Power training induced change in bradykinesia and muscle power in Parkinson’s disease

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A B S T R A C T

Power-based resistance training (PWT), using low load and high velocity, can improve physical function and quality of life in older persons. Patients with Parkinson’s disease (PD), exhibiting muscular weakness and reduced movement speed, have been shown to benefit from resistance training; however, little is known about the advantages of PWT for PD.

Purpose: To evaluate the effects of PWT on bradykinesia and muscular performance in older patients with PD.

Methods: Twenty-six patients with mild to moderate PD were randomly assigned to a PWT or control group (CON). The PWT program was three months, incorporating two sessions/wk of high-speed resistance training combined balance and agility drills. Outcome measures included: upper and lower limb bradykinesia scores, one repetition maximums (1RM) and peak powers on biceps curl, chest press, leg press, hip abduction and seated calf, and quality of life (PDQ-39).

Results: The PWT group produced significant improvement in both upper and lower limbs bradykinesia scores, 1RM and muscle peak power (p < .05), which surpassed the CON group except for power during the seated calf exercise. No significant correlations between changes in clinical measure of bradykinesia and muscle peak power were observed after training. Significant improvements were seen in the PDQ-39 overall score, subsections for mobility, activities of daily living and social support for the PWT group.

Conclusion: The 3-month PWT program significantly reduced bradykinesia and increased muscle strength and power in older patients with PD. Power training is an effective training modality to improve physical function and quality of life for PD.

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1. Introduction

Parkinson’s disease (PD), which predominately impairs motor function, affects 0.5-1% of individuals aged 65–69 years of age and 1–3% of those above 80 years of age [1]. One of the cardinal symptoms, bradykinesia, defined by James Parkinson in part as “lessened muscular power”, presents as slowness of movement [2]. In addition to bradykinesia, declines in muscle power are also associated with slower walking velocity [3], increased fall probability [4,5], and loss of physical independence [6]. Muscle weakness has been observed across various muscle groups in the upper [7] and lower limbs [4]. Electromyographic (EMG) studies have found decreased rates of force development, prolonged contraction time, segmentation of force production, and irregularly shaped force–time curves during isometric testing in PD patients [8,9].

Resistance training has become an increasingly popular intervention for preserving muscle function and enhancing functionality for people with PD. One systematic review examining the impact of resistance training on mild to moderate PD [10] reported significant improvement in muscle strength for a number of exercises, including biceps curl, chest press and leg extension, as well as improved mobility assessed using gait speed, stride length and stair descent. Additionally, a recent randomized control trial reported reduced bradykinesia during gait due to high-intensity resistance training [11].

A specific type of resistance training, power training (high-velocity, low resistance), has gained prominence as an effective exercise intervention for improving strength, power and physical performance in healthy older adults [12,13]. This explosive-type resistance training may result in an optimal combination of both
muscle hypertrophy and neural adaptation, and thus elicit gains in movement speed and muscle power [14]. Given that power training focuses on velocity by reducing training loads, it would be beneficial to examine its capacity to affect positive impacts on bradykinesia and muscle functions in older persons with PD. However, to our knowledge, no study has investigated the training effect of power-based resistance training on bradykinesia and muscular power in this population.

The purpose of this study, therefore, was to evaluate the effects of a specially designed power training program on bradykinesia, muscle strength and power in older adults with mild to moderate PD. We hypothesized that:

1. Our specially designed power training program would reduce upper and lower limb bradykinesia and increase muscle strength and power; and,
2. Changes in clinical measures of bradykinesia would correlate with changes in muscular power and movement velocity after power training.

2. Methods

2.1. Design and participants

This randomized controlled trial was part of a larger study examining the comparative impacts of power resistance training (PWT) and power yoga on overall UPDRS motor score, balance, mobility and leg press strength and power resulting from a 3-month exercise intervention. We used baseline and 3-month post-training data to conduct secondary analysis to examine the impact of PWT in comparison to a non-exercise control group (CON) in this study. All participants signed an informed written consent approved by the University of Miami Subcommittee for the Use and Protection of Human Subjects. All testing was conducted at the Laboratory of Neuromuscular Research and Active Aging 1 h after participants took their usual PD medications (“on” state), to minimize motor fluctuation and variability of motor symptoms among participants. The variables examined in this analysis were the UPDRS upper and lower limb bradykinesia subscores and strength and power for two upper body and three lower body movement patterns. Tests were administered in the following order: 1) the Unified Parkinson’s Disease Rating Scale (UPDRS) motor exam; 2) muscle strength tests; 3) muscle power tests. Pretests and post-tests were performed within a 2-week period before and after the intervention, respectively. All assessments were performed by the same testers. After baseline assessments, participants were allocated to the PWT or CON group using stratified randomization controlling for the Hoehn & Yahr Classification of Disability for PD (H&Y Scale) employing Excel software (Microsoft Excel 2013; Microsoft Corp., Redmond, WA).

Participants were recruited from local support groups, clinics and hospitals in the greater Miami area. Patients were included if they were aged 60–90 years, diagnosed idiopathic PD with mild to moderate impairment (H&Y stages I-II), capable of ambulation for at least 50 feet with or without an assistive device, able to get up and down from the floor with minimal assistance, and with no cognitive impairment (Folstein Mini-Mental State Examination (MMSE) < 24). Participants were excluded if they were experiencing unstable cardiovascular disease or other uncontrolled chronic conditions which would affect either their safety, the conduct of testing, or the interpretation of the results. Additionally, they may not have regularly practiced (1–2 times weekly) high-intensity resistance training within the past year.

2.2. Outcome measures

The primary outcome for this study was limb bradykinesia score. Secondary outcomes included muscle strength and power, and quality of life (QoL).

Bradykinesia: An upper limb bradykinesia subscore was derived by summing UPDRS motor exam items 23, 24 and 25 [15]; while a lower limb bradykinesia subscore was the sum of UPDRS motor exam items 26, 27, 29 and 31 [4]. Two testers evaluated subjects’ performance in the UPDRS motor examination separately and inter-rater reliability (r = .904) was high for this test.

Strength and power: Measurements of strength and power were taken during the performance of the biceps curl, chest press, leg press, hip abduction and seated calf. Muscle strength and power were assessed using computerized pneumatic resistance machines (Keiser A420, Keiser Sports Health Equipment, Fresno, CA). As resistance is adjustable for each machine, muscle strength and power could be measured at each participant’s unique movement speed profile, and therefore, be useful for measuring muscle strength independent of bradykinesia in these patients [4]. One repetition maximum (1RM) represented muscle strength in kilogram (kg). All tests were completed within six repetitions to reduce the likelihood that fatigue might affect the results.

Muscle power was assessed 20 min after measurement of the 1RM for each movement using the same pneumatic resistance machines. Peak power was assessed at seven relative intensities (30%, 40%, 50%, 60%, 70%, 80%, and 90% 1RM) for each exercise. The testing order was randomized to reduce any fatigue or learning effects. For strength testing participants were provided a 2-min recovery between trials; while for power testing, a 1-min recovery was provided.

Quality of life: The Parkinson’s Disease Questionnaire (PDQ-39) was used to measure the QoL before and after training. This questionnaire is sensitive to changes that matter to patients, but which are not the primary focus of clinicians’ assessments that concentrate on impairment and physical function [16].

2.3. Intervention

Power training: The PWT program used evolving optimal loads on 11 pneumatic machines, including: biceps curl, triceps push-down, chest press, seated row, lat pull-down, shoulder press, leg press, leg curl, hip abduction, hip adduction, and seated calf. Each session included 3 circuits of 10–12 repetitions on each machine, twice weekly, for 12 weeks. One circuit included alternating upper and lower body exercises on all 11 machines.

Training loads were determined using the peak power produced across seven relative intensities (30%–90% 1RM) on each machine. Following a one-week adaptation period, training loads for each exercise were increased each week from the third week onward based on participants’ reaching power plateaus. Briefly, when the patterns of power increase plateaued (within 5%) across two consecutive sessions, loads were increased by 5% and training continued until the next power plateau. For each exercise, participants were instructed to exert force as fast as possible during the concentric phase and move slowly through the eccentric phase. Additionally, two 2-week (weeks 5 and 6; weeks 11 and 12) translational training cycles were incorporated into the PWT program. These cycles utilized balance and agility activities, including line, cone, ladder, chair, step, and ball drills. The drills were designed to improve movement speed and coordination, thereby translating improvements in strength and power into improved functional performances by using motor skill practice [17].

Control: One-hour non-exercise, health education classes, concentrating on life style modification, medication, therapy and...
exercise, nutrition and long-term care, were provided once per month over the 12 weeks. Participants from the control group maintained their usual care and had been told to not change their exercise routine over the 3-month study period.

2.4. Data analyses

This current randomized controlled trial examining the effect of power training on bradykinesia and multiple upper and lower body strength and power contains analyses of significant new data from a previously reported study. Power calculations indicated that a sample size of 14 participants per group was required to detect an effect size of Cohen’s d = .56, a decrease of 5 points in the UPDRS motor score, a minimal clinically meaningful change for mild to moderate PD (Hoehn and Yahr stage I to III) [18], in the two exercise groups compared with the control group (power = .8, alpha = .05, correlation with covariate = .05). The sample size calculation allowed a 10% drop-out rate.

All statistical analyses were performed using SPSS (Version 22, IBM Corp., Chicago, IL). Differences in bradykinesia scores, IRM, and peak power between the PWT and CON groups across the 3-month training period were assessed using 2 (time: pretest/post-test) x 2 (condition: PWT/CON) repeated measures analyses of variance using pretest scores as covariates (ANCOVA). Post hoc analyses were performed using Bonferroni adjustments.

Bivariate correlations were calculated between the changes in the limb bradykinesia scores and measures of peak power. The 95% confidence intervals (95% CI) of mean differences were calculated, as were effect sizes (hedge’s g) and their 95% CI using adjusted means and pooled SD as standardizers to compare the magnitude of changes between PWT and CON. The interpretation of g is similar to that of Cohen’s d where .8 is considered large, .5 is considered medium, and .2 is considered small. A value of p = .05 was established a priori for statistical significance.

3. Results

Study flow and participants characteristics: The flow through this study and characteristics of the participants are presented in Fig. 1 and Table 1, respectively. No significant group difference were observed at the baseline and participants were mentally healthy with a MMSE score above 26, a cut-off point for distinguishing between demented and non-demented patients with PD [19].

Bradykinesia: The PWT group showed significant improvement in both upper and lower limb bradykinesia scores after training, and generated large effect sizes (upper limb: g = −1.31; lower limb: g = −.81; p < .05) compared to the CON group (Table 2).

Muscle strength and power: For muscle strength, the PWT group produced significant improvements for all five testing machines following training (p < .05). Significant differences were also seen between groups for changes across the training period with moderate effect sizes seen for the biceps curl (g = .54, p < .001), hip abduction (g = .62, p < .001) and seated calf (g = .76, p < .001), and small effect sizes for the chest press (g = .25, p < .001) and leg press (g = .21, p < .005).

For muscle power, significantly higher values were seen on all five testing machines for the PWT group after training (p < .05). Significant differences between conditions were also seen for changes across the training period with a large effect size for the leg press (g = .83, p < .002), moderate effect sizes for the chest press (g = .50, p < .019) and seated calf (g = .56, p < .075), and small effect sizes for the biceps curl (g = .24, p < .004) and hip abduction (g = .48, p < .019); however, there was no significant difference between the groups for the seated calf (Table 2).

Limb bradykinesia and muscle power: No significant correlations were detected between changes in the upper body or lower body bradykinesia scores and any power measurements.

Quality of life: The PWT group showed significantly reduced values in the Mobility, Activity of daily living (ADL), Social Support and PDQ-39 sum score after training (p < .05). Significant differences between groups were seen for changes across the training period with moderate effect sizes for the ADL (g = −.61, p = .018) and the social support (g = −.78, p = .037), and a small effect size for the PDQ-39 sum score (g = −.43, p = .028) (Table 3).

4. Discussion

This is the first study to investigate the impact of high-speed resistance training on bradykinesia, muscle function, and quality of life in older individuals with PD. The main findings of this study were: 1) the 3-month PWT program significantly reduced limb bradykinesia score, increased muscular strength and power, and improved quality of life; 2) no significant correlation were detected between the changes in limb bradykinesia scores and muscle power.

4.1. Effect of training on limb bradykinesia

For the bradykinesia score in the UPDRS motor assessment, no existing study has indicated the clinically important difference (CID) as a result of an intervention. However, for the UPDRS motor score, Schrag et al. reported that a minimal CID in the UPDRS motor score is 5 points for mild to moderate PD (Hoehn and Yahr stage I to III) [18]. In our study, for the PWT group, the decreases in the upper and lower limb bradykinesia score were 3.0 and 1.6, respectively (Table 2). Given that the bradykinesia score is part of the UPDRS motor examination, the decreased score in the bradykinesia measurement would drive the decrease in the UPDRS motor score.

It has been suggested that bradykinesia and muscle weakness might share common underlying mechanisms since nigral dopaminergic deficits result in reductions in excitatory drive to the motor cortex and thus may result in disruption of the cortical activation of skeletal muscle [20]. It has been further postulated that regular exercise may delay the deterioration of the dopamine systems, enhance the integrity of cerebral circulation, and exert trophic influences on the neurons that supply the muscle fibers in older people [21]. The neuropathological changes after resistance training in healthy populations include reduced motor evoked potential [22], facilitated functional plasticity in the cortex [23], and increased EMG activity levels [24]. These changes suggest enhanced excitability of the motor cortex and spinal cord motor neuron pools. These changes, however, have never been studied in people with PD, although cortical hyperexcitability was observed after high-speed treadmill training in patients with PD [25], and the activation of similar neural pathways has been suggested after an acute bout of forced cycling administered to reduce symptoms between dosages of PD medications (levodopa) [26].

In the current study, significantly improved bradykinesia scores were seen in both upper and lower limb for the exercise group suggesting that power training may enhance neuronal activity of the basal ganglia [27]. However, no direct measures of neural changes were made in this study and only the bradykinesia scores from the UPDRS motor section were used to examine whether the PWT program may have induced a “neuroprotective” effect and mediated basal ganglia function. Within the context of neuro-muscular responses, as they related to resistance training, it has been asserted for decades that strength and power gains in the early phases (2–8 wk) of training are considered to be the result of neural adaptation rather than muscle hypertrophy [28]. In this study we used progressive overload patterns based on each
Table 1
Participant characteristics. Data was presented as mean (SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>PWT (n = 14)</th>
<th>CON (n = 10)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>71.6 (6.6)</td>
<td>74.9 (8.3)</td>
<td>.78</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>9/5</td>
<td>4/6</td>
<td>NA</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.2 (12.0)</td>
<td>163.8 (9.9)</td>
<td>.10</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>78.0 (18.9)</td>
<td>71.5 (13.4)</td>
<td>.41</td>
</tr>
<tr>
<td>Disease duration (yr)</td>
<td>6.6 (4.4)</td>
<td>5.9 (6.2)</td>
<td>.91</td>
</tr>
<tr>
<td>H &amp; Y stage (1–5)</td>
<td>2.2 (6)</td>
<td>2.1 (.7)</td>
<td>.89</td>
</tr>
<tr>
<td>MMSE score (0–30)</td>
<td>29.1 (.9)</td>
<td>29.4 (1.1)</td>
<td>.88</td>
</tr>
<tr>
<td>UPDRS motor score (0–108)</td>
<td>32.9 (12.0)</td>
<td>27.6 (7.8)</td>
<td>.72</td>
</tr>
<tr>
<td>Exercise level before intervention (hr/wk)</td>
<td>3.8 (3.3)</td>
<td>3.3 (3.2)</td>
<td>.81</td>
</tr>
<tr>
<td>Attendance</td>
<td>22.79 (1.2)</td>
<td>2.5 (2.3)</td>
<td>NA</td>
</tr>
</tbody>
</table>

Baseline differences were analyzed using t-test for independent samples.

PWT, power training; CON, control; H & Y, Hoehn & Yahr; MMSE, Mini-mental state examination; UPDRS, Unified Parkinson’s Disease Rating Scale.
individual's power plateaus over a 12-week training period when, arguably, participants were "learning" to better activate their available motor units [29]. The relative contributions of neural mechanisms and muscle structure (hypertrophy and sarcomerogenesis) during the current program, and similar programs of longer durations, remains to be determined.

4.2. Effect of training on muscle strength and power

In our study, PWT increased upper body muscle strength by 17% for biceps curl and 14% for chest press (Table 2); slightly lower than the reported increases of 23% for the biceps curl and 21% for the chest press reported by Hass et al. [30]. The more modest improvements in the current study may have been the result of the higher level of muscle function at the baseline. A more viable explanation may have been the loading patterns employed. The training intensities in the current study ranged from 40 to 60% of 1RM to allow training at higher thereby optimizing power; whereas training loads between 60% and 70% 1RM were used by Hass et al. [30]. Given the established relationship between load and strength development, it would be expected that the lower loads associated with PWT training would be associated with less substantial increases in strength [31].

Although the effects of resistance training on the upper body muscle has received little attention in PD patients, meta-analyses [32,33] on resistance training for PD did compare the impacts of predominantly lower body resistance training programs on lower limb strength, and indicated that progressive resistance exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33]. Meanwhile, Roeder and his colleagues [32] compared the training effect of resistance training on leg press exercise when compared to non-exercise or exercise control, and the SMDs varied from .44 to 1.18. The training effect for the leg press exercise were capable of increasing leg extension strength by a standardized mean difference (SMD) of .50 (95% CI .05 to .95) when compared to usual care [33].

The ankle plantar flexors, the improvement in the strength resulting from our study is consistent with results from a 10-week intervention by Hirsch et al. that [34] that combined resistance and balance training compared to balance training alone with the improvement in our study (mean difference: 29.2 kg [95% CI 17.9, 40.5]) somewhat higher than that of the earlier study (mean...
movement: 23.6 kg [95% CI: 13.0, 32.2]) [34]. This finding is not unexpected due to the higher optimal load (50–90% 1RM) used during PWT for the plantar flexors compared to the 60–80% 4RM was previously used. Because the ankle joint during plantar flexion constitutes a second class lever, the load used for this exercise was considerably higher than those used for all others. Moreover, our results add to a growing body of literature suggesting that patients with PD could experience a large training effect for the hip abduction strength in response to resistance training.

The effect of exercise on muscular power is rarely reported in the literature for patients with PD. The improvements after training in the current study (biceps curl: 9%; chest press: 24%; leg press: 35%; hip abduction: 22%; seated calf: 29%, Table 2) are similar to those reported in other populations using pneumatic resistance training. For example, Balachandran et al. [13] reported increases of 41% and 24% for leg press and chest press, respectively, in a sample of older individuals with sarcopenic obesity. Reid et al. [35] reported increases of 34.0% and 42.1% in leg extensor power for light and heavy power training, respectively, in mobility limited elders. Our results also compare favorably to leg press power outcome reported for high-speed training in community-dwelling individuals without reported limitations [36]; but are considerably lower than the improvements reported by Fielding et al. in an early study examining high-speed resistance training in older women [12].

Our results suggest that high-speed resistance training should be considered used an effective exercise strategy for increasing muscular power in the key muscle groups, which should be targeted to improve mobility and independence and reduce fall probability. Power training has been shown to be feasible and a little superior to conventional resistance training in improving physical functioning, such as balance, walking speed, leg muscle strength and power, as well as self-reported function in healthy general older adults [37]. In daily activities, leg power is a strong predictor of physical performance as indicated by comparisons to the short physical performance battery [38] and self-reported functional status [39] in older persons. Ankle plantar flexor strength and power are significantly lower in older than young persons and are associated with reduced walking speed and shortened step length [40]. Significant reduced peak torque of hip abductor decreasing with age is considered an indication of lateral instability [41] and type II fiber atrophy of gluteus medius is an independent risk factor for hip fractures resulting from falls in elderly women [42]. In fact, ankle plantar flexion, knee extension, and hip flexion strength are each associated increased probabilities of using a multiple-step, rather than single-step strategy for recovering from a stumble thereby increasing the likelihood of a subsequent fall [43]. For the upper limb functionality, the importance of upper body strength and power to independence is evidenced by the number of upper body tests used to assess daily function and the performance of the elbow flexion function is also a major determinant of functionality in older persons [44]. Additionally, chest press power is significantly correlated with functional status in elderly adults [39].

4.3. Correlation between bradykinesia and muscle power and movement velocity

We expected to see a positive correlation between changes in bradykinesia and muscle power after training as muscle weakness is considered a fundamental deficit affecting bradykinesia [4]. However, no significant correlations were detected possibly due to the fact that multiple muscle groups working in specific sequences (kinetic chains) were inherent in the UPDRS motor test, while our strength and power testing concentrated on isolated movement patterns. Similarly, no significant correlation was seen in the changes of leg muscle power and functional physical testing, such as timed up-and-go, or walking speed [45]. Furthermore, it has been demonstrated that the differential weakness levels between the flexor and extensor muscles in PD, especially for the elbow joint [46]. However, given the small sample size in this study, it is still inconclusive on the relationship between muscular power and movement speed. Further investigations are needed to evaluate the association between changes in physical attributes and physical performance in larger samples.

4.4. Effect of training on quality of life

Whether the improvement in muscle strength and power, especially for the leg press, as a measure of the efficacy of this intervention on neuromuscular capacity as it relates to mobility [5] and fall risk [47], could be transferrable to functional improvement is unclear. In the current study, the PWT group reported significant improvements in the PDQ-39 physical subsections (mobility, ADL), which largely contributed to the improvement in the overall score (Table 3). These findings are consistent with a previous study that reported improvements in the similar QoL outcomes using another type of resistance training, high intensity eccentric resistance training [11]. The minimal important difference scores reported by Petru and his colleagues [16] for increasing QoL score (getting worse) were 1.5, .7 and .6 for the overall scores, mobility, and ADL, respectively. Although the scores for these domains decreased significantly after intervention in our study, whether these decreases reflected clinically meaningful improvement is unclear. Future studies should continue to investigate the clinical meaningful important changes for PDQ-39 as a result of exercise interventions.

4.5. Strengths of this study

Our findings add to the results supporting resistance training in persons with PD evidence supporting the effectiveness of power training on bradykinesia, muscle function, and quality of life in older individuals with PD. This randomized controlled study suggests that high-speed training would reduce bradykinesia and consequently induce the improvement in the perceived quality of life. The established relationships between independence and fall reduction and power and strength of the muscle groups targeted in our study, coupled with the improvements seen with our high-speed intervention, highlight the importance of power training for increasing physical and functional levels. Furthermore, the interpretation of our results included an examination of injuries or other negative events and an assessment of our participants’ adherence to their training assignments. As can be seen in Fig. 1 and Table 1, there were no adverse events related to the training intervention that caused individuals to stop the PWT training, and there was high exercise adherence as indicated by attendance (22.79 ± 1.2 out of 24 sessions).

4.6. Limitations

One limitation of our study is the small sample size, which may have reduced the power to detect statistical significance, especially in the examination of correlations between changes in bradykinesia scores and muscle power. A second limitation is the short training duration employed. The extent to which power training combined balance training can produce long-term changes in bradykinesia and other motor functions remains unclear and warrants further investigation with larger samples. Moreover, we did not measure asymmetrical limb strength and power deficits...
although PD often affects one side of body to a greater extent and unilateral symptoms are manifested in patients with mild to moderate disease stages [4]. An assessment of the effect of training on body asymmetry is recommended in future studies employing power training.

5. Conclusion

Our specially-designed power training program can improve strength, power and motor function in older adults with PD. This well-tolerated exercise program can be applied as an exercise strategy that can be incorporated into outpatient rehabilitation for PD to reserve or improve movement function. Further studies are warranted to investigate the impacts of power training on other functional variables, such as activities of daily living and fall risks in larger populations of patients with severe PD symptoms and to explore the impact of long-term studies.

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Conflict of interest

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