Velocity-Based Training Affects Function, Strength, and Power in Persons with Parkinson's Disease

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Abstract

Calaway, CC, Martinez, KJ, Calzada Bichili, AR, Caplan, JH, Milgrim, WP, Mann, JB, Haq, I, and Signorile, JF. Velocity-based training affects function, strength, and power in persons with Parkinson's disease. *J Strength Cond Res* 38(10): 1800–1807, 2024—Velocity-based training (VBT) is commonly associated with high-level athletes. No study has examined the effects of VBT on performance in persons with Parkinson's disease (PD). The objective of the study was to compare the effects of 10 and 30% velocity-loss threshold protocols on changes in functional performance, strength, and power in persons with PD after 12 weeks of supervised VBT, 3 days per week. Twenty-one subjects with PD (72.9 ± 5.9 y) were randomly assigned to the 10% or 30% velocity-loss threshold group and performed the 6-m walk test at habitual and maximal gait speed ($6MWT_{Max}$), the 5 time sit-to-stand test (5 × STS), 1 repetition maximum (1RM), and peak power (PP) testing for the chest press (CP) and leg press (LP) exercise. A mixed ANOVA with significance was set a priori at 0.05 revealed that significant time effects were seen for the 6MWT at maximal speed (MDiff ± SD = 0.22 ± 0.04 $m·s^{-1}$, $p < 0.001$), 5-time sit-to-stand time (−1.48 ± 0.45 seconds, $p = 0.005$) and power (75.5 ± 22.7 W, $p = 0.005$), 1RM for CP (5.1 ± 1.1 kg, $p < 0.001$) and LP (12.6 ± 3.7 kg, $p = 0.005$), and LP-PP (43.6 ± 13.2 W, $p = 0.006$). Secondary analyses revealed time effects for the load at which PP was achieved for the CP exercise. A Wilcoxon signed-rank test revealed no significant differences in the percentage of 1RM at which PP was achieved for either condition. Results indicate that VBT is an effective training modality for improving functional capacity, strength, and power in persons with PD; however, shifts in force-velocity relationships were not evidenced.

Key Words: weight training, exercise, functional capacity, high-speed training

Introduction

Deficits in muscular power (force × velocity) are major neuromuscular factors responsible for declines in function in people with Parkinson's disease (PD), which can significantly decrease quality of life and functional independence (4). These deficits are most apparent when moving light to moderate loads, where velocity is the dominant factor affecting power production (28). In patients with PD, Nogaki et al. (24) demonstrated lower isokinetic force production with increased testing speeds for the more affected vs. less affected leg. Additionally, Allen et al. (4) noted that the muscle power at lighter loads was dependent on both strength and movement velocity, whereas power at higher loads was dependent on strength alone. These results demonstrate the need to target movement speed when designing programs to increase power in people with PD.

Power output is also a moderator of the quality of life in people with PD. For example, Allen et al. (4) reported that increases in power produced greater improvements in walking speed than increases in muscular strength. These researchers also noted that the ability to generate force quickly is required for the performance of many activities of daily living (4). Additionally, with age, power declines at nearly twice the rate of strength (31), thereby compounding the functional declines in persons with PD, as the onset of the disease typically occurs after the age of 60. Furthermore, positive changes have been shown after power training in the self-reported Parkinson's disease questionnaire, which is a measure of health-related quality of life and well-being (22,32).

Power training using pneumatic resistance machines is an exercise strategy that has been used successfully in older adults with PD (10,22,23,32). Ni et al. (22) demonstrated that high-speed power training significantly improved upper and lower limb bradykinesia scores, 1 repetition maximum (1RM) strength, and peak power (PP) ($p < 0.05$) above changes in inactive controls, which significantly improved the overall score and the mobility, activities of daily living, and social support subsections of the Parkinson's disease questionnaire (22). Cherup et al. (10) also demonstrated comparable significant reductions in neuromuscular deficits using strength training and power training, in PD subjects, whereas Strand et al. (32) reported significant improvements in the 30 s sit-to-stand ($p = 0.002$), seated medicine ball throw ($p = 0.003$), the Mini-BEST test ($p < 0.001$), and upper-body ($p = 0.002$) and lower-body strength ($p < 0.001$) as the result a periodized resistance training program that included a power training cycle.

Although power training has been demonstrated to be a viable exercise intervention intended to reduce neuromuscular symptoms in people with PD, it commonly uses the ability to complete increasingly higher loads to dictate progression. In contrast, velocity-based training (VBT), commonly used to increase power

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and movement velocity in competitive athletes, uses velocity, rather than load, as the criterion that dictates changes in loads as training progresses (30). This innovative training strategy allows practitioners to concentrate on deficiencies in velocity rather than load during training (30). Given its effectiveness in athletic populations (15,19,29), VBT has the potential to dramatically decrease neuromuscular symptoms in people with PD because of its unique capacity to target movement velocity.

Given the unique capacity of VBT to target velocity, we examined the effects of VBT on neuromuscular performance in a sample of older individuals with PD. Because Ni et al. (22) demonstrated shifts in the load-velocity spectrum using traditional power training, we hypothesized that VBT protocols that allowed a 10% decline in movement velocity (10% velocity loss threshold [10% VLT]) would produce greater shifts towards the velocity end of the load-velocity spectrum than VBT where a 30% VLT was employed. Further, we hypothesized that VBT training, regardless of the threshold used, would positively affect maximal strength, power, and functional capability.

Methods

Experimental Approach to the Problem

This study used a randomized parallel design with 2 active arms. All testing and training were completed in the laboratory. Functional performance was assessed using the 6-m walk test performed at perceived maximal and habitual speeds and the 5-time sit-to-stand (5xSTS). Neuromuscular leg press and chest press performances were assessed using information derived from the HUR computerized pneumatic machine spreadsheets (HUR Inc., Park Ridge, IL), including PP, 1 RM strength, load at which PP occurred, and percentage of 1RM at which PP occurred (% $1RM_{PP}$). Testing took place during the 2 weeks preceding and 2 weeks after the 8-week VBT intervention. Subjects were stratified by sex and randomized into either a group permitting a 10% VLT (n = 10) or a group allowed a 30% VLT (n = 11). The 10% VLT intervention required the subject to maintain 90% of the velocity they produced at their optimal load for power across 3 sets of 8 repetitions. If a subject failed to maintain that threshold, the set was stopped. In practice, the 10% VLT dictated occasional reductions in load in favor of maintaining the targeted movement velocity. In contrast, the 30% VLT protocol allowed the subject to continue a training set until they could no longer maintain 70% of the velocity they produced at optimal load for power for three 8-repetition sets. This allowed more repetitions and, therefore, more substantial increases in load while still targeting velocity. Subjects trained 3 times per week using 10 exercises including leg press, chest press, seated leg curl, lat pull-down, shoulder press, hip abduction and adduction, seated row, triceps push-down, and bicep curl. All exercises were performed on the HUR computerized pneumatic resistance machines.

Subjects

Sixty older individuals (>60 years) previously diagnosed with PD (determined through MDS UPDRS testing and verbal confirmation of diagnosis from the subject) were recruited to participate in this study. Of those contacted, 23 agreed to participate. The study was approved by the University of Miami, Coral Gables, FL Institutional Review Board, and all potential subjects were informed of the associated benefits and risks before signing an institutionally approved informed consent form. Subjects were recruited from the university population and from individuals residing in surrounding neighborhoods using flyers and from a phone list of persons who had expressed interest in participation. Inclusion criteria included planning to reside in the area for the duration of the study, Hoehn and Yahr stages 1–3 with stable use of medication (subjects reported consistent use of medication). Exclusion criteria included cognitive impairment (<23 score on the Montreal Cognitive Assessment); a history of any neuromuscular disorders other than PD; recent lower limb injury or surgery; or a history of serious cardiovascular or other systemic diseases not controlled through medication. Before the intervention, subjects completed the International Physical Activity Questionnaire, which measures the numbers of hours per week in which subjects engaged in vigorous and moderate activity, and walking and sitting (12).

Procedures

Functional Testing. The 6-m walk tests at habitual ($6MWT_{Hab}$) and maximal ($6MWT_{Max}$) speeds were assessed using electronic timing gates (SpeedTrap, Brower Timing Systems, Draper, UT) to evaluate subjects' gait speed (18). Subjects were instructed to stand on a starting line at the 0 m mark and the test started after the investigator's "3, 2, 1, Go!" cue. Timing gates were placed at the 2- and 8-m marks to reduce the impact of acceleration or deceleration on the results. Subjects performed 1 practice trial and 2 actual trials for each test. The best of the 2 times for each test was recorded. Habitual and fast gait speeds demonstrated excellent reliability in persons with PD between sessions (ICC = 0.92 and 0.96, respectively).

The 5xSTS test has been used as a measure of functional lower-body strength in PD (7). Subjects were given 1 practice trial and 2 actual trials, each separated by a 1-minute rest. The lowest of these 2 trial times was recorded. According to Duncan et al. (16), test-retest reliability for the 5XSTS is considered high (ICC = 0.76). Power outputs for the 5xSTS were computed using the equation developed by Alcazar et al. (3).

1 Repetition Maximum Testing. All strength and power tests were performed using 2 of the computerized pneumatic resistance machines, the chest press (CP) and the leg press (LP). Chest press 1-repetition maximum (CP-1RM) and leg press 1-repetition maximum (LP-1RM) were assessed using a protocol previously described by Cherup et al. (10). For each subject, a warm-up set of 10 repetitions at approximately 50% of their estimated 1RM was given. The weight was then increased to a load that allowed for 5 repetitions, and as a final warm-up, a set of 3 repetitions judged to be near the subject's maximum was provided. After this warm-up, lower-body exercise loads were increased by 10% and upper-body loads by 5% until the subjects reached their 1RM, which was determined when the subjects could no longer complete the exercise using adequate form. Rest periods of 2 minutes were allowed between attempts. In our laboratory, this testing method has been shown to have high test-retest reliability in older people (ICC = 0.93) (10).

Power Testing. After the completion of strength testing on day 1, subjects were provided with a 48-hour recovery before returning for the second testing day. On day 2, chest press peak power (CP-PP) and leg press peak power (LP-PP) testing began with a warm-up of 10 repetitions at 30% 1RM using 1–2s concentric and eccentric contractile phases. A second 5-repetition warm-up at the same load was then performed as rapidly as possible during the concentric contraction and at a controlled speed during the eccentric contraction. Peak muscle power was subsequently assessed at 5 relative intensities (40, 50, 60, 70, and 80% 1RM). The percentages were randomized to reduce any order effect. The concentric phase was performed as fast as possible for each repetition, and the eccentric phase was performed over 1–2s. Each repetition was verbally cued: "3, 2, 1, Go!" This testing protocol is commonly used for power testing of older individuals with and without PD (13,14,21,22). Any repetition not performed properly was repeated after a 1-minute recovery. Power outputs were recorded and visually represented as a bar graph on the display of each machine and then cross-referenced with the HUR electronic spreadsheets. A high test-retest reliability for 1RM testing has been demonstrated in our laboratory for older subjects (ICC = 0.93) (8).

Intervention. Subjects were randomly assigned to either the 10% VLT or 30% VLT group. Both groups were trained by undergraduate exercise physiology majors who received personal instruction by the research coordinator on the proper performance of each VLT training protocol. Additionally, each trainer was shadowed by the principal investigator and research coordinator to ensure adherence to each protocol. Training was provided 3 times per week for 12 weeks and completed 3 sets of 8 repetitions on the 10 pneumatic machines. Subjects were required to attend at least 80% of the training sessions to have their data included in the analyses. The loads at which they began training were equal to the loads at which PP occurred during pretesting. The maximal velocity produced at PP was recorded and used to compute each subject's VLT. If the subjects completed 3 successive repetitions below their assigned VLT, their load was decreased by 2.5% on upper-body machines or 5% on lower-body machines for the next training session. The load was similarly increased for the following session if subjects did not fall below their VLT for 3 consecutive repetitions or performed above their assigned VLT. These load changes were a modification of the velocity-based load progression methods used in several VBT studies (2,5,19,20). Subjects were provided visual feedback throughout their training using the tablets integrated with each machine. In younger individuals, this practice was shown to increase motivation, competitiveness, and performance during resistance training programs (34,35). Additionally, subjects were provided consistent verbal encouragement across training and testing sessions (6,33). All data including attendance, training volume, and load were recorded by the HUR computerized pneumatic machine spreadsheets (HUR Inc.).

Analyses. In both groups, the CP and LP load-velocity profiles were analyzed before and after the training interventions. Power curves were generated from the product of force and velocity at 40, 50, 60, 70, and 80% 1RM (32). The maximum power values among the loads were identified as the CP-PP (CP-Load$_{PP}$) and LP-PP (LP-Load$_{PP}$) and the percentage of 1RM at which PP occurred was determined for LP (LP-%1RM$_{PP}$) and CP (CP-%1RM$_{PP}$). Further, LP-1RM per unit body weight (LP-1RM·BW^{-1}) and LP-PP per unit body weight (LP-PP·BW^{-1}) were computed.

Statistical Analyses

For 1RM, PP, and Load$_{PP}$, separate 2 (time) × 2 (VLT group) mixed repeated measures ANOVA were used to determine significant main effects and interactions. When significant main effects or interactions were detected, an LSD pairwise analysis was used to establish the source. Paired sample t-tests were used to determine differences in demographics between groups at baseline. A Wilcoxon signed-rank test was used to determine changes in %1RM$_{PP}$ across the intervention period. Effect sizes for main effects and interactions during repeated measures ANOVA were computed as partial eta squared values (η_p^2). Interpretations of η_p^2 effect sizes are 0.01 = small effect size, 0.06 = medium effect size, and 0.14 = large effect size. Effect sizes during pairwise comparisons were reported as Cohen's *d*. For Cohen's *d*, 0.2 = small effect size, 0.05 = medium effect size, and 0.8 = large effect size. A Wilcoxon signed-rank test was used to assess the magnitude of change in %1RMPP, because this variable was ordinal (37). This nonparametric test is used to determine a change in scores among a matched pair sample across time (25). An effect size for Wilcoxon signed-rank test was also calculated $r = Z/(\text{sqrt}[n])$ (25). The interpretation of the *r* values is 0.1 = small effect size, 0.3 = medium effect size, 0.5 = large effect size (11). The significance level was set a priori at 0.05 for all analyses. All statistical analyses were performed with the IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 28.0 (IBM Corp., Armonk, NY), except for Cohens *d*, which was computed using a custom program written in Microsoft Excel (Microsoft Corp., Redmond, WA).

To calculate the overall sample size, an a priori power analysis using countermovement jump power as a primary outcome measure when comparing 15% VLT and 30% VLT in professional soccer players was implemented (26). Based on this study, an F-test for a mixed ANOVA with a medium effect size of 0.45, alpha level of 0.05, and a power of 0.95 yielded a sample size of 20 subjects.

Results

Subjects

A Consort chart showing the flow of subjects through the study is presented in Figure 1. Of the 60 subjects contacted, 21 were assigned to either the 10% VLT or 30% VLT group. Baseline characteristics of the 16 subjects who completed the study are presented in Table 1. No significant differences were seen between groups for any baseline characteristics ($p > 0.05$).

Functional Testing

For the analysis of the 5xSTS, there was a significant main effect for time ($F (1, 14) = 10.756, p < 0.005, \eta_p^2 = 434$). A main effect for time was also observed for 5xSTS power ($F (1, 14) = 11.039$, $p = 0.005, \eta_p^2 = 441$). Furthermore, a main effect for time was observed for the 6MWT$_{Max}$ ($F (1, 14) = 27.382, p < 0.001, \eta_p^2 = 0.662$); however, no significant main effects or interactions were detected for the 6MWT$_{Hab}$. Pairwise comparisons for all functional tests are presented in Table 2.

1 Repetition Maximum Testing

For the analysis of CP-1RM, a main effect for time was observed ($F (1, 14) = 19.956, p < 0.001, \eta_p^2 = 0.588$). Main effects for time were also observed for LP-1RM ($F (1, 14) = 11.423, p = 0.005, \eta_p^2 = 0.449$) and LP-1RM/BW ($F (1, 14) = 18.051, p < 0.001, \eta_p^2 = 0.563$). Table 2 presents the pretest and post-test

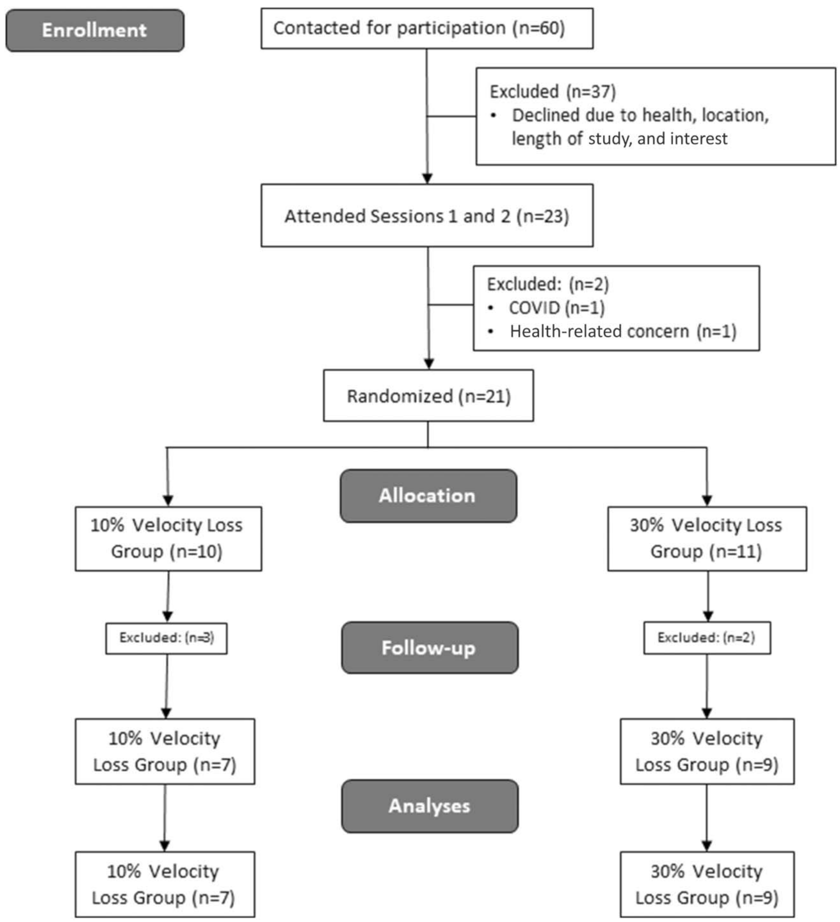

Figure 1. CONSORT chart showing the flow of subjects through the study.

Table 1

Descriptive characteristics of study subjects.*†‡

	10% VLT (n = 7)	30% VLT (n = 9)
Age (y)	75.0 ± 6.7	71.3 ± 5.2
Height (m)	1.72 ± 0.1	1.69 ± 0.07
Mass (kg)	80.4 ± 14.7	74.4 ± 11.5
Sex	6 M, 1 F	6 M, 3 F
Duration of disease state (y)	6.8 ± 4.8	5.7 ± 4.1
Exercise (h·wk^{-1})		
Vigorous	2.4 ± 3.7	2.8 ± 3.4
Moderate	4.6 ± 5.3	4.1 ± 3.2
Walking	4.1 ± 4.7	2.4 ± 2.4
Sitting	34 ± 23.7	42 ± 15.7
Side mostly affected (%)		
Left	18.75	18.75
Right	18.75	31.25
Symmetric	6.25	6.25
MDS UPDRS		
Part III motor score	32.5 ± 13.4	32.0 ± 15.6
Hoehn & Yahr stage	1.9 ± 0.9	1.8 ± 1.0
Subjects on PD medication (n)	7	9
Carbidopa, Levodopa	7	9
Ropinirole	1	1
Exercise adherence		
Total sessions	31.1 ± 1.5	30.8 ± 1.6

*10% VLT = 10% velocity loss threshold group; 30% VLT = 30% velocity loss threshold group; y = years; m = meters; kg = kilograms.
†Values are mean (SD).
‡No significant difference was seen in between groups for any variable.

values and pairwise comparisons of CP-1RM and LP-1RM for the sample.

Power Testing

For CP-PP, there were no significant main effects or interactions. However, main effects for time were observed for LP-PP (F (1, 12) = 11.008, p = 0.006, η_p^2 = 478) and LP-PP/BW (F (1, 12) = 11.415, p = 0.007, η_p^2 = 465). Table 2 presents the pretest and post-test values and pairwise comparisons for CP-PP, LP-PP, and LP-PP·BW^{-1} of the sample.

Load at Which Peak Power Occurs

For the analysis of the $Load_{PP}$ for both exercises, there were no significant main effects or interactions for the LP exercise. However, there was a significant main effect by time for the CP exercise (F (1, 14) = 4.629, p = 0.049 η^2 = 248). Pairwise comparisons showed a significant increase after the training period (MDiff ± SE = 1.726 ± 0.802; 0.005, 3.447; p = 0.049; d = 0.26).

Percentage of 1 Repetition Max at Which Peak Power Occurs

For all median scores, the Wilcoxon signed-rank test showed no significant differences among $\%1RM_{PP}$ between pretest and post-test. Results for the Wilcoxon signed-rank test for the CP using

Table 2
Pairwise comparisons for performance tests.*

Variable	Pretest	Post-test	MDiff (SE)	95% CI	*p*	*d*
Functional performance tests						
Five time sit-to-stand (n = 16)						
Performance time (s)	9.53 ± 2.69	8.06 ± 3.05†	−1.48 ± 0.45	−0.51 to −2.45	0.005	0.51
Power (W)	321.7 ± 99.7	395.8 ± 145.2†	75.5 ± 22.7	−124.2 to −26.7	0.005	0.59
Six-meter walk (n = 16)						
Habitual speed ($m \cdot s^{-1}$)	1.17 ± 0.21	1.20 ± 0.25	0.03 ± 0.40	−0.04 to 0.10	<0.403	0.13
Maximum speed ($m \cdot s^{-1}$)	1.77 ± 0.39	1.99 ± 0.44†	0.22 ± 0.04	0.14 to 0.31	<0.001	0.53
Neuromuscular performance tests						
Chest press 1RM (kg) n = 16	26.3 ± 12.8	31.4 ± 13.8†	5.1 ± 1.1	2.7 to 7.5	<0.001	0.39
Leg press 1RM (kg) n = 16	321.7 ± 99.7	395.8 ± 145.2†	12.6 ± 3.7	4.6 to 20.6	0.004	0.59
Relative leg press 1RM ($kg \cdot BWkg^{-1}$) n = 16	1.39 ± 0.42	1.58 ± 0.45†	0.19 ± 0.04	0.09 to 0.28	<0.001	0.44
Chest press PP (W) n = 14	317.6 ± 173.5	304.4 ± 195.6	17.0 ± 31.4	−51.3 to 85.4	0.597	0.07
Leg press PP (W) n = 14	451.9 ± 185.1	497.2 ± 195.2†	43.6 ± 13.2	15.0 to 72.3	0.006	0.24
Relative leg press PP ($W \cdot BWkg^{-1}$) n = 14	5.89 ± 2.23	6.54 ± 2.38†	0.63 ± 0.19	0.20 to 1.05	0.007	0.28

*Pretest and post-test scores are Mean (*SD*).
†Significant difference from pretest to post-test. MDiff (*SE*) = mean difference and standard error between pretest and post-test; 95% CI = 95% confidence interval of the difference; *d* = Cohen's *d* effect size.

a 10% VLT showed that the median shift was from 45% 1RM to 50% 1RM ($Z = -447$, $p = 0.665$). For the CP using a 30% VLT, the median shift was from 50% 1RM to 45% 1RM ($Z = -1.318$, $p = 0.187$). For the LP using a 10% VLT, there was no median shift ($Z = -0.707$, $p = 0.480$), whereas for the LP using a 30% VLT, the median shift was from 75% 1RM to 60% 1RM ($Z = -0.957$, $p = 0.339$). Frequency histograms showing the pretest and post-test values for CP of the 10% and 30% VLT groups are presented in Figure 2A, B, respectively, and for LP of the 10% and 30% VLT groups in Figure 2C, D, respectively.

Discussion

This study is the first to our knowledge to examine the ability of VBT provided at multiple VLTs to selectively improve functional performance, strength, power, and the load at which PP occurred in individuals with PD. Further, changes in %1RMPP for the sample were assessed after VBT. Both the 10% VLT and 30% VLT training conditions led to improvements in the $6MWT_{Max}$, 5xSTS, and in CP-1RM, LP-1RM, LP-1RM·BW^{-1}, LP-PP, and LP-PP·BW^{-1}. These findings support our hypothesis that VBT training using both VBT during pneumatic resistance training can significantly improve functional performance, strength, and power in people with PD.

Although the effects of VBT on PD-related functional impairment have not been examined previously, there is ample evidence to suggest that traditional power training can improve functional outcomes in PD (10,22,23). In a study by Ni et al. (22), older adults with PD, aged 60–90 y, participated in 12 weeks of power training and displayed significant improvements in upper-body and lower-body bradykinesia scores. In a second analysis, Ni et al. (23) demonstrated significant improvements in UPDRS motor function, functional measures including the Timed Up & Go test, and the 6MWT at habitual and maximal gait speeds in older adults with PD. Although the current study did not improve $6MWT_{Hab}$ performance, $6MWT_{Max}$ performance was significantly improved. Furthermore, the improvement in the $6MWT_{Max}$ ($0.22 \pm 0.04\ m \cdot s^{-1}$) was comparable with the large minimal clinically important difference reported by Hass et al. (17). This result is not unexpected as maximal gait speed is a better predictor of overall muscular power (18) and has a stronger correlation with PP than habitual gait speed. Although no minimal clinically important difference has been reported for the 5xSTS, an MDC of 2.4 s for PD patients was calculated by the American Academy of Neurologic Physical Therapy (1) using the Standard Error of the Measure from Paul et al. (27). Additionally, an MDC of 1.7 s was reported by Wong-Yu et al. (36) citing the work of Paul et al. (27). The reduction in performance time for the 5xSTS in our study (−1.48 ± 0.45) may be compared with these values.

Previous studies that examined the effects of VBT on maximal strength have included principally younger individuals and high-level athletes (11,26,29), yet their results are similar to those observed in the present study LP-1RM, LP-1RM·BW^{-1}, and CP-1RM. In a training study by Pareja-Blanco et al. (26) done in highly trained soccer players, 6 weeks of VBT using either a 15% or 30% VLT elicited 10 and 6% improvements in an isoinertial squat 1RM, respectively. However, only the 15% VLT 1RM reached statistical significance. In contrast, Rauch et al. (29) demonstrated similar improvements for 2 VBT modalities in the back squat, bench press, and deadlift 1RM of female collegiate volleyball players after 7 weeks of training reflecting the main effects seen for LP-1RM, LP-RM·BW^{-1}, and CP-1RM in the current study. Although no studies have reported changes in CP-1RM or LP-1RM of patients with Parkinson's after VBT, the increases of 19 and 23%, respectively, for these variables compare favorable to the 13 and 16% improvements resulting from the same protocol provided to a sample of older persons aged 64–88 y (10).

Previous studies examining the effects of power training on persons with PD demonstrated improvements in LP-PP and CP-PP (10,23). In a study by Cherup et al. (10), 35 older persons with mild to moderate PD were randomized into either a strength or power training intervention for 12 weeks. Although no between-group differences were found, a significant improvement was observed for the sample in both LP-PP (16%) and CP-PP (20%) (($p < 0.001$). Furthermore, Ni et al. (23) demonstrated significant improvements in LP-PP·BW^{-1} in 41 older adults with PD who performed 12 weeks of power training. Furthermore, the −4 and 10% changes in PP for the CP and LP exercises for the current

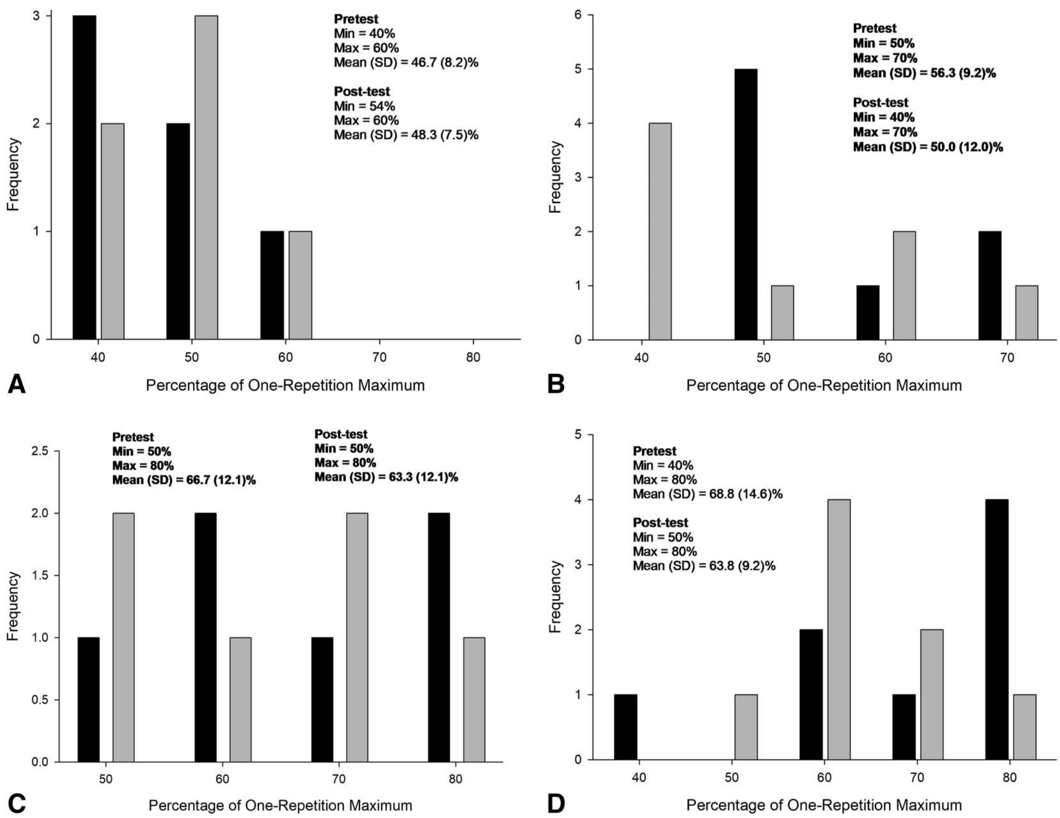

Figure 2. A) Frequency histogram of continuous field information for the chest press shifts in load at peak power for the 10% velocity loss group. B) Frequency histogram of continuous field information for the chest press shifts in load at peak power for the 30% velocity loss group. C) Frequency histogram of continuous field information for the leg press shifts in load at peak power for the 10% velocity loss group. D) Frequency histogram of continuous field information for the leg press shifts in load at peak power for the 30% velocity loss group.

study reflect a similar pattern of change (10% for CP, 0% for LP) that was observed when the same protocol was provided to older adults aged 64–88 y (9).

The failure of our subjects to produce significant improvements in CP-PP may be attributable to our testing methodology. During post-testing, the loads used for power testing were percentages of each subject's final 1RM. Given the increases in the $Load_{PP}$ for the CP after the training period, it is possible that the post-test loads negatively affected subjects' movement speeds and, therefore, reduced power outputs during post-testing. This argument is supported by the significant increase in LP-PP, where no significant changes in load at PP were observed.

The results for $Load_{PP}$ may provide insight into the nature of the PP changes in response to the 2 levels of velocity deficits used in the VBT interventions. For LP, there was a significant improvement in both 1RM and PP; however, there was no significant increase in the $Load_{PP}$. This indicates that improvements in velocity were the predominant driver of improvements in PP. In the case of CP, there were significant improvements in 1RM and a trend toward significance for load at PP ($p = 0.053$), with no significant improvements in PP, indicating that the greater exercise loads caused declines in movement speeds, reducing the potential for improvements in power.

To our knowledge, only 1 manuscript examined the percent of 1RM where PP occurred in individuals with PD. Ni et al. (21) demonstrated that high-speed resistance training in older adults with PD shifted the percent of 1RM at which PP occurred towards the velocity end of the curve for the bicep curl, leg press, hip abduction, and calf raise exercises. In the current study, no significant changes were found in this variable for the LP or CP exercises, in either condition. Figure 2A–D, however, illustrate a visible shift towards the velocity end of the load-velocity curve for both interventions. In addition to the differences in training methods, the differences in responses between the 2 studies may be attributable to the differences in disease state (Hoehn and Yahr stage, present study: 1.8 ± 0.9 (21);: 2.2 ± 0.7), and the more trained status of the current study population, half of whom had participated in a power training study approximately 3 months earlier, which may have reduced their potentials for adaptation given the nonlinear nature of the training curve. This warrants further investigation into the mechanisms and conditions required for significant changes in force-velocity profiling in persons with PD.

A number of limitations may have affected our results. First, the observed statistical power for several of the tests was low, reducing the probability of finding significance; therefore, this study should be repeated with a larger sample. Second, the testing methodology used in the power-testing battery employed percentages of the post-test 1RM values, which may have reduced movement velocity and, therefore, power outputs. As a result, it is suggested that a wider range of loads be used during power testing in future studies. Third, a control condition was not employed in this study, which makes it challenging to attribute the changes observed to the VBT protocol. Therefore, it is recommended that this study be repeated with the addition of a control group. Fourth, the short training period coupled with the absence of a detraining period brings into question the sustainability of the improvements observed. It is suggested that a study be conducted with a longer training period, and a detraining period be included. Finally, the higher age ranges used may make the results less generalizable to persons of PD in age groups or other stages. Therefore, these limitations should be considered when interpreting the results.

Practical Applications

The results of the present study suggest that VBT using velocity-based thresholds of 10 and 30% can induce changes in functional capacity, strength, and power in persons with PD when using pneumatic resistance training machines. Practitioners can apply this training style to a PD population to combat the compound effects of aging and neuromuscular disease that they experience. Subjects should complete initial 1RM testing and power testing to find their optimal load for power production. This will be their starting load and will complete 3 sets of 8 repetitions on all the machines in the exercise circuit provided. Loads should be adjusted (2.5–5%) based on both completion of the sets and velocity of the repetitions produced. A subject's load should be lowered on an exercise for the next session if (a) they cannot complete the 3 sets with full range of motion or adequate form or (b) they cannot maintain the adequate speed required for their given velocity threshold. The load should be increased for the following training session if they are able to complete all repetitions of an exercise with adequate movement speed. Subjects must always be supervised to ensure that proper load progression is achieved.

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References

1. Academy of Neurologic Physical Therapy. *Academy of Neurologic PT Outcome Measures Recommendations*. Available at: https://www.neuropt.org/practice-resources/neurology-section-outcome-measures-recommendations. Accessed April 4, 2024.
2. Alcazar J, Cornejo-Daza PJ, Sánchez-Valdepeñas J, Alegre LM, Pareja-Blanco F. Dose-response relationship between velocity loss during resistance training and changes in the squat force-velocity relationship. *Int J Sports Physiol Perform* 16: 1736–1745, 2021.
3. Alcazar J, Losa-Reyna J, Rodriguez-Lopez C, et al. The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people. *Exp Gerontol* 112: 38–43, 2018.
4. Allen NE, Canning CG, Sherrington C, Fung VS. Bradykinesia, muscle weakness and reduced muscle power in Parkinson's disease. *Mov Disord* 24: 1344–1351, 2009.
5. Andersen V, Paulsen G, Stien N, Baarholm M, Seynnes O, Saeterbakken AH. Resistance training with different velocity loss thresholds induce similar changes in strength and hypertrophy. *J Strength Cond Res* 38: e135–e142, 2024.
6. Argus CK, Gill ND, Keogh JW, Hopkins WG. Acute effects of verbal feedback on upper-body performance in elite athletes. *J Strength Cond Res* 25: 3282–3287, 2011.
7. Bohannon RW. Reference values for the five-repetition sit-to-stand test: A descriptive meta-analysis of data from elders. *Percept Mot Skills* 103: 215–222, 2006.
8. Buskard A, Zalma B, Cherup N, Armitage C, Dent C, Signorile JF. Effects of linear periodization versus daily undulating periodization on neuromuscular performance and activities of daily living in an elderly population. *Exp Gerontol* 113: 199–208, 2018.
9. Calaway C, Mishra S, Parrino R, Martinez KJ, Mann JB, Signorile JF. The impact of velocity-based training on load-velocity relationships in leg press and chest press for older persons. *J Strength Cond Res* 38: 1136–1143, 2024.
10. Cherup NP, Buskard AN, Strand KL, et al. Power vs strength training to improve muscular strength, power, balance and functional movement in individuals diagnosed with Parkinson's disease. *Exp Gerontol* 128: 110740, 2019.
11. Cohen JF. Tests on means in the analysis of variance and covariance. In: *Statistical Power Analysis for the Behavioral Sciences*. New York, NY: Routledge, 2013. pp. 274–288.
12. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 35: 1381–1395, 2003.
13. De Vos NJ, Singh NA, Ross DA, Stavrinos TM, Orr R, Fiatarone Singh MA. Optimal load for increasing muscle power during explosive resistance training in older adults. *J Gerontol A Biol Sci Med Sci* 60: 638–647, 2005.
14. De Vos NJ, Singh NA, Ross DA, Stavrinos TM, Orr R, Fiatarone Singh MA. Effect of power-training intensity on the contribution of force and velocity to peak power in older adults. *J Aging Phys Act* 16: 393–407, 2008.
15. Dorrell HF, Smith MF, Gee TI. Comparison of velocity-based and traditional percentage-based loading methods on maximal strength and power adaptations. *J Strength Cond Res* 34: 46–53, 2020.
16. Duncan RP, Leddy AL, Earhart GM. Five times sit-to-stand test performance in Parkinson's disease. *Arch Phys Med Rehabil* 92: 1431–1436, 2011.
17. Hass CJ, Bishop M, Moscovich M, et al. Defining the clinically meaningful difference in gait speed in persons with Parkinson disease. *J Neurol Phys Ther* 38: 233–238, 2014.
18. Lang JT, Kassan TO, Devaney LL, Colon-Semenza C, Joseph MF. Test-retest reliability and minimal detectable change for the 10-meter walk test in older adults with Parkinson's disease. *J Geriatr Phys Ther* 39: 165–170, 2016.
19. Mann JB, Ivey PA, Sayers SP. Velocity-based training in football. *Strength Cond J* 37: 52–57, 2015.
20. Marques DL, Neiva HP, Marinho DA, Marques MC. Velocity-monitored resistance training in older adults: The effects of low-velocity loss threshold on strength and functional capacity. *J Strength Cond Res* 36: 3200–3208, 2022.
21. Ni M, Signorile JF. High-Speed resistance training modifies Load-Velocity and Load-Power relationships in Parkinson's disease. *J Strength Cond Res* 31: 2866–2875, 2017.
22. Ni M, Signorile JF, Balachandran A, Potiaumpai M. Power training induced change in bradykinesia and muscle power in Parkinson's disease. *Parkinsonism Relat Disord* 23: 37–44, 2016.
23. Ni M, Signorile JF, Mooney K, et al. Comparative effect of power training and high-speed yoga on motor function in older patients with Parkinson disease. *Arch Phys Med Rehabil* 97: 345–354.e15, 2016.
24. Nogaki H, Kakinuma S, Morimatsu M. Movement velocity dependent muscle strength in Parkinson's disease. *Acta Neurol Scand* 99: 152–157, 1999.
25. Pallant J. *Survival Manual: A Step by Step Guide to Data Analysis Using SPSS* (4th ed.). Berkshire, United Kingdom: Open University Press, 2011. pp. 210–232.
26. Pareja-Blanco F, Sánchez-Medina L, Suárez-Arrones L, González-Badillo JJ. Effects of velocity loss during resistance training on performance in professional soccer players. *Int J Sports Physiol Perform* 12: 512–519, 2017.
27. Paul SS, Canning CG, Sherrington C, Fung VS. Reproducibility of measures of leg muscle power, leg muscle strength, postural sway and mobility in people with Parkinson's disease. *Gait Posture* 36: 639–642, 2012.

28. Pojednic RM, Clark DJ, Patten C, Reid K, Phillips EM, Fielding RA. The specific contributions of force and velocity to muscle power in older adults. *Exp Gerontol* 47: 608–613, 2012.
29. Rauch JT, Loturco I, Cheesman N, et al. Similar strength and power adaptations between two different velocity-based training regimens in collegiate female volleyball players. *Sports* 6: 163, 2018.
30. Sands WA, Wurth JJ, Hewit JK. *Basics of Strength and Conditioning Manual*. Colorado Springs, CO: National Strength and Conditioning Association, 2012.
31. Skelton DA, Greig CA, Davies JM, Young A. Strength, power and related functional ability of healthy people aged 65–89 years. *Age Ageing* 23: 371–377, 1994.
32. Strand KL, Cherup NP, Totillo MC, Castillo DC, Gabor NJ, 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: 1611–1619, 2021.
33. Weakley J, Wilson K, Till K, et al. Show me, tell me, encourage me: The effect of different forms of feedback on resistance training performance. *J Strength Cond Res* 34: 3157–3163, 2020.
34. Weakley JJS, Wilson KM, Till K, et al. Visual feedback attenuates mean concentric barbell velocity loss and improves motivation, competitiveness, and perceived workload in male adolescent athletes. *J Strength Cond Res* 33: 2420–2425, 2019.
35. Wilson KM, de Joux NR, Head JR, et al. Presenting objective visual performance feedback over multiple sets of resistance exercise improves motivation, competitiveness, and performance. In: Proceedings of the Proc Hum Factors Ergon Soc Annu Meet, 2018.
36. Wong-Yu IS, Mak MK. Task-and context-specific balance training program enhances dynamic balance and functional performance in parkinsonian nonfallers: A randomized controlled trial with six-month follow-up. *Arch Phys Med Rehabil* 96: 2103–2111, 2015.
37. Woolson RF. Wilcoxon signed-rank test. In: *Wiley Encyclopedia of Clinical Trials*. Hoboken, NJ: Wiley, 2007. pp. 1–3.