Can a targeted home-based exercise programme improve turning characteristics in individuals with Parkinson's disease?

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Abstract (Word Counts: 238)

Background: Turns are often cited as a difficult task for individuals with Parkinson's disease and often lead to falls, however targeted exercise interventions may help to reduce this problem. This study examined the effects of a 10-week home-based exercise program focusing on turns which may be an exercise approach for improving mobility and reducing falls in individuals with Parkinson's disease.

Methods: Turning and stepping characteristics were recorded using Inertial Measurement Units while participants performed a 180° standing turn. Eye movements were measured using a BlueGain electrooculography system. Clinical outcomes were assessed using the Movement Disorders Society-Unified Parkinson's Disease Rating Scale, Functional axial rotation-physical score and the Falls Efficacy Scale International.

Findings: Twenty individuals with Parkinson's disease were matched by severity using the Modified Hoehn and Yahr scale and were randomly allocated to an exercise (n = 10) or control group (n = 10). Significant improvements were seen after 10 weeks in the exercise group only for; onset latency of body segments, step size, number of fast phase eye movements, the Movement Disorders Society-Unified Parkinson's Disease Rating Scale in motor and rigidity scores, Functional axial rotation-physical score and the Falls Efficacy Scale International.

Interpretation: These results indicate that the home-based exercise programme targeting turning characteristics had positive effects on turning performance and clinical outcomes associated with falls in individuals with Parkinson's disease. These preliminary results support the notion that targeted home-based exercises may provide an effective intervention in this population.

Keywords: turning, exercise, eye movement, Parkinson's disease

Word Counts: 3,806

1. Introduction

Most individuals with Parkinson's disease (PD) suffer from turning dysfunction which has been shown to lead to an increase in the risk of falls (Anastasopoulos et al., 2011; Hulbert et al., 2015). En-bloc turning strategies have been identified in individuals with PD, which can be characterized by a simultaneous onset latency of body segments and a decreased head segmental angular separation between the trunk, pelvis and feet (Anastasopoulos et al., 2011; Hulbert et al., 2015). Previous evidence showed that healthy adults turn with a top-down sequence, starting with a shift of their gaze in the direction of the turn, followed by movements of the head and body in a coordinated process (Hollands et al., 2002; Hollands et al., 2004). This event is believed to represent an important part of the turning characteristics. However, several studies have reported that individuals with PD impaired a top-down sequence during turning, which can be partially explained by eye movement deficits (Anastasopoulos et al., 2011; Lohnes &Earhart, 2011; Ashburn et al., 2014). In 2011, Lohnes and Earhart found that individuals with PD turn slower and smaller initial fast phase eye movements, and make more total fast phase eye movements than healthy individuals (Lohnes &Earhart, 2011). These deficits not only affect the coordination of eye movement but also altered timing of segment rotations, head-on-trunk movements and smaller intersegmental rotations, which can alter stepping characteristics during direction changes and lead to less maintenance of stability, which can put them at a greater risk of falling while turning (Anastasopoulos et al., 2011; Lohnes &Earhart, 2011; Ashburn et al., 2014; Robins &Hollands, 2017). Currently, details of laboratory-based analysis of studies measuring whole-body coordination are limited as these investigations are time-consuming, expensive and currently restricted due to COVID-19. However, techniques involving devices such as an Inertial Measurement Unit (IMU) could be used in isolation to gather accurate data from individuals with PD within a real-life context.

The advantages of continuous monitoring of mobility with small sensors and low power requirements, allow characterization of fluctuations across the day and week, response to medication and other interventions and the influence of real-world distractions and complex environments (Horak, King and Mancini, 2015). In our study, the use of IMU devices can also provide the whole-body coordination and stepping characteristics during turning.

To date, several studies have shown that exercise interventions can improve turning deficits in individuals with PD (Willems et al., 2007; Abbruzzese et al., 2016; Cheng et al., 2016; Stuart et al., 2017; Ellis et al., 2021). However, there is a general lack of evidence in terms of the effects of exercises that target turning characteristics in individuals with PD (Choi et al., 2020; Radder et al., 2020). Although there is evidence to support the use of exercise rehabilitation delivered under physiotherapist supervision (Dereli &Yaliman, 2010; Khalil et al., 2017), there are limitations to supervised exercise interventions for PD which have been highlighted from recent restrictions due to the COVID-19 pandemic. Furthermore, the long-term effects of supervised exercise have been shown to provide limited impact on turning characteristics (Dereli &Yaliman, 2010; Flynn et al., 2019). Therefore, to address these issues one solution could be to move towards a greater use of home-based exercise intervention programmes. Home-based exercise was defined as exercise which is completed in the individual's home, one model of physiotherapy care. This has the potential to facilitate the development of a useful, long term pattern of exercise behavior, preventing deterioration of the symptoms in individuals with PD. However, there is a lack of evidence from a 100% home-based programme which has been designed specifically to target problems of individuals with PD.

It has been shown that exercises targeting axial mobility using rotational training can improve turning characteristics (Schenkman et al., 1998; Schenkman et al., 2000; Khobkhun et al., 2020a). These previous studies provided a 10 week exercise intervention in community-dwelling older individuals with early- and mid-stage PD and demonstrated significant improvements in functional axial rotation, functional reach and stepping during 360-degree turns in the exercise group compared to a usual care group.

The aim of this study was to investigate the effects of a targeted home-based exercise programme focusing on the turning characteristics in individuals with PD utilising the previous published programme by Schenkman et al. (Schenkman et al., 1998) by selecting specific elements that focused on improving turning dysfunction. It was hypothesized that this would improve turning dysfunction, and may be able to facilitate the development of a useful home based program for individuals with PD in response to the restrictions of clinical visits as a consequence of the COVID-19 pandemic.

2. Methods

2.1 Participants

Participants were individuals recruited from the Movement Disorder Clinic, Division of Neurology, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand and diagnosed with idiopathic PD by a neurologist (PS). Any interested individuals were signposted to the Faculty of Physical Therapy at Mahidol University for consideration using the following inclusion criteria: 1) individuals clinically diagnosed with PD stages 1.5 to 3 as assessed by the modified Hoehn and Yahr scale, 2) age between 50 and 75 years, 3) taking PD medication regularly with no signs of wearing-off phenomenon, 4) a score of ≥24/30 on the Mini-Mental State Examination Score (Thai version), 5) able to walk independently over 20 meters without any assistive device, and 6) able to visit the Physiotherapy clinic at Mahidol University at the beginning and end of a 10 week period for the assessments. The exclusion criteria were: 1) clinically diagnosed with other neurological disorders e.g. stroke induced-PD, Normal Pressure

Hydrocephalus, Alzheimer's disease, choreoathetosis and epilepsy, 2) musculoskeletal conditions of the lower limbs that could influence the turning test e.g. lower limb amputation, severe ankle instability and severe knee pain, 3) visual problems that could not be corrected with lenses or glasses.

All participants read a participant information sheet and signed an informed consent form before data collection commenced which was approved by the local Ethics Committee on Human Experimentation (MU-CIRB 2020/048.1902), and the clinical trial was registered on clinicaltrials.gov (NCT04810897).

2.2 Assessments

Individuals with PD who met the inclusion criteria were randomly assigned using a computer-generated program to one of two groups, an exercise group and a control group, which were matched using the modified Hoehn and Yahr scale and were assessed for severity using the Movement Disorders Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS). In addition, the two groups eye movement and turning characteristics were assessed at 0 weeks and 10 weeks using a Bluegain wireless electrooculography system and Inertial Measurement Units (IMUs), and clinical outcomes were taken using the Functional axial rotation-physical (FAR-p) and Fall Efficacy Scale International (FES-I).

2.2.1 Turning and stepping characteristics assessment

Turning and stepping characteristics were evaluated while participants performed a turn on level ground through 180° in a standing position. IMU sensors (XSENS, MVN, Xsens Technologies B.V., P.O. Box 559, 7500 AN Enschede, the Netherlands), which was used to measure turning and stepping characteristics at a sampling frequency of 100 Hz. were attached to the centre of the forehead, middle thorax, pelvis and the centre of the left and right foot using

Velcro straps (Khobkhun et al., 2021a). Furthermore, the parameters specific to turning and stepping characteristics included: reorientation onset of eye, head, thorax, pelvis and feet, peak head yaw velocity, peak head-segment angular separation angle, total step count, step duration, step frequency and step size.

2.2.2 Eye movement assessments

Eye movement characteristics were recorded using a BlueGain wireless electrooculography system (EOG) (Cambridge Research System Ltd., UK). A reference electrode was placed on the centre of the forehead and two surface electrodes were placed on the outer canthi of the eyes (Robins &Hollands, 2017). Eye movements were analysed in terms of fast phase characteristics similar to previous published methodologies (Robins &Hollands, 2017).

The test protocol consisted of 1) an animated video which demonstrated a random direction and provided a visual cue for the participant to turn, and 2) participants were instructed to “please turn to see the picture behind you as fast as you comfortably can.” A LabVIEW programme was used to control the visual cue and mark the time point within the EOG data capture software for data synchronization. Trials were recorded for turns to both the left and right which were randomly presented for each participant, and a two minute break was allowed between each test.

2.2.3 The Movement Disorders Society-Unified Parkinson’s Disease Rating Scale (MDS-UPDRS)

The Movement Disorders Society-Unified Parkinson’s Disease Rating Scale (MDS-UPDRS) has been evaluated for PD symptoms due to an easy-to-use instrument in clinical practice, which ranges from 0-132, with the higher score corresponding to a more severe symptom. The total motor and rigidity score of MDS-UPDRS were reported in this study.

2.2.4 Functional axial rotation – physical (FAR-p)

This test is used to measure axial mobility, and permissions were granted to use the test for this study (Schenkman et al., 1998). The participants were seated and the pelvis stabilized using straps and a hoop with symbols at 5° increments was suspended from two adjusted tripods at eye level. The participants wore a head piece to assess the cervical range of motion (CROM; Performance Attainment Associates, Roseville, MN). The participants were instructed to turn as far as possible and report the furthest symbol (numbers and letters) that could be seen, and the symbol with which the pointer aligned was recorded. The symbol correlate with the number of increments giving the angle of turning. The participants were first asked to turn to the right, then to the left. The average from two test trials was calculated, the mean being recorded in degrees (Schenkman et al., 1998). Each participant was allowed to carry out a practice trial which was similar to the testing protocol, only 2 trials, one to the left and one to the right). However, we did not proceed with the test protocol until the participant indicated that they understood the instructions and the researcher was satisfied that there was no confusion about how to perform the test.

2.2.5 Fall Efficacy Scale International (FES-I)

The FES-I is a self-reported questionnaire that assesses the fear of falling. This consists of 16 questions using four-point Likert scales and assessed concerns about the possibility of falling when performing 16 activities. The maximum score was 64 with a higher score indicating a greater fear of falling, and permission was granted to use this score for this study (Thiamwong, 2011).

2.3 The home-based exercise programme and the control group

One session of the exercise programme was about 60 minutes in total and included the following: deep breathing 3 repetitions for 5 minutes and posture correction; stretching 3 repetitions for 10 minutes; axial segment rotation training in supine, side lying, prone lying, sitting and standing positions 10 repetitions for each position over 30 minutes; and balance training and task-specific turning training 5 repetitions per side over 15 minutes. (Supplementary file 1). The exercise group received 70 home-based sessions over a 10-week period. This previous published programme was approved by the referring neurologist and PD rehabilitation experts (Khobkhun et al., 2021b). The participants were required to perform each of the abovementioned exercises to their maximum potential. Participants in the exercise group were asked to come to the clinic with their caregivers at the baseline assessment, then, they were asked to attend a workshop to explain how they should perform the exercise programme. Following this, they were asked to repeat the exercises in a step-by-step manner, and they received a booklet and video to use in their home. The exercise group were instructed to perform the exercise programme every day over 10-weeks. In addition, they were asked to record the daily exercises they performed in a diary. Whereas the control group, were instructed to continue their routine activities throughout the course of the study. The researcher called all participants once a week to check their adherence with the study protocol (Supplementary file 2).

2.4 Data processing

A MATLAB (R2020a) programme was used to analyse all measures from the kinematic datasets, using the following as dependent variables: reorientation onset time of the eye, head, trunk and feet and peak head-trunk separation which were used as measures of axial segment and intersegment coordination. The amplitude and velocity of yaw trajectory time from each body segment and fast phase characteristics of eye movement timing were inspected alongside head movement data, and temporo-spatial stepping characteristics (step onset, step frequency, step size, and turn duration). All dependent variables were analysed and extracted from MATLAB (R2020a) using a previously validated methodology (Robins &Hollands, 2017; Khobkhun et al., 2020b; Khobkhun et al., 2021a).

2.5 Statistical analysis

Statistical analyses were performed using IBM SPSS statistics version 24 (IBM Corporation, Armonk, NY) and the significance level was set to $p<0.05$. Independent t-tests were performed to compare the means and differences of demographic data. The Shapiro-Wilk test showed that the data distribution for turning, eye movement and stepping characteristics were normally distributed, therefore a two factor Mixed Model Analysis of Variance (MM ANOVA) was used to explore the main effects of group and time. Any interactions between group and time were further explored using post-hoc paired t-tests with a Bonferroni correction to determine any differences within each group between the two time points. Furthermore, the relationship between peak head yaw velocity and peak segmental angular separation was explored using regression analyses. However, the Shapiro-Wilk test showed that the clinical outcomes were not normally distributed, therefore, Mann-Whitney U tests were used to compare the clinical outcomes between the exercise and the control groups including the MDS-UPDRS, FAR and FES-I and Wilcoxon signed-rank tests were used to compare between baseline and 10 weeks within each group.

3. Results

Twenty-seven individuals with PD were recruited, 14 in the exercise group and 13 in the control group. However, seven individuals did not meet the criteria, therefore, 20 individuals in total (10 participants for each group) were included in the analysis. The demographic characteristics of participants are shown in Table 1 and independent t-tests showed no significant differences between the groups.

[Insert Table 1]

The results from MM ANOVA between group and time for turning and stepping characteristics are shown in Table 2, eye movements characteristics are shown in Table 3 and post-hoc comparison using paired t-test was tested for variables that showed a significant interaction are shown in Table 4.

[Insert Table 2]

[Insert Table 3]

[Insert Table 4]

3.1 Segment reorientation

Segment reorientation began with the head and eye, followed by thorax, pelvis and the feet, this sequence was preserved similarly in both group (Figure 1).

[Insert Figure 1]

The MM ANOVA tests revealed significant interactions between group and time on the mean onset latency for the head (F = 5.34, p = 0.027, η_p^2 = 0.14), thorax (F= 3.609, p = 0.046, η_p^2 = 0.09) and trailing foot (F = 4.55, p = 0.04, η_p^2 = 0.11) (Table 2). Further post-hoc analysis using paired t-tests found that the mean onset latency significantly decreased (p<0.05) between the baseline assessment and 10 weeks in the exercise group, whereas the head onset latency increased in the control group (Table 4).

3.2 Intersegmental relationship

MM ANOVA revealed no significant interactions or main effects between group and time for peak head-thorax and peak head-pelvis angular separations, however a significant interaction was seen for the peak head yaw velocity (F = 0.13, p = 0.022, η_p^2 = 0.03) (Table 2). Post-hoc analysis using paired t-tests found a significant difference between baseline and 10 weeks (p<0.05) for the peak head yaw velocity within the exercise group only (Table 4). A further regression analysis showed a significant but weak positive correlation (p<0.05, r=0.24) between peak head yaw velocity and the head-pelvis separation at the 10 week assessment but not at baseline within the exercise group (p=0.382, r=0.09). However, the control group demonstrated a similarity of regression analysis in peak segmental angular separations during post-assessment (p=0.478, r=0.21) compared to the baseline assessment (p=0.436, r=0.25). The existence of relationships between the head and pelvis after 10-weeks exercise indicates that the peak head-pelvis angular separation increases with an increase in the head velocity (Figure 2).

[Insert Figure 2]

3.3 Stepping characteristics

The MM ANOVA tests revealed interactions between group and time for step size (F = 0.474, p = 0.049, η_p^2 = 0.01) (Table 2). Further post-hoc analysis using paired t-tests found significant improvements (p<0.05) in step size between baseline and 10 weeks in the exercise group (Table 3). No interactions or main effects were seen for step duration, step frequency or total step count (Table 2).

3.4 Eye movement characteristics

No interactions or main effects were seen for fast phase eye movement characteristics, (Table 3), however an interaction was found in the number of fast phase eye movements (F = 0.629, p = 0.008, η_p^2 = 0.18), with a post-hoc paired t test showing a decrease between the baseline and 10 weeks assessments in the exercise group (p=0.025) (Table 4).

3.5 Clinical outcomes

Mann Whitney-U tests showed no significant differences between groups for MDS-UPDRS in motor and rigidity score and FES-I. However, the Wilcoxon signed-rank tests showed a significant improvement between the baseline and 10 weeks in the exercise group for; MDS-UPDRS motor score (Z = -2.68, p = 0.007), MDS-UPDRS rigidity score (Z = -2.64, p = 0.008), and FES-I (Z = -2.805, p = 0.005). No statistical differences were seen in any of the clinical outcomes in the control group between the baseline and 10 week assessments, (Table 5).

3.6 Adhesion reporting during a 10 week period for both groups

For the exercise group, three participants did perform the exercises 4 days from 7 days during the first week due to their own reasons. The researcher had to remind those participants and their caregivers to carry out the exercise every day in the rest of 9 weeks. Before participation in this study, one participants frequently spent long periods in the sitting position. After completing the exercise programme, both participant and caregiver have reported that he carried out other activities such as, walking around the house, doing housework and going to the market. In addition, from the booklet of participants in this group, all of the participants completed all exercise. They gave the information that they felt less stiffness and their movements were improved during a 10 week period exercise. No participant fell in this group.

Whereas, from the control group's follow up telephone recording, three participants exercised regularly on a daily basis. However, another two patients were frequently in sitting and lying down position and one participant from this group fell down once.

[Insert Table 5]

4. Discussion

The purpose of this study was to examine the effects of a 10-week home-based exercise programme focusing on turns in individuals with PD. In line with our hypotheses, we found that a 10 week home-based exercise programme resulted in improvement in turning and stepping characteristics (segment reorientation of body segments and step size), and improvement in the number of fast phase eye movements and clinical outcomes (MD-UPDRS in motor and rigidity scores, FAR-p and FES-I) observed in individuals with PD. Our findings are discussed in the context of those variables of turning in individuals with PD.

4.1 Segment onset latency and intersegmental relationships

This is the first study to investigate turning characteristics as a result of a targeted home-based exercise programme focused on turning dysfunction. The findings from the onset of segment reorientation and intersegmental relationships are consistent with those previously observed (Hulbert et al., 2015; Khobkhun et al., 2021a). The results demonstrated that the head, thorax and trailing foot onset latencies significantly decreased (p<0.05) after the 10 week home-based exercise programme. However, the pattern of segment onset latency at the 10 week assessment still showed the same order of magnitude when compared to the baseline. These findings are consistent with the proposal that turning is controlled as a result of a CNS control synergy (Hollands et al., 2004; Hulbert et al., 2015), providing a central motor programme for human movement. Timing of the segment showing en-bloc turning was consistent with previously documented studies in older adults and individuals with PD (Lohnes &Earhart, 2011; Hulbert et al., 2015). This suggests that en-bloc segmental reorientation patterns may be adopted to simplify control during turning and may be a compensatory mechanism to control postural stability and balance in this population during turning (Lohnes &Earhart, 2011; Hulbert et al., 2015). In addition, the reduction of onset latency may come from the increasing turn speed, as is increased peak head velocity, which can be associated with reduced onset times. The home-based exercise program may improve the movement during turning on-the-spot which involves anticipatory postural adjustments (APAs). APA's are generated prior to intentional motor preparation for predictable external perturbation and are also capable of short-term adaptation in response to immediate environmental changes (Lin et al., 2016). This present study shows that the onset latency of the head, thorax and trailing foot response thought to be linked to APA is improved by this 10 week home-based programme.

It was also found that there were no significant differences in the peak head-thorax and peak head-pelvis angular separations either between or within groups. This may be due to the en-bloc turning strategy, which is related to axial rigidity and leads to intersegmental coordination relationship deficit in individuals with PD (Cano-de-la-Cuerda et al., 2011; Hulbert et al., 2015). This angular segment rotation to increase flexibility could not be enough to encourage better in axial deficit through home-based exercise. Therefore, our study suggests that the exercise program be amended by more repetition of trunk and spinal training, relaxation training, BIG training during rotational exercise and application of cueing strategies during rotational movements. These changes may assist individuals with PD to have better axial rigidity and intersegmental coordination relationships which may lead to changes in the top-down sequence rather than en-bloc patterns seen during turning in individuals with PD. Also, the consensus is that individuals with PD may benefit as regards improvements in axial rigidity from a multidisciplinary approach, including levodopa therapy and deep brain stimulation and group therapy such as Yoga and Tai chi.

4.2 Stepping characteristics

The improvement in the step size and a positive trend in stepping characteristic variables in the exercise group may be as a result of the stretching exercise, segment rotational training, recreation and balance training and task-specific turning training all of which would lead to an increase in axial mobility, improved coordination and postural stability, leading to better dynamic balance control and an improvement in the spatio-temporal movement of stepping characteristics. Our stretching exercises with hamstring muscles, calf muscles and neck muscles may enhance muscle flexibility and facilitate movement of the lower limbs. This idea is supported by a previous study (Cristopoliski et al., 2009) which found that stretching the hip and calf muscles can improve temporo-spatial gait in the elderly. This previous work showed that the experimental group had an increased range of motion in the hip joint and increased step length compared to the control group after the stretching protocol. In addition, Rawson et al. (2019) found that stretching exercises twice a week, for 12 weeks can lead to improvement in backward walking in people with PD. Furthermore, the recreational and balance training exercises may lead to effective adaptation of the voluntary responses of trunk and limb muscles in challenging postural control and balance during step turning (Stozek et al., 2016). Finally, motor learning processes may be evoked by task-specific turning training which may improve memory pertinent to turning tasks in individuals with PD (Shumway-Cook and Woollacott, 2001). Taken together, stepping during turning requires muscle flexibility, the stabilization of various segments and is related to whole-body coordination and the augmentation of associated systems which are involved in the critical challenges in changing direction during turning (i.e. muscle working, balance, trajectory and stepping maintenance) (Rochester et al., 2010; Stuart et al., 2017). As stated, our exercise programme may lead to improved sensorimotor integration, intersegmental coordination, and the ability to switch between sensory modalities and compensatory stepping.

4.3 Eye movement characteristics

The only significant effect of the exercise programme on eye movements was a difference in the number of fast phase eye movements after the 10-week home-based exercise programme which may be associated with the improvement in step onset and step size during turning. These results may be explained by a strong correlation between the eye movement characteristics and stepping movements which relate to subsequent foot rotations or foot placement during whole-body segmental coordination turns (Anastasopolous et al., 2009). However, there is a limited of turning studies regarding methodological differences which report eye movement characteristics while completing a standing turn (Hollands et al., 2002; Anastasopoulos et al., 2011; Lohnes &Earhart, 2011; Lin et al., 2016). In contrast, a previous study by Stuart et al (Stuart et al., 2017) reported that the number of saccades increased during turning in PD compared to controls due to the impairment in smooth pursuit. Catch up saccades were found to result in a higher frequency of saccades during a turn in place and have been shown to rely more on visual than proprioceptive or vestibular inputs when walking (Robins &Hollands, 2017).

4.4 Clinical outcomes

Our results demonstrate a reduction in PD symptoms as measured by the MDS-UPDRS motor score and rigidity score following completion of this exercise program. These findings are consistent with previous studies that have shown improvements in UPDRS after participation in exercise programmes (Tomlinson et al., 2012; Ni et al., 2016; Stozek et al., 2016; Radder et al., 2020; Ellis et al., 2021). One possible explanation may be related to the facilitation of the motor learning, thereby reducing motor symptoms such as postural instability, gait, rigidity and bradykinesia (Patti et al., 1996). A previous study found that participating in a yoga programme can also significantly reduce UPDRS motor symptoms and UPDRS rigidity (Ni et al., 2016). The authors concluded that yoga is dependent on the brain circuitry involved in motor planning and movement execution, both of which are critical in PD. Another possible explanation may be related to the motor learning during the exercise programme, which is supported by previously reported increases in movement amplitude and speed in rotation or turning practice, which appear to transfer to increased amplitude and speed of finger and foot tapping (Petzinger et al., 2013).

Our results show that a decrease in the fear of falling as measured by the FES-I was found when comparing the specific variables in individuals at the baseline and 10-week assessments within the exercise group. Protas et al. (2005) described the benefits of a fully supervised 8-week programme of treadmill gait and step perturbation training in PD. They showed that exercise intervention leads to a significant reduction in the rate of falling and an improvement in gait and dynamic balance parameters. Similarly, a previous study investigated the impact of a 6-week programme in which individuals with PD were trained at home by physiotherapists to develop strategies to prevent falls. The exercise group carried out a range of movement, muscle strengthening, balance training and walking exercises, whereas the control group received usual care (Ashburn et al., 2007). When considered alongside our results, and those of previous studies, this suggests that the fear of falling in PD can be significantly reduced by exercise intervention. These improvements may be useful in preserving independence in individuals with PD.

There are several limitations to this study. First, the sample was small and this is likely to have affected the interpretation of the effect size and a follow-up training period and investigation using a greater number of participants is recommended. Secondly, exercise and measurement sessions in this study featured participants under an "on" medication state; future research is needed to examine and compare the effect of exercise in their "off" state. Finally, the results from the exercise group may have been influenced by the researcher contacting the participants every week. Self-reported exercise compliance is somewhat subjective as the individuals with PD would be seeking to please the researcher and may not always have completed the exercises to the necessary degree.

5. Conclusion

This study showed that a targeted 10-week home-based exercise programme focused on turning resulted in improvements in turning characteristics and clinical scores in individuals with PD. Clinicians should consider the use of home-based targeted exercise programmes focused on turning, however further work is required to determine the longer-term effects on falls and function in individuals with PD.

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Tables

Table 1. Participant demographics for the exercise (n=10) and control groups (n=10).

Demographic	Exercise group (n=10)	Control group (n=10)	*p*-value
Age (years ±SD)	66.50 ± 4.17	67.00 ± 4.37	0.797
Body mass index (kg/m^2 ±SD)	23.21 ± 2.91	23.39 ± 4.85	0.921
Onset duration of Parkinson's disease (years±SD)	6.36 ± 3.51	6.6 ± 3.87	0.858
Modified Hoehn and Yahr scale (stages±SD)	2.3 ± 0.48	2.3 ± 0.48	1.000
Mini-Mental State Examination (scores±SD)	28.6 ± 4.71	28.6 ± 4.72	1.000
Underlying disease (n, %)			
- Hypertension	5 (50%)	5 (50%)	-
- Diabetes mellitus	3 (30%)	2 (20%)	-
- Others	2 (20%)	3 (30%)	-
Taking L-DOPA with other medications (n)	10	10	-

* Indicates a significant difference (*p*<0.05).

Table 2. Mean, standard deviations (SD) and MM ANOVA results between group and time for turning and stepping characteristics

Variables	Exercise group (n=10)		Control group (n=10)		Group effect	Time effect
	Baseline	**10 weeks**	**Baseline**	**10 weeks**	***p*-value (η_p^2)**	***p*-value (η_p^2)**
Turning and stepping characteristics						
Eye onset (s)	0.78 (0.18)	0.61 (0.13)	0.74 (0.22)	0.85 (0.39)	0.226 (0.05)	0.682 (0.001)
Head onset (s) ǂ	0.72 (0.14)	0.56 (0.07)	0.62 (0.23)	0.80 (0.37)	0.350 (0.03)	0.865 (0.001)
Thorax onset (s) ǂ	0.74 (0.16)	0.59 (0.10)	0.65 (0.26)	0.79 (0.35)	0.479 (0.18)	0.940 (0.001)
Pelvis onset (s)	0.78 (0.34)	0.63 (0.11)	0.69 (0.23)	0.78 (0.34)	0.952 (0.01)	0.462 (0.01)
Leading foot onset (s)	1.04 (0.22)	0.82 (0.18)	0.93 (0.32)	1.06 (0.35)	0.429 (0.02)	0.632 (0.01)
Trailing foot onset (s) ǂ	1.50 (0.27)	1.27 (0.24)	1.46 (0.31)	1.60 (0.36)	0.106 (0.07)	0.613 (0.001)
Peak head yaw velocity (°s^{-1}) ǂ	111.4 (39.7)	126.8 (22.7)	100.6 (24.4)	108.4 (42.1)	0.177 (0.05)	0.281 (0.03)
Peak head-thorax angular separation (°)	17.71 (7.11)	21.43 (9.24)	20.77 (9.11)	18.18 (8.80)	0.972 (0.002)	0.838 (0.002)
Peak head-pelvis angular separation (°)	13.49 (8.44)	19.46 (11.08)	12.14 (6.86)	11.83 (8.27)	0.121 (0.07)	0.346 (0.05)
Total step (n)	6.44 (4.71)	4.81 (1.21)	6.88 (3.32)	7.27 (4.03)	0.207 (0.04)	0.587 (0.03)
Step frequency (n)	1.84 (0.44)	1.92 (0.33)	1.86 (0.44)	1.89 (0.38)	0.949 (0.06)	0.662 (0.05)
Step duration (s)	3.49 (1.52)	2.67 (0.40)	3.61 (0.95)	3.76 (01.36)	0.109 (0.07)	0.365 (0.06)
Step size (°) ǂ	67.5 (19.1)	74.5 (13.1)	60.5 (22.2)	59.0 (22.3)	0.077 (0.07)	0.660 (0.10)

ǂ Indicates a significant interaction (p<0.05) from MM ANOVA.

* Indicates a significant between two time points from MM ANOVA within the exercise group (p<0.05).

Table 3. Mean, standard deviations (SD) and MM ANOVA results between group and time for eye movement characteristics

Variables	Exercise group (n=10)		Control group (n=10)		Group effect	Time effect
	Baseline	**10 weeks**	**Baseline**	**10 weeks**	***p*-value (η_p^2)**	***p*-value (η_p^2)**
Eye movement characteristics						
First fast phase amplitude (º)	19.40 (9.26)	24.15 (12.04)	17.81 (7.37)	17.97 (7.80)	0.205 (0.05)	0.416 (0.02)
First fast phase velocity (°s-1)	223.57 (62.70)	212.37 (53.09)	254.57 (74.53)	252.65 (97.47)	0.207 (0.04)	0.927 (0.04)
First fast phase acceleration (°s^{-2}) x10^3	21.56 (11.04)	17.51 (6.56)	26.46 (19.58)	29.20 (12.41)	0.146 (0.06)	0.908 (0.05)
Maximum fast phase amplitude (º)	28.16 (7.69)	29.82 (10.76)	23.93 (7.86)	24.49 (8.63)	0.096 (0.07)	0.692 (0.05)
Peak fast phase velocity (°s^{-1})	322.4 (74.3)	292.6 (57.0)	345.2 (129.4)	366.8 (138.0)	0.155 (0.05)	0.902 (0.04)
Peak fast phase acceleration (°s^{-2}) x10^3	32.977(12.77)	26.47 (7.26)	44.06 (30.84)	46.38 (34.36)	0.051 (0.06)	0.786 (0.07)
Number of fast phase (n) ǂ	7.47 (2.74)	5.80 (1.11)	9.60 (3.94)	9.63 (4.62)	0.051 (0.04)	0.447 (0.05)
Nystagmus fast phase frequency (n)	2.07 (0.24)	2.05 (0.36)	2.33 (0.62)	2.14 (0.52)	0.245 (0.06)	0.486 (0.05)

ǂ Indicates a significant interaction (p<0.05) from MM ANOVA.

* Indicates a significant main effect (p<0.05).

Table 4. Post-hoc comparison using paired t-test was tested for variables that showed a significant interaction within MM ANOVA.

Groups	Variables	Assessments		Time effect
		Baseline	10 weeks	*p*-value
Exercise group	Head onset (s)	0.72 (0.14)	0.56 (0.07)	0.004*
	Thorax onset (s)	0.74 (0.16)	0.59 (0.10)	0.033*
	Trailing foot onset (s)	1.50 (0.27)	1.27 (0.24)	0.045*
	Peak head yaw velocity ($°s^{-1}$)	111.44 (39.74)	126.79 (22.71)	0.046*
	Step size (°)	67.49 (19.08)	74.48 (13.12)	0.014*
	Number of fast phase (n)	7.47 (2.74)	5.80 (1.11)	0.025*
Control group	Head onset (s)	0.62 (0.23)	0.80 (0.37)	0.032*
	Thorax onset (s)	0.65 (0.26)	0.79 (0.35)	0.092
	Trailing foot onset (s)	1.46 (0.31)	1.60 (0.36)	0.138
	Peak head yaw velocity ($°s^{-1}$)	100.66 (24.44)	108.45 (42.14)	0.267
	Step size (°)	60.49 (22.22)	58.97 (22.34)	0.346
	Number of fast phase (n)	9.60 (3.94)	9.63 (4.62)	0.953

* Indicates a significant difference ($p<0.05$).

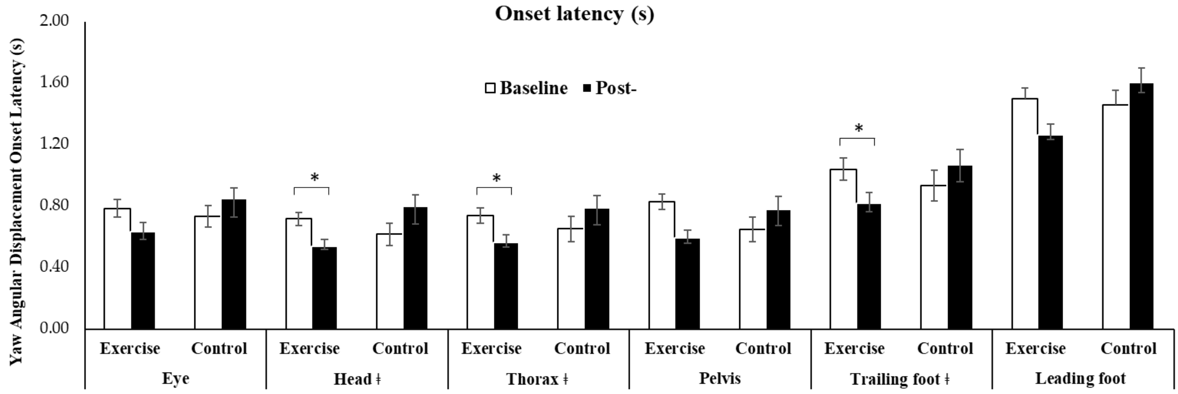
Table 5. Comparison of clinical outcomes between time points using Wilcoxon signed-rank tests.

Groups	Variables	Assessments		*p*-value
		Baseline Median (Q1, Q3)	**10 weeks Median (Q1, Q3)**	
Exercise group	MDS-UPDRS (Motor Score)	25 (18.50, 27.25)	19.50 (16.25, 22.50)	0.007*
	MDS-UPDRS (Rigidity Score)	2 (2, 3)	1 (1, 1.25)	0.008*
	FAR-p (degree)	148.41 (103.50, 160.48)	149.40 (110.72, 181.86)	0.799
	FES-I (score)	31.50 (28.75, 40.05)	28 (22.75, 29.50)	0.005*
Control group	MDS-UPDRS (Motor Score)	19 (18.25, 25.25)	20 (18.25, 27)	0.134
	MDS-UPDRS (Rigidity Score)	2 (2, 2)	2 (2, 2)	1.000
	FAR-p (degree)	139.84 (112.30, 169.33)	135.65 (112.65, 170.70)	0.515
	FES-I (score)	29 (26, 35.50)	31.50 (27.5, 35)	0.100

* Indicates a significant difference (p<0.05).

Q1: 25th percentile, Q3: 75th percentile

Figure 1. Bar graph showing the mean onset latencies of the baseline and 10 week assessments of the exercise and control groups. However, there was statistically significant interaction of the head, thorax and trailing foot.



ǂ Indicates a significant interaction (p<0.05) from MM ANOVA.

* Indicates a significant between two time points from MM ANOVA within the exercise group (p<0.05).

Figure 2. Representative of scatterplot showing a significant positive correlation (p<0.05) between peak head yaw velocity and the head-pelvis separation was found at the 10 week assessments but not at baseline in the exercise group.