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Benefits of Task-Specific Movement Program on En Bloc Turning in Parkinson's Disease: A Randomized Controlled Trial

Benefits of Task-Specific Movement Program on En Bloc Turning in Parkinson's Disease: A Randomized Controlled Trial

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Word count: 3000

Abstract

Introduction: En bloc turning highlights a lack of rotational intersegmental coordination, which commonly impacts turning ability in people with Parkinson's disease (PD). Whilst this turning deficit responds fairly well to medical treatment, it may be further mitigated by performing specific exercise training. Thus, the present study aimed to examine the effects of a four-week exercise program, which focused on task-specific movements (TSM program) on turning ability and clinical outcomes in people with PD.

Methods: Twenty-two adults (67 ± 6 years) with early-to-mid-stage idiopathic PD were randomly assigned to an experimental group (EG; n = 11) or a control group (CG; n = 11). The EG group received a 60-min per session TSM program for 4 weeks (a total of 15 sessions), while the CG group performed their routine rehabilitation program (a total of 12 sessions). Inertial measurement units were used to measure turning kinematics including; onset latency of body segments and stepping characteristics. Clinical outcomes included the Unified Parkinson's Disease Rating Scale (UPDRS), functional reach test (FRT), and fall efficacy scale international (FES-I). Assessments were conducted at baseline and after 4 weeks.

Results: In the EG, turning kinematics, UPDRS scores, FRT, and FES-I scale, were improved at the end of the 4-week program compared with the CG (all $p<0.05$).

Impact Statement: A 4-week TSM program could be a promising alternative rehabilitation program for improving “en bloc” turns and clinical outcomes in PD patients.

Keywords: IMUs; turning kinematics; fear of falling; UPDRS scores; task-specific

1. Introduction

Axial rigidity is a common symptom of Parkinson disease (PD). It is characterized by segmental rigidity with reduced trunk rotation and altered timing of segmental co-ordination (Huxham et al., 2008; Cano-de-la-Cuerda et al., 2011; Hulbert et al., 2015). High and unadaptable axial tone or rigidity might contribute to mobility problems, including turning difficulties, imbalance while walking, and increased risk for falls (Schenkman et al., 1998; Cano-de-la-Cuerda et al., 2011; Hulbert et al., 2015; Weaver et al., 2016). Unlike turning in healthy adults (Hollands et al., 2004; Anastasopoulos et al., 2011), turning in PD patients is a simultaneous rotation onset of the axial segments rather than the normal top-down sequence and represented “en bloc” movement strategy (Hulbert et al., 2015). Indeed, they turn more slowly and tend to move all segments of their body together in a near-simultaneous rotation resulting in a shuffling walking style (Huxham et al., 2008; Lohnes &Earhart, 2011).

For improving functional mobility in PD, levodopa therapy and deep brain stimulation are commonly prescribed treatments. However, the effectiveness of these treatments is equivocal (Schenkman et al., 1998a; Tomlinson et al., 2014). Recently, combining medications with therapeutic exercise has shown promise in decreasing axial rigidity and has been recommended for neuro-rehabilitation of PD patients (Schenkman et al., 1998a; Cano-de-la-Cuerda et al., 2011; Tomlinson et al., 2014). Since, people with PD have multiple aspects of the postural control system impairment (van der Kolk &King, 2013), the feasibility of specific exercise focused on the particular impairments has been carried out (Schenkman et al., 1998a; Dibble et al., 2006; Ashburn et al., 2007; Stozek et al., 2016; Rawson et al., 2019). For example, Schenkman et al. designed a specific exercise program in which patients learned to move in relaxation manner of the appropriated muscles and demonstrated improvements in functional axial rotation, functional reach, and 360 degrees turn following 10 weeks of the program (Schenkman et al., 1998). From a short report of Cheng et al. (Cheng et al., 2016), they compared two specific exercise programs (i.e., balance and strengthening exercise and turning-based treadmill exercise programs) with general exercise in individuals with PD and found that those two specific programs showed faster turning time (+33% changes in specific exercise, and +35% changes in turning-based training) than general exercise within a month of training. To the best of the author's knowledge, the effects of task specific movement exercise program on an improvement of en bloc turns in PD patients is not yet reported. The present study, therefore, hypothesized that the exercise program focusing on task-specific movements (TSM) could provide more benefits on “en bloc” turns and functional outcomes than the general exercise program in PD patients. Our study aimed to determine the effects of a 4-week TSM exercise program on turning kinematics (i.e., onset latency of body segments and stepping characteristics) and clinical outcomes (i.e., the Unified Parkinson’s Disease Rating Scale (UPDRS), functional reach test (FRT), and fall efficacy scale international (FES-I)) in individuals with early-to-mid-stage of PD.

2. Methods

2.1 Study design and setting

In this assessor blinded parallel-group randomized controlled trial, it was estimated that a total of 24 patients (12 per group) would enable the detection of large effect size ($f = 1.594$), assuming an α of 0.05, a statistical power (β) of 0.95, a critical t (18) of 2.07, and Lambda of 3.89 (G*Power 3.1.9.2).

2.2 Participants

Twenty-two older adults (age: 67 ± 6 years) diagnosed with idiopathic PD were recruited from the Movement Disorders clinic at a University Hospital. Patients were matched by age range and PD severity and randomly assigned to either an exercise group (EG: n = 11) or a control group (CG: n = 11) using a computer-generated program. The inclusion criteria included patients who were; clinically diagnosed with 1.5-3 stage PD using the modified Hoehn and Yahr (H&Y) scale, stable without anti-PD medications for at least one month to keep the dosage of antiparkinsonian medications at a consistent level which allowed us to evaluate the effect of the exercise and try to minimize any confounding effect due to changes in dosage of antiparkinsonian medications, could walk independently without an assistive device, and/or could follow commands and instructions. The exclusion criteria included; patients with dementia or other neurological or cardiopulmonary diseases, musculoskeletal problems, signs of the wearing-off phenomenon, any clinically significant medical conditions, and attending rehabilitation programs during participation in this present study.

2.3 Experimental procedures

After the explanation of the exercise protocol, testing procedures, and benefits and possible risks of the study, informed consent forms were signed. The study conformed to the Declaration of Helsinki and was approved by the local Institutional Review Board Ethics Committee. The study followed CONSORT guidelines (Figure 1). After obtaining the informed consent, participants were randomly allocated to one of two groups; an exercise group (EG) or a control group (CG). All parameters were evaluated at baseline and after the 4-week completion of the exercise programs.

[Insert Figure 1]

2.4 The exercise intervention

The TSM program was approved by two physiotherapists who specialize in PD rehabilitation and designed following the American College of Sports Medicine (ACSM) guidelines for individuals with PD (Moore G., 2016). The TMS program was composed of three phases. The 1st phase consisted of three supervised exercise sessions per week in the first two weeks, followed by the 2nd phase which comprised of two supervised and two home-based exercises per week in the third week, and the 3rd phase which comprised of five home-based exercises per week in the last week (Figure 2). The exercise program comprised of a 15-minute warm-up, a 60-minute TSM exercise intervention, and a 15-minute cool-down period. The main TSM exercise intervention consisted of 1) a 45-minute segmental rotation in different positions to increase flexibility and mobility of the body segments, 2) a 5-minute throwing-task movement to increase balance and challenge body movements, and 3) a 10-minute specific-turning-task exercise to increase the range of axial movements between segments and turning movements (Figure 2).

[Insert Figure 2]

Within four weeks, the patients in the EG performed a total of 15 TSM exercise sessions, comprising of 8 sessions under the supervision of a physical therapist and 7 sessions of home-based exercise. In addition, all patients were asked to record their exercise routine on an exercise diary form. The CG was instructed to continue their routine medication. The researcher followed up once a week to assess their compliance with the study protocol.

2.5 Assessments

2.5.1. Turning kinematics assessments

The Inertial Measurement Units (IMUs) (x-IMU, x-io Technologies Ltd., UK) have been previously used to assess turning kinematics in PD and all turning kinematics and stepping characteristics variables were analyzed using a previously validated methodology (Khobkhun et al., 2020). The IMU sensors were attached to the center of the head, middle thorax, and the center of the feet to determine the angular displacement of these segments regarding a global coordinate system. Turning kinematics, including onset latencies of body segments and stepping characteristics were recorded while participants performed a standard turn on level ground through 180°. In addition, onset latency of each body segment is a time point fitting all the onset criteria which directly preceded the sustained rotation, and was determined as the onset latency for each segment, with a shorter duration showing a more positive outcome. Furthermore, segment onset latencies are typically measured in order to determine the sequence of reorientation during turning. For the directions of turning, participants were asked to turn as fast as possible following the video animation. Each participant performed a total of 10 turn trials to the left and right which were randomly selected. MATLAB (R2019b) programming environment scripts were used to analyze all measures from the kinematic datasets, using the following as dependent variables: 1) Reorientation onset time of the head, trunk, and feet, as markers of axial segment coordination, and 2) Tempo-spatial stepping characteristics; step onset, step frequency, step size, the total number of steps during turning, and turn duration. The criteria to determine the rotation onset time, end time, and all dependent variables for each segment and individual stepping characteristics, were calculated using a previously published methodology (Robins &Hollands, 2017; Khobkhun et al., 2020).

Kinematic data were passed through a dual fourth-order Butterworth low pass filter using a cut-off frequency of 6 Hz. The displacement profiles were differentiated to yield velocity and acceleration profiles for each segment. The rotation onset for each segment was defined as the earliest time point that angular displacement was > 0° and < 5°, coinciding with an angular velocity > 0° per second (s). The end of the rotation was determined as the zero crossings in the velocity profile at the end of the movement.

As turn trials varied in duration, time-normalized profiles were created for the axial segments by using the onset and offset latencies from the head and thorax, which were calculated from the onset of head and thorax reorientation to the offset of overall heading trajectory. For the normalization procedure, the earliest onset latency and the final axial offset latency were chosen. A customized MATLAB function performed normalization, increasing each time series to 1000 data points (i.e., longer than all individual time series) and interpolated the missing data points, thus enabling comparison of segment kinematics over the entirety of the turning movement.

Individual steps were analyzed, and step onsets were defined as 1) a positive preceding zero-crossing and 2) a negative zero-crossing following a velocity value that reached 15% of the maximum angular foot yaw velocity (Robins &Hollands, 2017). Each step onset was then determined as the step interval's first frame with a velocity equal to or greater than 30 deg/s. Following the individual step's peak velocity, step end-time was defined as the first frame at which velocity fell below 30 deg/s. Thereafter, individual step characteristics were determined from step onset to step end. The average step size was measured from the yaw rotation of the foot during the swing phase in each step while turning. The total number of steps during turning was counted from the first step to the completion of the turn. the onset of the first step to the last foot placement during the turn. Finally, the step frequency was calculated from the number of steps taken divided by turning duration. All the aforementioned data analyses were performed using a previously published methodology (Robins &Hollands, 2017; Khobkhun et al., 2020).

2.5.2 Clinical outcome assessment

2.5.2.1 The Unified Parkinson's disease Rating Scale (UPDRS)

The UPDRS is the most specific and widely used scale for quantifying the overall severity of PD. The UPDRS total score, motor, and rigidity scores were utilized (Schenkman et al., 1997). Each item has multiple ratings: 0 for normal or no problems, 1 for minimal problems, 2 for mild problems, 3 for moderate problems, and 4 for severe problems. The higher scores indicate more severe PD problems in individuals.

2.5.2.2 Functional Reach Test (FRT)

The FRT is an assessment tool for ascertaining dynamic balance in one simple task. The test is predictive of falls (Duncan et al., 1992) and can be used reliably with individuals who have PD (Schenkman et al., 1997). To conduct measurements, participants were asked to stand with their dominant arm at 90 degrees of shoulder flexion. Next, they were instructed to reach out as far forward as possible along with the scale measurement without taking a step, while the researcher recorded the value on the scale (Demura &Yamada, 2007). Participants were allowed two practice attempts before performing 3 test trials.

2.5.2.3 Fall Efficacy Scale International (FES-I).

The FES-I is a self-report questionnaire, which is used to assess the fear of falling in the elderly population (Dewan &MacDermid, 2014). Participants were asked to rate the 16 items of the questionnaire on a four-point Likert scale depending on their concerns (1 = not at all concerned to 4 = very concerned) about the possibility of falling when performing 16 activities. The highest possible total score was 64 indicating greater fear of falling.

2.6 Statistical analysis

Shapiro-Wilk tests were used to examine the normality of the data, and all data were found to be suitable for parametric testing. In addition, the sphericity of data were considered using Mauchly's test of sphericity, and where the sphericity assumption was violated Greenhouse-Geisser corrections were used. Independent t-tests were performed to compare the means and differences of each dependent variable at baseline assessment. A two-factor mixed model analysis of variance (MM ANOVA) was used to evaluate the effect of treatment groups (CG, EG) and time (baseline, post-assessment). Any interactions between group and time were revealed using post-hoc paired t-tests with a Bonferroni correction to determine any differences within each group between the time points. The observed effect size was expressed as partial eta squared (η_p^2), with values of 0.1-0.29, 0.3-0.49, and $p>0.05$, representing a small, medium, and large effect size, respectively (Cohen, 1992). The statistical significance level was accepted at $p<0.05$. Data for baseline characteristics are reported as the mean ± SD, and all other variables are reported as mean ± SEM. All analyses were performed in SPSS version 24.0 (SPSS inc., Chicago, IL, USA).

3. Results

The patient's baseline characteristics are shown in Table 1. The patient's age, body mass index, modified H&Y Scale, and PD onset, were similar between the two groups. The patients were classified as being in the early-to-middle PD stage (H&Y stages 1.5 to 3), which are associated with axial rigidity and motor problems (Schenkman et al., 2001; Jankovic, 2007). Independent t-tests showed no significant differences between the EG and the CG groups at baseline for; turning kinematics, the UPDRS scores, the FRT and FES-I scale ($p > 0.05$) (Table 1).

[Insert Table 1]

For turning kinematics assessments, the MM ANOVA tests revealed significant interactions between group and time on the mean onset of latency for all segments (head: $F_{(1, 20)} = 9.83$, $p<0.05$, $\eta_p^2 = 0.42$; thorax: $F_{(1, 20)} = 7.84$, $p<0.05$, $\eta_p^2 = 0.34$; leading foot: $F_{(1, 20)} = 2.69$, $p<0.05$, $\eta_p^2 = 0.17$ and trailing foot: $F_{(1, 20)} = 2.39$, $p<0.05$, $\eta_p^2 = 0.43$). Further post-hoc analysis using paired t-tests found that the mean onset of latency significantly decreased ($p<0.05$) between the baseline assessments and post-assessments in the EG group only (Figure 3).

The comparison of turning speed, step size, total step and step duration at baseline and post-assessments between the two groups are shown in Figure 3. The MM ANOVA tests revealed significant interactions between group and time for step size ($F_{(1, 20)} = 9.60$, $p<0.05$, $\eta_p^2= 0.32$), total step ($F_{(1, 20)} = 3.18$, $p<0.05$, $\eta_p^2= 0.14$), step duration ($F_{(1, 20)} =$

6.54, $p<0.05$, $\eta_p^2 = 0.25$) and turn speed ($F_{(1, 20)} = 7.69$, $p<0.05$, $\eta_p^2 = 0.22$). Further post-hoc analysis using paired t-tests found significant improvements ($p<0.05$) in step size, total step and step duration in the post-assessment compare to the baseline in the EG group.

[Insert Figure 3]

The MM ANOVA also showed interactions between group and time for the UPDRS variables (total score ($F_{(1, 20)} = 63.68$, $p<0.001$, $\eta_p^2 = 0.76$), motor score ($F_{(1, 20)} = 21.91$, $p<0.001$, $\eta_p^2 = 0.53$), rigidity score ($F_{(1, 20)} = 18.52$, $p<0.001$, $\eta_p^2= 0.48$) (Figure 4). Further post-hoc analysis using paired t-tests revealed that there was a significant decrease ($p<0.05$) in UPDRS total scores, UPDRS motor scores and UPDRS rigidity scores between the baseline and post-assessments within the EG group (Figure 4), showing an improvement of PD severity in the EG group. In addition, a significant group-time interaction was found for FRT ($F_{(1, 20)} = 26.19$, $p<0.001$, η_p^2 =0 .57) and FES-I ($F_{(1, 20)} = 24.12$, $p<0.001$, $\eta_p^2 = 0.55$) when compare the EG to the CG at post-assessment. Further, post-hoc tests revealed that there was a significant increase ($p<0.05$) in FRT, demonstrating an improved balance and also spinal mobility and in the EG group, whereas there was a significant decrease ($p<0.05$) in FES-I between the baseline assessments and post-assessments in the EG group, showing a reduction of fear of falling (Figure 4).

[Insert Figure 4]

4. Discussion

The main finding of this study was that a 4-week specific home-based exercise program, which focused on task-specific movements, could improve en bloc turning and clinical outcomes in people with early-to-mid stage PD.

En bloc turning is an impairment of segmental coordination of rotation, whereby PD patients reduce the dimensionality of the interconnected chain of axial segments to create a degree of freedom while turning (Cano-de-la-Cuerda et al., 2011; Hulbert et al., 2015). This is the first study to demonstrate the feasibility of using the IMUs to measure turning kinematics in a clinical setting. The results elucidated that before training, PD participants reoriented their whole-body segments simultaneously during 180° turning, rather than a typical top-down sequence indicating an en bloc movement pattern. However, after four weeks of the TSM program, the results showed a decrease in onset latencies for all segments and faster turning speeds in the EG compared to the CG who only perform a routine rehabilitation program. This result could be explained by the fact that the repetition of the desired movement and task-specific training should enhance motor learning by reducing the complexity of motor planning and decreasing the reliance on sensory feedback (Behm et al., 2004; Bartolo et al., 2010; Petzinger et al., 2013).

Task-specific training is one of the concepts of motor learning and may induce cellular or/and molecular plasticity changes by form either short-term and/or long-term memory which related to change in motor planning and sensory feedback. The formation processes of short-term memory include: 1) changes in the excitation-secretion coupling at the presynaptic level through phosphorylation and $Ca2+$ influx; 2) $Ca2+$ influx at the postsynaptic level and increased neurotransmitter release (Petzinger et al., 2013). If short-term memory is reinforced, it will be transformed to be long-term memory. The sustained stimulation leads to persistent activation of the protein kinase A (PKA) and MAP kinase Erk (MAPK) pathways (Petzinger et al., 2013). These changes express proteins involved in protein synthesis, axon growth, synaptic structure and function in related neural circuits. Therefore, this motor learning process may be evoked by our task-specific training and improve short-term memory in individuals with PD.

Consistent with our results, Cheng et al. (2016) reported that the beneficial effects of a turning-based training program using a rotational treadmill could improve turning time in participants with PD. Also, Stozek et al. (2016) found that a specific exercise program focused on mobility, balance, and gait training could increase the range of trunk rotations in PD. Therefore, our results indicate that a 4- week specific exercise program focused on segmental rotation and task-specific movement training could have benefits on turning kinematics and in turn improve en bloc turning in PD. Furthermore, the present study showed that not only the en bloc turns was improved following the TMS program, but the clinical outcomes, including the UPDRS, FRT, and FES-I were also improved compare to the control. This result is consistent with the findings from Bartolo et al. who reported a decrease in the UPDRS III score following a 4-week trunk specific rehabilitation program, and suggested that a program specifically targeting restricted trunk motion could alleviate the motor impairment in people with PD (Bartolo et al., 2010). Additionally, the present study found that people with PD who trained with the TMS program exhibited a better postural control and dynamic balance as measured by the FRT, and also a decrease in fear of falling measured using the FES-I, indicating improvements in balance and coordination while turning (Weiner et al., 1992; Patti et al., 1996; Dewan &MacDermid, 2014).

In conclusion, a 4-week TSM exercise program produced positive effects on turning kinematics and clinical outcomes in people with PD. Moreover, improved en bloc turning was seen through a reduction in the time taken to initiate a 180-degree turn, an increase in step size, and faster and less frequent steps.

The limitations of this study included the control group not being provided a similar amount of attention to those in the experimental group. Therefore, this cannot be ruled out as a factor contributing to group differences. Secondly, we did not investigate the long-term effects of the exercise program, future investigations should be conducted over a longer follow-up period.

Implications on Physiotherapy Practice

An exercise program that specifically targets segmental rotation and task-specific movements could be a promising alternative rehabilitation program for improving “en bloc” turns and clinical outcomes in PD patients.

Conflict of interest

The authors have no conflict of interest to report.

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Table 1. Comparison of baseline characteristics and variables of the participant between the exercise (EG) and control (CG) groups.

Variables	EG (n=11) mean ± SD	CG (n=11) mean ± SD	p-value
Gender (male/female)	4/7	7/4	-
Age (years)	67.45 ± 5.26	65.73 ± 5.92	0.910
Hoehn and Yahr Scale	2.32 ± 0.46	2.32 ± 0.46	1.00
Body Mass Index (BMI) (kg/m^2)	23.32 ± 2.79	23.65 ± 4.68	0.114
PD onset (years)	6.24 ± 3.35	6.96 ± 3.81	0.640
Turning kinematics			
Head onset (s)	0.72 ± 0.13	0.61 ± 0.22	0.199
Thorax onset (s)	0.74 ± 0.15	0.73 ± 0.35	0.947
Eye onset (s)	0.79 ± 0.17	0.72 ± 0.21	0.453
Leading foot onset (s)	1.02 ± 0.22	0.91 ± 0.32	0.323
Trailing foot onset (s)	1.52 ± 0.22	1.42 ± 0.32	0.421
Stepping characteristics			
Total step (n)	6.51 ± 4.48	6.74 ± 3.19	0.892
Step duration (s)	3.62 ± 1.50	3.52 ± 0.95	0.846
Step Frequency (n)	1.82 ± 0.39	1.88 ± 0.43	0.727
Step size (°)	65.78 ± 18.96	61.55 ± 21.37	0.629
Turn speed ($^{\circ}s^{-1}$)	55.74 ± 17.39	54.24 ± 12.59	0.819
Clinical ability variables			

UPDRS Total Score(score)	37.36 ± 7.34	37.64 ± 7.68	0.933
UPDRS Motor Score (score)	22.91 ± 4.87	21.00 ± 4.31	0.342
UPDRS Rigidity Score (score)	2.09 ± 0.70	1.73 ± 0.65	0.220
FRT (inch)	7.55 ± 1.73	7.34 ± 1.98	0.627
FES-I (score)	32.45 ± 7.13	31.09 ± 5.74	0.794

Abbreviation :BMI =Body Mass Index; kg =kilogram; m^2 = square meter, s = second, $°s^{-1}$= degree per second, ° = degree, n =number of step

Figures

Figure 1: CONSORT flow diagram showing the experiment procedure.

Figure 2: One session of exercise program.

Figure 3: The mean values of onset latencies of head, thorax, and leading and trailing foot at baseline (white bar) and post-(dark bar) assessments of the exercise (EG) and the control (CG) shown in Figure A1 and 2, respectively. The mean values of turn speed, step size, total steps, and step duration between the EG (dark bar) and the CG (white bar) at baseline and post-assessments shown in Figure B, C1, 2 and 3, respectively. Values are mean +SEM.

Figure 4: The mean values of total score, motor score and rigidity score of Unified Parkinson's Rating Scale (UPDRS) between the exercise (EG, solid line) and the control (CG, dashed line) groups at baseline and post- assessments shown in Figure a, b and c, respectively. The mean values of functional reach test (FRT) and fall efficacy scale

international (FES-I) between the EG (dark bar) and the CG (white bar) at baseline and post-assessments shown in Figure d and e, respectively. Values are mean +SEM.

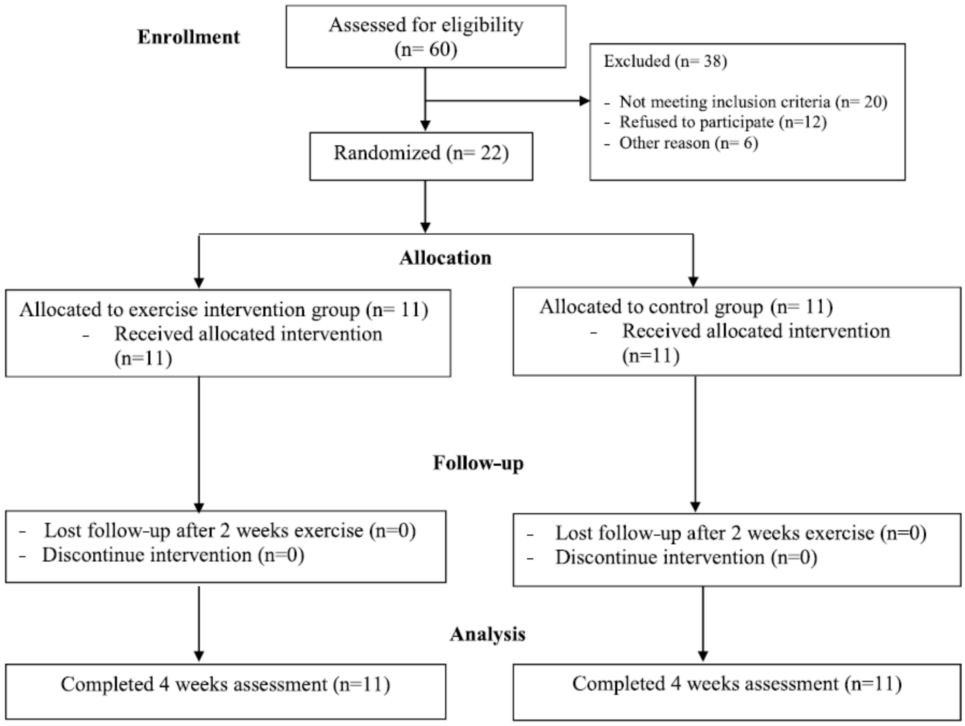
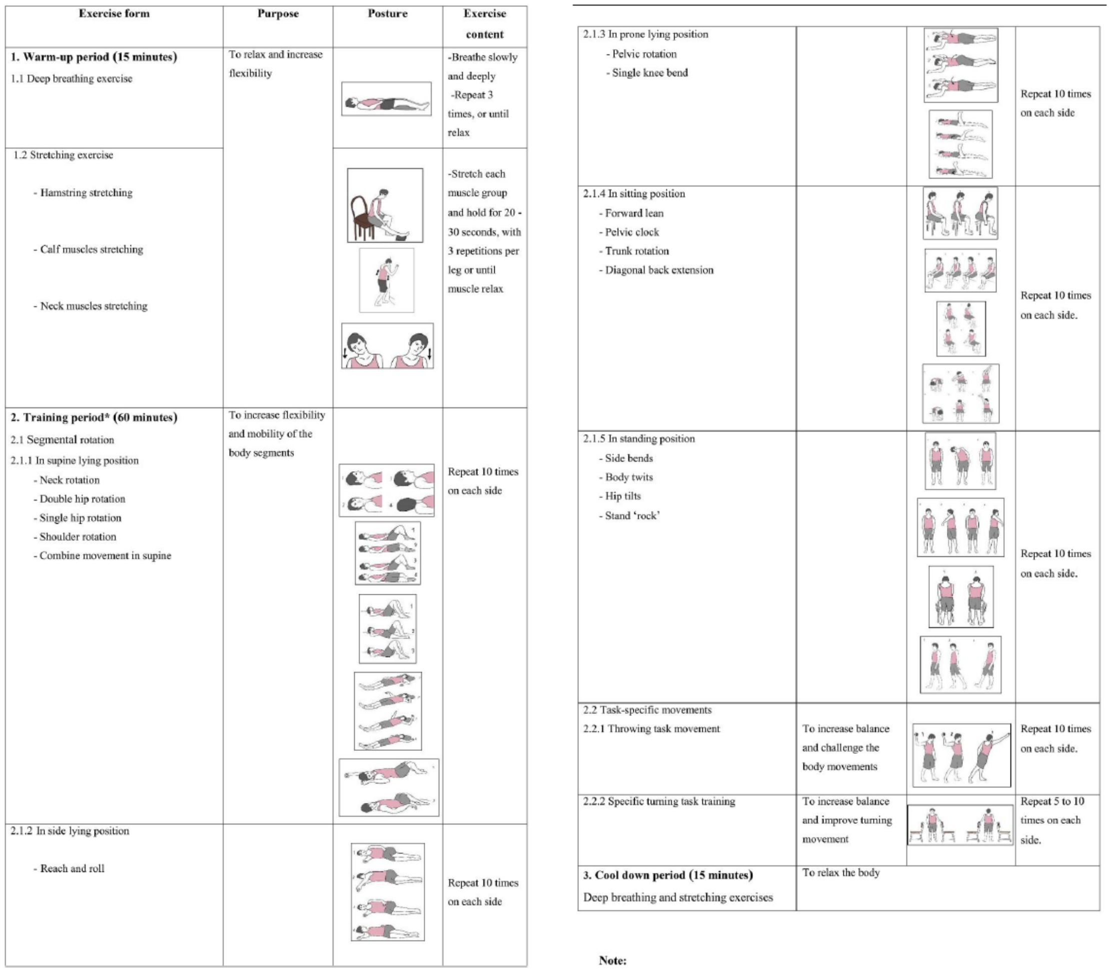


FIGURE 1 CONSORT flow diagram showing the experiment procedure



Exercise form	Purpose	Posture	Exercise content
1. Warm-up period (15 minutes) 1.1 Deep breathing exercise	To relax and increase flexibility		-Breathe slowly and deeply -Repeat 3 times, or until relax
1.2 Stretching exercise - Hamstring stretching - Calf muscles stretching - Neck muscles stretching			-Stretch each muscle group and hold for 20 - 30 seconds, with 3 repetitions per leg or until muscle relax
2. Training period* (60 minutes) 2.1 Segmental rotation 2.1.1 In supine lying position - Neck rotation - Double hip rotation - Single hip rotation - Shoulder rotation - Combine movement in supine	To increase flexibility and mobility of the body segments		Repeat 10 times on each side
2.1.2 In side lying position - Reach and roll			Repeat 10 times on each side
2.1.3 In prone lying position - Pelvic rotation - Single knee bend			Repeat 10 times on each side
2.1.4 In sitting position - Forward lean - Pelvic clock - Trunk rotation - Diagonal back extension			Repeat 10 times on each side.
2.1.5 In standing position - Side bends - Body twits - Hip tilts - Stand 'rock'			Repeat 10 times on each side.
2.2 Task-specific movements 2.2.1 Throwing task movement	To increase balance and challenge the body movements		Repeat 10 times on each side.
2.2.2 Specific turning task training	To increase balance and improve turning movement		Repeat 5 to 10 times on each side.
3. Cool down period (15 minutes) Deep breathing and stretching exercises	To relax the body		

Note:

Figure 2: one session of exercise program

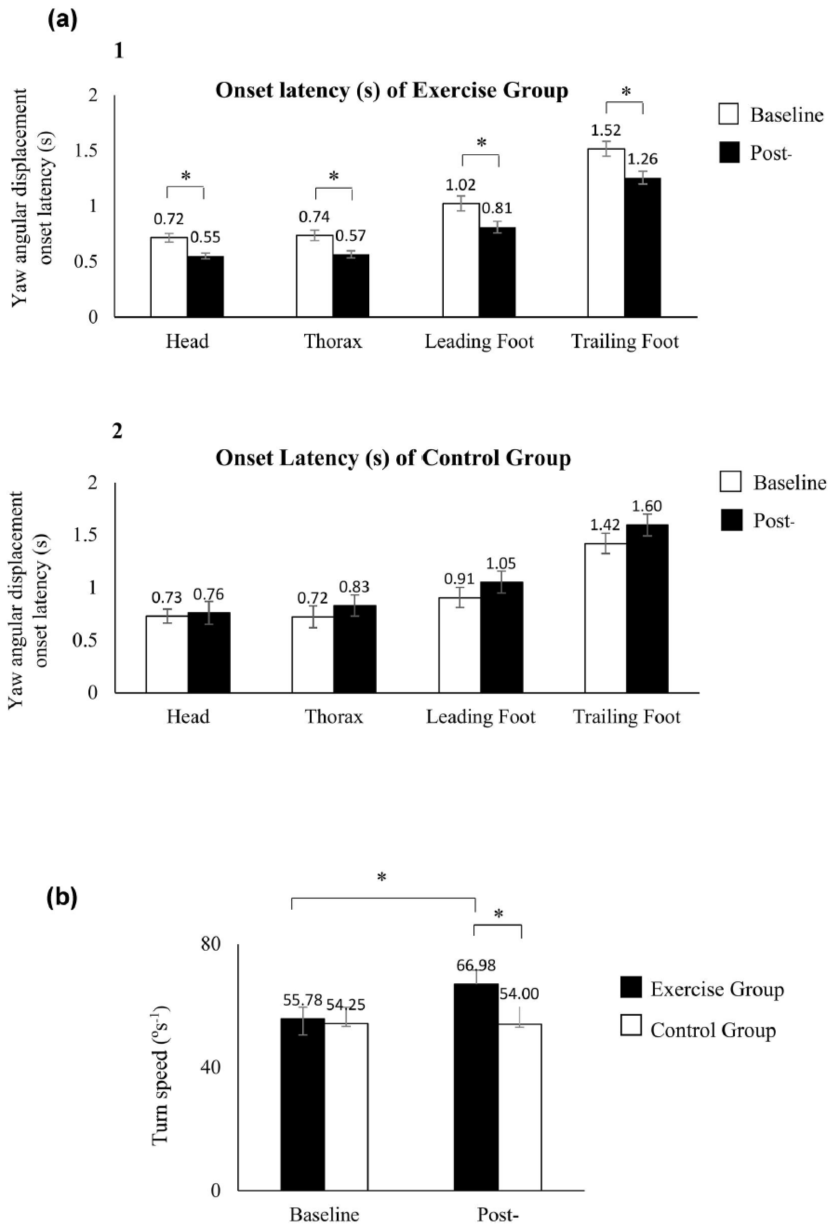
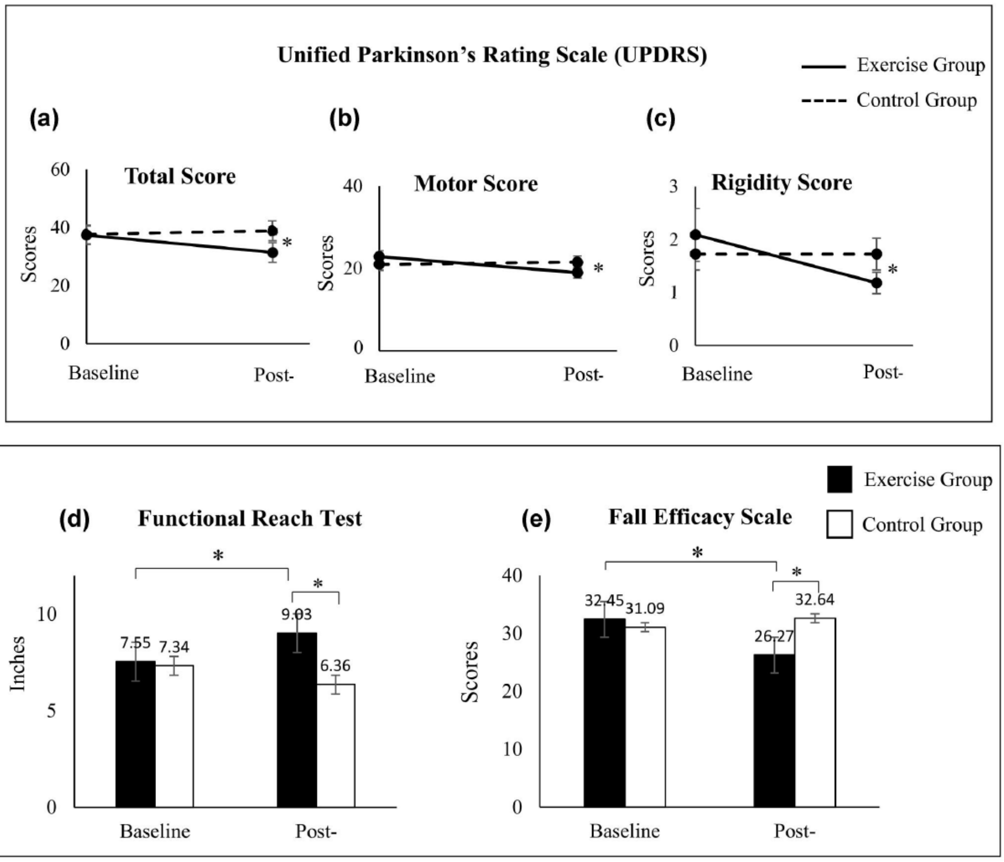


FIGURE 3 The mean values of onset latencies of head, thorax, and leading and trailing foot at baseline (white bar) and post-(dark bar) assessments of the exercise (exercise group (EG)) and the control (control group (CG)) shown in Figure A1 and 2, respectively. The mean values of turn speed, step size, total steps, and step duration between the EG (dark bar) and the CG (white bar) at baseline and post-assessments shown in Figure B, C1, 2 and 3, respectively. Values are mean + SEM



* = significant differences p<0.05 from mixed methods ANOVA.

FIGURE 4 The mean values of total score, motor score and rigidity score of Unified Parkinson's Rating Scale (Unified Parkinson's Disease Rating Scale (UPDRS)) between the exercise (exercise group (EG), solid line) and the control (control group (CG), dashed line) groups at baseline and post-assessments shown in Figure a, b and c, respectively. The mean values of functional reach test (FRT) and fall efficacy scale international (FES-I) between the EG (dark bar) and the CG (white bar) at baseline and post-assessments shown in Figure d and e, respectively. Values are mean + SEM