). However, compared with controls, the PD participants did report poorer balance confidence and a greater prevalence of physical difficulties affecting their quality of life.

Insert Table 1 about here.

Significant main effects for group and condition indicated that, irrespective of task, walking speed was significantly reduced for the PD group and that both participant cohorts descended the stairs more slowly than they ascended them. A significant group*condition interaction for cadence indicated that, irrespective of task, PD participants exhibited reduced cadence compared with controls and that control participants had a significantly increased cadence during stair descent compared with stair ascent (Table 2).

Insert Table 2 about here.

Statistical analysis of the harmonic ratios returned significant group*condition interactions for the AP, ML and VT movements of the trunk. Pairwise comparisons indicated that, irrespective of group, movement rhythmicity of the trunk along all three axes of motion was significantly poorer (lower HRs) during stair descent. Interestingly, compared with controls, participants with PD were observed to have improved AP trunk rhythmicity during stair ascent; although ML trunk rhythmicity was significantly poorer during this task for the patient cohort.

The differences observed in movement rhythmicity were complemented by differences in movement amplitude, which were represented by the RMS accelerations. Significant group*condition interactions indicated that VT trunk accelerations were significantly increased during stair descent for both groups. Interestingly, these pairwise comparisons also indicated that, compared with the PD cohort, the control participants exhibited increased VT trunk accelerations during stair ascent and stair descent. Repeating the LMM analyses with walking speed entered as a covariate returned the same statistical outcomes; suggesting that differences in

walking speed between the groups did not explain the differences in trunk rhythmicity. Furthermore, linear regression analyses indicated that neither symptom severity assessed via the MDS-UPDRS or self-reported balance confidence assessed with the ABC scale were significant predictors of the trunk rhythmicities exhibited by either group during stair ascent or descent.

4. Discussion

The HR has traditionally been used to examine gait stability for a range of populations during level-ground walking, but to our knowledge, this is the first study to use this acceleration-derived measure to investigate gait rhythmicity during stair ambulation in people with PD. The lower HRs recorded during stair descent for participants with PD and the age-matched controls suggest that older adults experience greater difficulties with maintaining rhythmic trunk movements during this task. It should be noted, however, that difference in walking speed have been shown to influence HR values (Cole, Sweeney, Conway, Blackmore, & Silburn, 2016); hence, it could be argued that the significantly slower walking speed observed for the two cohorts during the descending task may have contributed to the poorer rhythmicities observed. However, the inclusion of walking speed as a covariate in our models did not alter the significant statistical findings recorded between the groups or the walking tasks; suggesting that our findings were not biased by the slower speeds evident during stair descent. Compared with other steady-state gait tasks (e.g. overground walking), the HRs reported in this study were markedly lower, which suggests that stair ambulation likely poses a greater challenge to maintenance of rhythmic trunk control (Latt et al., 2009; Lowry et al., 2009). Given that the trunk contributes nearly two-thirds of an individual's body weight and that control of these segments is critical to maintaining dynamic equilibrium during locomotion (Winter, 1995), and subsequently poorer

gait rhythmicity has been associated with falling in people with PD (Cole et al., 2017; Latt et al., 2009) and that epidemiological research suggests a percentage of the falls experienced by people with PD occur during locomotor tasks (Ashburn et al., 2008), the lower HRs observed during stair descent may explain why a greater proportion of falls are attributed to stair descent than stair ascent (Startzell et al., 2000).

Interestingly, linear regression analyses suggested that neither differences in symptom severity or self-reported balance confidence significantly influenced the AP, ML or VT trunk rhythmicities of the PD participants or the older adults during stair negotiation. This finding was somewhat unexpected, as previous research has suggested that the alternate movement patterns adopted by community-dwelling older adults to ambulate stairs may be reflective of their increased concerns about falling (Brodie et al., 2015). Furthermore, previous prospective research has shown that poorer self-reported balance confidence is a significant independent predictor of future falls in people with PD (Cole, Rippey, Naughton, & Silburn, 2016). Collectively, these results support the hypothesis that impaired balance confidence has the potential to negatively influence falls risk in older adults and people with PD. However, the results of the current study suggest that this increased falls risk may not be evident during tightly regulated tasks, such as stair negotiation.

It is known that an important role of the trunk during locomotion is to attenuate the movement-related accelerations that threaten to destabilise the head (Kavanagh et al., 2004) and degrade the visual and vestibular information involved in balance control (Winter, 1995). Although both groups exhibited similar changes in stability between the two walking tasks, the

statistical outcomes suggested that participants with PD generally had poorer ML trunk stability than the older adults during stair ascent. This finding may be explained by the progressive nature of PD, which often leads to patients experiencing significant increases in muscle coactivity and joint stiffness with advanced disease state (Fasano, Aquino, Krauss, Honey, & Bloem, 2015). In situations where patients exhibit an increase in trunk stiffness, there is likely to be a commensurate reduction in the capacity of this segment to perform its role as a biological shock absorber. In turn, the rhythmicity of trunk movements will also be impaired, which can ultimately impact head stability and overall equilibrium. Support for this notion is provided by a recent study, which showed that people with PD who reported falling over a 12-month period exhibited greater levels of multifidus and erector spinae activity that were linked with the increased head, trunk and pelvis movements (Cole, Naughton, et al., 2016). Interestingly, however, despite these declines in ML trunk rhythmicity, the PD group were observed to have improved AP trunk rhythmicity during stair ascent. The improved AP rhythmicities evident for the PD cohort during this task may have been influenced by the patients using the horizontal edges of the steps as stationary visual cues. In recent years, there has been a growing body evidence to suggest that specific types of visual cues may be effective at alleviating or reversing the debilitating motor symptoms experienced by people with PD (Azulay et al., 1999; Ballanger et al., 2006). This transient ability for patients to overcome their motor limitations and to perform a once difficult task in a near to normal fashion is often referred to as paradoxical kinesia and has been most widely investigated in the context of restoring gait parameters in people with PD (Bagley, Kelly, Tunnicliffe, Turnbull, & Walker, 1991; Lewis, Byblow, & Walt, 2000). With this in mind, it could be argued that the visual cues provided by the horizontal edges of the steps may

have helped to improve the gait patterns of the PD participants during the stair walking tasks and, ultimately contributed to the relatively few differences recorded between the two cohorts.

While this study highlighted numerous differences in gait rhythmicity during stair walking, it is important to consider the possible influence of a number of limitations on the reported outcomes. First, although participants were contacted using a randomised strategy, the specific inclusion criteria (e.g. the ability to complete the stair walking tasks without the use of the handrails) meant that the patients recruited into this study typically had mild to moderate symptoms. Furthermore, patients were assessed while receiving their usual anti-Parkinsonian medications (1 took no medications), which may mean that the results are only applicable to patients whose symptoms are well managed with traditional pharmacological therapies. Nevertheless, it is important to consider that symptoms of postural instability and gait difficulties are only partially responsive to oral medications (Grimbergen, Munneke, & Bloem, 2004), suggesting that the reported findings may be applicable to the wider PD community with mild to moderate symptom severity. Second, although this study investigated movement rhythmicity using a similar laboratory-based staircase to previous studies (Adkin et al., 2003; Bosse et al., 2012), it could be argued that participants were unable to achieve a true steady-state gait pattern. Given this point, it is possible that the transferability of these findings may be limited to everyday tasks that require individuals to negotiate a small number of steps. Future research might seek to evaluate gait rhythmicity during longer bouts of stair negotiation to examine whether movement patterns are more rhythmic while ascending or descending a longer flight of stairs.

In summary, both older adults and people with PD exhibit significantly poorer trunk rhythmicities while descending three-step staircase compared with ascending the same set of stairs. The poorer trunk rhythmicities recorded during stair descent suggest that older individuals with and without PD face similar challenges during stair negotiation. Furthermore, the significant association identified between balance confidence and trunk rhythmicity also suggested that those who were more fearful of falling were more likely to exhibit less rhythmicity while descending the stairs. Collectively these findings indicate that acceleration-based measures of trunk motion may provide useful insight into the dynamic stability requirements involved with stair negotiation.

Authors' Contributions

1. **Research project:** A. Conception B. Organization C. Execution
2. **Data Analysis:** A. Design B. Execution
3. **Manuscript:** A. First draft B. Review & Critique
4. **Other:** A. Study supervision

Mr Zachary J. Conway	1A, 1B, 1C, 2A, 2B, 3A
Dr Tim D. Blackmore	1C, 2A, 3B
Prof Peter A. Silburn:	1A, 1B, 3B, 4A
Dr Michael H. Cole	1A, 1B, 1C, 2A, 2B, 3B, 4A

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Table 1: Demographics, falls history, fear of falling, cognition, quality of life, medication use and disease-specific scores for the Parkinson’s disease and control participants. Data represent mean (+1 SD), absolute numbers (percentage sample)[†] or medians (range)[‡].

	Parkinson’s Disease	Controls	Test	p-value
<i>Demographics</i>				
Age (years)	67.1 (8.2)	62.9 (8.0)	1	0.215
Height (m)	1.7 (0.1)	1.7 (0.1)	1	0.489
Mass (kg)	73.8 (14.9)	79.7 (13.3)	2	0.564
Body Mass Index (kg/m ²)	26.1 (3.8)	27.3 (3.0)	2	0.684
Number of males	8 (66.6%)	6 (50.0%)	3	0.408
<i>Falls and Fear of Falling</i>				
Previous falls [†]	3 (25.0%)	3 (25.0%)	3	1.000
ABC-6	66.0 (28.1)	92.6 (5.5)	1	0.004
<i>Cognition and Quality of Life</i>				
SMMSE	29.2 (1.0)	29.8 (0.4)	2	0.062
SF-8 Physical component	48.2 (5.4)	56.6 (4.2)	2	0.001
SF-8 Mental component	54.3 (4.3)	56.6 (3.9)	2	0.104
PDQ-8	21.6 (15.9)	-	-	-
<i>Neurological exam</i>				
Disease duration (years)	4.3 (2.0)	-	-	-
MDS-UPDRS III	26.6 (11.9)	-	-	-
No PD medications [†]	1 (8.3%)	-	-	-
Levodopa dose (mg/day)	695.3 (362.8)	-	-	-
Dopamine agonists [†]	2 (16.7%)	-	-	-
COMT inhibitors [†]	6 (50.0%)	-	-	-
MAO inhibitors [†]	4 (33.3%)	-	-	-
Benzodiazepines [†]	0 (0.0%)	-	-	-
N-FOG	8.6 (11.3)	-	-	-
Hoehn & Yahr [‡]	1.5 (1.0-3.0)	-	-	-
Schwab & England ADL scale	83.3 (8.6)	-	-	-

ABC-6: 6-item Activities-specific Balance Confidence scale; **SMMSE:** Standardized Mini-Mental State Examination; **SF-8:** 8-item Short-Form Questionnaire; **N-FOG:** New Freezing of Gait questionnaire; **PDQ-8:** 8-item Parkinson’s Disease Questionnaire; **MDS-UPDRS III:** Motor subscale of the Unified Parkinson’s Disease Rating Scale; **COMT Inhibitors:** Catechol-O-Methyl Transferase inhibitors; **MAO Inhibitors:** Monoamine oxidase inhibitors; **ADL:** Activities of Daily Living; **Test 1:** one-way ANOVA; **Test 2:** Kruskal-Wallis Test;

Test 3: Chi-square.

Table 2: Walking speed, cadence and anterior-posterior (AP), medial-lateral (ML) and vertical (VT) trunk harmonic ratios and root mean square accelerations for the Parkinson's disease and control group during stair ascent and stair descent. Data represent the means (and standard deviations).

		STAIR ASCENT		STAIR DESCENT		Main Effects		Interactions
		Parkinson's Disease	Control	Parkinson's Disease	Control	Group	Condition	Group*Condition
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)			
Gait Characteristics								
	<i>Walking Speed (m/s)</i>	0.31 (0.06)	0.37 (0.06)	0.28 (0.12)	0.34 (0.15)	¥	Ω	ns
	<i>Cadence (steps/min)</i>	83.66 (12.85)	97.69 (15.40)	80.46 (13.19)	99.17 (20.42)	¥	Ω	ƒ, b, i, ii
Harmonic Ratios								
	<i>AP</i>	1.99 (0.64)	1.69 (0.47)	1.08 (0.30)	1.06 (0.21)	¥	Ω	ƒ, a, b, i
<i>Trunk</i>	<i>ML</i>	1.83 (0.44)	2.00 (0.52)	1.38 (0.34)	1.38 (0.32)	ns	Ω	ƒ, a, b, i
	<i>VT</i>	2.23 (0.74)	2.05 (0.74)	1.27 (0.26)	1.42 (0.27)	ns	Ω	ƒ, a, b
Root Mean Square Accelerations (m/s²)								
	<i>AP</i>	0.15 (0.03)	0.16 (0.03)	0.12 (0.02)	0.14 (0.03)	¥	Ω	a, b
<i>Trunk</i>	<i>ML</i>	0.12 (0.02)	0.14 (0.03)	0.14 (0.03)	0.16 (0.04)	¥	Ω	a, b
	<i>VT</i>	0.20 (0.03)	0.23 (0.05)	0.23 (0.05)	0.30 (0.07)	¥	Ω	ƒ, a, b, ii

ns = no significant differences; ¥ = Significant Group effect; Ω: Significant Condition effect; ƒ = Significant Group*Condition interaction; a = Stair ascent significantly different to stair descent for PD; b = Stair ascent significantly different to stair descent for AC; i = PD significantly different to controls during ascent; ii = PD significantly different to controls during descent