Gait biofeedback training in people with Parkinson's disease: a pilot study

Kate McMaster
Australian Catholic University - Brisbane Campus
Michael H Cole
Australian Catholic University - Brisbane Campus
Daniel Chalkley
Australian Catholic University - Brisbane Campus
Mark W. Creaby (mark.creaby@acu.edu.au)
Australian Catholic University - Brisbane Campus https://orcid.org/0000-0002-7959-7203

Research

Keywords: Idiopathic Parkinson disease, Biofeedback, Gait, Biomechanics

Posted Date: March 8th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-277548/v1

Abstract

Background

People with Parkinson's disease (PD) are at a high risk of falls, with ~ 60% experiencing a fall each year. Greater mediolateral head and pelvis motion during gait are known to increase the risk of falling in PD, however the ability to modify these aspects of gait has not been examined. Thus, this study aimed to examine whether mediolateral trunk, head and pelvis motion during walking could be successfully decreased in people with PD using real-time biofeedback.

Methods

Participants were provided with real-time biofeedback regarding their mediolateral trunk lean via a visual projection whilst walking along an 8-metre indoor walkway.

Using the feedback provided, they were asked to reduce the magnitude of their mediolateral trunk lean. Gait was recorded for four conditions (i) Baseline, (ii) Intervention, (iii) immediately Post-Intervention, and (iv) one-week Follow-Up. Biomechanical variables associated with falls risk were compared between conditions, including normalised mediolateral motion, gait velocity and stride length.

Results

A reduction in mediolateral trunk lean, step length and gait velocity from Baseline to the Intervention and Post-intervention conditions was observed. Contrary to this, increased normalised ML pelvis and trunk motion was observed between the Baseline and Intervention conditions, but returned to Baseline levels in the Post-Intervention condition.

Conclusions

Results from the current study suggest that real-time visual biofeedback may be effective at modifying specific gait characteristics that are associated with falls in PD. Further research is required to better understand the influence of this intervention approach has upon falls incidence.

Trial Registration:

Australian New Zealand Clinical Trials Registry ACTRN12620000994987. Registered 10 June 2020 - Retrospectively registered, https://anzctr.org.au/Trial/Registration/TrialReview.aspx?id=380324.

Background

PD is a neurologically degenerative disease that inhibits motor control, inducing bradykinesia, muscle rigidity and akinesia. These symptoms likely contribute to ~ 60% of people with PD experiencing at least one fall a year [1]. Of these falls, about half occur during ambulation [2]. A recent meta-analysis identified a shorter step length and a slower preferred gait velocity as two biomechanical factors that increase an individual's risk of falling [3]. While some interventions have been able to increase step length and gait velocity, they have not been associated with a reduction in falls incidence [4, 5]. Interestingly, the meta-analyses also identified that, when normalized to gait velocity, greater frontal plane motion of the axial skeleton during walking increases the risk of falls in those with PD [3]. Yet, to date, the effect of modifying the frontal plane motion of the axial skeleton on gait mechanics associated with falls risk has not been investigated.

During walking, the motions of the body's center of mass (COM) are heavily influenced by the motions of the axial skeleton (head, trunk, and pelvis), which represent ~ 77% of the body's overall mass [6]. In PD gait, as in healthy gait, the body's COM oscillates mediolaterally (ML) to help maintain balance by placing it closer to the base of support (i.e. the position of the supporting foot). This oscillation is partially achieved by leaning the trunk from side-to-side in the frontal plane.

The increased falls risk associated with greater frontal plane motion of the axial skeleton in PD fallers may be indicative of a reduction in mechanical stability as a result of moving the COM too far laterally relative to the base of support.
Minimizing ML trunk lean may therefore contribute to a reduction in ML displacement of the COM, permitting a more stable posture. In addition, healthy gait allows the pelvis and trunk to modulate the motion of the head, allowing for more stable visual and vestibular information that may also facilitate falls avoidance. Individuals with PD however often exhibit an 'en bloc' motion pattern. This pattern is characterized by a more rigid interaction between the pelvis, trunk and head, with less attenuation from the lower segments (i.e. pelvis) to those higher (i.e. head). Decreasing ML head, trunk or pelvis motion may therefore improve COM control and sensory perception, consequently enhancing stability and decreasing falls risk.

An emerging body of evidence indicates that subtle changes to walking mechanics can be achieved in a relatively short period of time by utilizing real-time biofeedback. This approach typically involves measuring specific gait mechanics which are then immediately fed-back to the participant in visual, audible or tactile form. Studies in other populations have demonstrated changes in ML trunk lean with as little as a single session of feedback [7, 8]. Whilst there is limited evidence for the use of biofeedback during walking in individuals with PD, similar biofeedback protocols during balance tasks suggest that it has the potential to modify motion patterns in this population [9, 10].

The purpose of this study was therefore to determine i) the short-term effects of a real-time biofeedback intervention on ML trunk lean in people with PD and ii) the short-term effects of a real-time biofeedback intervention on other gait parameters associated with falls risk or balance. We hypothesized that i) ML

trunk lean would decrease as a result of the real-time biofeedback intervention and ii) other gait parameters would change in a direction suggestive of improved balance and/or reduced falls risk.

Methods

Participants

Twenty-four individuals with clinically diagnosed idiopathic PD (18 male and 6 female, 68 ± 7.6 years) participated in this cross-sectional laboratory-based study.

Participants were a convenience sample recruited from the local community (Brisbane, Australia) between October 2018 and September 2019.
Participants were eligible provided they: (a) were diagnosed with PD by a neurologist; (b) presented with PD-related symptoms ranging in severity from 1–3 on the Hoehn & Yahr scale; (c) had no significant surgery within the last three months affecting their gait; (d) experienced no recurrent pain or injury affecting their gait; (e) were able to walk without assistance; (f) had no significant visual (Bailey-Lovie high contrast visual acuity < 0.30 logMAR) or cognitive impairment (Mini Mental State Exam (MMSE) score ≥ 24/30); (g) had not received deep brain stimulation; and (h) were aged under 80 years.

All participants provided written informed consent prior to testing in accordance with the Declaration of Helsinki.
Data presented here are reported in accordance with the STROBE guidelines and were collected at the Australian Catholic University, Brisbane as approved by the institution's Research Ethics Committee (Ref: 2018-196H). Sample size was estimated using G-Power [11] based on a Repeated Measures ANOVA study design, across four time points. As no previous data were available regarding changes in ML trunk lean, the default medium effect size was selected. For an alpha level of 0.05 and power of 80%, the estimated sample size was n = 24.

Protocol

Participants were assessed for symptom severity (i.e. Hoehn & Yahr and MDS-UPDRS part III), cognition (MMSE), vision (Bailey-Lovie High Contrast visual acuity) and falls efficacy (FES-I). Following these assessments, reflective markers were placed on anatomical landmarks in accordance with the full-body Plug-in-Gait kinematic model (Vicon Nexus, Version 2.6, Oxford Metrics Ltd., Oxford, United Kingdom).

Participants were barefoot and wore shorts and a crop top for women or no top for men.

Three-dimensional gait analysis was completed over 4 conditions across 2 sessions. Session 1 (Baseline, Intervention and Post-intervention conditions) lasted ~ 1.5 hours, whilst Session 2 (Follow-up condition) lasted ~ 1 hour and was completed 7 days (± 1 day) after Session 1. Participants completed both assessments in an optimally medicated state (i.e. ON-phase).

Session 1 consisted of participants completing the Baseline condition walking trials, which involved walking at their own self-selected pace along an 8-metre walkway (5–10 trials).
Following the Baseline condition feedback familiarization commenced; participants were asked to stand in the center of the walkway, face the projection screen displaying biofeedback, and slowly move their trunk from left to right with increasing amplitude.
Once the biofeedback tool and task were understood, participants completed a minimum of three walking familiarization trials.
The Intervention condition required participants to focus on the biofeedback displayed on a 2.16m^2 projector screen placed at the end of the walkway. Calculation and display of the biofeedback is described below. Following walking familiarization, 20 biofeedback Intervention trials were completed. Immediately following the Intervention trials, participants rested for 3-minutes, then completed 2-minutes of walking without feedback.
Participants then completed the Post-intervention condition, where they walked without feedback.

For Session 2, participants returned to the laboratory to complete the Follow-up condition, where they walked without feedback along the walkway, again, adhering to the Baseline condition protocol.
For each condition a minimum of 5 trials were recorded.

Data Collection

During all walking trials, a 20-camera Vicon three-dimensional motion analysis system (Oxford Metrics Ltd., Oxford, United Kingdom) recorded gait kinematics at 150 Hz. This system was synchronized with a single ground-embedded force plate (1500 Hz; Advanced Mechanical Technology Inc., Watertown, MA, USA) located in the center of the walkway to determine foot-strike and toe-off events.

Biofeedback

Trunk marker trajectories were computed in real-time using Vicon Nexus software (Version 2.6, Vicon Motion Analysis, Oxford, England) and streamed to MATLAB (MathWorks, Massachusetts, USA), where a customized program calculated the ML lean of the trunk in the frontal plane of the laboratory. These data were projected onto a graph (Fig. 1) and displayed as a moving line. The horizontal axis representative of the magnitude of ML trunk lean (degrees) and the vertical axis representative of time (seconds).

During the Intervention condition, participants were provided with a target reduction of 30% of their peak ML trunk lean relative to Baseline.
This desired modification was visually represented in real-time on the biofeedback projection by a centrally located white space (target zone), with neighboring red outer boundaries used to indicate motion beyond the target (Fig. 1).

Data analysis

Three-dimensional reconstruction of marker trajectories was performed in Vicon Nexus. Marker trajectories were filtered using a generalized cross-validation quintic smoothing spline with a mean

squared error of 15mm^2 [12]. Filtered trajectory data were then used to model segment kinematics and COM trajectories as well as spatiotemporal gait parameters (Vicon Plug-in-Gait). Trials were cropped to remove the first and last 2-meters of each trial to ensure data represented constant velocity walking; with multiple steps in each of the five trials per condition (final 5 trials of intervention condition), approximately 20 strides per condition were analyzed. Peak ML trunk lean in the frontal plane of the laboratory was averaged across left and right peaks and then averaged across trials. Absolute ML head, trunk and pelvis motion were measured by calculating the average range of motion of the mathematically-derived COM of each segment in the ML direction, relative to the plane of progression. Absolute ML motion values were then normalized to gait velocity (mean ML motion/gait velocity). Other variables evaluated because of their association with falls risk and balance were step length [13], gait velocity [14–16] and COM to base of support distance [17].

All statistical analyses were conducted using SPSS version 25 (IBM Corporation, New York, USA), with an alpha level set at $p = 0.05$. A repeated measures analysis of variance was used to compare variables across the four conditions (i.e. Baseline, Intervention, Post-Intervention, Follow-up). Data were checked for normality using the Shapiro-Wilk's test and sphericity using Mauchly's test. Where normality could not be assumed, data were log transformed and reassessed for normality prior to inferential statistics. Where assumptions of sphericity ($p < 0.05$) were violated, the Greenhouse-Geisser adjustment (ε) was utilized. For comparisons where significant main effects were present ($p < 0.05$), post-hoc comparisons were completed using the Tukey's Least Significant Difference method. Standardised mean differences (SMD; Cohen's *d*) were calculated as a measure of effect size.

Results

Twenty-five individuals participated in Session 1, however one individual did not complete Session 2 due to travel issues (Additional file 1). Only participants who completed both Sessions (n=24) were included in our analysis (Table 1).

Gait Biomechanics

All outcome measures were normally distributed, apart from normalized ML head, trunk and pelvis motion. These outcomes were log-transformed and reassessed for normality prior to further analysis. The primary variable of ML trunk lean was significantly different between conditions, ($F(3,69)=9.22$, $p<0.001$). Post-hoc analysis show ML trunk lean decreased from Baseline to Intervention and Post-intervention conditions, with medium and small effect sizes (SMD=0.5 and 0.32, respectively). However, no difference was observed between Baseline and Follow-up conditions (Table 2).

Consistent with the primary analysis, absolute ML head motion was lower in the Intervention and Post-Intervention conditions when compared with Baseline ($F(1.83,42.16)=2.14$, $p=0.001$; Table 2). Absolute ML pelvis motion was lower than Baseline at the Post-Intervention and Follow-up conditions ($F(3, 69)=4.49$; $p=0.003$), despite no difference between the Baseline and Intervention conditions.

Normalized ML motion data, i.e. divided by gait velocity, did not follow the same pattern as the absolute ML motion data, with no differences observed in normalized ML head motion. Normalized ML trunk ($F(1.88, 43.13)=7.87$, $p=0.002$) and pelvis ($F(1.83, 42.05)=8.57$, $p=0.001$) motion in fact increased from the Baseline to the Intervention condition with medium effect sizes (SMDs=0.5 and 0.54, respectively). Both outcomes returned to levels similar to Baseline in the Post-Intervention and Follow-Up conditions.

Analysis of gait velocity ($p<0.001$) and stride length ($p=0.001$) indicated participants walked slower ($F(1.74, 39.93)=16.59$) and took shorter strides ($F(1.87, 43.17)=18.77$) during the Intervention condition compared with Baseline. These decreases were sustained during the Post-intervention condition, although the effect sizes were small (SMDs=0.25) and both returned to baseline levels at Follow-up (Table 2). COM to base of support distance also decreased from the Baseline to Intervention conditions with a small effect ($F(2.49, 57.17)=3.26$; SMD=0.34), but no other differences were observed.

Discussion

This is the first study to examine whether it is possible to modify the normalized ML motion of the axial skeleton during walking gait in people with PD. Our findings support the primary hypothesis and demonstrate that people with PD can decrease ML trunk lean during gait with the assistance of visual biofeedback. The differences observed between the Baseline and Intervention conditions are in line with previous literature that found individuals with PD are able to utilize visual biofeedback to modify trunk position and lateral swaying motions during standing [18, 19].

ML trunk lean was also reduced relative to Baseline in the Post-intervention condition.
This provides evidence of short-term retention of the biofeedback-induced adaptations. No retention of effect was observed during the one-week Follow-up condition however. These findings suggest that one intervention session was insufficient to allow for notable skill retention in individuals with PD. Whilst skill retention in a young healthy population is achievable following a single biofeedback session [20], it has been reported that repetition over several sessions (e.g. weeks or months) is required for people with PD [21, 22]. Future research may seek to determine whether longer lasting effects can be achieved with greater exposure to the biofeedback method over an extended time period.

Despite the efficacy of the intervention for reducing ML trunk lean, the provision of biofeedback also resulted in changes in kinematic and spatiotemporal outcomes that may be suggestive of decreased mechanical stability and thus an increased likelihood of falls. Of note, gait velocity and stride length decreased during the Intervention condition relative to all other conditions. As gait velocity is the result of distance covered per unit of time, concurrent decreases in stride length were not surprising and may be suggestive of a decrease in stability [3]. Decreased dynamic stability was also reflected in a decreased COM to base of support distance during the Intervention condition, indicative of greater ML motion of the whole-body COM. Given the influence gait velocity has on several measures of walking stability, the biomechanical consequences of biofeedback interventions on gait velocity and subsequent measures of stability must be given further consideration.

Normalized ML trunk and pelvis motion (i.e. that divided by gait velocity) increased from the Baseline to Intervention condition, before decreasing again during the Post-intervention and Follow-up conditions. Contrary to this, there was no difference in absolute ML trunk and pelvis motion between Baseline and Intervention conditions. Thus, it appears likely that the observed increase in normalized ML trunk and pelvis motion during the Intervention condition occurred primarily as a result of the decrease in gait velocity during this condition. The reduction in gait velocity and subsequent effect upon normalized ML motion measures may be explained by the use of a cueing strategy that sought to provide individuals with greater spatial awareness. As PD individuals are often found to exhibit a decreased postural reserve (i.e. muscle strength, sensory motor integration and higher-level cortical control), increased attention is required to maintain posture and stability. Re-weighting of attention to a separate motor or cognitive task diminishes the attention that can be assigned to controlling mechanical stability and may result in inhibition of the automaticity of gait [23]. In conjunction, a deliberate reduction in gait velocity may have been utilized to allow greater time to adequately process the additional visual information prior to making a postural adjustment. Similar re-weighting of attentional resources has been noted in dual-tasking research where individuals often prioritize all elements of the task equally, rather than giving greatest importance to mechanical stability [24, 25].

It is interesting to note that the increases in normalized ML trunk and pelvis motion were not accompanied by a significant change in normalized ML head motion. These findings may be indicative of successful dampening of motion by the pelvis and trunk, preventing unfavorable ML motion of the head [26, 27]. While both greater head and pelvis motion have been linked with increased falls risk in PD [3], they are strongly correlated with each other. Thus, it is not known which of these measures, or potentially both, are causative of the observed increased falls risk. Regardless, as there was no decrease in either of these measures with the intervention, an alternative approach should be considered in any attempt to translate the observed reduction in ML trunk lean to normalized ML head and pelvis motion.

Visual biofeedback proved able to successfully decrease ML trunk lean, yet the influence of this approach upon falls risk is less clear given the observed changes in ML pelvis and trunk motion. A revised biofeedback intervention approach may therefore be necessary to achieve the desired gait modification, with the consideration of biofeedback effect on gait velocity of importance. Use of a treadmill would allow gait velocity to be controlled across conditions, potentially removing the influence of gait velocity changes on normalized ML motion. This form of intervention would allow for greater exposure to the biofeedback, which may enhance the potential effects of the intervention. The use of treadmill-based interventions is supported by prior literature, which shows it can successful modify step length and gait velocity [28, 29].

There are limitations to this study that must be acknowledged. First, it was beyond the scope of this research to restrict individuals to meet specific gait impairments. Individuals with greater baseline ML motion may have had greater scope to decrease ML motion, potentially impacting the observed responses to the biofeedback. Nevertheless, given the known association between greater ML motion and falls risk, any decrease to ML motion has the potential to benefit all individuals with PD, particularly

considering the high incidence of falls in this population. Second, the biofeedback employed a target reduction in trunk lean of 30%. This is less than biofeedback studies in otherwise healthy populations that targeted reductions of 50 and 80% [7, 20]. As the current study was targeting a movement pattern associated with falls in a population at high risk of falling, based on pilot investigations, we considered the 30% target to represent a significant challenge for participant's without unduly elevating falls risk. It should be noted that a larger target reduction may have elicited a greater change in our outcome variables. Third, despite findings suggesting it was feasible to modify absolute ML head motion through changes to ML trunk lean, resultant changes to falls risk cannot be assumed without prospective falls analysis. The current study serves to inform future prospective research by reporting the immediate and short-term effects of the intervention on biomechanical factors associated with falls risk in PD.

Conclusions

In conclusion, ML trunk lean was found to decrease as a result of real-time biofeedback but returned to baseline levels following cessation of biofeedback. Despite observed decreases in ML trunk lean, normalized ML trunk and pelvis motion increased as a result of the intervention. This potential decrease in walking stability may be explained by the reduction in gait velocity observed in response to an elevated attentional demand. These findings suggest that while the biofeedback approach used in this study may be useful for effecting short-term changes in trunk lean for people with PD, the potential negative effect upon other gait outcomes must be further evaluated. Additional research is needed to better understand how biofeedback can be used as a potential tool for biomechanical alteration within the PD population.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was provided by the Australian Catholic University, Human Research Ethics Committee (Ref: 2018-196H). All participants provided written informed consent prior to testing in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The dataset used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sector.

Authors' contributions

KM, MHC, DC and MWC contributed towards the design, organization and execution of the study, and interpretation of the statistical analyses. DC authored the real-time biofeedback software. KM executed the statistical analyses and wrote the first draft of the work. MHC, DC and MWC provided substantive revision of the manuscript drafts. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

Abbreviations

PD: Parkinson's Disease

COM: Centre of mass

ML: mediolateral

MMSE: Mini mental state exam

SMD: Standardised mean difference

References

1. Allen, N.E., et al., *The effects of an exercise program on fall risk factors in people with Parkinson's disease: a randomized controlled trial.* Mov Disord, 2010. 25(9): p. 1217-25.
2. Ashburn, A., et al., *The circumstances of falls among people with Parkinson's disease and the use of Falls Diaries to facilitate reporting.* Disability and Rehabilitation, 2008. 30(16): p. 1205-1212.
3. Creaby, M.W. and M.H. Cole, *Gait characteristics and falls in Parkinson's disease: A systematic review and meta-analysis.* Parkinsonism & Related Disorders, 2018. 57: p. 1-8.
4. Ashburn, A., et al., *A randomised controlled trial of a home based exercise programme to reduce the risk of falling among people with Parkinson's disease.* J Neurol Neurosurg Psychiatry, 2007. 78(7): p. 678-84.
5. Protas, E.J., et al., *Gait and step training to reduce falls in Parkinson's disease.* NeuroRehabilitation, 2005. 20(3): p. 183-90.
6. Plagenhoef, S., F.G. Evans, and T. Abdelnour, *Anatomical Data for Analyzing Human Motion.* Research Quarterly for Exercise and Sport, 1983. 54(2): p. 169-178.

7. Davis, J.R., et al., *Trunk sway reductions in young and older adults using multi-modal biofeedback.* Gait Posture, 2010. 31(4): p. 465-72.
8. Simic, M., et al., *Trunk lean gait modification and knee joint load in people with medial knee osteoarthritis: the effect of varying trunk lean angles.* Arthritis Care Res (Hoboken), 2012. 64(10): p. 1545-53.
9. Mirelman, A., et al., *Audio-biofeedback training for posture and balance in patients with Parkinson's disease.* J Neuroeng Rehabil, 2011. 8: p. 35.
10. van den Heuvel, M.R.C., et al., *The effects of visual feedback during a rhythmic weight-shifting task in patients with Parkinson's disease.* Gait Posture, 2016. 48: p. 140-145.
11. Faul, F., et al., *Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses.* Behav Res Methods, 2009. 41(4): p. 1149-60.
12. Woltring, H., *A Fortran package for generalized, cross-validatory spline smoothing and differentiation.* Advances in Engineering Software, 1986. 8(2): p. 104-13.
13. Cole, M.H., et al., *Imposed Faster and Slower Walking Speeds Influence Gait Stability Differently in Parkinson Fallers.* Arch Phys Med Rehabil, 2017. 98(4): p. 639-648.
14. Hausdorff, J.M., et al., *Gait variability and basal ganglia disorders: stride-to-stride variations of gait cycle timing in Parkinson's disease and Huntington's disease.* Mov Disord, 1998. 13(3): p. 428-37.
15. Lord, S., et al., *Predicting first fall in newly diagnosed Parkinson's disease: Insights from a fall-naive cohort.* Movement Disorders, 2016. 31(12): p. 1829-36.
16. Morris, M.E., et al., *The biomechanics and motor control of gait in Parkinson disease.* Clinical Biomechanics, 2001. 16(6): p. 459-470.
17. Cole, M.H., et al., *Falls in Parkinson's disease: Kinematic evidence for impaired head and trunk control.* Movement Disorders, 2010. 25(14): p. 2369-2378.
18. Caudron, S., et al., *Evaluation of a visual biofeedback on the postural control in Parkinson's disease.* Neurophysiol Clin, 2014. 44(1): p. 77-86.
19. van den Heuvel, M.R., et al., *Effects of augmented visual feedback during balance training in Parkinson's disease: a pilot randomized clinical trial.* Parkinsonism Relat Disord, 2014. 20(12): p. 1352-8.
20. Creaby, M.W. and M.M. Franettovich Smith, *Retraining running gait to reduce tibial loads with clinician or accelerometry guided feedback.* J Sci Med Sport, 2016. 19(4): p. 288-92.
21. Nieuwboer, A., et al., *Cueing training in the home improves gait-related mobility in Parkinson's disease: the RESCUE trial.* J Neurol Neurosurg Psychiatry, 2007. 78(2): p. 134-40.
22. Schlick, C., et al., *Visual cues combined with treadmill training to improve gait performance in Parkinson's disease: a pilot randomized controlled trial.* Clin Rehabil, 2016. 30(5): p. 463-71.
23. Wu, T., M. Hallett, and P. Chan, *Motor automaticity in Parkinson's disease.* Neurobiol Dis, 2015. 82: p. 226-234.

24. Bloem, B.R., et al., *Prospective assessment of falls in Parkinson's disease.* J Neurol, 2001. 248(11): p. 950-8.
25. Yogev, G., et al., *Dual tasking, gait rhythmicity, and Parkinson's disease: which aspects of gait are attention demanding?* Eur J Neurosci, 2005. 22(5): p. 1248-56.
26. Kavanagh, J.J., S. Morrison, and R.S. Barrett, *Coordination of head and trunk accelerations during walking.* Eur J Appl Physiol, 2005. 94(4): p. 468-75.
27. Mazza, C., et al., *Control of the upper body accelerations in young and elderly women during level walking.* J Neuroeng Rehabil, 2008. 5: p. 30.
28. Ganesan, M., et al., *Partial Body Weight-Supported Treadmill Training in Patients With Parkinson Disease: Impact on Gait and Clinical Manifestation.* Arch Phys Med Rehabil, 2015. 96(9): p. 1557-65.
29. Herman, T., et al., *Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: a pilot study.* Arch Phys Med Rehabil, 2007. 88(9): p. 1154-8.

Tables

Table 1. Participant demographics at baseline.

	Participants (n = 24)
Demographics	
Age (years) *	68 (7.59)
Gender (male : female)	18 : 6
Height (cm)*	173 (7.08)
Mass (kg)*	83 (15.90)
BMI (kg/m^2)*	28 (5.15)
Falls History and Fear of Falls	
Falls efficacy scale (/64) #	24 (8)
Fallers: Non-fallers^	12 : 12
Cognitive Functioning	
Mini-mental state exam (/30) #	29.5 (2)
Disease Severity	
H & Y Score (1 : 2 : 3)	6 : 16 : 2
MDS-UPDRS Score (/132) #	23 (10.75)

Note. * Data are continuous and reported as Mean (Standard Deviation). Mean values are expressed to the nearest whole. # Data are scale based and reported as Median (Interquartile range). ^Fallers defined as having experienced a fall in the 12 months prior to data collection. H&Y: Hoehn and Yahr. MDS-UPDRS: Movement Disorder Society – Unified Parkinson's Disease Rating Scale.

Table 2. Spatiotemporal and kinematic characteristics of participants during the four walking conditions.

	Condition (mean (SD))					Effect size (SMD)				
	Baseline	Intervention	Post-Intervention	Follow-Up	*Sig.*	B - I	B - PI	B - FU	I - PI	I - FU	PI - FU
ɔtemporal cteristics											
velocity (m/s)	1.12 (0.16)	1.01 (0.21)	1.10 (0.17)	1.12 (0.19)	a, b, d, e	.67	.27	-	.50	.67	-
le length (m)	1.22 (0.16)	1.13 (0.20)	1.20 (0.17)	1.22 (0.17)	a, b, d, e, f	.56	.25	-	.37	.58	.29
ental motion											
Trunk lean (°)	4.19 (1.40)	3.48 (1.50)	3.88 (1.46)	4.04 (1.50)	a, b, d, e	.50	.32	-	.39	.57	-
olute ML Head n (cm)	5.77 (1.39)	5.38 (2.07)	5.33 (1.23)	5.55 (1.49)	a, b	.49	.45	-	-	-	-
olute ML Trunk n (cm)	5.01 (1.15)	5.04 (1.24)	4.81 (1.07)	4.85 (1.14)	ns	-	-	-	-	-	-
olute ML Pelvis n (cm)	4.80 (0.89)	4.74 (0.91)	4.51 (0.79)	4.57 (0.74)	b, c, d	-	.44	.46	.39	-	-
malised ML motion n•s^{-1})	5.38 (2.07)	5.71 (2.71)	5.07 (1.83)	5.22 (2.15)	ns	-	-	-	-	-	-
malised ML motion n•s^{-1})	4.67 (1.70)	5.41 (2.35)	4.57 (1.57)	4.57 (1.76)	a, d, e	.50	-	-	.46	.51	-
malised ML motion n•s^{-1})	4.45 (1.40)	5.03 (1.86)	4.27 (1.24)	4.26 (1.32)	a, d, e	.54	-	-	.52	.57	-
M to base of rt distance	4.69 (1.17)	4.37 (1.20)	4.51 (1.24)	4.48 (1.28)	a	.34	-	-	-	-	-

Note. “SD”, standard deviation. “SMD”, standardised mean difference. “ML”, mediolateral. “ns”, no difference between conditions. “a”, difference between baseline and intervention. “b”, difference between baseline and post-intervention. “c”, difference between baseline and follow-up. “d”, difference between Intervention and post-intervention. “e”, difference between intervention and follow-up. “f”, difference between post-intervention and follow-up. Sig: Statistically significant difference between conditions. “B”, Baseline. “I”, Intervention. “PI”, Post-intervention. “FU”, Follow-up.

All statistically significant differences are to the $p < 0.05$ level. SMD values; Small = 0.2-0.5; Medium = 0.5-0.8; Large > 0.8.

Figures

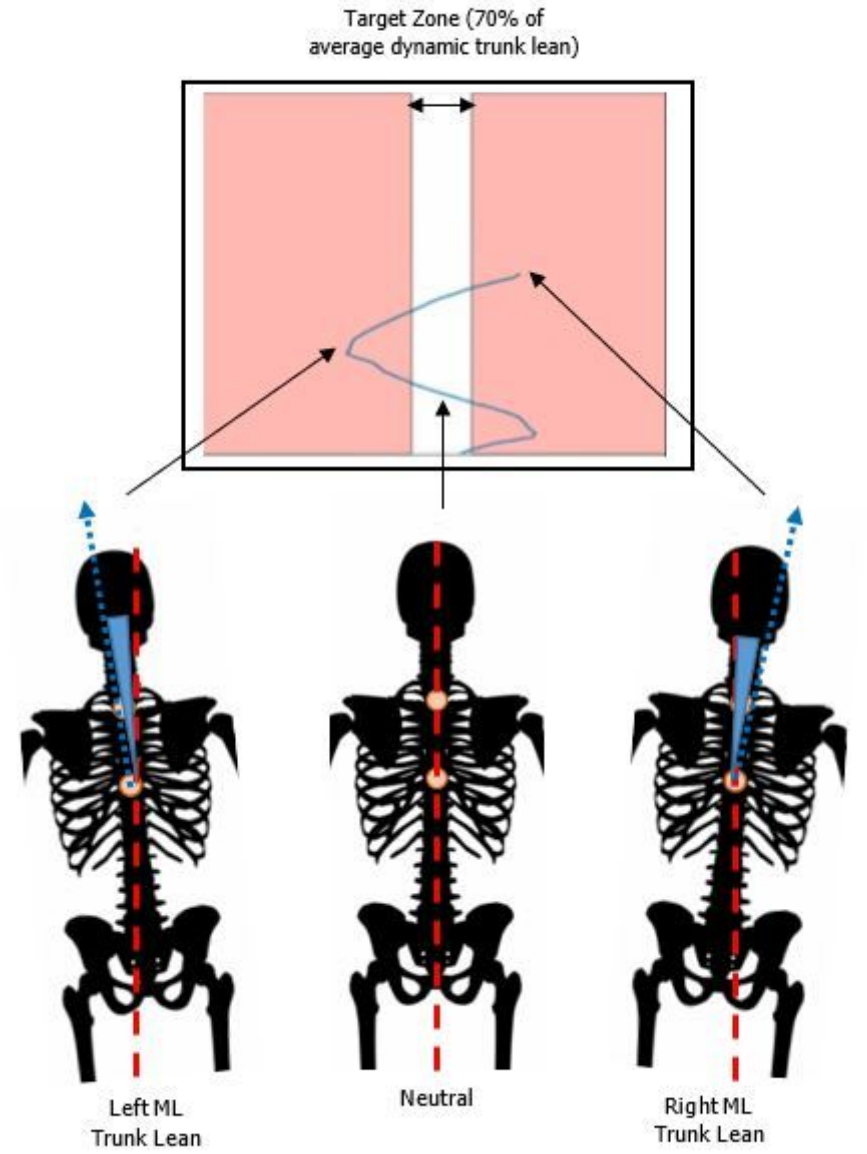

Figure 1

Representation of the visual projection of biofeedback during the Intervention walking condition.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Coverletter.pdf