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The Comparative Impacts of a Specifically Designed Yoga Program and Power Training on Neuromuscular and Functional Performances in Older Adults with Parkinson's Disease

Meng Ni
University of Miami, mni@med.miami.edu

UNIVERSITY OF MIAMI

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Meng Ni

Approved:

Joseph F. Signorile, Ph.D.
Professor
Kinesiology and Sports Sciences
Sciences

Arlette C. Perry, Ph.D.
Professor
Kinesiology and Sports

Moataz Eltoukhy, Ph.D.
Assistant Professor
Kinesiology and Sports Sciences
Sciences

Christopher Kuenze, Ph.D.
Assistant Professor
Kinesiology and Sports

Corneliu Luca, M.D., Ph.D.
Assistant Professor of Neurology
Neurology

M. Brian Blake, Ph.D.
Dean of the Graduate School

James G. Moore, Ph.D., P.T.
Assistant Professor
Physical Therapy

NI, MENG (Ph.D., Exercise Physiology)

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The Comparative Impacts of a Specifically Designed Yoga Program and Power Training on Neuromuscular and Functional Performances in Older Adults with Parkinson's Disease

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BACKGROUND: Impaired balance and walking function, reduced muscular strength and power, and flexed posture are common in Parkinson's disease (PD). The benefits of power yoga (YOGA) and power training (PWT) which have been shown to improve physical function in the elderly have yet to be examined in older PD patients. Therefore, the purpose of this research was to compare the effects of YOGA and PWT on neuromuscular performance, balance, gait and perceived quality of life in older PD.

METHODS: Forty-one patients (72.2±6.5 y) were randomly allocated to the YOGA, PWT or control (CON) group. YOGA or PWT included 3-month (2 sessions per week) of progressive yoga or high-speed resistance training, respectively. Outcome measures included: the Unified Parkinson's Disease Rating Scale (UPDRS) motor, Berg Balance Scale (BBS), Mini-Best test (MB), timed up-and-go (TUG), functional reach (FR), single leg stance (SLS), postural sway test (PS), 10-m walking test (10-MWT) at normal (Nwalk) and fast walking (Fwalk) speeds, and one repetition maximum (1RM) and peak power on biceps curl, chest press, leg press, hip abduction and seated calf, joint kinematics during gait cycle (hip, knee, ankle, shoulder, elbow), standing posture, and quality of life (PDQ-39). Participants completed 3 testing sessions: pretest, post-test after 3-months of training, and follow-up 3 months after the post-test.

All measures, except PS, standing posture, and biomechanical gait analyses, were administered during pretest, post-test and 3-month follow-up. The PS, standing posture, and biomechanical gait analyses were only performed during the pretest and post-test.

RESULTS: For the post-test, both training groups produced significant improvement in the UPDRS motor, BBS, MB, TUG, FR less affected side by PD, Nwalk and Fwalk for 10-MWT, and 1RM for all five testing machines and peak power in leg press compared to the pretest. Both training groups showed significantly greater performances in UPDRS motor, BBS, MB, FR less affected side, Nwalk of 10-MWT, 1RM in biceps curl, leg press, hip abduction, calf, and peak power in leg press than the CON. The PWT group showed significant improvement in the FR more affected side, SLS more affected side, peak power in biceps curl, chest press, hip abduction and seated calf, and the medio-lateral average displacement in the PS test eyes closed condition compared to the pretest. This group also showed significant differences in the FR more affected side and peak power of all five machines compared to the CON group. The YOGA group yielded significant improvement in the SLS less affected side, 95% of an ellipse fitted to the overall center of pressure trace and anterior-posterior average displacement and standard deviation for the PS test, and the mobility domain of PDQ-39 compared to the pretest. Additionally YOGA showed better performance in TUG, Fwalk of 10MWT, and the mobility domain of PDQ-39 than CON. Differences were also detected between the YOGA and PWT in the medio-lateral and anterior-posterior average displacement in the PS test in the eyes closed condition. During follow-up testing, both training groups maintained significantly better values in the UPDRS motor, BBS, MB, TUG, Fwalk of 10-MWT, 1RM in leg press and seated calf, and peak power in leg press compared to the pretest. The results for the UPDRS motor, MB, and 1RM and peak power in leg press were also significantly better than the CON. Additionally, the PWT group maintained improvements in the FR more affected side and peak power in hip abduction; while the YOGA group maintained performance in the Nwalk of 10-MWT compared to the pretest. The MB and hip abduction 1RM showed significant declines compared to the post-test for both training groups. No significant changes in any measure were seen for the CON over the study period.

CONCLUSION: Both the 3-month PWT and the specially-designed YOGA programs were shown to significantly improve balance and motor functions in older PD patients. However, PWT has a more widespread impact on muscular power than YOGA training, while the YOGA training tends to improve balance function to a greater degree than the power training.

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Chapter One: INTRODUCTION

Parkinson's disease (PD) affects between .5 and1.0% of persons aged 65-69 years, and between 1 and 3% of those 80 years of age and older [1], with approximately 60,000 new diagnosed cases per year [2]. Reduced mobility in this population usually results in loss of independence, increased incidence of falls and related injuries, and reduced activity levels. The loss of mobility due to PD can be characterized by rigidity, bradykinesia, and gait disturbance [3-5]. Using functional tests, several studies examining the effects of rigidity have reported representative symptoms including flexed posture [6], lack of spinal flexibility and trunk rotation [7], and reduced joint range of movement during postural transitions [8] and gait cycles [3]. Bradykinetic movement is described as commonly include: slowness of voluntary movement and reduced movement amplitude [4, 9]. Another frequently reported symptom, freezing, is defined as difficulty in initiating movements, motor block, or sudden inability to move during the execution of a movement sequence [3, 9]. A study of 990 patients with PD reported that 318 of them had motor blocks, defined as freezing episodes and related phenomena, with 86% of these patients having blocks in gait initiation and 45% having blocks when turning during walking [10].

Results of systemic reviews and meta-analyses [11-13] suggest that physical exercise, including physical therapy, aerobic and resistance training, martial arts (i.e. Tai Chi), and other exercise strategies, such as dance and yoga, can benefit people with PD by improving physical functioning, health-related qualify of life, strength, balance and gait, and by reducing the incidence of falling. Power-based resistance training (high-velocity, low resistance) has been used to improve strength, power and physical performance in healthy older adults for over two decades [14]. This type of training not only increases individuals' capacities for rapid force production; it also improves gait speed, balance, and whole-body physical function [14]. Additionally, translational drills allow the application of newly developed physical capacities to daily activities [15]. Based on results showing significant losses of power at lighter loads due to bradykinesia and muscle weakness [16], power training, with emphasizing high speed but low to moderate resistance level, may be a feasible new treatment modality for physical therapy in PD.

Yoga, developed in ancient India, is becoming increasingly more popular as a health-based activity. The reported benefits of yogic training for healthy populations include improving muscle strength and endurance [17-21], muscle power [22], flexibility [17, 20, 21], balance and coordination [18, 21], body composition [22, 23] and health-related functions [24]. Additionally, yoga-based treatments have the potential to relieve pain [25], reduce the risk of falling [24, 26], address metabolic problems [27] and improve quality of life [28] in individuals with musculoskeletal and metabolic disorders. As noted by Taylor, yoga therapeutics offer a highly refined, specifically delineated practice for affecting human behavior primarily through the close integration of the central and peripheral nervous systems during yoga performance [29]. Although yogic therapeutic principles and interventions have been adopted by major rehabilitation clinics and hospitals across the country, very little controlled scientific research has been conducted to examine the efficacy of yoga as an intervention for PD. One pilot study [30] indicated that a 12-week Iyengar yoga intervention significantly improved motor Unified Parkinson's Disease Rating Scale (UPDRS) scores, balance function, flexibility, posture, and locomotion compared to a control group receiving no intervention [30].

To our knowledge, no study has examined the effects of power training on persons with PD; and, there is a paucity of scientific studies with high statistical power that suggest that yoga training can improve motor function in individuals with PD. Therefore, it was reasonable to examine the therapeutic effects of yoga and power training on PD patients. This study compared power training and yoga as separate exercise interventions for older adults with PD. To assess the comparative effectiveness of these interventions we compared their impact on strength, power, motor function, gait, posture, balance, and perceived quality of life in a sample of patients with mild to moderate PD. Using these two high-speed exercise interventions, we hypothesized that both power training and yoga practice would attenuate PD symptoms, improve physical performance, and improve quality of life in older PD patients.

Chapter Two: METHODS

Design

This study used a randomized controlled trial design incorporating two 3-month exercise interventions, power training (PWT) and yoga training (YOGA) in older people with PD. Participants were recruited from local supportive groups and hospitals in the greater Miami area. After baseline assessments, participants were allocated to an intervention (PWT or YOGA) or a control (CON) group using block randomization. The block randomization procedure was performed based on the Hoehn & Yahr Classification of Disability for PD (H&Y Scale). Participants were assessed at the Laboratory of Neuromuscular Research and Active Aging, one hour after taking their usual PD medication. The order of test administration was standardized among subjects and testing sessions. Pretests and post-tests were performed within a 2-week period before and after the intervention, respectively. Additionally, follow-up tests were administered three months after the post-test. All assessments were performed by the same testers.

Participants

Patients with idiopathic PD participated in this study. Participants were mildly to moderately impaired (H&Y stages I-III). All patients were capable of ambulation for at least 50 feet with or without an assistive device and able to get up and down from the floor with minimal assistance. They also had a score of 24 or above on the Folstein Mini-Mental State Examination.

Exclusion criteria included: greater than stage III symptoms on the H&Y Scale; a decline in immune function such as pneumonia or systemic infection; progressive degenerative disease besides PD; spinal fusion or other orthopedic surgery in the past six months; severe visual deficits; major depression or dementia; greater than minimal assistance required for gait and transfers; inability to make regular time commitments to the scheduled YOGA or PWT sessions; or engaging in regular practice (1 to 2 times weekly) of yoga or high-intensity resistance training or balance training within the past year. All participants signed an informed written consent approved by the University of Miami Subcommittee for the Use and Protection of Human Subjects.

Intervention

Power training: The 12-week PWT program used evolving optimal loads on eleven pneumatic machines (Keiser A420, Keiser Sports Health Equipment, Fresno, CA). Exercises included: biceps curl, triceps push-down, chest press, seated row, lat pull-down, shoulder press, leg press, leg curl, hip abduction, hip adduction, and seated calf. Maximal strength (one repetition maximum: 1RM) was determined on each machine according to the methods delineated below. The PWT group performed 3 circuits of 10–12 repetitions on each machine twice per week. One circuit was considered to have been completed when the participant completed one set on all 11 machines while alternating upper and lower body exercises. To determine training loads for the PWT group, peak power was evaluated on all 11 machines at intensities ranging from 30 to 90% 1RM. Following a one week adaptation period, training loads for each exercise were increased every week from the fourth week onward based on participants' reaching power plateaus for that exercise. Briefly, when the patterns of power increase plateaued (within 5%) across two consecutive sessions, loads were increased by 5% and training continued until the next power plateau. Participants were instructed to exert force as fast as possible during the concentric contraction phase of each exercise and move slowly during the eccentric contraction phase. Visual feedback of the power output was provided for each repetition. Additionally, two 2-week (weeks 5 and 6; weeks 11 and12) transitional (translational) training cycles were incorporated into the PWT program. These cycles utilized balance and agility activities, including line, cone, ladder, chair, step, and ball drills, designed to improve movement speed and initiation, reaction time, and coordination, thereby translating improvement in strength and power into improved functional performance by using motor skill practice.

Yoga: The yoga program was designed to improve muscle strength and power, movement speed, balance and coordination specific to PD-related decrements. This targeted yoga program was based on our earlier studies showing that muscle utilization patterns differed among Vinyasa yoga poses [31, 32], and that a 12-week, 2 times/week specially designed yoga program could improve balance function in older fallers to the same degree as an established balance training program and Tai Chi [26]. Based on the characteristic of Power Vinyasa yoga, the program used fast transitions from one posture to another [33], thereby targeting bradykinesia and rigidity caused by PD. Additionally, strength, power, flexibility, and balance were addressed by stabilizing body extremities and strengthening core muscles through the YOGA intervention. The yoga intervention was given as a group class for 12 weeks, 2 sessions/week, 1 h/session. During the practice, participants were instructed to perform fast transition pose sequences, holding one position for no more than 3 breathes. This program incorporated three difficulty levels, which became progressively more challenging throughout the study. During the first four weeks, the training incorporated predominantly standing poses and a floor and balance series at mild to moderate intensity. For the next four weeks, the same pattern was used; however, more advanced poses were incorporated into the training. In the remaining weeks, the program incorporated progressively more difficult poses and transitions. The program was taught by three certified yoga instructors.

Control: For the CON group, participants received their usual care and health education classes were provided over the 12 weeks, with one class per month (a total of three classes) on life style modification, medication, therapy and exercise, nutrition and long-term care.

Outcome Measures

The UPDRS motor score, Berg Balance Scale (BBS), Mini-Balance Evaluation Systems Test (MB), timed up-and-go test (TUG), functional reach (FR), single leg stance (SLS), normal and fastest perceived 10-meter walking speeds (10-MWT Nwalk, Fwalk), muscular strength and power, and the Parkinson's Disease Questionnaire (PDQ-39) were administered during the pretest, post-test and 3-month follow-up. The postural sway (PS) test, standing posture, and biomechanical gait analyses were performed during the pretest and post-test.

UPDRS motor score: The UPDRS motor score was used as the primary outcome measure to evaluate the effectiveness of the two interventions in addressing motor dysfunction [34]. The test was conducted by a licensed physical therapist in its administration. The UPDRS motor examination also was used to determine participants' less and more affected side of the body by PD.

Balance: Two evaluation systems, the BBS [35] and the MB [36]; two static balance tests, the SLS [37] and the PS tests [38]; and, two dynamic balance tests, the TUG [35] and the FR [35], were used to evaluate balance. For the PS test, a portable force platform (AccuSway System, Advanced Mechanical Technology, Inc., Watertown, MA) recorded the sway area (95th percentile of an ellipse fitted to the overall center of pressure trace: COP_{area}), the medial–lateral and the anterior–posterior displacement (MLD_{avg}, APD_{avg}) and standard deviation (MLD_{SD}, APD_{SD}), and the average velocity of the center of pressure (V_{avg}) while standing on the platform in bipedal stance for 10s with eyes open (EO) and closed (EC). Three trials were provided under each condition.

Strength and power: Measurements of strength and power were taken during the performance of the leg press, chest press, seated calf, hip abduction and biceps curl, with special attention directed toward knee extensor muscle strength and power, as measures of the efficacy of the interventions on neuromuscular capacity as it relates to fall risk [39]. Muscle strength and power were assessed using computerized pneumatic resistance machines (Keiser A420, Keiser Sports Health Equipment, Fresno, CA). Muscle strength was measured using a 1RM. The 1RM test began with a five repetition warm-up at 30% body weight for leg press and seated calf, 5% body weight for biceps curl and triceps pushdown, and 10% body weight for all other exercises. This was followed by a three repetition warm-up at 35% body weight for leg press and seated calf, 15% body weight for biceps curl and triceps pushdown, and 20% body weight for all other exercises. All tests were completed within 6 repetitions. After measurement of the 1RM for each movement, power was assessed using the same pneumatic resistance machine. Peak power was assessed at seven relative intensities (30%, 40%, 50%, 60%, 70%, 80%, and

90% 1 RM) for each exercise. The testing order was randomized to reduce any fatigue or learning effects. For strength testing participants were provided a 2-minute recovery between trials; while for power testing, a 1-minute recovery was provided.

Walking function and gait initiation. The 10-MWT Nwalk and 10-MWT Fwalk were used as primary outcome measures for gait function. Additionally, three-dimensional biomechanical analyses, including kinematics of the gait cycle and gait initiation, were used to further assess the effectiveness of our interventions. Five trials were performed. For gait initiation, subjects were asked to stand with their feet hip-width apart and with each foot on a separate force platform. Each trial took 16s, the first 10s being quiet standing. A verbal cue was given to prepare the participant. Upon a second verbal cue, participants initiated walking forward at their own pace using a self-selected foot. One or two practice trials were allowed to ensure that subjects fully understood the task. Gait initiation variables included time to release (heel off), time to unload (toe off), horizontal force at toe off, and time to heel contact 1. Variables included have been shown to be significantly lower in older PD patients compared to their healthy counterparts [3].

After the gait initiation test, participants were asked to walk on a 10m walkway at a self-selected walking speed for a minimum of three trials. Walking function was tested without walking aid, such as walkers or canes, and without ankle-foot-orthoses, when possible. From a functional perspective, subjects did not use walking aids at all times [40]. The kinematics of the gait cycle included joint angles (hip, knee, ankle, shoulder and elbow) at heel contact and toe off.

The biomechanical data was processed using Vicon Nexus software (Vicon Motion Systems Ltd. UK). For gait initiation, the point that corresponded to the first swing limb heel-off was labeled *release*; the point of first swing limb toe-off was labeled *unload*. The time between the verbal cue and *release*, the time between the verbal cue and *unload*, and the time between the verbal cue and the *heel contact 1* was calculated in each trial. The changes in the force output indicated by the force plate were used to determine each time point (release, unload, heel contact 1). The horizontal force at release was also recorded in each trial. For gait cycle, kinematics of ankle, knee, hip, shoulder, and elbow joints were be recorded from the 4^{th} to 8^{th} m.

Posture. Spinal curvatures, including neck and trunk flexion angles, were measured. While in a standing position without shoes, feet hip-width apart and arms resting at their sides, participants' skin was marked over the tragus of the ear, the spinous processes of C7, T1, T12, midway between T1 and T12 (Tmid), and at S1. A lateral photograph was taken in the standing position to evaluate the craniovertebral angle (the angle between the horizontal line through the spinous process of C7 and a line joining the spinous process of C7 with the tragus of the ear [41]) and curvature of upper dorsal segment (the difference between the angle at T1 and Tmid), lower dorsal segment (the difference between the angle at Tmid and T12), and dorso-lumbar segment (the difference between the angle at T12 and S1) [42] . Kinovea software was used to measure the angles.

Parkinson's Disease Questionnaire (PDQ-39): There are 39 items in this questionnaire, which are divided into eight categories: mobility (10 items), ADL (6), emotional well-being (6), stigma (4), social support (3), cognitive impairment (4), communication (3), and bodily discomfort (3). The PDQ-39 was used to measure the quality of life of the PD patients before and after training, and after follow-up. This questionnaire is sensitive to changes that matter to patients, but which are not the primary focus of clinicians' assessments that concentrate on impairment and physical function [43]. The sensitivity for mobility (.55) and ADL (.43) suggests a reasonable response and the changes are consistent with patients' retrospective judgements of changes [43].

Activity log: Participants were asked to record the physical activities during the 3-month follow-up period, including exercise mode, frequency, and perceived effort (Borg Scale of Perceived Exertion).

Data Analyses

Power calculations (G-power, Universitat Dusseldorf, Germany) indicated that a sample size of 14 participants per group was required to detect an effect size of Cohen's d=.56 for reduction in the UPDRS motor score in the exercise groups compared with the control group (power=.8, alpha=.05, correlation with covariate=.05). The sample size calculation allowed a 10% drop-out rate.

All statistical analyses were performed with SPSS (Chicago, IL, Version 22). An analysis of covariance (ANCOVA) of repeated measures was used to examine time (pretest vs. post-test vs. follow-up) and group (PWT vs. YOGA vs. CON) differences while using the pre-score as the covariate. Post hoc test by Bonferroni adjustment was used to detect the statistical significance of the change in outcome variables between the baseline and the 3-month training period and the 3-month follow-up period for each group, and the group difference at each time point. For skewed data, the Friedman test was used to compare the group difference and Mann–Whitney U test was used to compare the time difference for each group. The 95% confidence intervals (95%CI) of mean differences were also calculated. Effect sizes (hedge's g) and its 95% CI were also computed using adjusted means and pooled SD as standardizers to compare the magnitude of changes between intervention groups and CON (PWT vs. CON; YOGA vs. CON). The interpretation of g is similar to that of Cohen's d: .80 is considered large, .50 is considered medium, and .20 is considered small. A value of p=.05 was required to establish significance.

Chapter Three: RESULTS

Flow of Participants through the Trial

Forty-eight participants were randomized into the PWT, YOGA or CON groups. Figure 3.1 shows the study design and flow of participants through the study.

The characteristics of the participants are presented in Table 3.1. At the beginning of the study, 27 intervention group (PWT or YOGA) participants were taking carbidopa/levodopa (Sinemet). Four PWT group participants were taking Sinemet as a single medication and nine were taking it in combination with other PD medications. Five YOGA group participants were taking Sinemet as a single medication and ten were taking it in combination with other PD medications. Two participants (one for each intervention group) were not taking any PD medications. Twelve CON group participants were taking Sinemet, four were taking it as a single medication, and eight were taking it in combination with other PD medications.

During the study period, one PWT participant had her Sinemet dose increased. No modification in Sinemet dosing patterns were reported for the YOGA or CON group.

During the 3-month follow-up period, two PWT, one YOGA, and one CON group participants increased the dosage of their PD medications, and two YOGA participants decreased the dosage of their PD medications.

Effect of Intervention

Results for field tests of motor performance, balance and gait speed are presented in Table 3.2.

UPDRS motor score: Both of the intervention groups produced significantly higher scores during the post-test and follow-up test compared to the pretest; however, no significant differences were seen between post-test and follow-up scores for each group. The PWT and YOGA groups showed significantly higher scores than the CON group for the post-test ($p<.001$) and follow-up test ($p=.003$). In the post-test, a mean difference of 10.65 (95%CI: 6.16, 14.15) was see between the PWT group and CON ($g=-1.07$, 95%CI: -1.91, -.23), while a mean difference of 11.22 (95%CI: 7.24, 15.20) was detected between the YOGA and CON ($g=-1.2$, 95%CI: -2.07, -.33). For the follow-up test, a mean difference of 8.75 (95%CI: 2.21, 15.29) was seen between the PWT and CON ($g=-.72$, 95%CI: -1.81, .37), and of 9.18 (95%CI: 2.82, 15.55) between the YOGA and CON ($g=-.84$, 95%CI: -1.92, .24). No significant group difference was detected between the PWT and YOGA group at any time point.

Balance: Both of the PWT and YOGA groups showed significantly higher values in BBS score after training and for the 3-month follow-up period than during the pretest. Additionally BBS scores were significantly greater than the CON group in the post-test ($p<.001$), with a mean difference of 3.39 (95%CI: 1.47, 5.32) for the PWT group ($g=.75$, 95%CI: -.07, 1.57) and 3.51 (95%CI, 1.58, 5.44) for the YOGA group ($g=.84$, 95%CI: .01, 1.67). For the MB test, both intervention groups demonstrated statistically higher scores for the post-test and follow-up test than the pretest, followed by a significant decline in follow-up compared to the post-test scores. Meanwhile, both training groups showed significantly higher scores than the CON group for the post-test ($p<.001$) and follow-up test ($p=.008$), with a mean difference between PWT and CON of 2.77 (95%CI: 1.57, 3.96) with a moderate effect size (g=.57, 95%CI: -.23, 1.37) and of 3.61 (95%CI, 2.38, 4.83) between YOGA and CON with a moderate effect size (g=.73, 95%CI: -.09, 1.55) in the post-test, and a mean difference of 1.96 (95%CI: .18, 3.73) between PWT and CON (g=.29, 95%CI: -.76, 1.34), and of 3.01 (95%CI: 1.23, 4.80) between YOGA and CON (g=.63, 95%CI: -.43, 1.69) for the follow-up test.

For the TUG test, though both training groups demonstrated significantly shorter times in the post-test and follow-up test compared to the pretest, only the YOGA group produced a significantly shorter time than the CON group in the post-test, with a mean difference of 2.58s (95%CI: .75s, 4.41s) with a large effect size (g=-1.2, 95%CI: -2.07, -.33).

For the FR test, both intervention groups showed significantly greater post-test reach scores than CON on the less affected side ($p<.001$); but only the PWT showed a significantly greater reach distance than CON on the more affected side ($p=.026$) for the post-test. Both intervention groups produced significantly greater reach scores for the less affected side for the post-test compared to the pretest, and the PWT group showed a significantly shorter reach during the follow-up compared to the post-test. For the less affected side's performance, the PWT group showed a 6.12 cm (95%CI: 3.53 cm, 8.69 cm) longer reach distance with a large effect size (g=.92, 95%CI: .09, 1.75) and the YOGA group show a 4.57 cm (95%CI: 1.96 cm, 7.19 cm) longer reach distance with a large effect size (g=.65, 95%CI: -.19, 1.45) compared to the CON group during the post-test. For the more affected side, the PWT group show a 4.32 cm (95%CI: .38 cm, 8.26 cm) longer reach distance compared to the CON group (g=.63, 95%CI: -.19, 1.45) during the post-test.

For the SLS test, the PWT and YOGA groups yielded a better performance for the more affected side and the less affected side during the post-test compared to the pretest, respectively. No group differences between the intervention and control groups were seen for the SLS test.

Additionally, no group difference was detected between the PWT and YOGA group in the BBS, MB, TUG, and FR for the post-test or follow-up test.

Static Balance Test. For the PS test (see Table 3.3), the YOGA group showed significantly smaller COP_{area} and lower V_{avg} for the post-test compared to the pretest under the EO and EC condition. Also, the YOGA group showed significantly reduced COP_{area} (p=.006) and V_{avg} (p=.026) compared to the CON for the post-test. Both intervention groups show significantly lower anterior-posterior SD compared to the CON (p<.048). Finally, the PWT group produced significantly lower medio-lateral and anterior-posterior average displacement compared to the YOGA and CON group (p<.05) in the post-test.

Walking Speed. For the 10-MWT Nwalk, both the PWT and YOGA groups showed significantly shorter performance times compared to the CON during the post-test (p=.003), with a mean difference of 1.91s (95%CI: .53s, 3.29s) between the PWT and CON (g=.52, 95%CI: -.28, 1.32), and 1.80s (95%CI: .39s, 3.21s) between the YOGA and CON (g=.55, 95%CI: -.26, 1.36) . In contrast, only the YOGA group showed a significantly shorter time than CON for the 10-MWT Fwalk during the post-test (p=.04), with a mean difference of .85s (95%CI: .02s, 1.68s) and moderate effect size (g=.56, 95%CI: -.26, 1.38). Both training groups produced significantly shorter times in the Nwalk and Fwalk during the post-test and follow-up test compared to the pretest; with the exception of the PWT group which didn't show a significant difference between the pretest and follow-up values.

Walking function and gait initiation: For the kinematics during gait cycle (Table 3.4) no significant differences were observed between the pretest and the post-test among groups. The gait initiation results, including time to release, time to unload, and time to heel strike 1, showed a slight decrease (improvement), but no significant difference was detected among time points or groups.

Posture: No group or time differences were detected in any posture variable (Table 3.5).

Strength: Strength results are presented in Table 3.6. Both training groups showed significantly higher 1RM values for all five machines in the post-test compared to the pretest, and significantly higher 1RM values for leg press and seated calf in the follow-up test compared to the pretest. Both groups showed significantly lower 1RM values for hip abduction in the follow-up test compared to the post-test. Meanwhile, both PWT and YOGA showed significantly greater values than CON for biceps curl (PWT: g=.54, 95%CI:-.26, 1.34; YOGA: g=.52, 95%CI: -.29, 1.33), leg press (PWT: g=.21, 95%CI:-.57, .99; YOGA: g=.35, 95%CI: -.45, 1.15), hip abduction (PWT: g=.62, 95%CI:-.19, 1.43; YOGA: g=.55, 95%CI: -.26, 1.36) and seated calf (PWT: g=.76, 95%CI:-.05, 1.57; YOGA: g=.80, 95%CI: -.03, 1.63) in the post-test, and for leg press in the follow-up test.

Only the PWT showed significant greater value than CON for chest press in the post-test (g=.09, 95%CI:=-.97,1.15).

Power: Results for power are summarized in Table 3.7. The PWT group show significantly greater post-test power outputs for all exercises than those seen during the pretest, and these values were higher than those produced by CON (biceps curl: g=.24, 95%CI: -.55, 1.03; chest press: g=.50, 95%CI: -.30, 1.30; leg press: g=.83, 95%CI:.04, 1.62; hip abduction: g=.48, 95%CI: -.32, 1.28; seated calf: g=.56, 95%CI: -.24, 1.36) ($p<.05$). For the leg press (g=.81, 95%CI: -.24, 1.85) and chest press (g=.59, 95%CI: -.48, 1.66), the PWT group also exhibited significantly higher follow-up power values than during the pretest and these values were higher in the PWT than CON. In contrast, the YOGA group demonstrated higher post-test and follow-up values than pretest for the leg press only, and a difference between YOGA and CON (post: g=.72, 95%CI: -.08, 1.52; follow-up: g=.93, 95%CI: -.10, 1.96) was seen at these time points for this exercise alone.

PDQ-39: For PDQ-39 (Table 3.8), the YOGA group produced significantly better scores in the mobility domain for the post-test and follow-up test compared to the pretest, also significant differences were seen between the YOGA and CON groups in the post-test (p=.007) and follow-up test (p=.01), with a mean group difference of 7.32 (95%CI: 1.71, 12.93) in the post-test and of 6.91 (95%CI: 1.54, 11.88) in the follow-up test. For YOGA, most participants reported less problem with “walk half a mile” and “getting around the house or in public”; they also reported decreased levels of “feeling frightened or worried about falling over in public” during post and follow-up test. No group differences were detected between the PWT and CON in the post-test or follow-up test for the mobility domain, and no time differences were seen in any other domains of the PDQ-39.

Chapter Four: DISCUSSION

The principal finding of the current study is that over a 3-month training period, both PWT and our specially designed power YOGA program were effective interventions for improving performance in older adults with PD. However, variations in the levels of improvement for specific variables differed between the two exercise interventions. Additionally, these results were achieved without adverse effect or injury.

Both PWT and YOGA produced statistically significant improvements in the primary outcome measure, the UPDRS motor score. This suggests that both interventions can attenuate PD symptoms and improve movement function. The decrease of 10 points for the PWT group and 11 points for the YOGA group from pretest to post-test, and the decrease of 8 points for the PWT group and 7 points for the YOGA group from pretest to follow-up test, are in agreement with results from previous studies showing the beneficial effect of exercise interventions on the motor symptoms of PD. These studies reported decreases in the UPDRS total score ranging from 8 to 15 [44-46]. The minimal clinically important difference (MCID) for the UPDRS motor score is 5 out of 108 points; 11 points indicates "much improved" and 12.3 points indicates "very much improved" [47]. The score changes suggest that our interventions produced a meaningful training effect. Meanwhile, participants' self-report on the quality of life (PDQ-39) suggesting improved mobility and reduced fear of falling also indicates increased movement function. Additionally, these improvements persisted for 3 months, which may be due in part to the modification of participants' lifestyle, as evidenced by the increased hours of weekly exercise reported when comparing pretest and follow-up values (Table 3.1). However, the relative contributions of increased activity levels versus a prolonged training effect to the maintenance of UPDRS motor score improvements cannot be determined. The lack of significant differences between the PWT and YOGA group indicates that, when targeting improvements in motor function, patients have the opportunity to choose either program depending on their exercise preference. They may also use both YOGA and PWT in either a periodized program or as complementary interventions to maximize the level of adaptation.

For the six balance measurements (Table 3.2), PWT generated significant improvement in the BBS, MB, TUG, FR more and less affected side and SLS more affected side across the training period and all changes, except SLS more affected side, were maintained after the 3-month follow-up period. YOGA also produced significant improvement in the BBS, MB, TUG, FR both sides; while improving SLS on the participants' less affected rather than more affected side. With the exception of SLS less affected side these improvements were again maintained for three months after the training occurred. PWT and YOGA produced approximately a five point increase in BBS score following training. These increases represent a clinically meaningful improvement [35]. They are also noteworthy, because the scores produced by each group at pretest (PWT=48.1; YOGA=49.2) indicated a low risk of falling (46-58: low fall risk; 21-40: median fall risk; 0-20: high fall risk) and improvements were most likely limited by a ceiling effect where the sensitivity of the BBS was modest for patients with low fall risk. In contrast, the MB test is more sensitive than the BBS in detecting abnormal postural responses in PD patients. For the MB a suggested cut-off point for detecting deficits is below 21 [36]; while the suggested cut-off for people with balance disorders during the MCID is 4 points [48]. For the pretest both the PWT (17.6) and YOGA (18.9) groups were below the cut-off value. In response to PWT and YOGA, increases of 3.4 and 4.0 points were seen, respectively, increasing the scores for both groups to the cut-off point after training. For the TUG test, the performance for all three groups in our study was superior to the normative data for PD (16.4s) [49]. Both intervention groups showed significant improvements for the post-test and follow-up test; however, the YOGA group produced statistically greater improvement than CON for the post-test, while the PWT group did not. This difference may be attributable to the more functional characteristics of yoga training which have a greater capacity to transfer power into daily activity compared to PWT. It should be noted that the changes of 1.3s and 2.2s for PWT and YOGA, respectively, were below the minimal detectable change of 3.5s reported by Huang et al. [50] to represent a true change beyond random measurement error. For the FR test, the performances on the less affected side for both intervention groups showed significant improvements after training (PWT=35.1, YOGA=32.6), which were above the published cut-off of 31.75 cm indicating fall risks for patients with PD [51]. In contrast, the only significant improvement on the more affected side was by the PWT group (31.0). The fact that improvements on the more affected side were restricted to the PWT group may be explained by the fact that power training using our pneumatic machines is predominantly bilateral allowing the less affected side to compensate so that sufficient overload could be applied to both limbs. By comparison, many of the poses in YOGA are unilateral in nature thereby restricting patents' abilities to effectively perform the exercises and subsequently receive a significant training response. Additionally, the unilateral nature of YOGA may have required greater levels of exertion, further reducing the effectiveness of this intervention compared to PWT. Based on this finding, cautions should be placed during yoga training to ensure symmetric movement and yoga instructors should motivate patients to exert maximal effort in their more affected side of the body. Meanwhile, perceived effort scales, such as the Borg Scale of Perceived Exertion, should be used to evaluate subjects' self-reported efforts in future studies. Finally, the lack of significant differences in the SLS test for the intervention groups compared to the CON group may have been due to the large variability between subjects. Both intervention groups did produce statistically better performance in the post-test and follow-up test compared to the pretest. While the positive impact of the YOGA intervention may be explained by the concentration on balance inherent to yogic practice; the success of the PWT group is likely more complex. Balance was undoubtedly affected by increases in strength and power [52] of the lower body musculature predominantly; however, the transitional balance training cycles incorporated in the PWT may also have positively impacted this variable.

For Nwalk speed (Table 3.2), values below 1.0 m/s in older adults have been suggested as a cut-off indicating higher risk for adverse health issues [53] and mortality in PD patients [54]. The minimally clinically important difference is .05 m/s for small meaningful change and .13m/s for substantial meaningful change for general older people [55]. Both of training groups raised their normal walking speed above the cut-off after training and maintained these levels for at least three months (PWT- pretest:.91 m/s, post-test:1.05 m/s, follow-up: 1.03 m/s; YOGA - pretest: 1.03m/s, post-test: 1.23m/s, follow-up: 1.15m/s). For Fwalk speed, the significant improvement seen after training and maintained for three months (PWT- pretest:1.38 m/s, post-test:1.62 m/s, follow-up: 1.48 m/s; YOGA - pretest: 1.45m/s, post-test: 1.70m/s, follow-up: 1.61m/s) may be attributed to the increased leg muscle power in both training groups. Increased leg power has been shown to be positively correlated to the maximal walking speed [56].

For PS (Table 3.3), the significant reductions for EO and EC COP_{area} across the training period observed for the YOGA group indicates this intervention's potential to improve postural stability [57] and reduce associated fall risks [58]. The ellipse area of Parkinson's is larger than normal people due to the increased sway in the AP direction, and the decreased area of the 95% ellipse fitted to the overall center of pressure trace suggests improved postural sway [59]. The improvement may be due to the necessity for participants to hold one position statically during yoga practice, which may have induced improvement in static balance. The YOGA group also showed decreased APD_{SD} under EO and EC conditions after training; suggesting that participants shifted to a more erect, rather than forward leaning, position. Although YOGA did not produce a significant change in posture, this interpretation is supported by findings that PD patients with stooped posture show increased but insignificant anterior-posterior displacement compared to PD patients with more erect stances [60]. Our results, showing that PWT decreased EC MLD_{avg} after training, may have been the combined result of increased power and improved proprioceptive feedback. The increases in hip abduction power, as well as increases in leg press and seated calf power, have been shown to positively affect postural control, such as postural sway while standing on sliding and tilting platform, or repeated chair rise [52, 61]. Additionally, the high training speeds used during PWT may have positively increased the speed at which patients could adjust their body positions during the test [62]. The translational balance cycles included in this intervention may have improved proprioceptive feedback just as the poses and pose transitions did during the YOGA intervention. This mechanism is supported by discussions in previous studies that used Tai Chi and standard balance training strategies for older fallers [26, 63].

In this study, we also attempted to improve patients' stooped postures by prescribing seated row during PWT and giving specific poses for correcting posture during YOGA. Unfortunately, no significant improvement was observed for either intervention (Table 3.5), which may be due to the comparatively long duration of the disease in our patients (ap. 6 y) relative to the short duration of the interventions (12 wk). Further studies with longer training duration are needed to examine the potential for these interventions to effect improvements in stooped posture.

In a healthy population, during a normal gait cycle at heel strike, the hip flexes approximately 30 deg, the knee flexes 0 to 10 deg, and the ankle plantar flexes approximately 0 deg; while at toe off the angle is between 0 to 10 deg for hip extension, approximately 40 deg for knee flexion, and 30 deg for plantar flexion [64]. The shoulder reaches a maximum flexion of approximately 40 deg, and an extension of 32 deg. The elbow achieves a maximum flexion of approximately 56 deg and never extends beyond 20 degree flexion [65]. In our study, subjects exhibited a rigid walking pattern (Table 3.4), with less range of movement and greater hip flexion at heel strike and toe off; which may have been due to their more flexed posture. Although patients from both training groups showed slightly increased hip extension and shoulder flexion during all phases of the gait cycle, the differences were negligible. It is likely that our training modalities, which did not incorporate targeted gait training, did not employ sufficient biomechanical specificity to produce meaningful changes in the joint kinematics. Furthermore, our patients did not show any significant improvement in gait initiation after training and our results are consistent with previous study showing no significant difference in the performance of the first two steps of gait initiation with and without auditory cues [66]; but did show better performances than those reported in previous studies with PD patients not using PD medications [3]. It is possible that the "on" status resulting from the medications used during our study may have produced increased levels of performance, which could have partially reduced the possibility of resulting changes reaching statistical significance.

Concerning neuromuscular performance variables, PWT increased upper body strength by 15% for the biceps curl and 13% for the chest press, and increased lower body muscle strength by 11% for the leg press, 28% for hip abduction, and 42% for the seated calf when comparing pretest and post-test values. These strength gains are slightly lower than those reported in previous studies using resistance training, where the improvement in biceps curl was 23%, in chest press was 21% [67] and in leg extension was 25% [68] . The lower magnitude improvements in our study may have been due to the high level of muscle function in our patients at the baseline, or from the lower loading patterns in our study, which were reduced in favor of movement velocity as we targeted power, rather than strength. YOGA training also improved upper body (biceps curls = 16%, chest press = 10%) and lower body strength (leg press = 19%, hip abduction = 23%, seated calf = 38%) across the training period. It is likely that during PWT the larger improvements seen in all strength tests, with the exception of the leg press, were the result of the higher loading patterns seen in these muscles during the isolated PWT exercises compared to the more diverse, and therefore less intense, overloads applied to the muscles during most yoga poses. The only exception appears to have been in leg press strength, where YOGA may have provided a greater volume of work due to the predominance of standing positions and particular use of the lower body musculature during most transitions (Table 3.6).

The effect of exercise on muscular power is rarely reported in the literature for patients with PD. For patients in our study, the PWT group produced significant improvements in all five power assessments, while improvements by the YOGA group were limited to the leg press test. These results clearly suggest that high-speed resistance training is more effective at increasing muscle power than the high-speed pose transition used during our YOGA intervention. Although poses with upper body weight-bearing were incorporated during YOGA class, the training intensity may have been lower than that during PWT. Additionally, the overload was predominantly static during YOGA, while PWT was more dynamic in nature. However, the comparative improvement in power observed in both groups for the leg press does suggest that further modifications in the YOGA poses and transitions, which allow the high-speed transitions to be performed using a higher percentage of the individual's body weight, may further increase the effectiveness of our modified YOGA program in targeting power outputs for specific muscles. Furthermore, we suggest adding more applied power tests, such as chair stands, ramp or stair climbing, or object transfers, so that the effectiveness of these interventions can be assessed under more practical conditions that use kinetic chains rather than isolated movements. Nevertheless, both of the interventions can be considered effective at increasing leg extension power, which can improve mobility [69], preserve independence [70] and reduce fall risks [71], as leg power is a strong predictor of physical performance [72] and functional status [73] in older persons (Table 3.7).

Exercise has been found to improve health related quality of life in people with PD [13]. In the current study, however, only the YOGA group reported improved mobility as measured by the PDQ-39 over the 3-month training and 3-month retention periods (Table 3.8). Given that both interventions produced comparative improvements in walking speed and gait variables, it appears that our specially designed YOGA program may have had a greater impact on participants' perception of their improvement in mobility, which is indicated by the reduced perceived difficulty in "walk in half a mile" and "getting around the house and in public". Moreover, it is likely that YOGA could diminish the fear of falling, as evidenced by most of the participants indicating reduced level of "feeling frightened or worried about falling over in public".

The effect of detraining on PD symptoms, balance, and muscle strength have been reported in training studies of PD patients, however, this is first study to report detraining patterns as they relate to muscle power as a result of power training or yoga. In a previous study using combined resistance and balance training with PD patients, a 10% loss in average muscle strength was seen after 1 month of detraining [74]. Additionally, muscle strength never declined to baseline levels. However, these results should be considered in light of the modest changes in strength resulting from the intervention. In our study, a 6% loss in average muscle strength, with the major losses in the hip abduction (11%) and biceps curl (10%), was seen after the 3-month follow-up with muscle strength never returning to pretest levels. The negligible decline in the leg press strength (PWT = .8%; YOGA = 2.2%) and power (PWT =.4%; YOGA = 3%) could be considered important indicator of the maintenance of mobility and functional levels. For the UPDRS motor score, patients in our study showed 10% and 19% declines for the PWT and YOGA groups, respectively; once again, values remained above pretest levels. In one study using training strategies that included external cueing, attentional training, functional mobility tasks, aerobic training, and health education [75], the UPDRS ADL and motor score improved (4.0 points) after 13 session training, with a trend towards decline (2.7 points) in the performance after 3-month follow-up. The longer training duration in our study (24 sessions) in conjunction with higher intensity and more targeted training likely induced greater maintenance of the training effect. For balance function and walking speed, performances were maintained across the 3-month follow-up period, except for the MB test, which showed a significant decline compared to the post-test. The follow-up test results for walking speed are consistent with a result of a study using12-sessions of conventional physical therapy combined with medication that reported no significant decline in normal walking speed improvement after 3-month follow-up [76].

Care must be taken when interpreting the follow-up results from our study. It is tempting to assert that these results indicate that the two interventions provided improvements which persisted during three months of detraining. However, a number of factors may have affected these results, thereby making such an interpretation problematic. The most prominent of these is that there were a reduced number of participants for the follow-up test, and it is reasonable to assume that the patients who agreed to take part in the follow-up assessments may have been more active than those who did not. This argument is supported by the increased levels of activity that the follow-up group reported compared to pretest values. Therefore, it may be argued that these changes were maintained across a 3-month maintenance period; however, due to our research design we are not able to assess the intensity, duration or nature of the exercise sessions reported by these participants. These results do establish a framework for the development of a periodized model in which targeted cycles, employing variations in intensity, frequency and intervention type may be incorporated to maximize benefits to PD patients.

Finally, the interpretation of our results would not be complete without an examination of injuries or other negative events and an assessment of our participants' adherence to their training assignments. As can be seen in Figure 3.1., there were no adverse events related to the training interventions that caused individuals to stop training. As to exercise adherence 14 of 14 patients completed the PWT program and 13 of 15 patients completed the YOGA program. The average number of sessions attended by each group was 22.79±1.2 for PWT and 22.08±1.2 for YOGA. A further indication of subjects' satisfaction with the exercise interventions was the return of 8 of 14 participants from the PWT group and 9 of 13 from the YOGA group for the 3-month follow-up testing sessions. These results indicate that both interventions were well-tolerated by the PD patients involved and that they were motivated as evidenced by their adherence during the intervention period and their reported increases in weekly exercise time during the 3-month follow-up period.

There were some limitations associated with this study. First, it was not tester-blind and this may have affected testers' evaluations. Second, the sample was small and this likely affected our power to detect differences in some measures, such as the gait and posture analyses. Third, participants' walking function was not severely impaired and only a small number of participants had problems with movement initiation, which may have reduced the potential for significant improvements in gait initiation outcomes. Fourth, anti-Parkinsonism medication modification may also have had an impact on the performance in physical functioning test during the follow-up; but, we postulate that the positive impact of exercise may reduce the dosage of patients' medication.

Chapter Five: CONCLUSION

Three months of twice-weekly PWT and our specially-designed YOGA programs were able to alleviate PD symptoms, improve balance function, and increase muscle strength and power in H & Y stage I-III patients. PWT improved muscular power to a greater extent than the YOGA training, while YOGA training had a greater impact on balance function. Both interventions proved to be well-tolerated by patients and resulted in an exceptional level of exercise adherence. The PWT and YOGA programs should be considered be viable interventions to increase function in PD patients with PD either alone, in concert, or as components of a planned periodized program designed to translate improvements in physical function into improvements in daily performance, reductions in fall probability and increases in self-efficacy.

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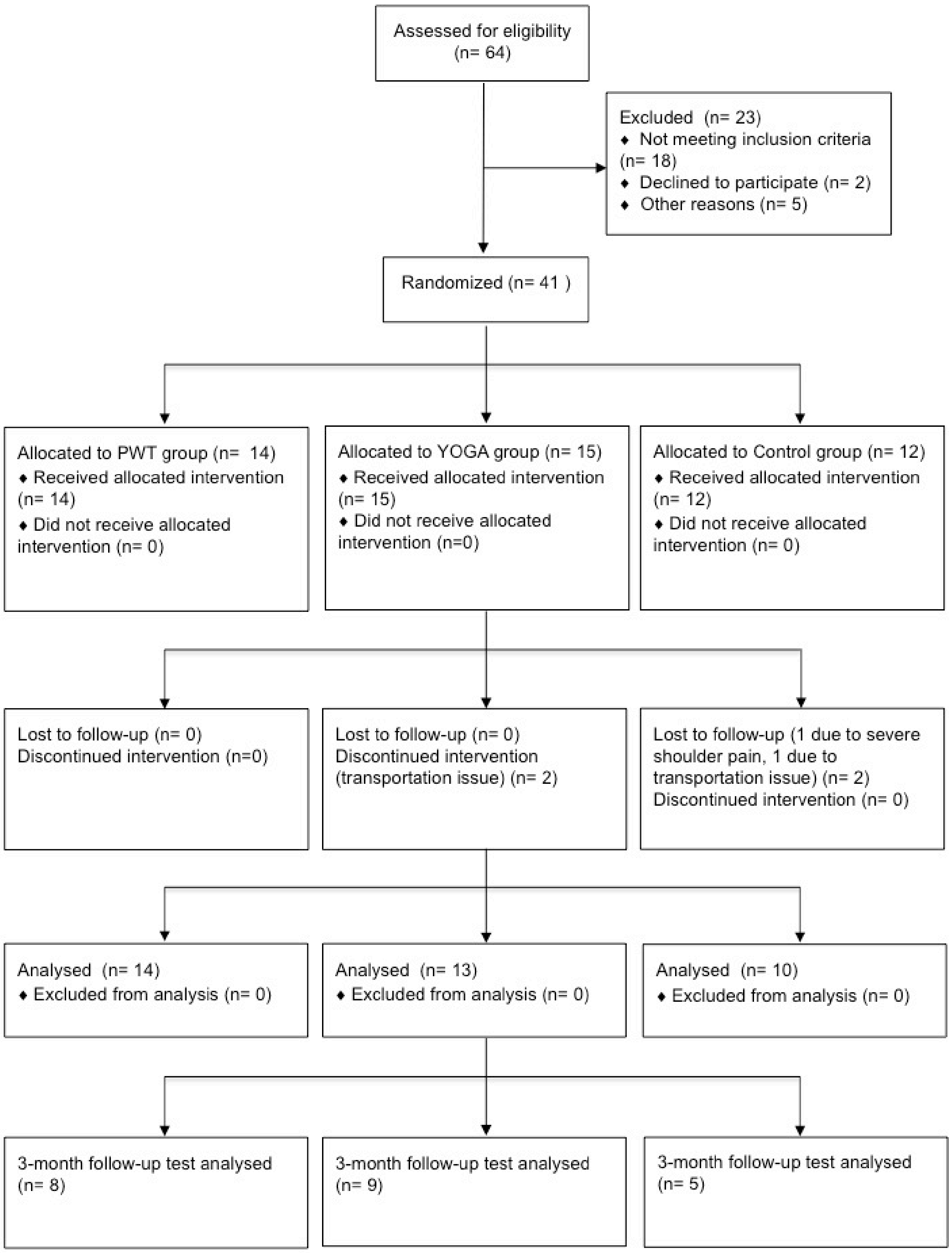
Figure 3.1 Consort Flow Chart



Tables

Table 3.1. Participant characteristics. Values are mean (SD). H&Y stage, Hoehn and Yahr stage.

	PWT (n=14)	YOGA (n=13)	CON (n=10)
H&Y stage	2.2 (.6)	2.2 (.7)	2.1 (.7)
Gender (M/F)	9/5	11/2	4/6
Age (y)	71.6 (6.6)	71.2 (6.5)	74.9 (8.3)
Weight (kg)	78.0 (18.9)	75.1 (11.9)	71.5 (13.4)
Height (cm)	173.2 (12.0)	172.5 (8.0)	163.8 (9.9)
Length of disease (y)	6.6 (4.4)	6.9 (6.3)	5.9 (6.2)
Exercise at pretest (hr/wk)	3.8 (3.3)	3.6 (2.8)	3.3 (3.2)
Exercise during 3-mon after post-test (hr/wk)	4.6 (2.5)	4.2 (3.0)	3.5 (4.3)

Table 3.2. Means (SD) for the outcome measures related to physical abilities and balance for the power training (PWT), yoga (YOGA) and control (CON) groups

	PWT (n=14)			**YOGA (n=13)**			**CON (n=10)**		
	Pre	Post	3-month	Pre	Post	3-month	Pre	Post	3-month
UPDRS motor[a]	32.86 (12.0)	22.14 (10.4)*†	24.33 (11.7)*†	28.15 (11)	17.23 (8.9)*†	20.56 (9.6)*†	27.60 (7.8)	28.00 (8.6)	27.20 (6.1)
BBS	48.11 (7.0)	53.00 (4.8)*†	52.00 (5.5)†	49.22 (3.9)	54.22 (1.4)*†	53.8 (1.1)†	52.00 (2.6)	52.60 (2.6)	52.80 (2.5)
MB	17.64 (4.6)	21.00 (3.8)*†	19.67 (5.2)*†^	18.92 (3.9)	22.92 (3.4)*†	21.56 (2.7)*†^	16.9 (5.1)	17.6 (5.1)	17.4 (3.6)
TUG (s)[a]	10.83 (6.6)	9.40 (6.4)†	9.73 (7.0)†	10.87 (4.4)	8.06 (1.1)*†	8.14 (.6)†	9.11 (2.0)	9.36 (2.1)	8.98 (1.8)
FR less affected (cm)	29.49 (5.8)	35.13 (3.6)*†	31.47 (6.1)^	29.36 (4.8)	32.59 (3.3)*†	31.75 (2.8)	28.45 (5.3)	27.69 (3.6)	28.19 (2.5)
FR more affected (cm)	26.39 (5.3)	31.04 (4.8)*†	29.49 (4.1)†	27.94 (3.8)	28.09 (3.8)	29.21 (4.3)	26.16 (4.6)	26.67 (3.8)	26.16 (3.8)
SLS less affected (s)	4.86 (3.9)	20.13 (20.8)	23.71 (26.2)	9.24 (7.4)	30.57 (37.3)†	23.11 (37.1)	22.42 (35)	18.52 (26)	31.8 (34.0)
SLS more affected (s)	4.23 (4.1)	18.64 (24.4)†	18.62 (38.3)	6.11 (2.6)	11.55 (7.8)	10.67 (6.9)	10.54 (8.2)	12.95 (17)	13.72 (18.1)
Nwalk (s)	10.94 (5.1)	9.51 (3.9)*†	9.68 (3.4)	9.72 (1.5)	8.13 (1.2)*†	8.72 (1.0)†	8.90 (.8)	9.24 (1.2)	9.09 (1.2)
Fwalk (s)	7.23 (3.5)	6.61 (3.52)†	6.77 (3.0)†	6.91 (1.2)	5.88 (.9)*†	6.21 (1.0)†	7.13 (1.4)	7.29 (1.5)	6.97 (1.2)

*Significant difference from CON, are adjusted for baseline (pretest) score based on ANCOVA

†Significant difference from Pretest.

^ Significant difference from Post-test.

[a]High score reflects poor performance.

UPDRS, Unified Parkinson's Disease Rating Scale; BBS, Berg Balance Scale; MB, Mini-Best Test; TUG, Timed Up-and Go; FR, Functional Reach; SLS, Single Leg Stance; Nwalk, 10-m normal walking; Fwalk, 10-m fast walking.

Table 3.3. Means (SD) for outcome variables in the postural sway test. Higher scores indicate poorer performances (cm).

	PWT (n=14)		**YOGA (n=13)**		**CON (n=10)**	
	Pre	Post	Pre	Post	Pre	Post
Eyes Open						
COP_{area} (cm^2)	.71 (.58)	.64 (.38)	.56 (.53)	.41 (.30) *†	.46 (.43)	.64 (.71)
MLD_{avg} (cm)	.66 (2.08)	.58 (1.73)	.48 (1.24)	.51 (1.40)	.25 (1.09)	1.09 (1.52)
APD_{avg} (cm)	-2.54 (1.30)	-2.13 (1.55)	-2.90 (1.75)	-2.87 (1.52)	-1.42 (1.12)	-2.41 (1.78)
MLD_{SD} (cm)	.20 (.08)	.20 (.08)	.15 (.08)	.13 (.05)	.15 (.14)	.18 (.10)
APD_{SD} (cm)	.48 (.15)	.43 (.10) *	.43 (.20)	.41 (.20) *†	.33 (.15)	.41 (.20)
V_{avg} (cm/s)	2.16 (.99)	2.21 (.76)	1.55 (.66)	1.50 (.61) *	1.45 (.71)	2.03 (1.32)
Eyes Closed						
COP_{area} (cm^2)	.94 (.84)	.99 (.64)	.97 (1.63)	.43 (.30) *†	.61 (.76)	.89 (1.12)
MLD_{avg} (cm)	.79 (2.11)	.18 (2.01) *†#	.38 (1.55)	.79 (1.17)	.25 (1.12)	1.09 (1.57)
APD_{avg} (cm)	-2.87 (1.30)	-2.18 (1.37) *#	-2.59 (1.70)	-3.07 (1.63)	-1.42 (1.30)	-2.57 (1.75)
MLD_{SD} (cm)	.23 (.13)	.25 (.10)	.18 (.15)	.15 (.08)	.15 (.13)	.20 (.18)
APD_{SD} (cm)	.56 (.20)	.51 (.13)	.53 (.36)	.38 (.15) †	.43 (.23)	.43 (.25)
V_{avg} (cm/s)	2.72 (1.40)	2.67 (.86) *	1.91 (.86)	1.78 (.86) *	1.75 (.94)	2.64 (1.93)

*Significant difference from CON, are adjusted for baseline (pretest) score
#Significant difference from YOGA, are adjusted for baseline (pretest) score
†Significant difference from Pretest.
COP_{area}, 95th percentile of an ellipse fitted to the overall center of pressure trace; MLD_{avg}, medial–lateral average displacement; APD_{avg}, anterior–posterior average displacement; MLD_{SD} medial–lateral displacement standard deviation; APD_{SD}, anterior–posterior displacement standard deviation; V_{avg} average velocity of the center of pressure

Table 3.4. Kinematics during gait cycle and gait initiation.

	PWT (n=14)		YOGA (n=13)		CON (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Gait Cycle Heel Strike (deg)						
Hip Right	37.68	38.52	35.02	32.60	37.53	42.76
	(11.2)	(9.4)	(8.3)	(10.0)	(6.1)	(10.4)
Hip Left	42.83	38.59	36.79	31.72	36.76	41.31
	(9.9)	(10.4)	(9.5)	(10.0)	(7.7)	(15.4)
Knee Right	5.79	7.94	3.11	6.04	9.76	9.81
	(6.3)	(5.5)	(7.9)	(5.9)	(8.8)	(4.8)
Knee Left	9.72	7.32	5.77	5.66	15.98	7.18
	(8.4)	(7.2)	(6.7)	(5.3)	(7.4)	(7.6)
Ankle Right	2.19	3.73	3.02	2.24	-3.38	.48
	(4.5)	(5.8)	(8.1)	(7.2)	(.48)	(8.3)
Ankle Left	3.63	2.86	5.82	1.78	4.26	3.04
	(7.8)	(4.3)	(7.2)	(6.8)	(2.3)	(3.3)
Gait Cycle Toe Off (deg)						
Hip Right	13.78	12.19	7.96	3.78	13.42	11.67
	(12.5)	(10.0)	(13.4)	(12.9)	(25.8)	(20.5)
Hip Left	15.18	10.61	9.55	4.47	14.56	12.22
	(9.9)	(12.2)	(13.2)	(12.1)	(27.9)	(22.0)
Knee Right	38.14	45.56	34.88	36.22	39.14	43.62
	(9.8)	(8.1)	(10.7)	(13.7)	(11.9)	(8.0)
Knee Left	44.53	42.36	40.06	39.54	43.25	44.70
	(9.7)	(8.8)	(11.9)	(6.5)	(10.5)	(14.6)
Ankle Right	-3.79	-3.32	-6.99	-3.53	-3.53	-3.95
	(5.7)	(5.5)	(4.9)	(4.8)	(11.8)	(3.6)
Ankle Left	-6.68	-5.69	-5.22	-4.70	.13	-.85
	(11.6)	(8.9)	(6.0)	(6.9)	(5.5)	(5.8)
Gait Cycle Upper Body Movement Range (deg)						
Flexion						
Shoulder	4.51	15.93	8.69	15.71	14.99	8.84
Right	(8.3)	(23.3)	(8.94)	(10.3)	(10.2)	(15.7)
Shoulder Left	9.10	6.16	4.36	12.39	14.45	10.83
	(11.3)	(11.8)	(7.7)	(11.9)	(11.9)	(8.6)
Elbow right	57.42	41.76	53.23	45.02	58.06	61.54
	(9.8)	(20.4)	(7.9)	(23.5)	(17.7)	(18.1)
Elbow Left	56.66	54.40	55.33	57.48	53.43	54.16
	(9.0)	(6.6)	(8.9)	(13.9)	(9.2)	(12.1)
Extension						
Shoulder	21.71	23.69	20.50	18.22	18.21	22.77
Right	(12.6)	(6.2)	(9.8)	(16.1)	(16.3)	(11.6)

Shoulder Left	18.26 (11.5)	17.58 (6.5)	17.15 (10.0)	18.89 (13.3)	15.85 (16.5)	13.55 (14.9)
Elbow right	41.07 (6.1)	30.56 (19.9)	40.6 (5.8)	38.37 (6.1)	43.05 (13.7)	45.21 (11.3)
Elbow Left	40.23 (7.5)	41.05 (9.8)	44.30 (7.1)	38.21 (7.4)	37.19 (5.8)	37.33 (1.7)
Gait Initiation						
Time to release (s)	.33 (.11)	.28 (.09)	.31 (.11)	.27 (.09)	.27 (.08)	.27 (.07)
Time to unload (s)	.47 (.13)	.43 (.12)	.44 (.12)	.37 (.10)	.40 (.08)	.39 (.11)
Hrz force at TO (N)	13.65(4.9)	13.00(10.7)	13.54(4.9)	15.17(5.3)	9.31(3.1)	9.76(3.1)
Time to HS1 (S)	.81 (.15)	.76 (.13)	.78 (.13)	.70 (.12)	.80 (.11)	.71 (.86)

TO, toe off; HS, heel strike; Hrz, horizontal.
Hip, knee extension (<0) and flexion (>0) position; ankle plantar flexion (<0) and dorsiflexion (>0) position.

Table 3.5. Posture results

	PWT (n=14)		YOGA (n=13)		CON (n=10)	
Degree	Pre	Post	Pre	Post	Pre	Post
Cervical	31.89 (16.3)	35.67 (13.4)	33.67 (7.3)	32.56 (9.9)	36.75 (3.3)	34.38 (9.7)
Upper dorsal	55.44 (7.8)	59.89 (6.4)	54.22 (7.5)	58.11 (6.1)	52.38 (6.1)	58.13 (6.3)
Lower dorsal	87.00 (6.4)	88.44 (6.1)	85.00 (4.5)	84.44 (8.8)	84.25 (4.2)	84.75 (10.8)
Dorso-lumbar	84.11 (4.6)	84.56 (5.2)	87.33 (3.9)	85.11 (5.4)	85.50 (2.2)	83.25 (4.3)

Table 3.6. Means (SD) for muscular strength (1RM) in kg for the power training (PWT), yoga (YOGA) and control (CON) groups

	PWT (n=14)			**YOGA (n=13)**			**CON (n=10)**		
	Pre	Post	3-month	Pre	Post	3-month	Pre	Post	3-month
Biceps curl	14.61 (6.7)	16.87 (6.5) *†	14.55 (6.7)	12.83 (7.0)	14.90 (6.7) *†	13.89 (5.4)	8.70 (5.4)	8.15 (7.3)	8.15 (6.9)
Chest press	24.66 (13.2)	27.83 (14.5) *†	25.27 (11.7)	23.16 (11)	25.54 (12.8)†	24.69 (11.8)	18.84 (16)	18.66 (15)	18.12 (14.2)
Leg press	111.0 (50.6)	124.72 (42.6) *†	123.82 (37.3) *†	109.9 (43)	131.22 (33.6) *†	128.10 (29.2) *†	114.1 (77)	115.5 (77)	108.7 (69.6)
Abduction	38.05 (17.8)	48.87 (15.5) *†	42.13 (12.8) ^	34.33 (12)	42.28 (10.5) *†	38.25 (11.2) ^	31.89 (15)	32.80 (14)	29.90 (10.4)
Seated calf	78.17 (32.4)	111.49 (28.4) *†	109.98 (24.1)†	87.77 (29)	121.35 (24.9) *†	114.95 (35.9)†	91.96 (43)	97.85 (40)	101.0 (38.7)

*Significant difference from CON, are adjusted for baseline (pretest) score based on ANCOVA

†Significant difference from Pretest.

^ Significant difference from Post-test.

Table 3.7. Means (SD) for power in watts (W) for the power training (PWT), yoga

	PWT (n=14)			YOGA (n=13)			CON (n=10)		
	Pre	Post	3-month	Pre	Post	3-month	Pre	Post	3-month
Biceps curl	105.3 (66.0)	110.94 (55.9) *†	107.13 (50.3)	90.89 (47.8)	98.78 (45.0)	94.17 (46.0)	59.0 (43)	56.8 (38)	57.1 (34.4)
Chest press	199.3 (119)	237.06 (123)*†	228.17 (113)*†	194.3 (83.7)	201.8 (83.6)	205.3 (87.3)	162.7 (117)	148.0 (117)	129.8 (65.8)
Leg press	544.6 (205)	732.83 (273) *†	729.78 (294) *†	467.7 (199)	640.5 (224) *†	661.4 (238) *†	495.8 (195)	487.2 (203)	458.2 (178)
Abdu-ctor	121.0 (52.6)	141.13 (42.1) *†	144.38 (44.5) †	103.4 (35.1)	115.2 (35.9)	114.6 (39.4)	103.5 (57)	104.9 (56)	95.20 (37.1)
Seate-d calf	197.6 (124)	238.39 (106) *†	232.67 (93.2)	185.3 (44.2)	203.0 (72.2)	298.9 (248)	202.4 (69)	206.2 (63)	172.1 (56.7)

(YOGA) and control (CON) groups

*Significant difference from CON, are adjusted for baseline (pretest) score based on ANCOVA
†Significant difference from Pretest.
^ Significant difference from Post-test.

Table 3.8. PDQ-39 results. High score reflects decreased perception of quality of life.

	PWT (n=14)			**YOGA (n=13)**			**CON (n=10)**		
	Pre	Post	3-month	Pre	Post	3-month	Pre	Post	3-month
Mobility (10)	13.86 (2.1)	11.57 (6.2)	11.97 (5.4)	14.54 (2.8)	8.92 (5.6) *†	9.72 (5.9) *†	15.90 (4.0)	17.00 (11.1)	16.45 (8.9)
ADL (6)	6.71 (1.1)	5.71 (1.0)	5.52 (1.4)	6.77 (1.8)	5.38 (1.7)	6.01 (1.6)	4.20 (.8)	5.40 (1.0)	5.30 (.8)
Emotional Well-being (6)	5.64 (.9)	5.43 (1.1)	5.65 (1.0)	5.69 (1.5)	4.54 (1.1)	5.00 (1.2)	2.00 (.8)	2.60 (1.0)	2.21 (1.0)
Stigma (4)	2.29 (.8)	2.29 (.7)	2.25 (.8)	3.92 (1.1)	2.62 (1.0)	3.10 (1.1)	2.21 (.5)	2.50 (.6)	2.88 (.6)
Social support (3)	2.29 (.6)	1.29 (.4)	1.56 (.5)	.92 (.6)	1.00 (.6)	1.11 (.6)	1.40 (.6)	2.00 (.6)	1.80 (.6)
Cognitive impairme-nt (4)	4.50 (.7)	4.21 (.8)	4.32 (.6)	4.46 (.9)	4.00 (.8)	4.21 (.8)	3.70 (.7)	3.72 (.9)	3.54 (.8)
Communi-cation (3)	3.36 (.7)	3.50 (.8)	3.44 (.7)	3.69 (.9)	2.69 (.7)	3.10 (.8)	2.30 (.9)	2.20 (.8)	2.20 (.8)
Bodily discomfort (3)	3.79 (.7)	4.86 (.6)	5.21 (.7)	4.15 (.6)	3.46 (.8)	3.88 (.8)	4.30 (.8)	5.00 (.8)	4.49 (.7)
Sum	42.43 (4.4)	38.86 (3.9)	39.92 (4.1)	44.15 (9.0)	32.62 (7.0)	36.13 (8.5)	35.20 (6.4)	40.40 (5.4)	38.87 (5.8)

*Significant difference from CON, are adjusted for baseline (pretest) score based on ANCOVA