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Periodized Resistance Training With and Without Functional Training Improves Functional Capacity, Balance, and Strength in Parkinson's Disease

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Abstract

Strand, KL, Cherup, NP, Totillo, MC, Castillo, DC, Gabor, NJ, and Signorile, JF. Periodized resistance training with and without functional training improves functional capacity, balance, and strength in Parkinson's disease. *J Strength Cond Res* 35(6): 1611–1619, 2021—Periodized progressive resistance training (PRT) is a common method used to improve strength in persons with Parkinson's disease (PD). Many researchers advocate the addition of functional training to optimize translation to activities of daily living; however, machine-based PRT, using both force and velocity training components, may elicit similar benefits. Thirty-five persons with PD (Hoehn and Yahr I–III) were randomized into a strength, power, and hypertrophy (SPH; $n = 17$) or strength, power, and functional (SP + Func; $n = 18$) group, training 3 times weekly for 12 weeks. Both groups performed machine-based strength and power training on days 1 and 2 each week, respectively; whereas, on day 3, SPH group performed machine-based hypertrophy training and SP + Func group performed functional training. Functional performance was tested using the timed up and go, 30-second sit-to-stand (30-s STS), gallon-jug shelf-transfer, and seated medicine ball throw (SMBT) tests. Balance (Mini-BESTest), strength, motor symptoms (UPDRS-III), quality of life, and freezing of gait (FOG) were also assessed. Repeated measures analysis of variance revealed a main effect for time ($p \leq 0.05$) with significant improvements for the sample in the 30-s STS ($p = 0.002$), SMBT ($p = 0.003$), Mini-BESTest ($p < 0.001$), upper-body strength ($p = 0.002$) and lower-body strength ($p < 0.001$). A significant group × time interaction was seen for FOG, with SP + Func alone showing improvement ($p = 0.04$). Furthermore, the SPH group produced a clinically important difference for the UPDRS-III (mean difference = 4.39, $p = 0.18$). We conclude that both exercise strategies can be equally effective at improving functional capacity, balance, and muscular strength in individuals with PD. In addition, FOG and motor symptoms may be targeted through SP + Func and SPH, respectively. The results provide options for individualized exercise prescriptions.

Key Words: physical exercise, multicomponent training, power training, UPDRS-III, quality of life, freezing of gait

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder that primarily affects older adults. Motor dysregulation is an ongoing concern, with loss of muscular strength, bradykinesia (slowness of movement), rigidity, postural instability, and freezing of gait (FOG), leading to reduced voluntary movement (13,24,30,32). The associated reduction in activity results in further deterioration, affecting the ability to perform activities of daily living (ADL) and jeopardizing independence. Consequently, quality of life (QoL) declines because individuals rely more on others for care (3). This rapid degeneration has led some researchers to describe PD as *accelerated aging* (15). Although medication is typically the first line of treatment for PD, physical activity is also recommended to attenuate losses in motor function; however, the most therapeutically beneficial and accessible approach is yet to be determined.

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The inclusion of progressive resistance training (PRT) in PD treatment has long been prescribed to address disease-related and age-related losses in muscular strength and muscle mass (15,39). However, it has been suggested that if the aim is to improve independence and ADL performance, task-specific training, also known as functional training, may be optimal (11). Typically, this method applies dynamic, multijoint actions requiring energy transfer in a kinetic chain across several planes of motion. If paired with PRT, functional training can be viewed as translational training because it transfers strength and power gains made during PRT into ADL-associated movements. Parkinson's disease interventions combining PRT with functional tasks have provided evidence for improved muscular strength (20,29,44), functional capacity (1,29,44), balance (20,29), motor symptoms (Unified Parkinson's Disease Rating Scale, motor scores [UPDRS-III]) (29,44), QoL (44), and FOG (1). Nonetheless, the inclusion of functional training may not be feasible in many training environments because the necessity for supervision by physical therapists or trainers and the equipment and space requirements may be cost prohibitive. In addition, the fear of falling and injury may discourage many from performing functional exercises. Therefore, it would be beneficial if the same improvements could be made through machine-based PRT strategies alone, given that

PRT requires only a gymnasium membership and that weight machines provide supported exercise.

Traditional machine-based PRT methods include strength training (slow speed, high resistance, and low repetitions) and hypertrophy training (slow speed, moderate-to-high resistance, and high repetitions). A large number of studies have established the efficacy of both PRT strategies for improving muscular strength in subjects with PD, providing conflicting evidence regarding improvements in functional capacity and balance (7,8,12,18,39,40,44). Only 1 study directly compared PRT alone (strength and hypertrophy training) with PRT with functional elements in individuals with PD (44). At the end of 12 weeks, strength gains were found in both exercise groups, but only the combination group improved the timed up and go (TUG), UPDRS-III, cognition, and QoL compared with a control group. However, no velocity element was provided in their PRT program, suggesting the need for further research.

The association between reduced muscular power and bradykinesia, rigidity, increased fall risk, and reduced walking speed in PD (32) has led a number of researchers to investigate high-velocity power training programs (8,10,29,36). High-velocity resistance training has been shown to be more effective in improving ADL performance than strength training in older adults (19,37); however, a recent study from our laboratory did not support these findings in persons with PD (8). This study compared the effectiveness of 12 weeks of machine-based power training with strength training. Although muscular strength and power improved in both groups, no improvements were found for the TUG or balance. It has been suggested that a multicomponent training program including power training may be necessary to increase ADL-related functional performance (23).

Periodization is a planned variation of acute program variables (i.e., exercise selection, load, velocity, sets, repetitions, and recovery) designed to maximize performance gains. Combining strength and power training into a periodization model in a population with PD may enhance benefits and elicit neuromuscular adaptations not realized by either method alone. In the 2-year Progressive Resistance Exercise Training in Parkinson's Disease (PRET-PD) trial (10,36), a periodized PRT group (alternating strength and power training every 8 weeks) was compared with a Modified Fitness Counts group (an at-home program consisting of nonprogressive strengthening, stretching, breathing, and balance exercises). Similar improvements were reported between groups in functional capacity, balance, and walking speed at 6 months and at 2 years, both on and off medication (36); however, the PRT group showed greater improvements for QoL at 6 months and strength gains, movement speed, and off-medication UPDRS-III at 2 years (10). These results provide support for a periodized weight training program that includes both force and velocity components.

A comparison of a periodized machine-based PRT program including strength, power, and hypertrophy training to a combination program substituting functional training for hypertrophy training would provide further knowledge to determine whether patients with PD require a PRT program including functional training to reduce neuromuscular symptoms and delay disease progression. There are 2 predominant periodization models: daily undulating periodization (DUP) and linear. The former allows frequent program alterations within a week, whereas the latter divides training emphases into cycles lasting weeks to months. In this investigation, DUP methods were examined because this strategy has been shown to be as effective as linear periodization for improving strength, power, and functional performance in older adults (6). Therefore, the purpose of this study was to compare the effectiveness of 2 DUP PRT programs, strength, power, and hypertrophy training (SPH) and strength, power, and functional training (SP + Func), on measures of upper-body and lower-body functional performance, balance, muscular strength, motor symptoms, QoL, and FOG in persons with PD. We hypothesized that there would be no significant differences between groups for any measure.

Methods

Experimental Approach to the Problem

This study used a prospective, parallel-group, randomized controlled design. The purpose of this study was to compare the effects of 2 periodized PRT programs on ADL-related function in persons with PD. To achieve this aim, we used a battery of tests designed to assess upper-body and lower-body functional performance, balance, muscular strength, motor symptoms, QoL, and FOG. Although there is seemingly some overlap in the assessments, an effort was made to include measurements that would encompass multiple facets of function and QoL. The DUP training interventions were provided 3 times a week for 12 weeks. The first 2 weekly sessions were identical for both groups, using weight machine-based strength and power protocols, respectively. On day 3, the SPH group completed the hypertrophy protocol, whereas the SP + Func group incorporated the functional training protocol. Hypertrophy training was provided using volumes (sets and repetitions) comparable with functional training. Testing order was standardized among subjects for pretesting and posttesting over 3 sessions. On the first day, assessments included anthropometric measures, gallon-jug shelf-transfer (GJST) test, and Mini-Balance Evaluation Systems Test (Mini-BESTest). On the second day, the subjects completed the Parkinson's Disease Questionnaire-39 (PDQ-39) and FOG Questionnaire (FOG-Q). Motor symptoms (UPDRS-III) and Hoehn and Yahr (H&Y) PD stage were then assessed by a Movement Disorder Society–certified specialist. Subsequently, the 30-second sit-to-stand (30-s STS) and the seated medicine ball throw (SMBT) were completed. For pretesting alone, 1 repetition maximum (1RM) familiarization was then provided for the leg press (LP1RM) and chest press (CP1RM). On the third day, LP1RM and CP1RM were determined. After baseline assessments, subjects were stratified by sex and H&Y stage and randomly assigned to either an SPH (n = 17) or SP + Func (n = 18) group, using computer-generated block randomization. We chose not to include a nonexercise control group because there is overwhelming evidence regarding the detrimental effect of inactivity in this population. Asking control subjects to remain sedentary during the course of the study was deemed unethical. Assessors were constant across testing sessions, as was time of day, to reduce the impact of medication on results. All subjects were on their usual medication during testing and training.

Subjects

Thirty-five community-dwelling men and women with PD (69.4 ± 9.7 years) were recruited from local clinics and support groups. Characteristics of the study subjects can be found in Table 1. Subjects were informed of the risks and benefits of the study before any data collection and then signed an institutionally approved written informed consent document. Inclusion criteria included the following: (a) aged 50–89 years; (b) H&Y stages

Table 1
Characteristics of study subjects (*N* = 35) at baseline by group.*

Characteristic	SPH (*n* = 17)	SP + Func (*n* = 18)	*p*
Demographic			
Age (y)	70.19 ± 9.06	68.63 ± 10.54	0.65
Men/women (n)	9/8	11/7	0.63
Anthropometric			
Height (m)	1.65 ± 0.09	1.67 ± 0.15	0.25
Body mass (kg)	72.92 ± 15.86	74.13 ± 14.08	0.81
BMI ($kg \cdot m^{-2}$)	26.65 ± 5.10	26.97 ± 5.73	0.92
Clinical			
Hoehn and Yahr stage	2.00 ± 0.71	1.91 ± 0.63	0.21
Disease duration (y)	5.45 ± 4.11	5.83 ± 3.47	0.77
MMSE	28.44 ± 2.53	28.21 ± 2.04	0.79
Activity level ($h \cdot wk^{-1}$)	3.41 ± 2.94	3.73 ± 3.12	0.37
Antiparkinson medication (%)	82.4	83.3	0.94
Comorbidities			
Hypertension (%)	41.2	27.8	0.40
Dyslipidemia (%)	35.3	11.1	0.09
Depression (%)	52.9	44.4	0.62
Diabetes (%)	0.0	5.6	0.32

*SPH = strength, power, and hypertrophy group; SP + Func = strength, power, and functional group; BMI = body mass index; MMSE = Mini-Mental State Examination.
†Values are mean ± SD unless otherwise stated.

I–III; (c) Mini-Mental State Examination score more than 23; and (d) physician's clearance to exercise. Exclusion criteria included the following: (a) currently participating in another exercise or pharmaceutical study; (b) recent myocardial infarction; (c) severe musculoskeletal impairment; (d) uncontrolled epilepsy or severe orthostatic hypotension; or (e) having lifted weights regularly (>1 day weekly) in the past 6 months. This study was approved by the Institutional Review Board of the Human Subjects Research Office at the University of Miami (IRB20181119) and posted in clinicaltrials.gov (NCT03867877).

Sample size was calculated using G*Power (version 3.0, Universitat Kiel, Germany). Data from previous studies from our laboratory comparing 2 resistance training programs produced very small between-group effect sizes (6,8), which, if used for a power analysis, would require a sample size exceeding feasibility. Therefore, the sample size estimation for this study was based on 3 previous studies comparing resistance training programs with a nonexercise control group reporting moderate or large effects for the TUG, 30-s STS, SMBT, balance, strength, UPDRS-III, and QoL (26,37,44). A required sample size of 28 subjects was computed based on a moderate effect size of 0.25, an α level of 0.05, and a power of 0.80. Allowing for a 20% dropout rate, the final sample size of 34 subjects was calculated.

Procedures

Lower-Body Functional Performance. The TUG was used to measure functional mobility and dynamic balance. Subjects sat with their spine against the back of an armless chair and on verbal command, stood up, walked 3 m around a cone, and returned to the chair. A familiarization attempt was provided, and the best of 2 test trials was analyzed. Subjects were given 1-minute rest periods between trials. An adequate test-retest reliability has been reported for the TUG in subjects with PD with an intraclass correlation coefficient (ICC) value of 0.85 (45).

Functional lower-extremity strength and power was assessed using the 30-second sit-to-stand 30-s STS test (25). Subjects sat in an armless chair with arms crossed across the trunk and on verbal command stood up and sat down as many times as possible within 30 seconds. In 76 persons (70.7 ± 7.0 years), Jones et al. (25) reported a high ICC test-retest reliability of 0.92 for men and 0.96 for women across 2 testing days, 2–5 days apart, for the 30-s STS.

Upper-Body Functional Performance. The GJST was used as an indicator of upper-body ADL ability (42). The subjects were timed as they moved five 1-gallon, water-filled jugs as quickly as possible from a knee-height shelf to an upper shelf adjusted to shoulder height. Subjects were instructed to use the same hand to move each jug and that the other hand could be used to help support the jug. A familiarization trial was given, followed by 2 test trials, with a 1-minute between-trial recovery. The best trial, indicated by the lowest time to completion, was analyzed. Intraclass correlation coefficient values of 0.98 and 0.98–0.99 were reported for GJST reliability in our laboratory on the same day and between days separated by 2 weeks, respectively (42).

To further assess upper-body function, the SMBT was used to evaluate upper-extremity power (17). Subjects sat in an armless chair and were asked to throw a 3-kg medicine ball as far forward as possible while keeping their spines against the back of the chair. The horizontal distance thrown was recorded in centimeters. Before administration of the test, arm length was accounted for by moving the zero mark of the measuring tape to the subject's extended arms and fingertips. Subjects were allowed 2 familiarization attempts, followed by 2 test trials, with 1-minute recoveries between trials. The best effort was used for analysis. In older adults, high test-retest reliability has been reported for the SMBT with an ICC of 0.96 (17).

Balance. Balance was assessed using the Mini-BESTest, which demonstrated a high test-retest reliability (ICC ≥0.88) in individuals with idiopathic PD (27). The assessment is composed of 14 items, divided into 4 domains of dynamic balance including anticipatory postural adjustments, postural responses, sensory orientation, and balance during gait.

Muscular Strength. To assess lower-body and upper-body maximum muscular strength, LP1RM and CP1RM were determined, respectively. Testing was performed on computerized pneumatic resistance machines (Keiser A420; Keiser Corp., Fresno, CA). Strength was quantified using a protocol previously described (8). A high test-retest reliability for 1RM testing has been demonstrated in our laboratory for older subjects (ICC > 0.93) (6).

Motor Symptoms, Quality of Life, and Freezing of Gait. The Movement Disorder Society UPDRS-III was used to assess motor symptoms. Excellent test-retest reliability for the UPDRS-III (ICC = 0.90) was reported in a sample of 404 patients with PD by academic movement disorder specialists (41). Quality of life was evaluated using the PDQ-39, which has been found to provide good test-retest reliability (ICC = 0.86–0.96) (5). Finally, the FOG-Q was used to assess perceived FOG severity. The questionnaire has demonstrated high reliability with Cronbach alpha measures of 0.96 (14).

Interventions. An overview of the training protocols is presented in Table 2. Each of the 3 weekly sessions lasted approximately 60 minutes with a 48-hour recovery between. Both men and women performed the same training protocols. The intervention included a 2-week adaptation phase and a 10-week training phase. The adaptation phase was used for exercise familiarization and to

Table 2

Training intervention details for the SPH (strength, power, and hypertrophy) and SP + Func (strength, power, and functional) groups.*

	SPH group				SP + Func group			
Day	Protocol	Set × reps, loads	Tempo	Recovery	Protocol	Set × reps, loads	Tempo	Recovery
1	Strength	3 × 8 at 80% 1RM	2–3 second concentric and eccentric	90 s	Strength	3 × 8 at 80% 1RM	2–3s concentric and eccentric	90 s
2	Power	3 × 6 at 50% 1RM	Maximal concentric velocity, 1–2 second isometric hold, 2–3 second eccentric	120 s	Power	3 × 6 at 50% 1RM	Maximal concentric velocity, 1–2s isometric hold, 2–3s eccentric	120 s
3	Hypertrophy	3 × 12 at 70% 1RM	2–3s concentric and eccentric	60 s	Functional	Table 3		

*1RM = 1 repetition maximum.

minimize delayed onset muscle soreness. A 10- to 15-minute warm-up, consisting of walking, gentle dynamic stretching, and exercise-specific movements, was provided before each session. A 5- to 10-minute walk was encouraged at the completion of the workout as a cooldown.

Resistance Training Protocols. Sets, repetitions, loads, tempo, and recovery between sets varied between strength, power, and hypertrophy protocols (Table 2). The exercise performance sequence for all resistance training protocols was leg press, chest press, leg curl, seated row, hip adduction, lat pull-down, triceps push-down, and biceps curl. Keiser pneumatic machines were used for all resistance training. Preintervention, submaximal 1RM tests (targeting 5–10 repetitions) were administered for each exercise (except leg and chest presses, which were evaluated during pretests). Maximal strength was computed using the method described by Brzycki (4). These estimated 1RMs were used to calculate initial training loads. Weight training workouts were performed at 20 and 10% below each protocol's training loads for weeks 1 and 2, respectively. A conservative 10-repetition exercise-specific warm-up set was performed using 50% of subjects' 1RM for leg and chest presses throughout the intervention. All lifts were supervised one-on-one by a trained research assistant to ensure proper form, range of motion, and tempo. Sets where proper form could not be maintained were stopped, and any remaining sets were completed after an adequate recovery. If all sets were completed, subjects moved to the next exercise.

For the strength and hypertrophy training protocols, when subjects met their repetition goal for 2 subsequent sessions, exercises were progressed by 5% for upper-body and 10% for lower-body exercises. For power training, subjects were encouraged to surpass their previous peak power output with each successive repetition. Peak power during a training session was used as baseline. If the subject surpassed baseline during 2 subsequent sessions, loads were increased 5 and 10% for upper and lower body, respectively. These training protocols are well tolerated in subjects with PD (8,29) and can improve functional measures during periodized training (6,29).

Functional Training Protocol. The functional training protocol, including exercises, training volume, and the focus of each exercise, is presented in Table 3. Additional descriptions and progressions of each exercise are provided in the supplementary material (see Supplemental Digital Content 1, http://links.lww.com/JSCR/A258, which details the functional training protocol with progressions). Familiarization for functional training used reduced sets or repetitions, with gradual increases to full volume by week 3. The SP + Func group performed functional training exercises designed to improve balance, mobility, strength, and power using ADL motor patterns. All functional training was administered one-on-one by a trained research assistant, and task progression was individualized.

Statistical Analyses

Separate 2 (group) by 2 (time) repeated measures analyses of variance (ANOVAs) were performed for all outcome measures. Significant main effects or interactions were further examined using Bonferroni post hoc analyses. One-way ANOVAs and χ^2 tests were used to examine between-group differences at baseline. Effect sizes (eta squared, η^2) were computed and interpreted as small (0.01), medium (0.06), and large (0.14) (9). All statistical analyses were conducted using SPSS software (version 26, IBM Corp., Chicago, IL) and were 2-tailed, with a significance level of $p \leq 0.05$.

Results

Of the 35 subjects randomized, 28 (SPH group, $n = 13$; SP + Func group, $n = 15$) successfully completed all aspects of the study. Figure 1 shows the subjects' flow through the study. No significant between-group differences were detected for any baseline characteristics (Table 1). Three subjects, 1 from the SPH group and 2 from the SP + Func group, withdrew for medical reasons unrelated to the study (2 subjects fell at home, 1 injuring a hip and the other breaking an arm; the third subject was admitted to the hospital for an extended period with cognitive difficulties). Two additional subjects from the SPH group withdrew from the study voluntarily because of scheduling conflicts. After the intervention,

Table 3

Functional training details.

Circuit	Focus	Exercise	Volume
1	Strength/mobility	Weighted walk	3 × 50 m
	Balance	Anterior-posterior go-stop	3 × 30 s
	Balance	Lateral go-stop	3 × 30 s
2	Strength/mobility	Sit-to-stand transfers	3 × 5 each direction
	Power	Standing medicine ball throw	3 × 10
3	Balance/mobility	Forward ladder drills	2 × 4 drills
	Balance	Medicine ball wood chops	2 × 5 each side
	Balance/mobility	Lateral ladder drills	2 × 4 drills
	Power	Lateral medicine ball throws	2 × 5 each side
4	Strength	Step-ups	2 × 10 each leg
	Power	Ball bounce pass and catch	2 × 10
	Strength/balance	Cone lunges	2 × 10 each leg

2 subjects, 1 from each group, were excluded from the analyses because of low adherence (<75% attendance). Furthermore, 2 subjects, 1 from each group, were excluded from the analysis of the TUG as extreme outliers because of FOG. At posttesting, 2 subjects from the SPH group and 1 from the SP + Func group did not complete the CP1RM because of exacerbation of prestudy injuries. These adverse events were reported as discomfort while performing the chest press exercise during workout sessions and required no medical attention. For these subjects, the chest press exercise was eliminated during subsequent sessions when necessary. Within-group and between-group results for all outcome measures are presented in Table 4.

Lower-Body Functional Performance

Repeated measures ANOVAs presented a significant time main effect for the 30-s STS (F (1,26) = 11.87, $p = 0.002$, $\eta^2 = 0.31$), but no group main effect or group × time interaction was evidenced. Post hoc tests showed improvements from baseline for the 30-s STS (mean difference [MD] = −2.33 repetitions; $SE = 0.68$; 95% confidence interval [CI]: −3.71 to −0.94). No significant main effects or interactions were found for the TUG.

Upper-Body Functional Performance

There was a significant time main effect for the SMBT (F (1,26) = 10.67, $p = 0.003$, $\eta^2 = 0.26$). No group main effect or group × time interaction was observed. Post hoc analyses revealed significant improvements for the SMBT (MD = −2.47 m; SE = 1.13; CI: −4.79 to −1.47). For the GJST, there were no significant main effects or interactions.

Balance

A statistically significant time main effect was found for the Mini-BESTest (F (1,26) = 25.49, $p < 0.001$, $\eta^2 = 0.51$); however, no significant group main effect or group × time interaction was found. Post hoc analyses showed a significant difference at 12 weeks from baseline (MD = −3.22; SE = 0.64; CI: −4.53 to −1.91), indicating an improvement in balance.

Muscular Strength

Muscular strength results showed a significant time main effect for the LP1RM (F (1,26) = 21.15, $p < 0.001$, $\eta^2 = 0.45$) and CP1RM (F (1,23) = 12.03, $p = 0.002$, $\eta^2 = 0.45$). No significant group effect or group × time interaction was evidenced. Post hoc analyses showed a significant improvement in the LP1RM (MD = −30.64 kg; SE = 6.66; CI: −44.33 to −16.94) and the CP1RM (MD = −5.88 kg; SE = 1.70; CI: −9.38 to −2.37).

Motor Symptoms, Quality of Life, and Freezing of Gait

No statistically significant main effects or interactions were found for the UPDRS-III or PDQ-39; however, moderate effect sizes for the PDQ-39 were found for both group (F (1,26) = 1.59, p = 0.22, $\eta^2 = 0.06$) and time (F (1,26) = 1.92, $p = 0.18$, $\eta^2 = 0.07$). A clinically important difference (CID) was found for the UPDRS-III after SP + Func training (MD = 4.39; SE = 2.68; CI: −1.12 to −9.89; $p = 0.11$). The CID is considered to be more than 3.25 for improvement and less than −4.63 for worsening (21).

There was a significant group × time interaction for the FOG-Q (F (1,26) = 6.31, $p = 0.02$, $\eta^2 = 0.22$); no main effects were detected. A post hoc analysis revealed that the SP + Func group significantly improved FOG-Q scores at 12 weeks (MD = −3.27; SE = 1.54; CI: −6.13 to −0.13; $p = 0.04$), whereas the SPH group showed worsened scores (MD = 2.62; SE = 1.64; CI: −0.0.75 to −5.98; $p = 0.12$).

Discussion

This randomized controlled trial demonstrated that both exercise methods were equally effective at improving functional capacity, balance, and muscular strength in persons with PD. We hypothesized that implementing a DUP strength and power PRT intervention incorporating specific functional training techniques would produce improvements similar to methods lacking this

Table 4
Within-group and between-group outcomes after SPH and SP + Func exercise interventions.*

	SPH (n = 13)				SP + Func (n = 15)				Between groups		
Assessment	Baseline mean ± SD	12 wk mean ± SD	η²‡	p	Baseline mean ± SD	12 wk mean ± SD	η²‡	p	Adjusted mean diff (95% CI)	η²‡	p
TUG (s)§	8.64 ± 2.95	7.76 ± 3.28	0.06	0.25	8.14 ± 3.18	7.24 ± 1.58	0.07	0.20	0.51 (−1.51 to 2.53)	0.01	0.61
30-s STS (reps)	12.08 ± 2.69	14.54 ± 4.63	0.19	0.02†	13.27 ± 4.46	15.47 ± 5.78	0.18	0.03†	−1.53 (−4.94 to 1.88)	0.02	0.51
GJST (s)§	11.36 ± 2.42	10.76 ± 2.51	0.04	0.29	11.10 ± 1.88	10.52 ± 2.36	0.05	0.28	0.25 (−1.35 to 1.85)	0.00	0.75
SMBT (m)	2.43 ± 0.96	2.74 ± 0.75	0.14	0.05†	2.49 ± 0.90	2.80 ± 0.97	0.16	0.04†	−1.34 (−8.28 to 5.60)	0.00	0.85
Mini-BESTest	22.42 ± 4.08	25.58 ± 2.35	0.31	0.003†	21.80 ± 3.39	25.07 ± 2.69	0.37	0.001†	0.57 (−1.60 to 2.74)	0.01	0.60
LP1RM (kg)	181.6 ± 81.7	206.4 ± 83.2	0.20	0.02†	197.6 ± 79.8	234.1 ± 85.8	0.38	0.001†	−21.9 (−84.8 to 41.0)	0.02	0.48
CP1RM (kg)	32.6 ± 14.3	37.7 ± 14.1	0.17	0.04†	35.2 ± 16.9	42.7 ± 22.5	0.32	0.003†	−3.8 (−17.8 to 0.2)	0.01	0.58
UPDRS-III§	28.85 ± 12.91	24.46 ± 10.81	0.09	0.11	25.07 ± 11.11	23.73 ± 11.13	0.01	0.60	2.25 (−5.86 to 10.37)	0.01	0.57
PDQ-39§	21.69 ± 14.20	18.80 ± 11.05	0.04	0.30	16.91 ± 8.64	14.57 ± 8.38	0.03	0.37	4.51 (−2.84 to 11.85)	0.06	0.22
FOG-Q§	6.62 ± 8.06	9.23 ± 9.44	0.09	0.11	7.40 ± 7.85	4.13 ± 6.89	0.16	0.04†	2.26 (−3.67 to 8.19)	0.02	0.46

*SPH = strength, power, and hypertrophy training group; SP + Func = strength, power, and functional training group; CI = confidence interval; TUG = timed up and go; 30-s STS = 30-second sit-to-stand; GJST = gallon-jug shelf-transfer; SMBT = seated medicine ball throw; Mini-BESTest = Mini-Balance Evaluation Systems Test; LP1RM = leg press 1 repetition maximum; CP1RM = chest press 1 repetition maximum; UPDRS-III = Unified Parkinson's Disease Rating Scale, motor score; PDQ-39 = Parkinson's Disease Questionnaire-39; FOG-Q = Freezing of Gait Questionnaire.
†Significant ($p \le 0.05$).
‡η^2: eta-squared effect size interpreted as large (0.14), medium (0.06), and small (0.01).
§Lower score is better.

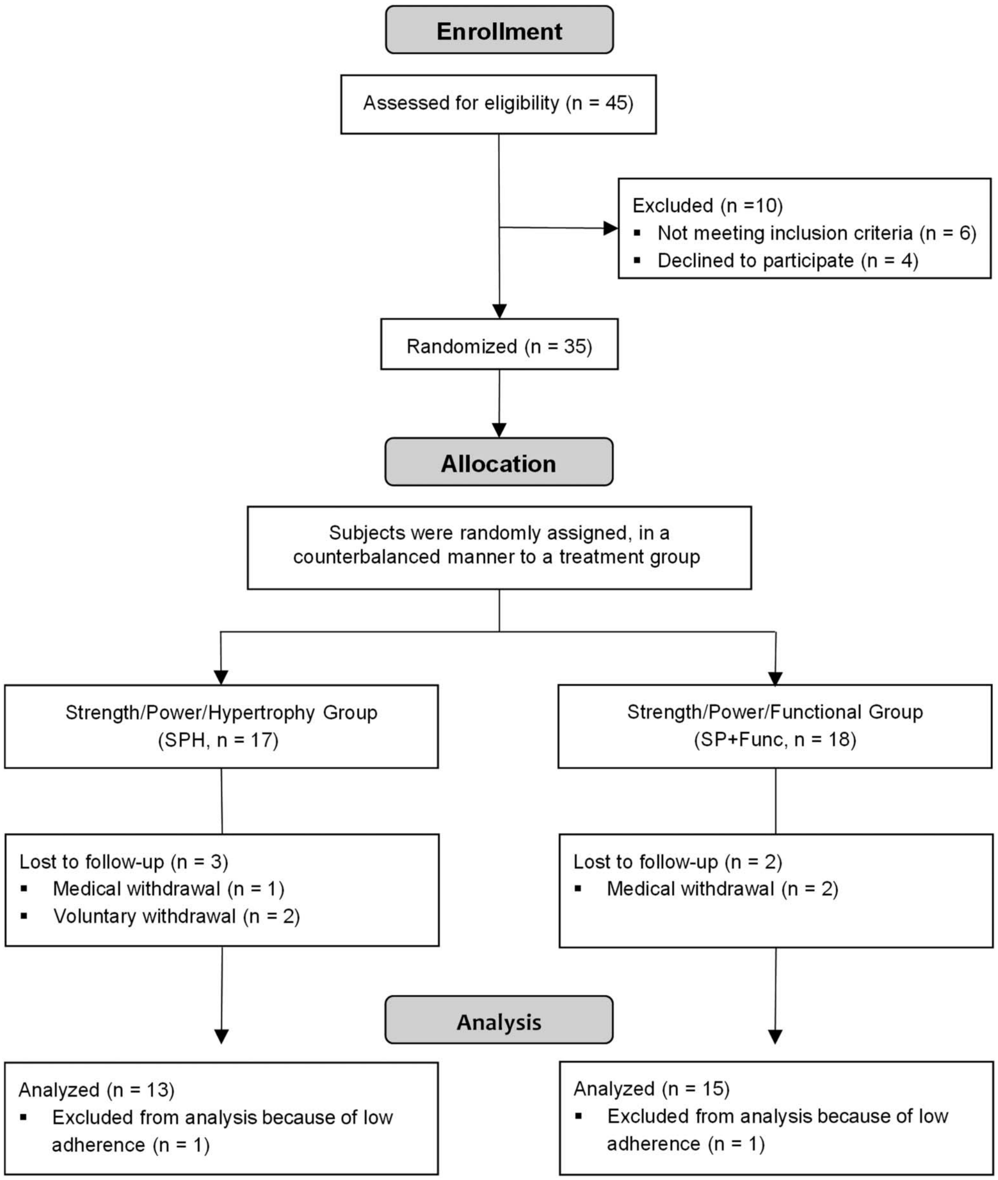

Figure 1. CONSORT subject flow diagram.

functional training element. This hypothesis was partially supported because our major finding was that comparable results were achieved using either periodized approach with the exception of motor symptoms and FOG. Strength, power and hypertrophy training alone improved motor symptoms, as evidenced by an improvement above CID for UPDRS-III, whereas only SP + Func positively affected FOG. Our findings are notable because ADL-related training in the population with PD often requires supervision by physical therapists or clinicians and specialized equipment and environment, increasing personnel, financial, and time costs. Similar results between the 2 protocols, with differences limited to UPDRS-III and FOG, provide the opportunity to individualize exercise programs with minor adaptations. Nonetheless, future research is required to further examine the exercise program variables that maximize benefits in individuals with PD.

To our knowledge, Silva-Batista et al. (44) conducted the only study comparing PRT with PRT combined with a functional component in persons with PD. Importantly, their study differed from ours because they used a linear periodization program, offered only twice-weekly training sessions, provided no velocity training, and included subjects with higher average H&Y stages (2.5 ± 0.5) than our sample (1.9 ± 0.7). Nonetheless, they found no significant differences between their 2 intervention groups in any measure. Both groups improved LP1RM values over the 12-week training period; however, only their combination group improved TUG times. The researchers concluded their combination group's improvements were due to the highly demanding motor exercises, which included unstable devices. Divergent TUG results from our study could be attributable to our subjects' above average baseline performances. Pretest values for our cohort (8.4 seconds) surpassed normative values reported for older men and women (11.1 seconds) (22) and the 11.5 seconds TUG cutoff score discriminating fallers with PD from nonfallers (31). The TUG has been shown to be well correlated with gait speed and ADLs (34), suggesting our subjects had good function in these measures before the intervention. Because performance for the

TUG was already within the normal range, significant improvements proved difficult. Nonetheless, our subjects produced a medium effect size, indicating both our exercise programs had some benefits.

Lower-body functional strength and power showed improvement, as evidenced by significant improvements for the 30-s STS with a large effect for the sample. This reflects 30-s STS improvements previously reported after strength training (7) and power training combined with functional training (29) in persons with PD and after a power training program in healthy older adults (2). The 30-s STS, a measure of functional lower-body strength and power, is correlated with ADL measures such as the stair climb and walking speed (25) and can predict fall risk and age-related functional decline (28). It is well documented that lower-body strength and mobility losses are associated with disabilities of individuals with PD (1,30); therefore, our results for the 30-s STS are notable for this population.

Declining upper-body strength and power also compromise ADLs and other tasks requiring complex and rapid movements, which are further compromised by progressive PD symptoms, including bradykinesia and muscle weakness. Maintenance of upper-body function should, therefore, be considered essential when targeting PD. The SMBT, a test of upper-body power, has been found to be associated with the modified explosive push-up, a test of upper-body strength, power, and postural stability (17), as well as handgrip strength, a significant indicator of all-cause and cardiovascular mortality in older populations (35). Significant improvements and large effect sizes were found for the SMBT by our cohort, which agree with similar gains previously reported after PRT in healthy older adults (2,37). Regarding the GJST, an ADL-related transfer task, correlations have been found with common functional and performance tests in older adults, including the 30-second arm curl, 30-second stand-up, ramp power test, and isokinetic knee extension and elbow flexion tests (42). The lack of improvement for the GJST is in contrast to results of a recent study by Buskard et al. (6) comparing DUP with linear periodization that incorporated strength, power, and functional training in healthy older subjects, where improvements were found for the GJST in both groups. Disparities between the studies may be attributable to motor deficiencies and day-to-day symptom variability in persons with PD.

The Mini-BESTest assesses not only balance but also postural stability, mobility, and dual tasking, all of which are affected by PD (24). We demonstrated significant improvements and a large effect for the Mini-BESTest. The results for the SP + Func group was expected because of training specificity, which is in agreement with those of other investigations concerning the efficacy of targeted balance training programs in individuals with PD (20,29,44); however, comparable gains by our SPH group weaken any definitive argument. Contrary to our findings, Cherup et al. (8) found no significant improvement in balance in subjects with PD after 12 weeks of traditional strength or power PRT. The authors maintained the need for a function-specific training component to elicit functional gains. By contrast, in the PRET-PD trial, which alternated strength and power training, Prodoehl et al. (36) found improvements in balance after both 6 and 24 months. Taken together, the improvements seen in our study may be due to program element variations, reinforcing the need to incorporate strength and power with either hypertrophy or functional training into exercise programs that target balance improvements.

It should be noted that both groups were equally effective at improving upper-body and lower-body strength, although SP + Func training included lower PRT volume. These results are comparable with many other studies using different PRT and functional training techniques with subjects with PD (8,18,20,26,29,40,44). Thus, it seems that increasing exercise volume, regardless of modality, can improve strength in untrained subjects. However, in a 6-month at-home exercise intervention using progressive exercises to target leg strength, balance, and freezing, Allen et al. (1) found no improvements in strength in 48 subjects with PD. Their lack of improvement may be attributed to lack of supervision and access to exercise equipment normally found in a clinic or gymnasium facility, suggesting these factors are necessary for a successful strength program in persons with PD despite volume. Furthermore, their home-based strengthening program may not have provided sufficient training intensity to engender changes in strength because this is a critical variable, especially in shorter-duration interventions (43).

Concerning motor symptoms, the SPH intervention produced a CID and an improvement with a moderate effect for the UPDRS-III. Horváth et al. (21) proposed that the minimal CID for the UPDRS-III is asymmetrical, with 3.25 points for improvement and −4.63 for worsening. In response to training, improvements of 4.39 and 1.33 were seen for SPH and SP + Func training, respectively. By contrast, Silva-Batista et al. (44) found a CID in their combination group, but not in their PRT group. These researchers suggested that programs requiring increased motor complexity in conjunction with strength gains may be necessary to improve motor symptoms; however, our results do not support this premise. Despite the CID in the SPH group, we found no statistically significant changes in on-medication motor symptoms after either intervention. Although Corcos et al. (10) reported off-medication UPDRS-III significance after the 2-year PRET-PD intervention, evidence regarding improved on-medication motor symptoms is sparse (29), with many comparable studies reporting a lack in statistically significant changes after PRT exercise interventions (1,18,40,44). Lack of significant findings could be due to limitations associated with the test. In particular, the most debilitating motor symptoms, which are typically targeted during exercise interventions, provide little weight to the UPRDS-III score. For example, although tremors can often be one of the most obvious symptoms of PD, it is not necessarily disabling and responds well to medication (38); however, it comprises approximately 25% of the score. By contrast, postural instability, which increases the risk of falling (24) and differentiates H&Y stage 2 from 3, only comprises 3% of the score. Finally, FOG, a common debilitating symptom of PD that seriously impedes ADL and QoL (13), comprises only 3% of the score. Disproportions such as these require a more in-depth analysis. Because we found significant improvements in both groups for balance and in our combination group for FOG, the UPDRS-III may have lacked the sensitivity and specificity to detect significant motor changes in our sample.

Freezing of gait may not simply be a motor challenge but rather, the combination of motor, cognitive, and affective deficits (13). Outcomes in this study support this notion because the SPH program, which focused on specific gains in muscular strength, power, and muscle mass, did not elicit improvements in FOG. By contrast, SP + Func group, which incorporated more complex movements during functional training, produced improvements with a large effect. Allen et al. (1) also found improvements in a population with PD after their at-home 6-month exercise program; however, these researchers also provided specific cuing strategies for FOG, making comparisons difficult. Petzinger et al.

(33) postulated that movement complexity and cognitive engagement are important for neuroplasticity in PD. Therefore, potential associations between functional training that explicitly incorporate complex motor movements requiring decision making and procedural memory require further study.

In this study, QoL was statistically unaffected by training, although group and time main effects showed moderate effect sizes indicating some benefits. Other researchers have used the PDQ-39 to quantify QoL with divergent results (1,8,12,44). Although it is a widely used questionnaire, the instrument's validity has been called into question (16); therefore, PDQ-39 outcomes should be interpreted with caution. Our findings for the PDQ-39 could, once again, be attributable to subjects' higher QoL scores at baseline. As a point of comparison, Silva-Batista et al. (44) reported improvements in the PDQ-39 after their combined PRT and functional-type training; however, their pretest scores (40.4) were considerably higher than the current sample (19.1; lower scores indicate higher QoL). These differences could be due to different inclusion criteria, with our subjects displaying mild-to-moderate PD symptoms and Silva-Batista et al. including subjects with moderate-to-severe PD. Thus, future investigations should explore periodized training impacts on QoL improvements by disease stage.

Although this study provided insights into optimal training programs for targeting specific PD symptoms, some limitations must be addressed. First, there was a slightly higher attrition rate than expected in the SPH group, which may have affected our ability to detect differences across several outcome measures. Second, assessors at posttest were not blinded to group allocation, which may have introduced a level of bias. Third, this was a comparative study with no passive control group. Although informative, this approach did not address whether exercise interventions were better than no training for PD. Fourth, the SP + Func group only performed functional training 1 time per week. This may not have been a sufficient dose to realize different benefits from the SPH group in some of the outcomes. Finally, all assessments and training were performed in the on-medication state; therefore, similar results might not be obtained if training or assessments were conducted in the off-medication state.

In conclusion, the most notable finding of this study is that a 12-week DUP machine-based PRT program was equally effective as a PRT program with an additional functional component for improving upper-body and lower-body functional ability, balance, and strength outcomes among individuals with mild-to-moderate PD. This study suggests that persons with PD should undertake a periodized PRT program incorporating strength and power training to offset age-related and disease-related neuromuscular and functional decline and that hypertrophy and functional training can be incorporated as dictated by motor symptoms and FOG, respectively. Future research is warranted using longer interventions to allow the assessment of the importance of recovery cycles into the periodization models.

Practical Applications

People with Parkinson's disease face many physical challenges affecting their day-to-day life that become more difficult as the disease progresses. Exercise can slow down the functional decline caused by the disease and is strongly recommended. The findings of this study suggest that there are options for PRT periodization programs, using both force and velocity components, which can maximize results. As the base of the program, machine-based strength and power training should be performed on separate days of the week. Adding a third day of either machine-based hypertrophy or supervised functional training could provide optimal results for improvements in functional capacity, balance, and strength. If motor symptoms are of additional concern, then the hypertrophy training option seems to provide more benefit; whereas, if the individual wants to focus on FOG, then functional training may be more beneficial. Resistance training-based periodization methods should be manipulated to meet both the needs and means of individuals with Parkinson's disease. Clinicians, therapists, and trainers should consider these findings when constructing exercise programs to counter functional decline in similar populations.

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