Journal of Yoga & Physical Therapy

Colgrove et al., J Yoga Phys Ther 2012, 2:2
DOI: 10.4172/2157-7595.1000112

Research Article | Open Access

Effect of Yoga on Motor Function in People with Parkinson's Disease: A Randomized, Controlled Pilot Study

Yvonne Searls Colgrove*, **Neena Sharma, Patricia Kluding, Debra Potter, Kayce Imming, Jessica VandeHoef, Jill Stanhope, Kathleen Hoffman, and Kristen White**

Department of Physical Therapy and Rehabilitation Science, University of Kansas Medical Center, USA

Abstract

Yoga is a form of exercise that may be beneficial to those with Parkinson's disease (PD). There have been no randomized control research studies investigating the effect of yoga on those with PD. The objective was to determine if yoga can improve motor function in people with PD using a randomized controlled small group design. The PD participants were randomized into a yoga intervention group or a control group of no intervention. Assessment of physical function included motor examination scores from the Unified Parkinson's Disease Rating Scale, posture, measures of extremity ROM, flexibility and strength, and biomechanical measures of balance and gait that occurred at 3 time points: prior to starting the intervention, at 6 weeks of intervention, and immediately following 12 weeks of intervention. Thirteen adults with PD met the inclusion and exclusion criteria. All participants were unfamiliar with yoga. An Iyengar Hatha yoga program was tailored to fit participants with PD and designed to improve strength, flexibility, body alignment, and overall well-being. A 60-minute session, including physical postures, breathing, and meditation was implemented twice a week for 12 weeks. A significant improvement was found in motor UPDRS scores (p=0.004) and Berg Balance Scale scores (p=0.04) in the yoga group. A general trend of positive outcomes in the yoga group for strength, ROM and flexibility were noted with significant differences at p=0.05 in selected hip and ankle measurements. Qualitative improvements in posture were observed and there were significant improvements in the onset time of foot unloading and onset time of foot lift off. Findings suggest that yoga practice improves motor function which may be partially explained by improvements in balance, strength, posture and gait. Due to the progressive nature of PD yoga programs may offer a way to maintain wellness and perhaps quality of life.

Keywords: Yoga; Parkinson's disease; Physical function; Strength; Flexibility; Balance; Posture; Gait; Exercise; Motor UPDRS

Abbreviations: PD: Parkinson's disease; ROM: Range of motion; H&Y: Hoehn & Yahr; UPDRS: Unified Parkinson's Disease Rating Scale; COP: Center of Pressure; APA: Anticipatory Postural Adjustment; BBS: Berg Balance Scale

Introduction

Parkinson's disease (PD) is a progressive neurological pathology affecting over one million Americans that causes significant functional limitations, such as impaired gait and balance eventually leading to profound disability. Specifically, impaired balance is a major problem for people with PD. It has been reported that 46% of ambulatory PD participants without dementia experience a fall annually, with 33% reporting multiple falls annually [1]. Fall frequency increases with the severity of the disease, which could be related to the progressive loss of postural reflexes and increased postural instability. Remediable risk factors for falls include decreased balance, reduced muscle strength and freezing gait [2].

Akinesia or bradykinesia, a failure or slowness of voluntary movement is frequently observed in people with PD. Bradykinesia can lead to problems with gait initiation, which is the period between standing motionless and the completion of the first stride [3,4]. Gait initiation typically involves a shift of the body weight laterally and posteriorly towards the swing leg, laterally towards the stance leg, and finally forward momentum, which results in a step [5,6]. People with PD have delayed onset time and decreased amplitude of these anticipatory postural adjustments, which can be reversed by deep brain stimulation [3]. A shuffling gait pattern is the most prominent feature of gait seen in persons with PD with reduced stride length, decreased walking speed, and longer double-stance time [4,7].

Decreased overall muscle strength and loss of flexibility particularly in the spine is often noted in people with PD. Studies have found that people with PD have reduced lower extremity muscle strength, which make it difficult to perform everyday tasks such as rising from a chair [8,9]. The forward flexed posture seen in PD is attributed to the contractile elements of the flexors becoming shortened and the extensors becoming lengthened and weakened [10]. It is thought that bradykinesia and musculoskeletal limitations of the vertebral spine in turn create pulmonary dysfunction, which is one of the leading causes of mortality and morbidity in persons with PD [11]. Although pharmacological interventions can slow the progression of this disease, medications tend to become ineffective over a period of time, and non-pharmacological interventions may be important to address fall risk and secondary complications of immobility [12].

Current management of PD involves both pharmacological treatment and physical activity, but research demonstrates the benefits of physical activity in PD are widely varied in type and dosage of exercise intervention and application to disease severity. Outcome measures widely vary also [13]. Exercise regimes from more traditional treadmill training [14-16], balance exercise and progressive

***Corresponding author:** Yvonne Searls Colgrove, Department of Physical Therapy and Rehabilitation Science, University of Kansas Medical Center, USA, Tel: 913-588-0249; Fax: 913-588-4568; E-mail: ycolgrove@kumc.edu

Received March 23, 2012; **Accepted** April 30, 2012; **Published** May 02, 2012

Citation: Colgrove YS, Sharma N, Kluding P, Potter D, Imming K, et al. (2012) Effect of Yoga on Motor Function in People with Parkinson's Disease: A Randomized, Controlled Pilot Study. J Yoga Phys Ther 2:112. doi:10.4172/2157-7595.1000112

resistive strengthening [17-19] to alternative types of physical activity like Nordic walking [20], tango [21] and Tai Chi [22] have been investigated. Systematic reviews of exercise in PD [13,23,24] stress need for comparing specific types of exercise that may be prescribed as a part of physical therapy in rehabilitation. Although PD is a progressive disorder, several studies have found that increasing physical activity can improve aerobic capacity [25], strength and flexibility [26], balance [27,28], increase movement time [29,30] and gait parameters including speed [31,32] which in turn may contribute to independence in activities of daily living [33], improved physical function and mobility [34-36] and increased longevity [33]. Regular physical activity may delay the onset of PD symptoms [37]. Alternative approaches to physical exercise are important to explore for people who may not be able to participate in strenuous, intensive or even moderate activity because of limitations such as impaired balance or pulmonary dysfunction Iyengar Hatha yoga emphasizes postural alignment and movement within postures. This form of yoga provides a gentle alternative method of exercise that can be easily adapted in people with physical disability and neurological disorders because of the progression from body awareness to relaxation to flexibility to strength activities [38]. Props such as belts or cushions are incorporated to achieve body alignment in lying, seated, and standing positions. Yoga has been shown to produce strength and flexibility improvements in healthy adults [39]. Yoga has been shown to significantly improve measures of gait, fatigue, quality of life, and physical function in healthy elderly and people with neurologic disorders [40-43]. However, similar benefits of yoga have not been investigated in people with PD.

To our knowledge, only two case studies have investigated yoga in conjunction with physical therapy to treat a single patient with PD [44,45]. Another survey study investigated the use of complementary and alternative therapies including yoga in those with PD [46].

Therefore, the purpose of this project was to assess feasibility for the use of Iyengar- based Hatha yoga in people with PD, and to gather preliminary data on the effects of yoga on functional measures of motor performance on the UPDRS and Berge Balance Scale. Possible contributing factors such as, strength, joint ROM, muscle flexibility and posture, balance and biomechanical measures were also assessed.

Methods

Design overview

This pilot project followed a randomized clinical trial design with a small control group and intervention group to assess feasibility of Iyengar-based Hatha yoga.

Setting and participants

The CONSORT flow diagram (Figure 1) illustrates the recruitment and retention process for this study. The initial recruitment goal was 20 participants. Thirteen adults with PD consisting of 7 women and 6 men were recruited. Participants were included if they were: Hoehn & Yahr Classification of Disability [47,48] stage 1-2 who could ambulate with or without an assistive device for at least 50 feet and were able to get up and down from the floor with minimal assist or less and score 24 or above on the Folstein Mini-Mental State Exam [49]. Participants were excluded if they had any of the following: stage greater than 3 on the Hoehn & Yahr Classification of Disability, 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, mental disease/psychosis

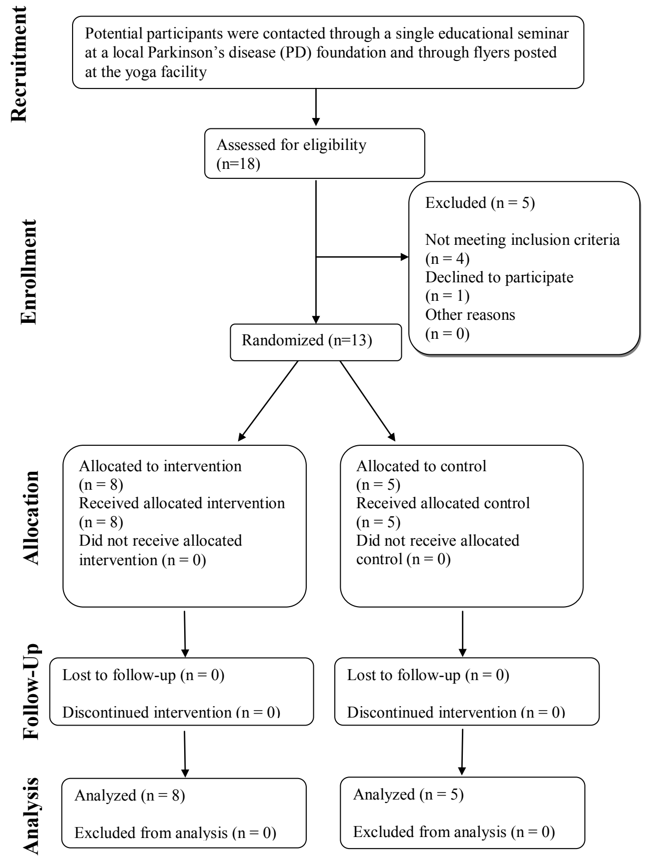

Figure 1: The CONSORT flow diagram. The recruitment, enrollment, allocation to groups, retention, follow-up and completeness of data analysis is illustrated for the pilot research study.

such as dementia, greater than minimal assistance required for gait and transfers, inability to make regular time commitments to the scheduled yoga sessions, or experience with regular practice of yoga within the past year. The number of potential participants assessed for eligibility was documented to give an indication of the attractiveness of the yoga program.

Randomization and interventions

Informed written consent was obtained just prior to the initial assessment. Participants were randomly assigned by a coin toss to a control group with no intervention (n=5) or an intervention group that received yoga training (n=8).

Participants assigned to the yoga intervention participated as a group in a 12-week Iyengar Hatha program. Yoga sessions were held twice weekly for 60 minutes each session under the design and direction of certified master yoga instructor with assistants that helped with positioning for a 2 – 2.5 participant to personnel ratio. Special therapeutic modifications were designed for the group as a whole. Participants were strongly urged to honor individual limits and notify the instructor so that poses could be modified to meet individual needs.

Each session began with 5-10 minutes of deep breathing exercises and relaxation techniques. The session then progressed to approximately 40 minutes of poses designed to begin with stretching and move into strengthening. Poses in lying, seated or standing positions were supported using props such as yoga pillows, blocks and straps as warranted. Each pose was typically held 3-7 minutes for a total of 5-8 poses per session. Each session ended with 10-15 minutes of meditation that included breathing and visualization techniques, and positive affirmations. The yoga program progressed from simple to more challenging poses over the 12 weeks as performance improved. Due to the individualized nature of the group on any given day, quantification of the complexity of the poses was not measured. Participants were given a tape promoting relaxation and weights for home use. Home practice with 1-2 simple poses was encouraged with handouts demonstrating poses made available. Participation in home practice was not measured.

Participants in the control group did not receive an intervention during the study, but they were invited to participate in 12 weeks of yoga sessions after the study at no cost to them.

Information on retention and adherence was acquired by tracking the number of participants who discontinued the intervention during the study and attendance of participants. Frequency of adverse events and major changes in medications were also assessed. If the participant had a major change in medication after enrollment in the study (e.g. dopaminergic drugs or melatonin) as indicated on the medical information form, the participant was allowed to complete the yoga training but relevant data was not used after the medication change.

Outcome measures and follow-up

Participants were assessed at 3 time points: baseline within one week prior to initiation of research study and then 6 weeks, and 12 weeks after baseline. Follow up was done on continued yoga participation of all participants at 6 and 12 months post intervention. The primary physical function outcome measures utilized the motor exam of the Unified Parkinson's Disease Rating Scale (UPDRS). Other physical function measures included selected extremity ROM, flexibility and strength measurements, and balance and posture assessments. Biomechanical measures of function included postural sway and gait initiation. Assessors were student physical therapists who were blinded to subject group assignment and remained consistent for the duration of the project.

Student assessors wrote protocols for each outcome measure assessed including order of and positioning for specific tests and measures, as well as standard instructions to the participants. Protocols were reviewed and revised if needed by the supervising investigator. Student assessors participated in practice sessions to review and enhance didactic curricular training in conducting each outcome measure to ensure proficiency. Student assessors were supervised by investigators during participant assessments.

To assess the effects of yoga on physical function, the motor examination of the UPDRS, clinical measures of ROM, flexibility, strength and posture, and biomechanical measures of balance and gait initiation were performed.

UPDRS Motor Examination: Speech, facial expression, body bradykinesia, posture, gait and tremors were observed and rated by the assessor during the course of other assessment activities while the remaining items were specifically tested by the assessor.

Berg Balance Scale (BBS): The 14 item scale was scored by the assessor. Scores range from 0-56 [50].

ROM and Flexibility Procedures: All ROM and flexibility measurements were obtained using a universal goniometer and standard protocol [51]. Each participant performed 2 trials of shoulder flexion; hip internal rotation, external rotation, flexion, and extension; knee flexion and extension, and ankle plantarflexion and dorsiflexion. Hamstring and hip flexor flexibility measurements were also taken.

Strength procedures: Strength was measured using the MicroFET 2 hand held dynamometer (Hoggan Health Industries, 8020 South 1300 West, West Jordan, UT 84088). It is more sensitive to small differences in muscle strength than manual muscle testing. The participant was positioned so that the dynamometer could be placed against a stationary object while the participant exerted a maximal isometric force midpoint within ROM. Strength measures were taken for hip flexion, extension, abduction; knee extension; ankle plantarflexion and dorsiflexion; shoulder flexion and extension, elbow extension. Three separate measurements were recorded with each test trial consisting of a maximal isometric contraction for about 3 seconds. A rest period of 5-10 seconds between trials was used to minimize variability due to fatigue. Standardized instructions were presented to decrease variability. Pre-established techniques were used to ensure consistent dynamometer placement, joint angles, stabilization, and limb position preventing muscle substitution (Appendix 1).

Posture measure procedures: Markers were placed over bilateral greater trochanters, greater tubercles of the humerus and lateral malleoli. Participants were asked to stand on floor markings behind a plumb line using standard protocol for alignment [52]. Pictures were taken from the side, back and front views with the camera remaining at a fixed distance using the same focus settings. From photographs, shoulder angles, hip angles or base of support were measured and the number of changes in alignment was recorded.

Assessment of photographs for qualitative postural changes was done by two assessors blinded to both group assignment and photograph time points. Agreements by both assessors on the postural deviations found between participants' two photographs were necessary to be counted. If there was disagreement, the deviation was not counted.

Biomechanical measures procedures: The biomechanical assessment of standing postural sway and gait initiation was conducted utilizing a force plate system. The participants' dominant leg was determined by observing the leg that the participants used most often to initiate gait. Ground reaction forces were measured with 2 adjacently positioned AMTI OR6-5AMTI Biomechanics Force Platforms (Advanced Medical Technology, Inc., 176 Waltham St, Watertown, MA, 02472) embedded in an extended walkway.

To assess standing postural sway, participants were positioned with one foot on each force plate. Participants were instructed to stand as still as possible and focus on a target that was positioned at eye level approximately 10 feet in front of them. The participants stood for 30 seconds per trial, a total of 5 trials. Participants were allowed to rest if necessary between trials. A trial was not accepted if the participant coughed, talked, or made any other obvious dynamic movements.

For the gait initiation task, participants were positioned with one foot on each force plate. A verbal "ready" cue was given to prepare the participant for the visual "go" cue, which was a green light. Upon visual cue, participants started walking forward. One or two practice trials were allowed to ensure comprehension of the task. A trial was not accepted if the participant initiated gait with the non-dominant leg. This was repeated until 5 acceptable trials were recorded. Participants were allowed to rest if necessary between trials.

Biomechanical measures: Data Processing. Custom-made computer programs developed in MATLAB® 6.5 (MathWorks, 3 Apple Hill Drive, Natick, MA 01760) were used to determine change of center of pressure (COP) sway in the x and y directions, COP area, onset time of anticipatory postural adjustment (APA) for gait initiation, amplitude of APA, onset time of foot unloading, onset time of foot lifting, amplitude of swing, and amplitude of stance.

Statistical analysis

Data analysis was done using Sigma Plot11.0 (SyStat Software, 1735 Technology Drive Suite 430, San Jose, CA 95110) Feasibility was assessed by a descriptive analysis of participant recruitment and retention variables. The percent of exclusion of subject enrollment was used to indicate the generalizability of the study results to the overall population of people with PD in our community.

Descriptive statistics (mean, standard deviation, median, and range) were calculated for all three assessment points. Data were assessed for normal distribution and to identify outliers. An independent *t* test was used to analyze baseline differences between the groups. If the equal variance test failed, then a Mann-Whitney Rank Sum test was used. This was the case for several ROM and strength measures. One Way Repeated Measures ANOVA was the primary analysis used on data sets to detect changes over time within groups. All Pair wise Multiple Comparison Procedures (Holm-Sidak method) were used to determine significance between time points. A paired t test was used as a secondary analysis to detect change in variables from baseline to post-intervention with a 0.05 significance level for a 2-tailed test for posture measures. The 95% confidence interval for the mean difference was also calculated. Due to the high variability in baseline measures, balance and gait initiation scores were converted to percent change for analysis.

Results

Feasibility and characterization of groups

As illustrated in the COHORT flow diagram (Figure 1), 18 potential participants were screened for eligibility; 4 participants were excluded because they did not meet the inclusion/exclusion criteria (22%) and 1 participant declined to participate (6%). All 13 participants who entered the study completed the study. The participants in the experimental group attended 99% of the twice weekly scheduled yoga sessions. All participants in the control group participated in the full 12 weeks of yoga following their control group assessments; however, compliance to the twice weekly sessions was not measured in the control group. Six month follow up shows that 10 of the 13 participants (76.9%) continued with yoga: 6 of 8 in the experimental group and 4 of 5 in the control group. One year follow up revealed 8 of the 13 participants (61.5%) still continued participation in a yoga program: 4 of the 8 in the experimental group and 4 of the 5 in the control group. No adverse complications were reported as a result of the intervention.

A description of the participants with selected baseline variables is presented in Table 1.

There were more men randomly allocated to the control group and more women to the yoga group even though the total number enrolled was fairly equal (6 men, 7 women). Although there was a greater range of ages (51-88 years) in the yoga group, the mean age was 62.8 years whereas the mean age in the control group was 73.5 years. Times since diagnosis and Hoehn & Yahr score were similar between groups.

Clinical measures

Functional motor and balance scales: A significant improvement (p=0.004, F=8.303, df=2) was shown in the UPDRS motor examination scores in the yoga group over time as compared to the control group (Figure 2). The yoga group started with overall higher scores (indicative of lower motor function) and ended with lower scores (indicative of better levels of function). The yoga group significantly improved from

Group	Age (y)	Sex	Time since diagnosis (mo./yr.)	H&Y score	Motor UPDRS at baseline	Gait Velocity (m/s) at baseline
Y	88	M	2 years? months	1	19	.73
Y	51	F	6 years 1 month	2	19	.97
Y	63	F	9 years 7 months	1	18	1.19
Y	59	M	4 years? months	1	37	1.03
Y	53	F	4 years 11 months	1	30	.86
Y	76	F	6 months	1	12	.53
Y	62	F	1 month	1	14	1.26
Y	50	F	3 years? months	1	4	.82
Y Group Mean (SD)	**62.8 (13.2)**		**3 years 2.75 months**	**1.25**	**19.12 (10.32)**	**0.92 (0.24)**
C	66	M	2 years 1 month	1	12	1.00
C	67	M	4 years? months	2	30	.94
C	75	F	6 years 2 months	1	17	.98
C	74	M	7 months	1	4	1.03
C	83	M	5 years 8 months	1	18	.80
C Group Mean (SD)	**73.4 (6.5)**		**3 years 8.4 months**	**1.2**	**16.2 (9.5)**	**0.95 (0.09)**

Table 1: Characteristics of Participants

UPDRS = Unified Parkinson's Disease Rating Motor Subscale, H&Y = Hoehn and Yahr scale score, Y = experimental yoga group, C = control group, M = male, F = female.

Citation: Colgrove YS, Sharma N, Kluding P, Potter D, Imming K, et al. (2012) Effect of Yoga on Motor Function in People with Parkinson's Disease: A Randomized, Controlled Pilot Study. J Yoga Phys Ther 2:112. doi:10.4172/2157-7595.1000112

baseline to 6 weeks (p=0.001) and baseline to 12 weeks (p=0.016) using a pair wise multiple comparison procedure (Holm-Sidak method).

Two participants in the yoga group and none in the control group demonstrated a ceiling effect using the BBS. Since, the mean baseline BBS scores for the yoga group were (52.125) below the control group (53.8) but the standard deviation was comparatively rather large (4.454) compared to the control group (1.483), a paired *t*-test comparing baseline and final assessment score changes was used for statistical analysis. Following the intervention, the yoga group demonstrated a positive trend (p=0.063) but when the two participants who demonstrated the ceiling effect were removed, balance from baseline to 12 weeks was significantly improved (p=0.047) as assessed by the BBS (Figure 3).

Joint range of motion: At baseline the yoga group had greater flexibility in hip flexion (left: p = 0.025; right p = 0.051), knee extension (left: p = 0.033), and shoulder flexion (right: p = 0.003). Following the intervention a trend of positive outcomes in active ROM (Table 2) was noted in selected hip internal rotation (left; p = 0.09, F = 2.867, df = 2; right: p = 0.058, F = 3.513, df = 2) and ankle dorsiflexion (left: p = 0.028 F = 4.680, df = 2; right: p = 0.107, F = 2.631, df = 2) (Figure 4) range of motions in participants who received yoga training as compared to

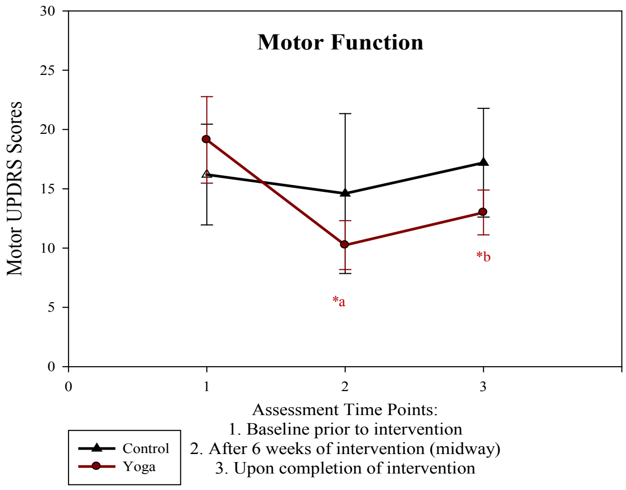

Figure 2: UPDRS Motor Examination Scores showed significant improvement (p=0.004, F=8.303, df2) in the yoga group over time as measured by One Way Repeated ANOVA. There was significant difference between baseline measures (1) and both the midway point (2) of 6 weeks of intervention (*a) (p=0.001) and the final point (3) of 12 weeks of intervention (*b) (p=0.016) using the Holm-Sidak method for all pair wise multiple comparison procedures.

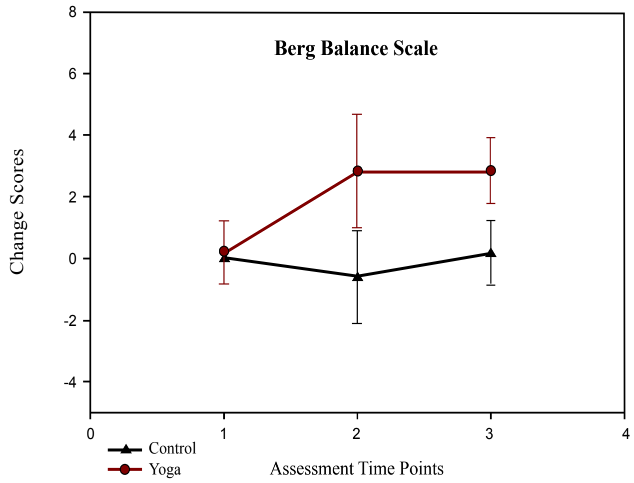

Figure 3: Berg Balance Scale. There was a significant improvement between baseline measures and the final 12 week point (p=0.047) in the yoga group but not in the control group (p=0.854).

Measurements Initial (+ SD) Final (+ SD)	Yoga Group: Right extremity	Yoga Group: Left extremity	Control Group: Right extremity	Control Group: Left extremity
Joint ROM				
Hip Internal Rotation	30.896 + 3.425 34.750 + 5.657	29.188 + 5.763 33.938 + 2.182	27.767 + 6.280 30.5 + 4.345	25.3 + 8.082 31.7 + 6.089
Ankle Dorsiflexion	5.438 + 6.603 15.0 + 8.164	6.750 + 6.193 13.688 + 7.24	9.667 + 6.06 10.1 + 3.927	4.834 + 7.645 9.1 + 4.159
Muscle Length				
Hip Flexor	-4.5 + 5.819 0.438 + 8.756	-5.357 + 7.081 1.375 + 6.186	-1.3 + 12.637 -4.7 + 8.822	-7.2 + 11.552 -6.3 + 11.037
Muscle Strength				
Hip Extension	24.5 + 7.04 31.417 + 8.915	23.875 + 8.539 29.396 + 8.516	43.833 + 16.106 36.6 + 15.754	33.8 + 14.072 32.933 + 12.731
Hip Abduction	10.25 + 2.81 11.0 + 2.016	9.875 + 2.532 12.521 + 2.484	13.0 + 4.848 11.867 + 9.529	13.533 + 8.258 12.727 + 7.537
Knee Extension	28.813 + 10.364 32.750 + 6.807	31.837 + 8.713 34.583 + 6.676	35.86 + 12.365 32.933 + 7.738	41.66 + 12.523 36.467 + 15.354
Ankle Plantarflexion	26.354 + 6.254 31.75 + 11.364	25. 813 + 5.693 28.875 + 8.828	36.734 + 17.880 37.0 + 11.277	39.333 + 17.203 41.867 + 11.869
Elbow Extension	13.729 + 3.249 14.75 + 5.111	12.188 + 2.986 15.167 + 3.409	20.533 + 7.294 22.333 + 11.39	24.2 + 6.292 22.333 + 9.863

Table 2: Initial and Final Measurements in ROM, Muscle Flexibility and Muscle Strength Selected joints and muscle groups measures with standard deviations. ROM and muscle flexibility measured by degrees. Muscle strength measured by pounds of force.

the control group. Interestingly in the upper extremity, right shoulder flexion was decreased (p = .035, F = 4.314, df = 2) in the yoga group over time with no change observed in left shoulder flexion.

Muscle flexibility: Following the intervention, there was improvement in hip flexor length (left: p = 0.083, F = 3.220, df = 2; right: p = 0.104, F = 3.050. df = 2) in the yoga group as measured by change from baseline measures (Figure 5, Table 2) although it was not significant. There were no significant changes in hamstring length of either group.

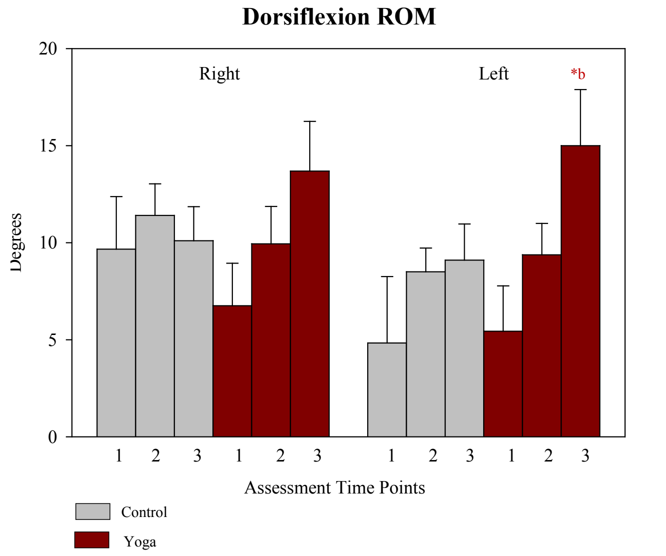

Figure 4: ROM
There was significant difference between baseline (1) ROM measures and the final (3) assessment (*b) for left ankle dorsiflexion in the yoga group (p=0.028, F=4.680, df=2). A similar trend was seen on the right side in the yoga group that was not significant (p=0.107, F=2.631, df=2).

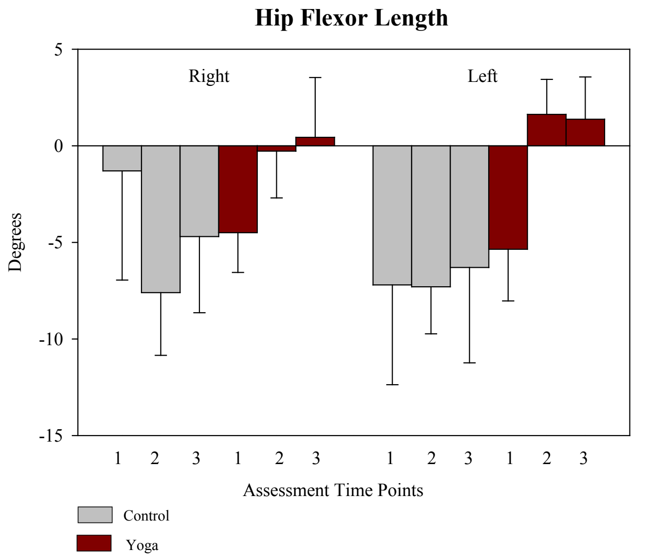

Figure 5: Muscle Flexibility34
Measurement of hip flexor length shows trends towards increasing flexibility in the yoga group although not significant.

Strength: The yoga group was significantly weaker at baseline for shoulder flexion (left: p=0.021; right: p=0.030), elbow extension (left: p = 0.002; right: p = 0.127), shoulder extension (left: p = 0.007; right: p = 0.065) and hip extension (left: p = 0.138; right: p = 0.030). Following the intervention, there was a significant increase in strength over time for hip extension (left p = 0.105, F = 2.654, df = 2; right p = 0.006, F = 7.512, df = 2) (Figure 5) and hip abduction (left: p = 0.022, F = 5.043, df = 2) in the yoga group as compared to the control group. Some improvement in other selected strength measures were also noted but were not significant (Table 2 and Figure 6).

Posture: Quantitative analysis of number of changes before and after yoga intervention was not significant as analyzed by a paired *t*-test (p = 0.14). There were variable changes in postural alignment that were not captured by measuring and statistically analyzing shoulder angles, hip angles or base of support. Qualitative examination of individual postures revealed that in the yoga group, 3 participants remained the same, 1 participant's posture declined in arm position showing an asymmetrical arm space and 4 participant's overall postural alignment improved in 1-2 aspects including increased base of support, increased supination of feet, improved cervical lordosis, decreased thoracic kyphosis, improved stance symmetry (weight shifted more evenly) and improved shoulder levels (Figure 7). In the control group, 4 participant's postures remained the same while 1 participant's posture showed a decline in head alignment.

Biomechanical measures of function

Static balance measures: There was not a significant difference in baseline measures for center of pressure area between groups (p=0.435), but there was more variability in baseline measures amongst the control group whereas the yoga group appeared to be more consistent. Center of pressure sway during standing and the sway during the onset of anticipatory postural adjustments during gait initiation determined by force plate measurements were not significantly changed over time for either group.

Gait initiation measures: Two gait initiation measures showed significant improvements over time in the yoga group; onset time of foot unloading (p = 0.039, F = 4.135, df = 2) and onset time of foot lift off (p = 0.044, F = 3.940, df = 2) as compared to the control group (Figure 8, Table 3). There was a significant difference in baseline measures of the onset time of foot loading between the yoga and control group (p = 0.039) and at post intervention this difference was no longer significant (p = 0.72).

Subjective reports of physical function: There were no reports of adverse events in either group. The post intervention survey yielded only positive subjective reports with yoga intervention to the question, "What positive and/or negative effects did you experience as a result of doing yoga?" Comments encompassed increased flexibility, decreased muscle tension or stiffness, increased steadiness with gait and balance, and improved level of functional activity such as playing more golf. One participant reported an improvement in pain with a pre-existing orthopedic problem. The participants also responded they appreciated the program was adaptable to each individual that participated.

Discussion

We conclude that the yoga intervention piloted in this project was feasible for the participants included in the study. Our high attendance rate for the intervention and large number of participants that continued the intervention after the study was over indicates

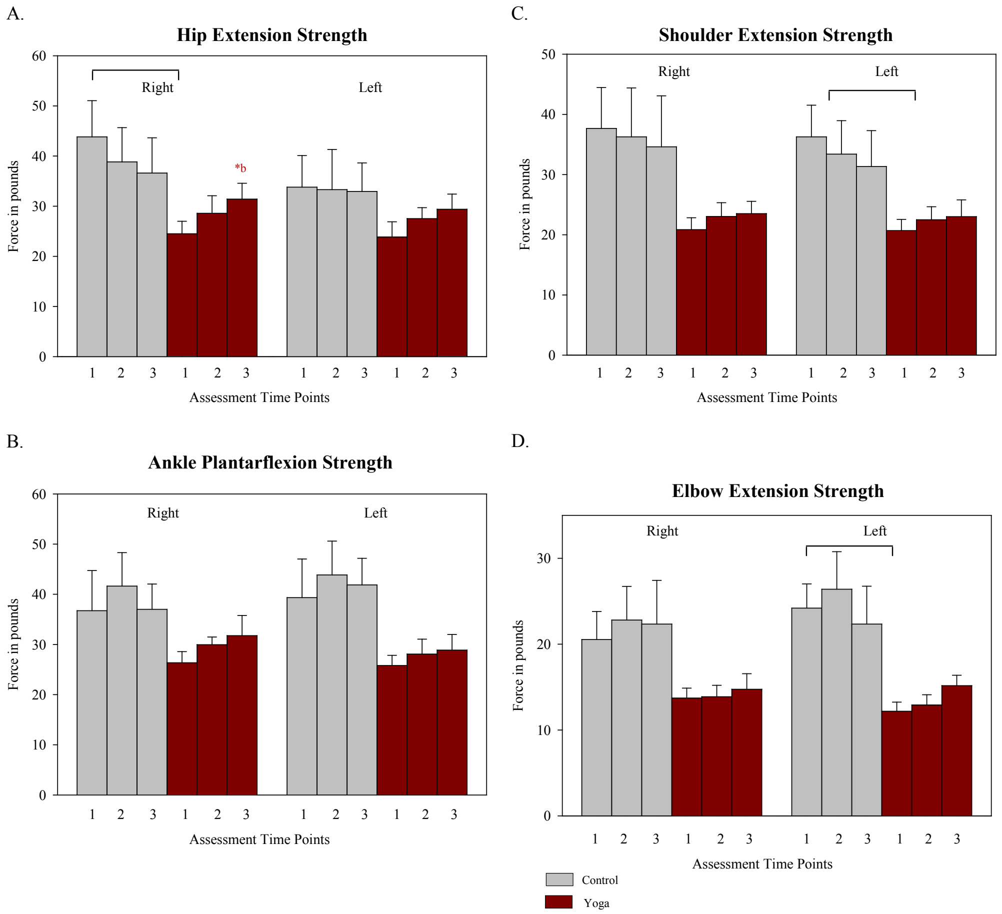

Figure 6: Strength

Strength measured by a digital dynamometer show trends towards increased strength over time in the yoga group with significance in hip extension (p=0.006, F=7.512, df=2 on the right and p=0.105, F= 2.654, df=2 on the left). Pairwise multiple comparison procedures shows significance between the baseline and last assessment (*b) (p=0.017). Similar trends were seen in ankle plantarflexion, elbow extension and shoulder extension that were not statistically significant. There were baseline differences between groups for as notated by brackets ( ).

that the yoga program was attractive to these participants and that the participants were compliant with the program. The translation of the yoga program into home practice was not measured. It could be possible that the intervention group participants who practiced at home showed greater gains in outcome measures than those who did not because they practiced more. The lack of adverse events indicates that the program was safe for participants using the inclusion and exclusion criteria established. However, the sample size for this study was less than what we had predicted and several participants who expressed interest in participating in the study but did not meet study criteria. Our time for recruitment was limited because our intervention was designed to be implemented with a cohort, but perhaps if we had permitted ongoing recruitment over a longer period of time we would have been able to contact a larger pool of potential subjects. We excluded participants for a variety of reasons to ensure homogeneity of participants and safety of the intervention, but perhaps these exclusion criteria should be revisited to allow an expansion of the target population. Previous studies of yoga in healthy elderly and in people with multiple sclerosis report that they enrolled approximately 50% of screened participants, and found a dropout rate of approximately 15% in the yoga intervention groups [40,41]. The intervention in these studies was 90 minutes one time weekly for 6 months, and the most common cause of drop-out was inability to attend classes. None of the participants in our intervention group dropped out of the study, perhaps because the duration of intervention was much shorter or the severity of disease in our participants were mild in this study. All participants in this study were functional community ambulators who required no assistive devices.

The participants who participated in the yoga intervention had a significant improvement in overall motor function as measured using the motor examination section of the UPDRS and the BBS. The largest magnitude of change was noted after the first 6 weeks of the intervention and appeared to be maintained for the remaining 6 weeks of intervention. The motor section of the UPDRS targets multiple areas of function that are typically impaired by PD including balance, coordination, posture, muscle tone and presence of abnormal movement including tremors, slowness and amplitude changes of movement and gait. Previous studies using the motor UPDRS scores show that both a home exercise program and physical therapist supervised exercise program significantly improve motor symptoms in mild to moderately impaired individuals with PD with 8 weeks of training [53] or 4 weeks of LSVT BIG training [54]. Other studies found that as little as 4 weeks of aquatic therapy could improve overall

UPDRS and BBS scores that were not seen in the same amount of time with land based therapy [55]. The results of our study found that the yoga intervention group had an improved motor UPDRS scores at 6 weeks of intervention. Yoga may be viewed as a gentle form of exercise that may be tolerated more easily by elderly or more functionally impaired participants with PD than other forms of exercise, but with similar improvements in motor function. Based on this finding, it may be valid to investigate the effectiveness of a shorter yoga intervention in future studies. It would also be worth investigating the sustained effect over a longer period of time. A defined intervention protocol of increasing complexity of yoga poses would assist in standardizing the intervention rather than relying on the skills of the individual yoga instructor which could give varying results.

It is difficult to identify a clinically meaningful change in motor UPDRS score as many contributing variables exist in motor function like strength, joint mobility, flexibility, balance and coordination to name a few. However, balance is a likely contributing factor. The BBS has been validated in patients with PD and shows significant correlation with UPDRS motor examination scores [56]. In the use of the BBS, the smallest meaningful change for a group was found to be 2.4 SEM (standard error of measurement) in people with stroke [57]. While fall risk may be associated with ankle strategies in static standing balance [58], there are other ways to assess functional balance and determine fall risk. The relationship between measures of static standing balance and dynamic balance needed for functional activities is debatable [59-61]. Falls in PD occur during dynamic activities and are obviously related to disease severity [62]. Freezing gait, lower extremity weakness and reduced balance have been shown to be independent predictors of fall in those with PD [63]. Clinical assessments of functional balance like the BBS, Functional Gait Assessment, Tinetti Mobility Test and the Balance Evaluation Systems Test are reliable measures and with gait velocity, UPDRS scores and HY scores are highly correlated with fall risk in PD [64-67]. Appropriate scales will need to be individually selected to counter ceiling effects.

In the early stages of PD, it is crucial to prevent muscular changes that cause decreased flexibility and strength. With consideration of age and independence with ADLs, baseline active ROM measurements were considered functional. The difference in gender predominance in each group may explain the initial baseline differences found between the groups for select measures of ROM, flexibility and strength. More dramatic loss of ROM and flexibility to begin with as is often seen in the progression of the disease may show more dramatic improvements in ROM with yoga. Decreased muscle strength is often associated with PD patients. One study found that subjects with PD had reduced muscle strength at the hip compared to controls, which may make it difficult to perform everyday tasks such as rising from a chair [8]. The gains in strength we observed tended to be more in the extensors of both the upper and lower extremities. Since many of the yoga poses were postural, this was an anticipated finding. Gains in lower extremity strength have been associated with improvements in postural stability and functional ambulation in a variety of healthy and disease conditions including PD

Figure 7: Posture
This yoga participant shows qualitative improvements in shoulder and head alignment (right) from the baseline postural analysis (left).

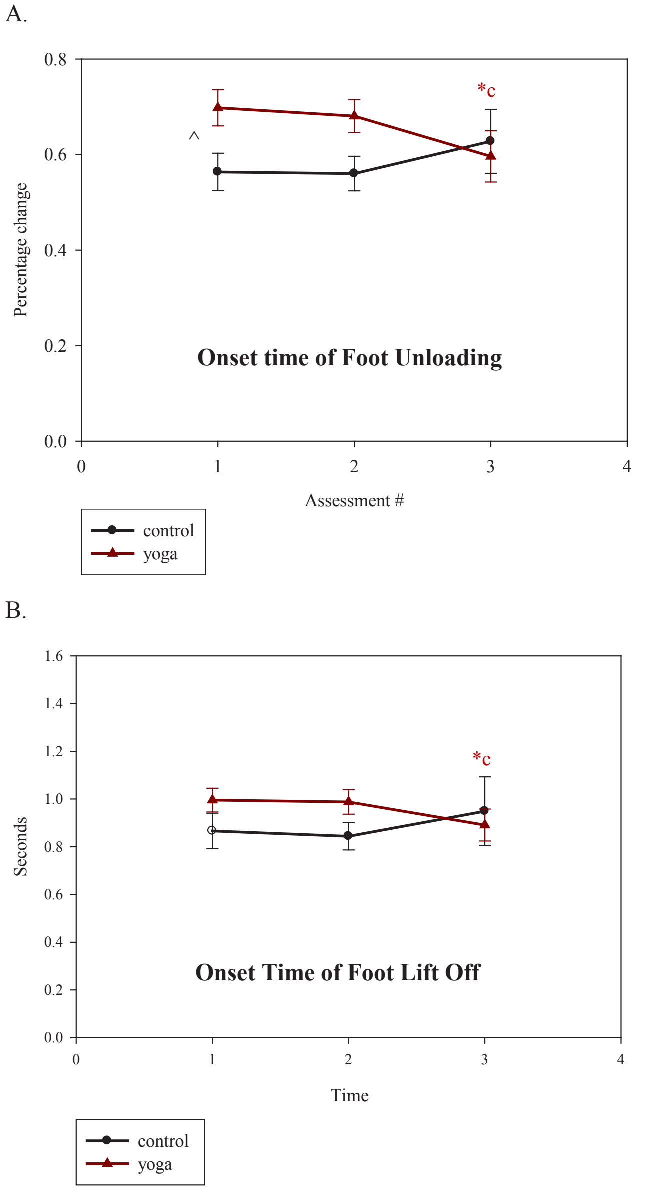

Figure 8: Gait
A difference (p=0.039) in baseline measures (^) but not ending measures were noted in onset time of foot unloading (A) with a significant difference (p=0.039, F=4.135, df=2) in repeated measures (*c) in the yoga group. There were no baseline differences in onset time of foot lift off but a significant different in repeated measures (p=0.044, F=3.940, df=2) in the yoga group (B).

	Baseline		6-weeks		12-weeks	
	Control	Yoga	Control	Yoga	Control	Yoga
Onset time of foot unloading (sec)	0.57	0.70	0.56	0.68	0.63	0.60
Onset time of foot lifting (sec)	0.87	1.00	0.84	0.99	0.95	0.89
Onset time of APA (sec)	0.16	0.18	0.14	0.18	0.17	0.18
Amplitude of APA (N)	124.93	77.16	151.69	73.07	140.73	66.21
Amplitude of swing (N)	23.59	14.19	26.04	16.78	19.48	13.95
Amplitude of stance (N)	76.17	51.20	81.50	57.01	75.39	60.75

Table 3: Gait Initiation Parameters Means of individual gait initiation parameters APA = anticipatory postural adjustment.

[68-72]. Since there were improvements in lower extremity strength with yoga training, it was anticipated that improvements in balance and gait might be detectable after just 12 weeks of intervention.

One characteristic of PD is a forward flexed posture. This posture is attributed to the contractile elements of the flexors becoming shortened and the extensors becoming lengthened and weakened [10]. Although we subjectively noted improved posture in some of our yoga participants, this was not a statistically significant finding.

We did not detect appreciable changes in static standing balance. There have been many studies investigating intersession reliability in center of pressure (COP) measures. One study suggests that mean velocity is the most reliable measure in healthy elderly people [73], while others have concluded that no single measurement of COP is significantly more reliable than others if measured over a 120 second period [74]. The 30 second time period our study used may have contributed to the variability in measures observed in the control group. However, the sway area (Table 2) and sway path lengths reported here are similar to previous reports of PD which is larger with more variable than healthy age matched subjects [75]. All participants showed higher sway area values than the healthy age matched population, as well as those with early stage disease without detectable clinical postural instability. Our participants were more in line with those PD subjects displaying postural instability of both fallers and non-fallers [76-79].

We did find positive improvements in lower extremity strength, UPDRS motor scores, BBS scores and in selected gait parameters of onset of foot unloading and lifting off with yoga intervention. Intensive exercise programs for individuals with PD that include aerobic training, flexibility, strength, coordination and balance training and an adaptive program that includes flexibility, strength, coordination and balance show similar improvements in balance and mobility after 6 months [80]. Interestingly, a study has suggested that a 12 week sensory attention focused exercise program that utilizes sensory awareness during gait and balance exercise may be more advantageous than aerobic exercise in those with PD in improving motor symptoms and functional movement control [81]. This is similar to improved motor symptoms as measured by the UPDRS motor section found with 12 weeks of yoga training.

There is growing interest in addressing falls in those with PD. A study currently in progress is being conducted analyzing a 6 month exercise program that consisted of lower extremity strengthening and balance in different modes in relation to fall prevention [2]. Abnormal posture, freezing gait, poor balance and lower extremity weakness have been identified as independent risk factors in falling in those with PD [63]. The results of this study suggest that yoga may be impacting all of these risk factors to some degree. Yoga provides an alternative method for addressing some of reversible factors that impact motor function like strength, flexibility and balance. The core strengthening that is part of yoga should be investigated for this reason. The individualized improvements in posture with yoga training we observed may have contributed to improved motor scores and noted gait parameters.

An 8-week yoga program in healthy elderly subjects showed increased peak hip extension and stride length [42]. However, this study did not have a control group, and gait parameters may be more malleable in healthy elderly than in people with PD. Another study showed a positive effect of a 12 week yoga program on fear of falling and balances in older healthy adults [82]. The results of our study also show the beneficial effects of yoga on those with PD which may make it viable alternative to standard exercise programs.

The primary limitation of this study was the limited number of participants. The lower end of the confidence interval may be used, along with the median and range scores, to estimate. Demonstration may decrease potential fear associated with trying a new activity. Further, yoga may be appropriate to investigate in participants with more significant balance, flexibility or strength deficits, or more advanced PD.

When designing an exercise program for a patient with PD, the following goals should be addressed: increasing movement (ROM and flexibility), improving balance, and maintaining or restoring functional mobility [83]. Yoga appears to be safe and well-tolerated by individuals with PD, and has demonstrated an improvement in motor UPDRS scores. Investigation of the factors like the potentially remedial balance, trunk and leg strength that may contribute to improved motor function an important area for future investigation. Due to the progressive nature of PD, we speculate yoga programs tailored for this population may offer an enjoyable, effective way to maintain quality of life. Physical therapists can incorporate yoga principles into developing a preventative exercise program for those with progressively deteriorating neurological diseases such as PD. Future studies should investigate persistence of the beneficial effects of yoga over time and comparison to other types of exercise for improvements in motor function.

Acknowledgements

This work was supported by an internal grant from the University of Kansas Medical Center's School of Allied Health Research Committee to Yvonne Searls. This committee had no role in the study's design, conduct, or reporting.

This project was made possible by Grant Number M01 RR023940 from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH), and its contents are solely the responsibility of the authors and do not necessarily represent the official view of NCRR or NIH. We would like to thank Suzette Scholtes for providing expert yoga intervention, Wen Liu for consultation using the force plate system, Byron Gajewski PhD for statistical consultation, and Christy Moorman and Richard Condray for their assistance with biomechanical data processing.

References

1. Balash Y, Peretz C, Leibovich G, Herman T, Hausdorff JM, et al. (2005) Falls in outpatients with Parkinson's disease: frequency, impact and identifying factors. J Neurol 252: 1310-1315.
2. Canning CG, Sherrington C, Lord SR, Fung VS, Close JC, et al. (2009) Exercise therapy for prevention of falls in people with Parkinson's disease: a protocol for a randomised controlled trial and economic evaluation. BMC Neurol 9: 4.
3. Liu W, McIntire K, Kim SH, Zhang J, Dascalos S, et al. (2006) Bilateral subthalamic stimulation improves gait initiation in patients with Parkinson's disease. Gait Posture 23: 492-498.
4. Rosin R, Topka H, Dichgans J (1997) Gait initiation in Parkinson's disease. Mov Disord 12: 682-690.
5. Elble RJ, Moody C, Leffler K, Sinha R (1994) The initiation of normal walking. Mov Disord 9: 139-146.
6. Adkin AL, Bloem BR, Allum JH (2005) Trunk sway measurements during stance and gait tasks in Parkinson's disease. Gait Posture 22: 240-249.
7. Sofuwa O, Nieuwboer A, Desloovere K, Willems AM, Chavret F, et al. (2005) Quantitative gait analysis in Parkinson's disease: comparison with a healthy control group. Arch Phys Med Rehabil 86: 1007-1013.
8. Inkster LM, Eng JJ, MacIntyre DL, Stoessl AJ (2003) Leg muscle strength is reduced in Parkinson's disease and relates to the ability to rise from a chair. Mov Disord 18: 157-162.
9. Schilling BK, Karlage RE, LeDoux MS, Pfeiffer RF, Weiss LW, et al. (2009) Impaired leg extensor strength in individuals with Parkinson disease and relatedness to functional mobility. Parkinsonism Relat Disord 15: 776-780.
10. Schenkman M, Butler RB (1989) A model for multisystem evaluation treatment of individuals with parkinson's disease. Phys Ther 69: 932-943.
11. Sabate M, Gonzalez I, Ruperez F, Rodriguez M (1996) Obstructive and restrictive pulmonary dysfunctions in Parkinson's disease. J Neurol Sci 138: 114-119.
12. Cutson TM, Laub KC, Schenkman M (1995) Pharmacological and nonpharmacological interventions in the treatment of Parkinson's disease. Phys Ther 75: 363-373.
13. Goodwin VA, Richards SH, Taylor RS, Taylor AH, Campbell JL (2008) The effectiveness of exercise interventions for people with Parkinson's disease: a systematic review and meta-analysis. Mov Disord 23: 631-640.
14. Skidmore FM, Patterson SL, Shulman LM, Sorkin JD, Macko RF (2008) Pilot safety and feasibility study of treadmill aerobic exercise in Parkinson disease with gait impairment. J Rehabil Res Dev 45: 117-124.
15. Kurtais Y, Kutlay S, Tur BS, Gok H, Akbostanci C (2008) Does treadmill training improve lower-extremity tasks in Parkinson disease? A randomized controlled trial. Clin J Sport Med 18: 289-291.
16. Herman T, Giladi N, Gruendlinger L, Hausdorff JM (2007) Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: a pilot study. Arch Phys Med Rehabil 88: 1154-1158.
17. Canning CG, Ada L, Woodhouse E (2008) Multiple-task walking training in people with mild to moderate Parkinson's disease: a pilot study. Clin Rehabil 22: 226-233.
18. Toole T, Hirsch MA, Forkink A, Lehman DA, Maitland CG (2000) The effects of a balance and strength training program on equilibrium in Parkinsonism: A preliminary study. NeuroRehabilitation 14: 165-174.
19. Hirsch MA, Toole T, Maitland CG, Rider RA (2003) The effects of balance training and high-intensity resistance training on persons with idiopathic Parkinson's disease. Arch Phys Med Rehabil 84: 1109-1117.
20. van Eijkeren FJ, Reijmers RS, Kleinveld MJ, Minten A, Bruggen JP, et al. (2008) Nordic walking improves mobility in Parkinson's disease. Mov Disord 23: 2239-2243.
21. Hackney ME, Kantorovich S, Levin R, Earhart GM (2007) Effects of tango on functional mobility in Parkinson's disease: a preliminary study. J Neurol Phys Ther 31: 173-179.
22. Hackney ME, Earhart GM (2008) Tai Chi improves balance and mobility in people with Parkinson disease. Gait Posture 28: 456-460.
23. Jobges EM, Spittler-Schneiders H, Renner CI, Hummelsheim H (2007) Clinical relevance of rehabilitation programs for patients with idiopathic Parkinson syndrome. II: Symptom-specific therapeutic approaches. Parkinsonism Relat Disord 13: 203-213.
24. Keus SH, Munneke M, Nijkrake MJ, Kwakkel G, Bloem BR (2009) Physical therapy in Parkinson's disease: evolution and future challenges. Mov Disord 24: 1-14.
25. Canning CG, Alison JA, Allen NE, Groeller H (1997) Parkinson's disease: an investigation of exercise capacity, respiratory function, and gait. Arch Phys Med Rehabil 78: 199-207.
26. Reuter I, Mehnert S, Leone P, Kaps M, Oechsner M, et al. (2011) Effects of a flexibility and relaxation programme, walking, and nordic walking on Parkinson's disease. J Aging Res 2011: 232473.
27. Stankovic I (2004) The effect of physical therapy on balance of patients with Parkinson's disease. Int J Rehabil Res 27: 53-57.
28. Dibble LE, Hale TF, Marcus RL, Gerber JP, LaStayo PC (2009) High intensity eccentric resistance training decreases bradykinesia and improves Quality Of Life in persons with Parkinson's disease: a preliminary study. Parkinsonism Relat Disord 15: 752-757.
29. Bergen JL, Toole T, Elliott RG, 3rd, Wallace B, Robinson K, et al. (2002) Aerobic exercise intervention improves aerobic capacity and movement initiation in Parkinson's disease patients. NeuroRehabilitation 17: 161-168.
30. Sunvisson H, Lokk J, Ericson K, Winblad B, Ekman SL (1997) Changes in motor performance in persons with Parkinson's disease after exercise in a mountain area. J Neurosci Nurs 29: 255-260.
31. Pohl M, Rockstroh G, Ruckriem S, Mrass G, Mehrholz J (2003) Immediate effects of speed-dependent treadmill training on gait parameters in early Parkinson's disease. Arch Phys Med Rehabil 84: 1760-1766.
32. Brichetto G, Pelosin E, Marchese R, Abbruzzese G (2006) Evaluation of physical therapy in parkinsonian patients with freezing of gait: a pilot study. Clin Rehabil 20: 31-35.
33. Kuroda K, Tatara K, Takatorige T, Shinsho F (1992) Effect of physical exercise on mortality in patients with Parkinson's disease. Acta Neurol Scand 86: 55-59.
34. Crizzle AM, Newhouse IJ (2006) Is physical exercise beneficial for persons with Parkinson's disease? Clin J Sport Med 16: 422-425.
35. Miyai I, Fujimoto Y, Yamamoto H, Ueda Y, Saito T, et al. (2002) Long-term effect of body weight-supported treadmill training in Parkinson's disease: a randomized controlled trial. Arch Phys Med Rehabil 83: 1370-1373.
36. Kluding P, McGinnis PQ (2006) Multidimensional exercise for people with Parkinson's disease: a case report. Physiother Theory Pract 22: 153-162.
37. Tsai CH, Lo SK, See LC, Chen HZ, Chen RS, et al. (2002) Environmental risk factors of young onset Parkinson's disease: a case-control study. Clin Neurol Neurosurg 104: 328-333.
38. Jacobs BP, Mehling W, Avins AL, Goldberg HA, Acree M, et al. (2004) Feasibility of conducting a clinical trial on Hatha yoga for chronic low back pain: methodological lessons. Altern Ther Health Med 10: 80-83.
39. Tran MD, Holly RG, Lashbrook J, Amsterdam EA (2001) Effects of Hatha Yoga Practice on the Health-Related Aspects of Physical Fitness. Prev Cardiol 4: 165-170.
40. Oken BS, Kishiyama S, Zajdel D, Bourdette D, Carlsen J, et al. (2004) Randomized controlled trial of yoga and exercise in multiple sclerosis. Neurology 62: 2058-2064.
41. Oken BS, Zajdel D, Kishiyama S, Flegal K, Dehen C, et al. (2006) Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life. Altern Ther Health Med 12: 40-47.
42. DiBenedetto M, Innes KE, Taylor AG, Rodeheaver PF, Boxer JA, et al. (2005) Effect of a gentle Iyengar yoga program on gait in the elderly: an exploratory study. Arch Phys Med Rehabil 86: 1830-1837.
43. Bastille JV, Gill-Body KM (2004) A yoga-based exercise program for people with chronic poststroke hemiparesis. Phys Ther 84: 33-48.
44. Taylor M (2001) Yoga Therapeutics in Neurologic Physical Therapy: Application to a Patient with Parkinson's Disease. Neurology Report 25: 55-62.
45. Hall E, Verheyden G, Ashburn A (2011) Effect of a yoga programme on an individual with Parkinson's disease: a single-subject design. Disabi Rehabil 33: 1483-1489.

46. Pecci C, Rivas MJ, Moretti CM, Raina G, Ramirez CZ, et al. (2010) Use of complementary and alternative therapies in outpatients with Parkinson's disease in Argentina. Mov Disord 25: 2094-2098.

47. Hoehn MM, Yahr MD (1967) Parkinsonism: onset, progression and mortality. Neurology 17: 427-442.

48. Goetz CG, Poewe W, Rascol O, Sampaio C, Stebbins GT, et al. (2004) Movement Disorder Society Task Force report on the Hoehn and Yahr staging scale: status and recommendations. Mov Disord 19: 1020-1028.

49. Folstein MF, Folstein SE, McHugh PR (1975) "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 12: 189-198.

50. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B (1992) Measuring balance in the elderly: validation of an instrument. Can J Public Health 83: S7-11.

51. White CC, White DJ (2009) Measurement of Joint Motion: A Guide to Goniometry. FA Davis. Philadelphia.

52. Kendall FP, Provance PG and Rodgers MM (2005) Muscles: Testing and Function, with Posture and Pain. Baltimore: Lippincott Williams & Wilkins. Baltimore.

53. Lun V, Pullan N, Labelle N, Adams C, Suchowersky O (2005) Comparison of the effects of a self-supervised home exercise program with a physiotherapist-supervised exercise program on the motor symptoms of Parkinson's disease. Mov Disord 20: 971-975.

54. Ebersbach G, Ebersbach A, Edler D, Kaufhold O, Kusch M, et al. (2010) Comparing exercise in Parkinson's disease--the Berlin LSVT®BIG study. Mov Disord 25: 1902-1908.

55. Vivas J, Arias P, Cudeiro J (2011) Aquatic therapy versus conventional land-based therapy for Parkinson's disease: an open-label pilot study. Arch Phys Med Rehabil 92: 1202-1210.

56. Qutubuddin AA, Pegg PO, Cifu DX, Brown R, McNamee S, et al. (2005) Validating the Berg Balance Scale for patients with Parkinson's disease: a key to rehabilitation evaluation. Arch Phys Med Rehabil 86: 789-792.

57. Liaw LJ, Hsieh CL, Lo SK, Chen HM, Lee S, et al. (2008) The relative and absolute reliability of two balance performance measures in chronic stroke patients. Disabil Rehabil 30: 656-661.

58. Nelson-Wong E, Appell R, McKay M, Nawaz H, Roth J, et al. (2012) Increased fall risk is associated with elevated co-contraction about the ankle during static balance challenges in older adults. Eur J Appl Physiol 112:1379-1389.

59. Moya GB, Siqueira CM, Caffaro RR, Fu C, Tanaka C (2009) Can quiet standing posture predict compensatory postural adjustment? Clinics (Sao Paulo) 64: 791-796.

60. Hsiao-Wecksler ET, Katdare K, Matson J, Liu W, Lipsitz LA, et al. (2003) Predicting the dynamic postural control response from quiet-stance behavior in elderly adults. J Biomech 36: 1327-1333.

61. Owings TM, Pavol MJ, Foley KT, Grabiner MD (2000) Measures of postural stability are not predictors of recovery from large postural disturbances in healthy older adults. J Am Geriatr Soc 48: 42-50.

62. Frenklach A, Louie S, Koop MM, Bronte-Stewart H (2009) Excessive postural sway and the risk of falls at different stages of Parkinson's disease. Mov Disord 24: 377-385.

63. Latt MD, Lord SR, Morris JG, Fung VS (2009) Clinical and physiological assessments for elucidating falls risk in Parkinson's disease. Mov Disord 24: 1280-1289.

64. Landers MR, Backlund A, Davenport J, Fortune J, Schuerman S, et al. (2008) Postural instability in idiopathic Parkinson's disease: discriminating fallers from nonfallers based on standardized clinical measures. J Neurol Phys Ther 32: 56-61.

65. Plotnik M, Dagan Y, Gurevich T, Giladi N, Hausdorff JM (2011) Effects of cognitive function on gait and dual tasking abilities in patients with Parkinson's disease suffering from motor response fluctuations. Exp Brain Res 208: 169-179.

66. Leddy AL, Crowner BE, Earhart GM (2011) Functional gait assessment and balance evaluation system test: reliability, validity, sensitivity, and specificity for identifying individuals with Parkinson disease who fall. Phys Ther 91: 102-113.

67. Kegelmeyer DA, Kloos AD, Thomas KM, Kostyk SK (2007) Reliability and validity of the Tinetti Mobility Test for individuals with Parkinson disease. Phys Ther 87: 1369-1378.

68. Nocera JR, Buckley T, Waddell D, Okun MS, Hass CJ (2010) Knee extensor strength, dynamic stability, and functional ambulation: are they related in Parkinson's disease? Arch Phys Med Rehabil 91: 589-595.

69. Orr R, Raymond J, Fiatarone Singh M (2008) Efficacy of progressive resistance training on balance performance in older adults : a systematic review of randomized controlled trials. Sports Med 38: 317-343.

70. Toole T, Park S, Hirsch MA, Lehman DA, Maitland CG (1996) The multicomponent nature of equilibrium in persons with parkinsonism: a regression approach. J Neural Transm 103: 561-580.

71. Buchman AS, Wilson RS, Boyle PA, Tang Y, Fleischman DA, et al. (2007) Physical activity and leg strength predict decline in mobility performance in older persons. J Am Geriatr Soc 55: 1618-1623.

72. Wolfson L, Judge J, Whipple R, King M (1995) Strength is a major factor in balance, gait, and the occurrence of falls. J Gerontol A Biol Sci Med Sci 50: 64-67.

73. Lafond D, Corriveau H, Hebert R, Prince F (2004) Intrasession reliability of center of pressure measures of postural steadiness in healthy elderly people. Arch Phys Med Rehabil 85: 896-901.

74. Ruhe A, Fejer R, Walker B (2010) The test-retest reliability of centre of pressure measures in bipedal static task conditions--a systematic review of the literature. Gait Posture 32: 436-445.

75. Blaszczyk JW, Orawiec R, Duda-Klodowska D, Opala G (2007) Assessment of postural instability in patients with Parkinson's disease. Exp Brain Res 183: 107-114.

76. Chastan N, Debono B, Maltete D, Weber J (2008) Discordance between measured postural instability and absence of clinical symptoms in Parkinson's disease patients in the early stages of the disease. Mov Disord 23: 366-372.

77. Raymakers JA, Samson MM, Verhaar HJ (2005) The assessment of body sway and the choice of the stability parameter(s). Gait Posture 21: 48-58.

78. Nardone A, Schieppati M (2006) Balance in Parkinson's disease under static and dynamic conditions. Mov Disord 21: 1515-1520.

79. Bauer C, Groger I, Rupprecht R, Gassmann KG (2008) Intrasession reliability of force platform parameters in community-dwelling older adults. Arch Phys Med Rehabil 89: 1977-1982.

80. Gobbi LT, Oliveira-Ferreira MD, Caetano MJ, Lirani-Silva E, Barbieri FA, et al. (2009) Exercise programs improve mobility and balance in people with Parkinson's disease. Parkinsonism Relat Disord 15: S49-52.

81. Sage MD, Almeida QJ (2009) Symptom and gait changes after sensory attention focused exercise vs aerobic training in Parkinson's disease. Mov Disord 24: 1132-1138.

82. Schmid AA, Van Puymbroeck M, Koceja DM (2010) Effect of a 12-week yoga intervention on fear of falling and balance in older adults: a pilot study. Arch Phys Med Rehabil 91: 576-583.

83. Umphred DA (2001) Neurological Rehabilitation: Elsevier Science Health Science.