International Journal of
EXERCISE SCIENCE

Original Research

Effects of Low-Volume Resistance Training on Muscle Strength and Functionality of People with Parkinson's Disease

MATHEUS BARBALHO*[1], ELREN P. MONTEIRO‡[2,3], ROCHELLE R. COSTA‡[3], and RODOLFO RAIOL‡[4]

[1]Faculty of Physical Education and Dance, Federal University of Goiás, Goiânia, GO, BR; [2]Neurosciences and Rehabilitation Laboratory, Federal University of Health Sciences of Porto Alegre, Porto Alegre, RS, BRAZIL; [3]Faculty of Physical Education and Dance, Federal University of Rio Grande do Sul, Porto Alegre, RS, BR; [4]Biological and Health Sciences Center, University Center of State of Pará, Belém, PA, BR

*Denotes undergraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 12(3): 567-580, 2019. Parkinson's disease (PD) is a progressive, neurodegenerative disorder of the central nervous system that affects the elderly and results in a decrease of functional capacity, motor control, and muscle strength. Resistance training (RT) has been shown to be a non-drug alternative in both elderly and parkinsonian patients in increasing functional capacity and muscle strength. The present study aimed to verify the effects of low-volume RT in people with PD in relation to muscular strength, body composition, anthropometry and functional capacity. Fifteen elderly patients with idiopathic PD were divided into two groups: 7 in the resistance-training group (RTG): RT twice a week for 12 weeks, and 8 in the control group (CG): No exercise. Before the training period, the subjects performed maximum strength (1-RM), body composition (Bioimpedance), anthropometry, and functional capacity (GDLAM protocol) tests. The endpoints were analyzed by the Generalized Estimates (GEE) with post hoc Bonferroni, being adopted for the analyses $\alpha < 0.05$. The results showed that the RTG had muscle strength gains: Bench Press 113.33%, Lat Pull Down 71.83% and Leg press 45º 94.48%, ($p < 0.001$), functional capacity (IG: -10.47%), and lean mass: 11.98%, ($p < 0.001$), while the GC presented significant changes before and after functional capacity only (GI: -1.61%) ($p < 0.001$). In addition, the RTG obtained reductions in the percentage of body fat (-2.30%) and in the waist-hip ratio (-2.22) without changes indicated in the CG. RT was efficient in improving muscle strength, functional capacity, body composition and anthropometric health indicators in individuals with PD.

KEY WORDS: Elderly, functional performance, volume training

INTRODUCTION

Parkinson's disease (PD) is a progressive and neurodegenerative disorder of the central nervous system, more specifically the extrapyramidal system, resulting in deficits in muscle coordination and activity (21), which explains the progressive pattern of motor manifestations that begin insidiously (29). It is characterized by the deterioration of dopaminergic neurons of the substantia nigra pars compacta and the presence of abnormal proteins called alpha-synucleins, also known as Lewy bodies (32), in brain areas where cell degeneration occurs (41). According to the World Health Organization, the prevalence of the disease is one in every 1,000 individuals over 65 years old, and one in every 100 after the age of 75. The incidence is higher in men than in women in the proportion of 2: 1 (29).

The cardinal symptoms are: resting tremor, muscular rigidity, bradykinesia that is characterized by slowness movement, postural instability, and gait alterations (39, 31). In addition, people with PD have less muscle strength in several muscle groups compared to healthy people of the same age (16). This reduction of muscle strength associated with postural instability and bradykinesia are preponderant factors for functional disability (23). These motor and muscular disorders have an impact on functional activities, such as functional mobility, provoking a lower social environment that contributes to depressive symptoms, with a very negative impact in the quality of life of individuals with PD (21).

Resistance training (RT) has been shown to be an effective strategy to increase muscle mass, muscular strength and functional capacity in healthy elderly (23, 5); and the American College Sports Medicine (2) recommends the practice for improving the quality of life of the elderly population. However, the heterogeneous nature of RT research in Parkinsonism, based too on studies in the elderly, makes it difficult to establish the most adequate parameters for exercise prescription. One aspect that is frequently debated is exercise volume, reflected in the number of sets performed in the week. In this regard, studies showed similar increases in muscle strength, endurance and size when older participants performed different number of sets (7, 1); however, there are also contradictory results (33). Although RT is mainly associated with neuromuscular adaptations, there is a growing evidence that it can also improve other important health outcomes in the elderly, such as body composition (3), waist circumference (9), cardiorespiratory fitness (14) and functional capacity (13).

In this sense, some studies in the literature that only analyzed people with PD, including systematic reviews and meta-analyzes (14, 11, 6, 40), suggest RT as a possibility of functional rehabilitation for patients with idiopathic PD, since it may promote neural adaptations, thus improving the recruitment of motor units and generating selective activation of the muscles, and consequently helping to reduce common motor symptoms in PD.

Despite this indication, according to the authors' knowledge, only three clinical studies were performed with isolated RT in people with PD (18, 38). However, the effects of different volumes of RT on these parameters have not been extensively investigated, considering that lack of time is a common barrier to maintaining an exercise routine and its continued adherence (44), the search for time-efficient programs can be of great importance (22). Our hypothesis is that isolated and low-volume resistance training will be capable of promoting increases in muscle strength and on the functionality of the individual with Parkinson’s disease. Therefore, the purpose of this study was to evaluate the use of low volume resistance training in isolation on muscular strength, body composition, metabolic aspects, and functionality of people with PD in 12 weeks

METHODS

Participants

This non-randomized study was approved by the local Ethics Committee of under the number (CAAE 69724617.7\.0000.5169). All volunteers were previously notified about the experimental procedures, benefits and risks of the study, and subsequently, a consent form. Fifteen elderly with mild and moderate PD participated in the study. The inclusion criteria were: individuals with idiopathic PD (stages 1 to 3 on the modified Hoehn and Yahr scale (37) and minimum age of 60 years old. Neurologists diagnosed the PD in the study participants, by using the criteria of the London Brain Bank (LBB) (20). While, the exclusion criteria were: Individuals with cognitive impairments were excluded from the sample through the Mental State Mini Exam (MMSE), showing more than 24 points in the MMSE. This consists of eight categories, with a score from 0 to 30 points, in which the score of 27 or more points is normal, between 21-24 as mild, 10 to 20 moderate points and ≤ 9 severe points. Another exclusion criterion was having changes that might impede the understanding of the tests and exercises, having orthopedic or cardiological alterations that could worsen as a result of their practice, as well as not being able to reach a minimum training attendance of 80% (16). Participants were asked not to change their nutritional habits (for example, changes such as: becoming vegetarian, restricting caloric intake, or using nutritional supplements/ergogenic substances).

Table 1. Demographic characteristics at baseline.

	Resistance Training Group (n = 7) Mean (SE)	Control Group (n = 8) Mean (SE)
Age (years)	77.14 (1.08)	77.63 (0.60)
Height (cm)	170.29 (2.38)	170.38 (0.94)
$HR_{resting}$ (bpm)	72.43 (2.11)	69.88 (1.19)
SBP (mmHg)	148.57 (3.15)	143.75 (3.03)
DBP (mmHg)	90.00 (2.86)	87.50 (2.34)

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; $HR_{resting}$: resting heart rate.

Protocol

The initial two weeks consisted of anthropometric evaluation and performance of the tests and retest of maximal strength (1-RM) in the exercises of bench press, frontal pull and leg press 45º, and functionality through the protocol of the Latin American Development Group for Maturity (GDLAM) (8). The tests in question were chosen because they were accessible and showed good results in the elderly (34, 35, 42). It is worth mentioning that the participants made the habitual use of their medications, according to medical criteria, in the evaluation and training phases.
After evaluating the eligibility criteria, the patients were divided by randomized block into two groups: 1) Resistance Training group (RTG) that performed only RT (n = 7); 2) Control group (n = 8). The present study is characterized as longitudinal of the comparative type.

The body mass and height were measured using a scale with a stadiometer (Filizola PL200) with an accuracy of 50g and one centimeter, respectively. The body mass index was calculated using the ratio between body mass in kilograms and height squared in centimeter (46). Waist circumference was measured at the midpoint between the lower costal margin and the iliac crest, using is tape measuring mm (Sanny SN-4010), as well as the circumference of body segments such as thorax, relaxed and contracted arms, forearm, thigh and calf on both sides (10). The waist-hip ratio (26) and waist-height relationships (24) were also calculated. The bioimpedance method (InBody120, Biospace, Seoul, Korea) was used to verify body composition, muscle mass and fat percentage.

Two weeks before the start of the training period and five to seven days after the last session, maximum strength was determined by the 1-RM assessment for pectoral, back and leg exercises according to previous studies (12). One week before the tests, the participants performed two training sessions for familiarization. The participants were instructed on the correct execution of the exercises and then initial values of the maximal strength test (1-RM) were obtained on the bench press, frontal pull and leg press 45º. During the familiarization sessions, each exercise was performed with a self-selected load that would comfortably allow the performance of 15 repetitions in two consecutive sets.

The 1-RM test was performed on a bench press, lat pull down machine and leg press 45º, in Righetto Fitness equipment, High On line, Brazil. Plates weighing 0.5 kg were used to adjust the load. On the day of the test, subjects performed a warm-up consisting of 8 repetitions of 40% to 50% of their estimated 1-RM. After a rest interval of 60 seconds, the participant performed 6 repetitions in 50% to 60% of their estimated 1-RM. Then, each subject took a maximum of five attempts to achieve the 1-RM load. If the repetition was successfully completed, the load was increased by 0.5 to 10 kilograms and after a 5 minutes interval, the subject performed the next repetition. The procedure was repeated until reaching the highest load with which the individual could perform a complete repetition. A maximum of 5 attempts per session has been allowed. If the maximum load was not obtained until the fifth attempt, the test was stopped and repeated after 48 hours.

The execution of the exercises was standardized for both exercises. For the bench press exercise, the subjects had to touch the bar to the chest at the end of the eccentric phase and return to a position with the elbows fully extended at the end of the concentric phase. In addition, the neck, head, shoulders and hips were kept in contact with the seat and throughout the exercise with their feet on the ground. In the lat pulldown exercise, the subjects had to keep the spine erect and flex the elbows to the chest height in the concentric phase and return extending the elbows in the eccentric phase. For leg press 45º, participants had to flex their knees to 100º (0º of full extension) at the end of the eccentric phase and return to a position with the knees fully extended at the end of the concentric phase. Subjects received verbal stimulation throughout the test, and the same group of researchers performed all test procedures. The retest was performed in the same manner, 48 to 72 hours after the test and the intraclass correlation coefficient (ICC) value was 0.98 for the bench press and 0.96 for the leg press.

The 10m walk test was used to evaluate gait velocity. Although this test is known as C10m, the walking speed is actually measured from 6 meters, considering the two initial and final meters for the acceleration and deceleration of the march, respectively. The test was conducted in a hallway with two marks on the floor (identified with adhesive tape) that indicate the two ends of a 10-meter course and two other marks identifying the 2 and 8 meters. The specific verbal instructions were given before the test: "I will say: prepare and go. When I say 'Go,' walk as fast as possible until I tell you to stop." Participants walked 10 meters (m) at their fastest speed and the 6-meter ride time was measured, starting when the toes crossed the 2-meter mark and stopping when the toes crossed the 8-meter mark (8).

The standing from a sitting position (SSP) test aims to evaluate the functional capacity of the lower limbs and consists of: the individual, starting from the position sitting in a chair, without support for the arms and the seat at a distance of approximately 50 cm from the ground, getting up and sitting down for five consecutive times (8).

The purpose of the rise from the ventral decubitus position (RVDP) test is to assess the individual's ability to lift off the ground. The test consists of: from the starting position in the ventral decubitus, with the arms along the body and the command "Go", the individual should change the position and stand up as soon as possible (8).

The objective of the get up from the chair and move around the house test (GCMH) is to evaluate the ability of the elderly in agility and balance in life situations (8). With a chair fixed to the floor, one should note the cones diagonally to the chair, four meters back and three meters to the right and left sides of the chair. The individual begins the test by sitting on the chair with feet off the floor, and following the "now" sign, the participant stands up, goes to the right, moves around the cone, returns to the chair, sits down and pulls both feet off the floor. Without hesitation, the subject makes the same move to the left. Immediately, the participant does the same course again, to the right and left, thus making the whole course and circling each cone twice, in the shortest possible time. Test times were measured in seconds by a stopwatch (Speedo, USA).

The objective of the dress and take off the shirt test (DTS) is to evaluate the time in which each elderly spent to dress and take off the shirt.

The training was performed twice a week, one day for upper limbs (bench press, lat pull down, military press and seated row) and one for the lower limbs (Leg 45º, barbell squat, leg curl, calf rise), using 3 series for multi-joint exercises (i.e. bench press, lat pull down, military press, seated row, leg 45º, barbell squat) and 2 series for single-joint exercises (i.e. leg curl, calf rise) , with at least 72 hours between the training sessions. Therefore, each muscle group was trained once a week. This study was based on previous studies that showed that one session per week is sufficient to promote increases in muscle size and strength (17) and also in studies comparing different weekly volumes when trained once a week (5). All participants were supervised and monitored in all exercises.

The training followed a model of non-linear periodization (45). During weeks 1, 5 and 9, participants performed 12-15-RM with 30-60 second rest intervals between sets. During weeks 2, 6 and 10, 4-6-RM were performed with 3-4-minute rest intervals. Weeks 3, 7, and 11 involved 10-12-RM with a 1-2-minute rest interval. During weeks 4, 8 and 12 the participants performed 6-8-RM with rest intervals of 2-3 minutes. Participants were instructed to perform each series until voluntary failure and when in case they able to perform more repetitions than suggested, a load was added from 2.5 to 5 kg for the next training session. The volunteers were instructed to perform the concentric and eccentric phases every two seconds without pause between contractions.

Statistical Analysis

The data of the scalar variables of the present study are presented in mean and standard error, while the data of categorical variables in absolute frequency (*n*). The comparison of the characterization data of the sample in the different groups was performed by means of a T-Test for independent samples, since normality was confirmed by the Shapiro-Wilk test and the Chi-Square test. For the analysis of the dependent variables, the comparison of the different groups in the pre- and post-intervention moments was carried out using the Generalized Estimating Equations (GEE) method with Bonferroni post-hoc test.

The GEE method was chosen in order to better apply the correct principles of analysis of longitudinal data in clinical trials. Considering that this method was designed to analyze paired and longitudinal data (25), and that the present study has two factors (2 groups and 2 moments of data collection), the GEE seems to be the most appropriate test to be performed. In addition, some advantages of this method contributed to the choice, for example, (i) the GEE could be applied regardless of the distribution of data; (ii) the assumption of sphericity between all the different moments is very difficult to be achieved in studies with health outcomes in humans, especially in clinical populations, as those of our study, and the GEE method does not have this requirement; (iii) GEE can handle missing data in longitudinal studies under the assumption that such data are missing completely at random; (iv) using GEE, the possible missing data of any participant will automatically be imputed without the interference of the researchers (this procedure contributes to avoid the selection bias and the choice of traditional imputation methods in which the researcher could influence the data and results) (4, 27).

For all analyses, $\alpha < 0.05$ was used. The analyses were performed in SPSS for Mac software version 22.0.

RESULTS

The present study had 15 participants, 7 of whom were in the experimental group and 8 in the control group. We performed the intention-to-treat analysis and all patients were included in the final analysis. Tables 2 and 3 present the characterization data of the sample, evidencing that the groups had similar characteristics when starting the study.

The maximum strength levels of front pull down showed a significant increase from pre to post-training in the strength group participants ($p < 0.001$) without significant changes in the values of the control group ($p = 0.423$). Similarly, the maximum strength of bench press was significantly increased in the elderly participants of the strength group ($p < 0.001$), without changes in the components of the control group ($p = 0.127$). In addition, maximal strength of leg press presented a pre-post training increase in the strength group ($p < 0.001$), without changes in the control group ($p = 0.546$) (Table 2).

The time it initially took for the subject to 10m walk was significantly reduced in the participants of the strength group after the training ($p < 0.001$), but in the control group this time remained unchanged ($p = 0.687$). This behavior resembles the results observed in the time to get up from the chair and move around the house test, which presented a significant reduction only in the elderly of the strength group ($p < 0.001$), without changes in the components of the control group ($p = 0.226$). Also, the time to get up from the position of the ventral decubitus presented a decrease in the participants who performed strength training ($p < 0.001$) and no changes in the control group participants ($p = 0.081$) (Table 2).

Differently, the time to get up from the sitting position was decreased in both groups ($p < 0.001$) after the 12-week period, as well as the time to put on and take off a shirt ($p < 0.001$). Furthermore, the GDLAM index (GI) presented reduction in both groups ($p < 0.001$) (Table 2).

Table 2. Muscular strength and functional capacity variables on pre and post-training moments of the resistance training and control groups.

	Resistance Training Group (*n* = 7)		Control Group (*n* = 8)	
	Pre-training Mean (SE)	Post-training Mean (SE)	Pre-training Mean (SE)	Post-training Mean (SE)
1-RM Bench press (kg)	7.14 (0.79)	16.00 (1.49)#*	6.56 (0.61)	6.10 (0.61)*
1-RM Pull down (kg)	7.07 (0.52)	12.20 (0.84)#*	6.50 (0.47)	5.82 (0.39)*
1-RM Leg press (kg)	15.50 (1.05)	31.70 (1.03)#*	14.76 (0.53)	15.00 (0.55)*
10m walk (s)	8.86 (0.37)*	7.40 (0.36)#*	9.75 (0.15)*	9.80 (0.18)*
SSP (s)	13.29 (0.60)	10.80 (0.72)#*	14.38 (0.17)	14.00 (0.00)#*
GCWH (s)	51.29 (1.93)	47.00 (2.26)#*	53.88 (0.57)	53.40 (0.73)*
RVDP (s)	7.71 (0.60)	6.40 (0.78)#	8.25 (0.23)	7.80 (0.33)
DTS (s)	14.86 (0.71)	13.00 (0.98)#	15.50 (0.18)	15.00 (0.28)#
GDLAM (score)	35.18 (1.55)	30.80 (1.95)#*	37.37 (0.29)	36.65 (0.29)#*

*Indicates significant difference between the groups at the same moment; #Indicates significant difference between pre- and post-training in the same group; SSP: standing from a sitting position; GCMH: get up from the chair and move around the house; RVDP: rise from the ventral decubitus position; DTS: dress and take off the shirt.

Body mass showed a significant increase in both groups ($p = 0.007$) after 12 weeks of the study. In contrast, BMI and fat mass percentage remained unchanged (BMI: $p = 0.121$; Fat Mass: $p = 0.921$). The percentage of lean mass was significantly increased in the group that performed strength training (p <0.001) and remained unchanged in the control group ($p = 0.148$) (Table 3).

Regarding the anthropometric variables, the right and left arm perimeters, as well as the right and left forearm presented a significant increase ($p < 0.001$, $p < 0.001$, $p < 0.001$, $p = 0.002$, respectively) in the participants who performed strength training, with no changes in the components of the control group ($p = 0.333$, $p = 0.222$, $p = 0.765$, $p = 1.000$, respectively). On the other hand, the perimeters of the chest, right and left calves were increased in both groups ($p = 0.031$, $p = 0.009$, $p = 0.008$, respectively) (Table 3).

Although waist circumference showed a significant decrease in both groups ($p = 0.043$), the abdominal perimeter remained unchanged in both groups ($p = 0.204$). The hip circumference, as well as the right thigh and left thigh, presented a significant increase from the pre-post training period ($p = 0.004$, $p < 0.001$, $p < 0.001$, respectively), without changes in the control group ($p = 0.849$, $p = 0.080$, $p = 0.113$, respectively). Finally, the waist-hip ratio was significantly reduced in the RT group ($p < 0.001$) without changes in the control group ($p = 0.649$).

Table 3. Anthropometric variables on pre and post-training moments of the resistance training and control groups.

	Resistance Training Group (*n* = 7)		Control Group (*n* = 8)	
	Pre-training Mean (SE)	Post-training Mean (SE)	Pre-training Mean (SE)	Post-training Mean (SE)
Body Mass (kg)	78.99 (2.14)	80.40 (1.95)#	78.65 (1.17)	80.98 (1.13)#
BMI (kg/m²)	27.34 (0.37)	27.70 (0.44)	27.07 (0.16)	27.48 (0.19)
Fat Mass (%)	36.23 (0.80)	36.56 (0.64)	35.66 (0.69)	35.24 (0.93)
Fat Free Mass (%)	33.57 (0.70)	37.58 (0.95)#*	33.30 (0.70)	32.60 (0.93)*
Contracted Right Arm (cm)	30.27 (0.21)	31.12 (0.14)#*	30.34 (0.14)	30.44 (0.15)*
Contracted Left Arm (cm)	30.14 (0.24)	31.04 (0.14)#*	30.20 (0.15)	30.36 (0.16)*
Relax Right Arm (cm)	29.71 (0.21)	30.54 (0.18)#*	29.76 (0.13)	29.80 (0.14)*
Relax Left Arm (cm)	29.60 (0.21)	30.44 (0.17)#*	29.61 (0.13)	29.74 (0.16)*
Right Forearm (cm)	25.86 (0.17)	26.38 (0.17)#*	25.94 (0.15)	25.90 (0.15)*
Left Forearm (cm)	25.85 (0.17)	26.36 (0.12)#*	25.80 (0.14)	25.80 (0.15)*
Chest (cm)	100.69 (0.72)	101.50 (0.86)#	99.80 (0.18)	100.10 (0.11)#
Abdomen (cm)	104.57 (0.72)	104.60 (0.78)	103.88 (0.33)	104.40 (0.46)
Waist (cm)	101.04 (0.38)	100.60 (0.36)#	101.15 (0.18)	101.00 (0.28)#
Hip (cm)	97.43 (0.63)	99.20 (0.33)#*	97.63 (0.17)	97.60 (0.22)*
Right Thing (cm)	61.29 (0.17)	62.82 (0.20)#*	61.70 (0.17)	61.44 (0.14)*
Left Thing (cm)	61.27 (0.16)	62.84 (0.16)#*	61.57 (0.17)	61.34 (0.19)*
Right Calf (cm)	35.26 (0.21)	35.64 (0.14)#	35.16 (0.23)	35.52 (0.12)#
Left Calf (cm)	35.16 (0.22)	35.58 (0.14)#	35.05 (0.25)	35.46 (0.15)#
Waist/Hip (cm)	1.04 (0.01)	1.01 (0.01)#*	1.04 (0.01)	1.03 (0.01)*

DISCUSSION

The objective of the present study was to verify the effects of 12 weeks of resistance training on body composition, metabolic aspects and functional capacity of individuals with Parkinson's disease. The main findings in the group that underwent resistance training, gains in muscle mass, muscle strength and functional tests, compared to the control group. These results confirm the initial hypothesis that isolated resistance training is capable of promoting increases of >70%

found in muscle strength results and 10% on the functionality score of the individual with Parkinson's disease. This might be explained by the low initial strength levels of the participants. It is important to note that the results of force, especially of the lower limbs, positively influenced the locomotion function of RTG patients by increasing their speed. This data is extremely important for rehabilitation because it makes the patient more independent. On the other hand, the control group reflects the deterioration of these capacities caused by the disease. Our results demonstrate the favorable effect for the gait improvement of individuals with PD. Resistance training can promise changes in cortical level that increase the movement improvement of these patients.

Toole et al., (43) compared resistance training associated with equilibrium exercises on unstable surfaces. The sample was divided into two groups, one control (two men and one woman, 71 years) and the one experimental group (two men and two women, 73 years). The experimental group trained three times a week for ten weeks, performing three sets of ten repetitions at 60% of 4-RM. The results showed that the experimental group experienced a significant improvement in balance and an increase in strength (7%). On the other hand, the control group showed no improvement in balance and presented a reduction of knee extensors and flexors strength. Although there were significant improvements in muscle strength using unstable bases associated with resistance training, the study by Toole et al., (43) presented lower gains than the present study. Moreover, when comparing RT on unstable bases and resistance training with stable bases, the superiority of the use of stable bases has already been evidenced on the gain of muscle strength (30).

In another study, with a similar sample to the present one, Hirsch et al., (19) conducted a randomized clinical trial, aiming to observe strength and balance gains in individuals with PD. The trial consisted of 15 individuals with PD divided into two groups: control - with balance exercises; experimental - with equilibrium associated with high intensity resistance training. After 10 weeks, as in the present study, the authors found a significant increase (52%) in the strength of the experimental group when compared to the control group. As in the present study, in which the RTG presented significant strength gains in the tests in the supine (113%), pulled (71.83%) and leg press 45º (94.48%), the CG presented loss in the strength tests. These results confirm the hypothesis that instability training should not be used in order to increase strength.

Hass et al., (18) conducted a study on 15 subjects with PD (9 in the experimental group and 6 in the control group) for 10 weeks. The experimental group performed resistance training for lower limbs and trunk, composed of 6 exercises, in addition to 4 exercises with theraband directed to the ankle, for the lower limbs was performed 16 weekly series, divided into two workouts. When compared to the control group, the group submitted to resistance training significantly improved walking gait and length, thus demonstrating the improvements in functional performance using only resistance training, as in the present study. In addition, a 76% increase in knee extension strength and a 57% increase in knee flexion in the RT group were observed.
Scandalis et al., (36) investigated 20 individuals (14 in the intervention group with PD and 6 in the control group, elderly without PD) for 8 weeks. The experimental group performed

resistance training for lower limbs and trunk, twice a week, composed of 5 exercises, 4 for lower limbs, performing 8 weekly series with loads of 60% of 1-RM. Both groups presented similar gains in muscular strength; however, the PD group improved gait velocity.

The last study, to our knowledge, to analyze resistance training in isolation was the study by Schilling et al., (38) in which he investigated the effect of moderate volume with high loads on the lower limbs of people with Parkinson's, performing twice a week, three exercises (leg press, seated leg curl and calf press) and three series in each totaling 18 weekly series. The study verified strength in the leg press and functional parameters such as time up-to-go test and 6-minute walk. However, only the force showed significant improvement with gains from 2.1 to 2.7 in the reactive force, whereas the control did not present difference. In the functionality parameter, both groups had no significant difference between pre and post and between groups. In this context, studies dealing with lower volume corroborates the results of studies regarding high volume that subjects with PD that performed the RT between 8 and 12 weeks improved the muscular strength and functional mobility. It may be explained maybe by neuroplastic changes in the primary motor cortex and neural adaptations provoked by RT, thus improving the recruitment of motor units and generating selective activation of the muscles, and consequently helping to reduce motor symptoms in PD, especially the mobility impairment (47). In the functional tests of the present study, the RTG also presented significant gains in comparison to the CG, with improvement in all the tests and in the final GDLAM score, as indicated by a meta-analysis (11), which indicates that resistance training has a positive effect on the progression of the disease and functional capacity. Again showing that the resistance training performed in isolation may present functional and conditioning improvements to the Parkinsonian individual.

Our results demonstrate that the RTG obtained reductions in the percentage of body fat (-2.30%) and in the waist-hip ratio (-2.22) without changes indicate in the CG. Another important finding of the present study was that body weight and waist circumference decreased while there was an improvement in body composition, an aspect that was not evaluated in other with Parkinson's studies cited. Based on this, reductions in waist circumference are associated with improvements in health and quality of life. According to previous studies, a reduction of ~ 4 cm (~ 5%) in waist circumference is associated with an increase in life expectancy of approximately 5 years (48). The reductions in body mass, waist circumference, and lean mass increases found in the present study may be related to training intensity (ie training for momentary muscle failure), as reported in previous studies in which low volume and high intensity RT promoted positive changes in elderly body composition (49).

In addition, this study is significant because to our knowledge it’s the first study that evaluate body composition and anthropometrics variables in subjects with PD. Beside that in the author’s knowledge, this was the first study to analyze the resistance training alone with non-linear periodization and leading to muscular failure in individuals with PD, revealing the effectiveness of this training model to increase strength and functionality gains, and changes on the body composition. In this way, it is possible to replicate our protocol of low-volume resistance in future studies as a form of complementary therapy for functional rehabilitation of the subjects with PD.

The present study is innovative in assessing the effects of low volume RT in individuals with Parkinson's disease by demonstrating effects on strength, which was already expected, but also demonstrating significant gains in body composition and functionality, which are important aspects in daily life and risk of patient mortality. However, the limitations of the study are primarily the low *n*-sample, which is common in Parkinson's studies, and the lack of application of the UPDRS (Unified Parkinson's Disease Rating Scale) in the patient's evaluation. Thus, our results could be only generalized for this population. Future studies focusing strategies of rehabilitation should be conducted with subjects in different stage of PD.

It is concluded, according to the results of the present study, that 12 weeks of resistance training performed in isolation is capable of promoting significant strength and functional gains, and changes on body composition in individuals with Parkinson's disease and it is proven a safe protocol for this population, as well as a fundamental tool for a drug-associated treatment for the disease. However, it is still necessary to develop more studies in the area, considering their scarcity to this population.

REFERENCES

1. Abrahin O, Rodrigues RP, Nascimento VC, Silva-Grigoletto ME, Sousa EC, Marçal A. Single- and multiple-set resistance training improves skeletal and respiratory muscle strength in elderly women. Clin Interv Aging 9: 1775-1782, 2014.

2. American College of Sports Medicine. Exercise and physical activity for older adults. Med Sci Sports Exerc 41(7): 1510-1530, 2009.

3. Avila JJ, Gutierres JA, Sheehy ME, Lofgren IE, Delmonico MJ. Effect of moderate intensity resistance training during weight loss on body composition and physical performance in overweight older adults. Eur J Appl Physiol 109(9): 517-525, 2010.

4. Ballinger GA. Using generalized estimating equations for longitudinal data analysis. Organ Res Methods 7(2): 127-150, 2004.

5. Barbalho MSM, Gentil P, Izquierdo M, Fisher J, Steele J, Raiol RA. There are no no-responders to low or high resistance training volumes among older women. Exp Gerontol 99: 18-26, 2017.

6. Brienesse LA, Emerson MN. Effects of resistance training for people with parkinson’s disease: A systematic review. J Am Med Dir Assoc 14(4): 236-241, 2013.

7. Cannon J, Marino FE. Early-phase neuromuscular adaptations to high- and low-volume resistance training in untrained young and older women. J Sports Sci 28(14): 1505-1514, 2010.

8. Castro KV, Alves CH, Sauaia BA, et al. Effects of low intensity resistance training on the risk of falls and functional autonomy in the elderly. JEPonline 19(1): 33-38, 2016.

9. Cottell KE, Dorfman LR, Straight CR, Delmonico MJ, Lofgren IE. The effects of diet education plus light resistance training on coronary heart disease risk factors in community-dwelling older adults. J Nutr Heal Aging 15(9): 762-767, 2011.

10. Croft JB, Keenan NL, Sheridan DP, Wheeler FC, Speers MA. Waist-to-hip ratio in a biracial population: Measurement, implications, and cautions for using guidelines to define high risk for cardiovascular disease. J Am Diet Assoc 95(1): 60-64, 1995.

11. Falvo MJ, Schilling BK, Earhart GM. Parkinson's disease and resistive exercise : Rationale, review, and recommendations. Mov Disord 23(1): 1-11, 2008.

12. Fisher J, Steele J, Smith D. High- and low-load resistance training: interpretation and practical application of current research findings. Sports Med 47(3): 393-400, 2017.

13. Fisher JP, Steele J, Gentil P, Giessing J, Westcott WL. A minimal dose approach to resistance training for the older adult; the prophylactic for aging. Exp Gerontol 99: 80-96, 2017.

14. Frank P, Andersson E, Pontén M, Ekblom B, Ekblom M, Sahlin K. Strength training improves muscle aerobic capacity and glucose tolerance in elderly. Scand J Med Sci Sports 26(7): 764-773, 2016.

15. Frazzitta G, Ferrazzoli D, Maestri R, et al. Differences in muscle strength in parkinsonian patients affected on the right and left side. *PLoS One* 10(3): 1-8, 2015.

16. Gentil P, Bottaro M. Effects of training attendance on muscle strength of young men after 11 weeks of resistance training. Asian J Sports Med 4(2): 101-106, 2013.

17. Gentil P, Ferreira-Junior JB, Bemben MG, Ferreira D, Bottaro M. The effects of resistance training on lower and upper body strength gains in young women. Int J Kines Sports Sci 3(3): 18-23, 2015.

18. Hass CJ, Buckley TA, Pitsikoulis C, Barthelemy EJ. Gait & posture progressive resistance training improves gait initiation in individuals with Parkinson's disease. Gait Posture 35(4): 669-673, 2012.

19. Hirsch MA, Farley BG. Exercise and neuroplasticity in persons living with Parkinson's disease. Eur J Phys Rehabil Med 45(2): 215-229, 2009.

20. Hughes AJ, Daniel SE, Kilford L, Lees AJ. Accuracy of clinical diagnosis of idiopathic Parkinson's disease : A clinico-pathological study of 100 cases. J Neurol Neurosurg, Psychiatry 55(3): 181-184 1992.

21. Inkster LM, Eng JJ, Macintyre DL, Jon A. Leg muscle strength is reduced in PD and relates to the ability to rise from a chair. Mov Disord 18(2): 157-162, 2012.

22. Izquierdo M, Ibañez J, Hakkinen K, Kraemer WJ, Larrión JL, Gorostiaga EM. Once weekly combined resistance and cardiovascular training in healthy older men. Med Sci Sports Exerc 36(3): 435-443, 2004.

23. Kakinuma S, Nogaki H, Pramanik B, Morimatsu M. Muscle weakness in Parkinson's disease : Isokinetic study of the limbs. Eur Neurol 39(4): 218-222, 1998.

24. Leahy S, Leahy S, Neill CO, Jakeman P. A comparison of dual energy X-ray absorptiometry and bioelectrical impedance analysis to measure total and segmental body composition in healthy young adults. Eur J Appl Physiol 112(2): 589-595,2012.

25. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika 73(1): 13-22, 1986.

26. Lin W, Lee L, Chen C, et al. Optimal cut-off values for obesity: using simple anthropometric indices to predict cardiovascular risk factors in Taiwan. Int J Obes Relat Metab Disord 26(9): 1232-1238, 2002.

27. Liu M, Wei L, Zhang J. Review of guidelines and literature for handling missing data in longitudinal clinical trials with a case study. Pharm Stat 5(1): 7-18, 2006.

28. Lou J, Benice T, Kearns G, Sexton G, Nutt J. Levodopa normalizes exercise related cortico-motoneuron excitability abnormalities in Parkinson's disease. Clin Neurophysiol 114(5): 930-937, 2013.

29. Marsden CD. Parkinson's disease. J Neurol Neurosurg, Psychiatry 57(6): 672-681, 1994.

30. Mcbride JM, Blaak JB, Triplett-mcbride T. Effect of resistance exercise volume and complexity on EMG, strength, and regional body composition. Eur J Appl Physiol 90(5-6): 626-632, 2003.

31. Monteiro EP, Wild LB, Martinez FG, Pagnussat AS, Peyré-Tartaruga L. Biomechanical aspects of locomotion people with Parkinson's disease: Review study. Rev Bras Ciênc Esporte 39(4): 450-457, 2017.

32. Morris ME. Movement disorders in people with Parkinson disease: A model for physical therapy. Phys Ther 80(6): 578-597, 2000.

33. Radaelli R, Botton CE, Wilhelm EN, et al. Time course of low- and high-volume strength training on neuromuscular adaptations and muscle quality in older women. Age (Dordr) 36(2): 881-892, 2014.

34. Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontologist 53(2): 255-267, 2013.

35. Ruiz JR, Sui X, Lobelo F, et al. Association between muscular strength and mortality in men: Prospective cohort study. *BMJ* 337: a439, 2008.

36. Scandalis TA, Bosak A, Berliner J, Helman LL, Wells MR. Resistance training and gait function in patients with Parkinson's disease. Am J Phys Med Rehabil 80(1): 38-43, 2001.

37. Schenkman ML, Clark K, Xie T, Kuchibhatla M, Shinberg M, Ray L. Spinal movement and performance of a standing reach task in participants with and without Parkinson disease. Phys Ther 81(8): 1400-1411, 2001.

38. Schilling BK, Pfeiffer RF, Ledoux MS, Karlage RE, Bloomer RJ, Falvo MJ. Effects of moderate-volume, high-load lower-body resistance training on strength and function in persons with Parkinson's disease: A pilot study. Parkinsons Dis 16: 1-6, 2010.

39. Sethi KD. Clinical aspects of Parkinson disease. Mov Disord 15(4): 457-460, 2002.

40. Shulman LM, Katzel LI, Ivey F, et al. Randomized clinical trial of 3 types of physical exercise for patients with Parkinson disease. JAMA Neurol 70(2): 183-190, 2015.

41. Sulzer D, Surmeier DJ. Neuronal vulnerability, pathogenesis and Parkinson's disease. Mov Disord 28(1): 41-50, 2014.

42. Suresh KP. An overview of randomization techniques: An unbiased assessment of outcome in clinical research. J Hum Reprod Sci 4(1): 8-11, 2011.

43. Toole T, Hirsch MA, Forkink A. The effects of a balance and strength training program on equilibrium in Parkinsonism: A preliminary study. NeuroRehabilitation 14(3): 165-174, 2000.

44. Trost S, Owen N, Brown WJ, et al. Correlates of adults' participation in physical activity: Review and update. Med Sci Sports Exerc 34(12): 1996-2001, 2003.

45. Williams TD, Tolusso DV, Fedewa MV, Esco MR. Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis. Sports Med 47(10): 2083-2100, 2017.

46. World Health Organization. Obesity: Preventing and managing the global epidemic. 2000.

47. Ni M, Signorile JF. High-speed resistance training modifies load-velocity and load-power relationships in Parkinson's disease. J Strength Cond Res 31(10): 2866-2875, 2017.

48. Cerhan JR, Moore SC, Jacobs EJ, Kitahara CM, Rosenberg PS, Adami HO, et al. A pooled analysis of waist circumference and mortality in adults. Mayo Clin Proc 89(3): 335-345, 2014.

49. Paoli A, Pacelli F, Bargossi AM, Marcolin G, Guzzinati S, Neri M., et al. Effects of three distinct protocols of fitness training on body composition, strength and blood lactate. J Sports Med Phys Fitness 50(1): 43-51, 2010.