

High-Intensity Resistance Training Amplifies Muscle Hypertrophy and Functional Gains in Persons With Parkinson's Disease

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Abstract: Strength deficits in persons with Parkinson's disease (PD) have been identified as a contributor to bradykinesia. However, there is little research that examines the effect of resistance training on muscle size, muscle force production, and mobility in persons with PD. The purpose of this exploratory study was to examine, in persons with PD, the changes in quadriceps muscle volume, muscle force production, and mobility as a result of a 12-week high-force eccentric resistance training program and to compare the effects to a standard-care control. Nineteen individuals with idiopathic PD were recruited and consented to participate. Matched assignment for age and disease severity resulted in 10 participants in the eccentric group and 9 participants in the control group. All participants were tested prior to and following a 12-week intervention period with testing and training conducted at standardized times in their medication cycle. The eccentric group performed high-force quadriceps contractions on an eccentric ergometer 3 days a week for 12 weeks. The standard-care group exercise program encompassed standard exercise management of PD.

The outcome variables were quadriceps muscle volume, muscle force, and mobility measures (6-minute walk, stair ascent/descent time). Each outcome variable was tested using separate one-way analyses of covariance on the difference scores. Muscle volume, muscle force, and functional status improvements occurred in persons with PD as a result of high-force eccentric resistance training. The eccentric group demonstrated significantly greater difference scores for muscle structure, stair descent, and 6-minute walk ($P < 0.05$). Magnitude of effect size estimators for the eccentric group consistently exceeded those in the standard-care group for all variables. To our knowledge, this is the first clinical trial to investigate and demonstrate the effects of eccentric resistance training on muscle hypertrophy, strength, and mobility in persons with PD. Additional research is needed to determine the anatomical and neurological mechanisms of the observed strength gains and mobility improvements. © 2006 Movement Disorder Society

Key words: Parkinson's disease; eccentric; resistance training; muscle hypertrophy

Comorbid medical conditions associated with aging often results in physical activity restrictions for many elderly individuals. When coupled with Parkinson's disease (PD), this impaired ability to be physically active or exercise amplifies the aging-induced peripheral muscle atrophy and weakness (collectively termed sarcopenia).¹ As a result of the combined central nervous system

(CNS) impairments and peripheral muscular impairments, many individuals with PD enter into a downward spiral of immobility. With that, a deleterious positive feedback loop leads to progressively increasing deficits in muscle strength, mobility, and quality of life.² Consequently, these muscle and mobility deficits in inactive elderly individuals with PD is above and beyond that which may result directly from the CNS-mediated PD process.

To date, only 3 studies were found in the literature that have examined whether those with PD benefit from muscle-strengthening exercise.^{3–5} The paucity of research regarding resistance training is surprising as individuals with PD have concentric and eccentric strength deficits, and weakness has been implicated in bradykinesia.^{6–12}

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Since the primary goal of resistance training is to hypertrophy muscle in order to improve strength and function, this study examined the ability of persons with PD to break the downward spiral of muscle atrophy and impaired mobility with resistance training.

In order to examine systematically the efficacy of high-intensity resistance training, our approach to the problem has been to examine measures of muscle growth (MRI-determined muscle volume), muscle force production, and mobility during an eccentric training regimen known to produce some of the highest muscle forces possible.^{13,14} To put the high force of these contractions into perspective, in a previous study, elderly persons with sarcopenia undergoing this training increased their workload by nearly fourfold during a training period and ended at an average workload of about 250 watts.¹⁵ This corresponds to very high forces (roughly equivalent to lifting a 50 kg mass 30 cm 1,500 times per session). The rationale for utilizing this eccentric training regimen lies in the fact that high level of muscle forces are generated with minimal oxygen consumption demands relative to an equivalent amount of positive (concentric) work.^{16–18}

In the present exploratory study, we examined the anatomical and functional responses of persons with mild to moderate PD to high-force eccentric resistance training relative to a standard-care control group. Our hypotheses were that, even in the context of PD, there would be anatomical and functional adaptation of skeletal muscle to increased loading, and the increased intensity of the eccentric group would result in larger physiological and functional benefits over the training period as compared to the standard-care group.

PATIENTS AND METHODS

Participant Selection Criteria

Persons with PD were recruited through the accessible population of persons receiving care for PD through the movement disorders clinics at local hospitals and physician offices. The sample size was determined using muscle size outcomes from previous research [mean (standard deviation) pretraining fiber cross-sectional area = 3,295 (366.0) μm^2 and mean posttraining fiber cross-sectional area = 5,273 (963.5) μm^2 , which corresponded to a standardized effect size of 2.83 for the main effects of time on the muscle size outcome variable].¹⁵ Because we were interested in between-group differences, we chose to be more conservative and utilized a standardized effect size of 1.0. Based on this effect size, an alpha level set at 0.05 for a directional hypothesis and a desired power level of 0.80, 14 participants (7 per group) were predicted to be needed. To account for potential attrition

and to control additionally for the risk of type 2 statistical errors, 20 participants were recruited to participate.

Inclusion Criteria

Inclusion criteria included diagnosis of mild to moderate idiopathic PD (Hoehn and Yahr 1–3), patient age between 40 and 85 years, willingness, and ability to comply with a 12 week resistance training program.

Exclusion Criteria

Exclusion criteria included unpredictable motor fluctuations or dyskinesias not controlled by medications. In addition, potential participants were excluded from the study if they had a history of any neurological, cardiovascular, hematological, or orthopedic condition that limited their ability to participate in resistance exercise or tolerate the testing procedures.

Procedures

Prior to beginning the study, study procedures were reviewed and approved by the University of Utah Health Sciences Center Institutional Review Board. After receiving explanations about the purpose and procedures of the study, all participants provided written informed consent. Participants were then placed into groups by matching for age and disease severity (Fig. 1). All participants were tested and trained in an *on* medication state. That is, testing and training were started 1–1.5 hours after taking their PD medications to minimize the effects of medication status on functional performance.¹⁹ Such a control made it necessary to perform testing on multiple days.

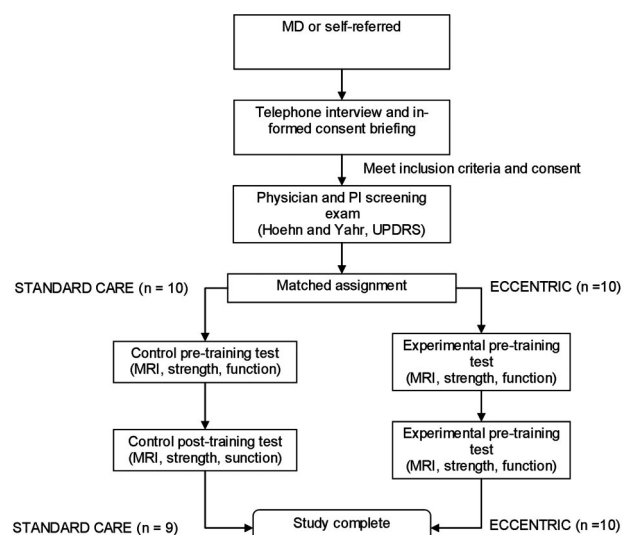


FIG. 1. Study methods flowchart.

Demographic and Morphological Characteristics

The following data were collected from participants on the first day of testing: age, gender, height, weight, duration of PD, predominant PD symptoms, most affected side of the body, current medication regimen, PD severity (Hoehn and Yahr Scale rating), and Unified Parkinson's Disease Rating Scale (UPDRS) motor subsection score.

Muscle Structure

Bilateral thighs were imaged to assess the muscle volume of the quadriceps. Participants were placed supine in the magnetic resonance imaging (MRI) magnet with the legs relaxed. All scans were performed on one 1.5 Tesla whole body MR imager (Signa Lightning LX 8.4; General Electric Medical Systems, Milwaukee, WI). To establish the region of interest (ROI), a coronal fast-spoiled gradient echo scout scan was used to identify the superior and inferior boundaries of the scans (the femoral head and the tibiofemoral joint line). Once the ROI was established, axial T1-weighted images were acquired in the standard body coil using a fast-spin echo sequence with Repetition Time/Time to Echo = 550/9.2, 8-mm slice thickness, 15-mm interslice distance, and a 320×320 matrix. Depending on thigh length, the number of sections acquired ranged from 17 to 22. The axial MRI images were then digitized and saved to compact disk for later analysis.

After electronic data transfer of images, cross-sectional area (CSA) measurements and calculations were performed by use of custom-written image analysis software (MatLab; Mathworks, Natick, MA) on a desktop personal computer. For each image, the muscles of interest, e.g., vastus lateralis, vastus medialis, vastus intermedius, and rectus femoris (independent of skin, bone, and fat) were identified from the displayed images and manually traced by using a computer mouse, allowing overall CSA to be automatically computed. The outcome variable (muscle volume) was then determined by summing the volumes from each slice (area \times slice thickness) to give total volume as described by previous researchers.²⁰⁻²² The same investigator, blinded to time point of the scan and slice location, performed measurements of individual participants before and after training. To establish intra-investigator reliability of CSA measurement, the same investigator performed two separate measurements of quadriceps CSA of 18 different images on six study participants. The repeat measurements were separated by measurement of other images or rest periods. The average interclass correlation coefficient (ICC) across the 18 images was 0.99 (range, 0.89-0.99). The validity of the volume measurement was determined by

analysis of images obtained from a cadaveric thigh phantom that approximated the size of the quadriceps femoris muscle group. The volume of the phantom, measured by water displacement 5 hours after MRI scanning, was 100.7% of the MRI-determined value. There was a 0.012% difference between repeat volume displacement measurements of the phantom by the same investigator.

Muscle Function

Lower extremity knee extension strength was quantitatively assessed by unilateral maximal voluntary isometric force (MVIC) on a KinCom dynamometer (Chattanooga, Hixson, TN). Previous research has supported the reliability, validity, and sensitivity to change of this measure.²³⁻²⁵ Both lower extremities were tested and these strength measures were assessed prior to and following the training interventions. Participants were seated and their knees were fixed at 60° of flexion. Prior to testing, participants practiced submaximal contractions at 50% and 75% of their maximal effort. One practice MVIC trial was then performed. After a brief rest period, three separate maximal contractions were performed, each held for 5 seconds with a 3-minute rest between trials. The muscle force outcome variable was operationally defined as the average torque of three trials. Overall, these strength testing procedures lasted 20 minutes. The order of testing (more affected vs. less affected limb) was randomized among subjects. Subjects were stabilized by chest and thigh straps and asked to fold their arms across their chest while performing these tests.²⁶

Mobility Measures

A battery of three strength-related gait tasks regularly employed with elderly and exercise-limited populations was used to determine the functional relevance of any muscle strength changes. All mobility measures were performed by one of two investigators and all participants underwent this series of tests prior to and following training. The 6-minute walk test (6MW), a measure of the distance a subject walks in 6 minutes, was used to assess overall locomotor ability and locomotor fatigue.²⁷⁻²⁹ Participants were asked to cover as much distance as possible within 6 minutes without running. Stair ascent and descent time were used to assess functional use of concentric and eccentric lower extremity muscle force production abilities, respectively.³⁰ Participants were asked to ascend and descend one flight of stairs under close or contact supervision as quickly and safely as possible. Time was recorded to the nearest 0.01 second from a verbal go signal to final foot placement on

a standard flight of 10 stairs. Previous research has supported the validity of these measures.^{31,32}

Leg Pain and Perceived Exertion

Because no previous studies have examined the safety of eccentric training in a sample of persons with PD, as control variables, we documented the participants' subjective interpretation of whether the eccentric training induced any leg pain and/or they perceived the training to be too stressful to their body. A 10-cm visual analog scale (VAS) for leg pain was filled out by the subject before each training session (to document residual leg pain from previous sessions).³³ Ratings of perceived exertion (RPEs) were scored during each session.³⁴ The RPEs assessed both the subjective measure of local (legs) and overall (body) exertion during each training session and were utilized as a means of progressing the intensity of the lower extremity exercise. Based on previous studies in nonneurologically impaired individuals, we expected that leg pain would be minimal and subside within the first 2 weeks of eccentric training. In addition, it was expected that this would be accompanied with a very low perceived exertion to the whole body, but a moderately high exertion of the legs (Appendixes I and II).^{14,15,23,35}

Participant Training

Once participants were recruited, they were assigned to either the experimental eccentric exercise group or the standard-care control group. The study design utilized standard-care controls, i.e., individuals engaged in an existing rehabilitation program appropriate for their disease and impairments. The standard exercises utilized by all participants included light calisthenics and stretching, walking on a treadmill, riding a (standard) cycle ergometer, and lifting weights (both machines and free weights) with the upper extremities. Both groups performed their respective exercises 45 to 60 minutes 3 days/week for 12 weeks. The progression of the standard exercises is detailed in Appendix I.

The eccentric group participants substituted high-force eccentric resistance training for traditional lower extremity resistance strength training. Thus, all participants engaged in the same components of exercise training with the exception of differing in the mode of lower extremity resistance training only.

The eccentric group experienced high muscle forces that were generated on an eccentric ergometer (Fig. 2). The progression of the eccentric exercise work rate was determined as a function of the perceived exertion (RPE) using a target workload on a computer monitor. The

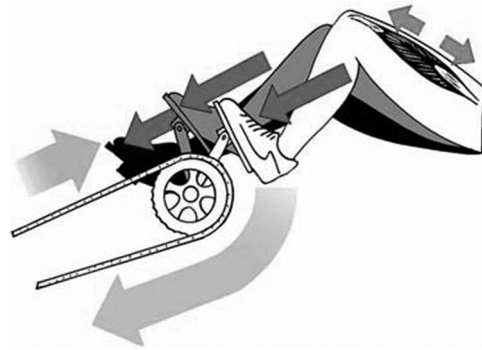


FIG. 2. Eccentric resistance training ergometer. High muscle forces are generated on an eccentric ergometer powered by a 3 hp motor that drives the pedals in a backward rotation. As the motor rotates the pedals at a set speed in a reverse direction (large arrows), the subject attempts to slow down the reverse moving pedals by applying force to the pedals (medium arrows). Because the magnitude of force produced by the motor exceeds that produced by the subjects, the pedals continue backward, resulting in the eccentric lengthening of the, e.g., quadriceps muscles (small arrows).

progression of training and RPE for the experimental group is summarized in Appendix II.

Statistical Methods

Data were analyzed with SPSS Version 13.0 (SPSS, Chicago, IL). Descriptive statistics were calculated for demographic variables and dependent measures. The assumptions of parametric statistical tests were tested via tests of normality and homogeneity of variance. In all cases, the assumptions were met and therefore parametric tests were performed.

In the analyses, we evaluated the training effect on muscle structure and function. Specifically, the following questions were examined. One, were the groups comparable at baseline? To answer this question, pretraining values for each variable were assessed using *t* tests for independent samples. Two, was the high-intensity eccentric training more effective than the traditional training? To answer this question, each dependent variable was analyzed using separate one-way analyses of covariance on the difference scores (posttraining values – pretraining values). For each analysis, the pretraining values for each dependent variable were used as the covariate. To gain a clearer picture of the differential response of the groups, the magnitude of effect from preintervention to postintervention tests was estimated using calculations of effect size and % change for all dependent variables. The level of significance was set at $P < 0.05$. Corrections to control for increased type I error risk were conducted on each category of secondary outcome variables.

TABLE 1. Participant characteristics

Group	Experimental (n = 10)	Control (n = 9)
Age, yr: mean (SD)	64.3 (9.6)	67.0 (10.2)
PD duration, yr: mean (SD)	6.1 (3.9)	6.5 (4.3)
PD severity ^a : mean (SD)	2.5 (0.5)	2.5 (0.7)
Number on dopamine replacement	5/10	5/9
UPDRS motor subsection score	12.20 (6.2)	12.67 (3.7)
Predominate signs		
Akinesia	2/10	1/9
Bradykinesia	6/10	6/9
Postural instability	1/10	0/9
Rigidity	5/10	4/9
Tremor	5/10	4/9

^aReported on Hoehn and Yahr scale.

RESULTS

Nineteen individuals with PD completed the trial (10 eccentric group participants, 9 controls). One participant was dropped from the standard-care group because of unrelated health issues. Both groups were similar in age, body morphology, duration and severity of PD, and predominate PD signs. There were no significant differences between the groups on any of the outcome measures at the preintervention tests (Tables 1 and 2). During training, eccentric group participants demonstrated minimal leg pain that subsided within the first 2 weeks of eccentric training. On average, the RPE of the legs progressed from training week 1 to training week 4 and then remained stable through week 12 (Appendix I).

Muscle Volume

The mean difference in quadriceps femoris muscle volume between groups was significantly different for

both the more affected extremity and the less affected lower extremities (more affected, $P = 0.014$; less affected, $P = 0.03$). The muscle volume increases demonstrated by the participants in the eccentric group exceeded those demonstrated by the standard-care group in both their more affected and less affected extremities over the course of training (eccentric group more affected +6%, ES = 0.27; less affected 6%; ES = 0.26; standard-care group more affected -0.3%, ES = 0.04; less affected +1%, ES = 0.14; Fig. 3, Table 2).

Average Torque

The mean differences in average torque between groups were not significantly different for both the more affected and less affected lower extremities (more affected, $P = 0.08$; less affected, $P = 0.40$). However, 95% confidence intervals (CIs) of the difference scores for both lower extremities in the eccentric group did not encompass zero, while the 95% CIs of the difference scores for both lower extremities in the standard-care group did encompass zero. In addition, examination of the magnitude of effect estimators revealed that the average torque increases demonstrated by participants in the eccentric group consistently exceeded those demonstrated by the standard-care group in both their more affected and less affected extremities over the course of training (eccentric group more affected +29%, ES = 0.77; less affected +19%, ES = 0.73; standard-care group more affected +7%, ES = 0.25; less affected +2%, ES = 0.06; Table 2).

TABLE 2. Muscle structure and function outcomes

Variable	Eccentric (n = 10)		Mean difference (95% CI)	Standard care (n = 9)		Mean difference (95% CI)
	Pre-	Post-		Pre-	Post-	
Muscle volume (cm ³)						
More affected	1,363.13 (318.71)	1,444.59 (314.14)	43.32 (13.05-73.59) ^a	1,462.13 (426.44)	1,458.19 (437.20)	-1.77 (-29.17 to 20.62)
Less affected	1,408.09 (332.80)	1,488.54 (308.13)	44.19 (12.66-75.91) ^a	1,663.66 (510.38)	1,682.16 (542.15)	7.97 (-14.48 to 30.43)
Average torque (Nm)						
More affected	69.94 (23.98)	90.74 (31.03)	20.13 (5.52 to 34.72)	71.20 (15.77)	76.07 (30.73)	4.87 (-14.80 to 23.82)
Less affected	71.29 (19.27)	84.80 (20.39)	13.50 (3.67-23.34)	84.79 (15.09)	87.03 (33.02)	10.85 (-12.39 to 34.27)
Six-minute walk (m)						
Stair descent (sec)	575.12 (142.37)	694.37 (219.31)	119.04 (34.46-203.60) ^b	544.72 (133.13)	572.82 (161.96)	19.00 (-38.98 to 76.98)
Stair ascent (sec)	5.05 (2.13)	4.16 (1.38)	-0.89 (-1.53- to 0.23) ^b	5.14 (2.35)	5.16 (2.77)	0.02 (-0.35 to 0.40)
Stair ascent (sec)	5.05 (1.75)	4.48 (1.10)	-0.57 (-1.22 to 0.08)	5.90 (2.67)	5.98 (3.20)	0.08 (-0.45 to 0.60)

Pre- and posttraining values reported represent actual mean (SD) values, not those adjusted with the covariate.

^aSignificant differences between the eccentric group mean difference and the standard care group mean difference ($P < 0.05$); ^bsignificant differences between the eccentric group mean difference and the standard-care group mean difference ($P < 0.015$).

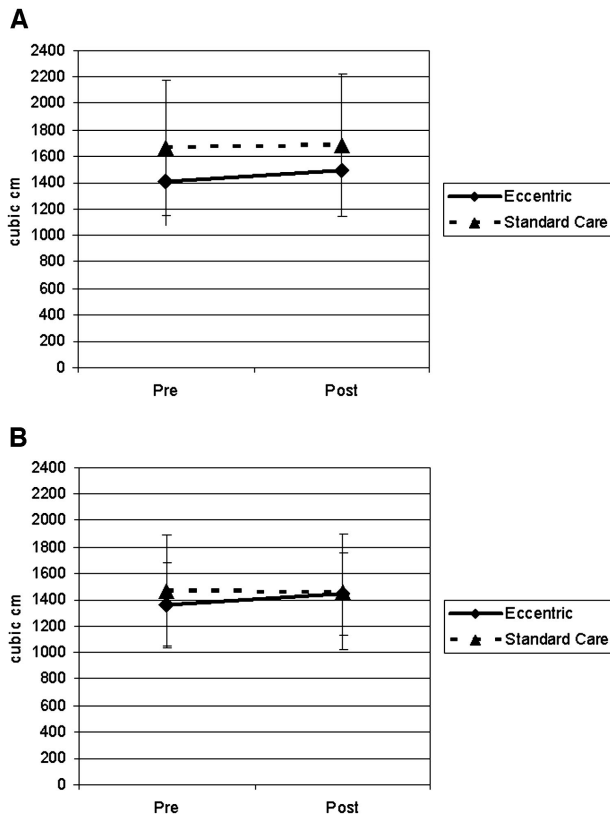


FIG. 3. Muscle volume changes. Graphs of mean (SD) for both (A) the less affected and (B) the more affected extremities are presented. In both the less affected and the more affected extremities, the eccentric group (solid lines) demonstrated 6% increases in muscle volume. The standard-care group (dashed lines) demonstrated a 1% increase and no change in muscle volume of the less affected and more affected extremities, respectively.

Mobility Task Performance

The mean difference in 6MW and stair descent between groups was significantly different, while the mean difference for stair ascent approached significance (6MW, $P = 0.013$; stair descent, $P = 0.007$; stair ascent,

$P = 0.06$). The mobility increases demonstrated by the participants in the eccentric group exceeded those demonstrated by the standard-care group in all tasks over the course of training (eccentric group 6MW +21%, ES = 0.68; stair descent +18%, ES = 0.53; stair ascent +11%, ES = 0.41; standard-care group 6MW +5%, ES = 0.20; stair descent 0%, ES = 0.01; stair ascent +1%, ES = 0.03; Fig. 4, Table 2)

DISCUSSION

Parkinson's disease is a degenerative disease of the CNS that results in deficits in muscle function leading to weakness, bradykinesia, decreased ambulatory ability, and increased disability.^{2,36} Although the weakness in those with PD likely results in part from central impairments in neural drive to muscle, it is not clear to what extent peripheral muscle changes arise from the inactivity/immobility commonly associated with the diagnosis. In this study, we hypothesized that, in a sample of persons with PD, anatomical and functional adaptation of skeletal muscle would occur as a result of high-intensity loading of the quadriceps. Furthermore, we predicted that the increased intensity of muscle loading associated with our eccentric group would result in amplified benefit relative to our standard-care control group.

Our results demonstrated that a 12-week program of high-force eccentric resistance training can produce muscle hypertrophy, increase strength, and improve mobility in persons with mild to moderate PD. To our knowledge, this is the first clinical trial to demonstrate the effects of eccentric resistance training on muscle hypertrophy in persons with PD.

In the present study, significant quadriceps femoris hypertrophy (6%) occurred in the eccentric group. These results appear to have clinical significance in that muscle mass and muscle strength have recently been reported to be associated with mobility limitations in older men and

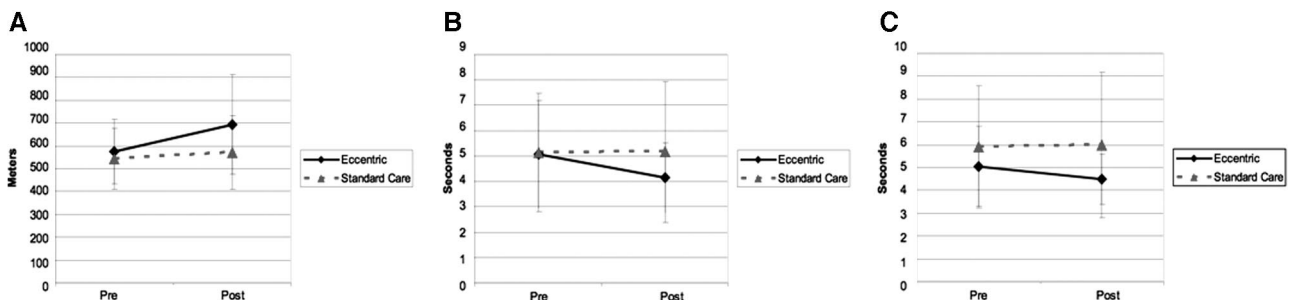


FIG. 4. Mobility task changes. Graphs are of mean (SD) for (A) 6-minute walk, (B) stair descent, and (C) stair ascent. In each graph, both the eccentric group (solid lines) and the standard-care group are presented. Over the intervention period, the eccentric group demonstrated 17%, 22%, and 13% improvements in the 6-minute walk, stair descent, and stair ascent tasks, respectively. The standard-care group (dashed lines) demonstrated 5%, 0%, and -1% change in the 6-minute walk, stair descent, and stair ascent tasks, respectively.

women.³⁷ This amount of hypertrophy is less than that seen in younger nonneurologically impaired individuals exposed to the same resistance training regimen.^{14,15,23}

One potential reason that the response of persons with PD did not meet the muscle hypertrophy changes seen in healthy younger and older individuals exposed to the same training may be the altered neural drive to the muscle in persons with PD. Adequate neural drive to muscle has been shown to be a powerful anabolic stimulus.^{38,39} Studies of EMG and motor cortex activity in persons with PD suggest that frequency modulation, one of the components of improved neural drive to muscle, is diminished in persons with PD above and beyond that seen in nonneurologically impaired age-matched controls.^{40–46} A systematic approach to examining strength gains in persons with PD would suggest that future research is needed to examine the relative contributions of hypertrophy and neural drive to muscle as the mechanisms for observed PD strength gains.

Previous research has demonstrated positive effects of strength training on muscle cross-sectional area and muscle strength in healthy elderly individuals. Our muscle force results corroborate these previously published reports of high-intensity resistance training in healthy elderly individuals and persons with PD.^{3–5,47–50} In the three studies of strength training in PD found in the literature, the authors report what appear to be clinically significant improvements in muscle force production in persons with PD. Although differences in outcome measures make comparisons difficult, the similarities of our results with these previous studies emphasize that PD does not preclude measurable improvements in behavioral measures of muscle function.^{3–5} These results extend the results of these previous studies in that they demonstrate additional functional benefits of resistance training (to stair ambulation and gait endurance).^{3–5} In addition, our results of greater improvement in the eccentrically demanding task of stair descent appear to indicate a contraction mode-specific benefit to the training (Fig. 4B–C).

While improvements in muscle size and force production provide evidence of the physiological efficacy of resistance training, such results are of little relevance if they do not produce concurrent, clinically meaningful mobility benefits. In the context of a neurodegenerative disease such as PD, the minimum expectation for treatments directed at safety and mobility may be to slow the progression of weakness/loss of mobility rather than to gain improvements.

Persons with PD in the standard-care group of our study made minimal gains and in some cases worsened slightly over the 12-week intervention period. This is a

cause for concern in that the exercise components and intensity of the standard-care group exceeded that recommended by leading PD patient advocacy organizations in the United States (American Parkinson Disease Association, Parkinson's Disease Foundation). In contrast, for all outcomes, the eccentric group participants consistently demonstrated clinically and statistically significant improvements over the intervention period (Figs. 3 and 4). Our results add to a growing body of literature that suggests that persons with varied CNS pathologies (PD, stroke, multiple sclerosis) can experience strength and mobility improvements in response to resistance training.^{24,51,52}

In conclusion, persons with PD in this study who performed high-force eccentric resistance training demonstrate the ability to hypertrophy their quadriceps femoris muscle group. These increases in muscle volume appear to be important in improving muscle force and mobility in persons with PD. This study included 19 participants and used matched assignment to groups. These design features limit the ability to generalize this findings beyond the sample studied and indicate that future studies are needed to corroborate these findings. The effect sizes observed in this study indicate that future research of resistance training in PD using these outcome measures will require larger sample sizes. In addition, future studies should examine both neural and hypertrophic responses to resistance training in PD and attempt to determine the relative contribution of each component. To utilize resistance training optimally as a therapeutic modality in persons with PD, there is a need for mechanistic studies combining contemporary high-resolution techniques such as MRI, muscle biopsy, and electrophysiological measurements.

APPENDIX I: STANDARD OF CARE EXERCISE PROGRAM DETAILS AND PROGRESSION

Both groups performed endurance, flexibility, balance, and upper extremity resistance exercises. The total duration of each session will be ~30 to 40 minutes. The upper extremity strength training was comprised of two exercises (upright rowing, latissimus pulldown). The progression of upper extremity resistance exercises was determined by their one repetition maximum (1) weight. Each week the 1RM weight for each exercise was assessed and the exercise prescription for that week included three sets of 12 to 15 repetitions with a weight that was 60% to 70% of the 1RM weight.

For the standard of care control group, there were three resistance exercises for quadriceps, gastrocnemius/soleus, and hip abductors (bilateral lower extremity squats on a Total Gym, standing heel raises, and pulley-resisted hip abduction). The progression of the lower extremity resistance exercises for the control group was conducted in the same fashion as the progression of upper extremity resistance exercises.

APPENDIX II: EXPERIMENTAL GROUP RESISTANCE TRAINING PROGRESSION

Week	Times/week	Training duration	Rating of perceived exertion for lower extremities
1	2	3-5 minutes	7 (very, very light)
2	3	5 minutes	9 (very light)
3	3	5-10 minutes	11 (fairly light)
4	3	10-15 minutes	11-13 (fairly light to somewhat hard)
5-12	3	15-30 minutes	13 (somewhat hard)

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