Arquivos Brasileiros de Educação Física
Brazilian Archives of Physical Education ABEF

Unilateral and bilateral resistance training effects, on motor control and strength in people with Parkinson's disease: a pilot study

Efeitos dos treinamentos resistidos unilateral e bilateral no controle motor e na força de indivíduos com a doença de Parkinson: um estudo piloto

Efectos de los entrenamientos resistidos unilateral y bilateral en el control motor y en la fuerza de individuos con la enfermedad de Parkinson: un estudio piloto

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Abstract

Introduction: In healthy individuals, if there some body member affected, it can be restored by the cross-education methodology, but it is not known if this methodology works in people with Parkinson's disease (PD). **Aim:** To verify the effect of two resistance training methodologies, unilateral and bilateral, on motor control and muscle strength in people with PD. **Method:** Sample consisted of 2 men clinically diagnosed with PD. The subject 1 (64 years; 85.7 kg; affected side: left; diagnosis time: 6 years; H&Y: 1) performed UNILATERAL training, while individual 2 (82 years; 70.4 kg; affected side: left; diagnosis time: 8 years; H&Y: 3) performed BILATERAL training, both had 17 training sessions. The nine-hole peg and box and blocks tests were performed to assess motor control of the upper limbs. The handgrip strength and knee extensors were performed to assess the upper and lower limbs strength, respectively. Delta variation was used to calculate the pre and post intervention difference. **Results:** The delta variation values for individual 1 were, nine-hole peg: right 7,95s , left -2,90s; box and blocks: right 2,08 blocks, left 4,76 blocks; average handgrip strength: right 12,94Kgf, left -5,85Kgf; hand grip strength higher value: right 15,78Kgf, left -4,87Kgf; pico de torque: right a 60º/s 11,58Nm, left a 60º/s 15,57Nm, right a 180º/s 5,68Nm, left a 180º/s 7,42Nm; time to peak torque: right a 60º/s -19,19Msec, left a 60º/s 0Msec, right a 180º/s -10,81Msec, left a 180º/s 21,73Msec; acceleration time: right a 60º/s -28,57Msec, left a 60º/s 0Msec, right a 180º/s 0Msec, left a 180º/s -50Msec. The delta variation values for individual 2 were, nine-hole peg: right -4,96s , left -3,44s; box and blocks: right -14,70 blocks, left 10,71 blocks; average handgrip strength: right -3,30Kgf, left 11,27Kgf; hand grip strength higher value: right 0Kgf, left 28,57Kgf; pico de torque: right a 60º/s -25,46Nm, left a 60º/s 0,20Nm, right a 180º/s -20Nm, left a 180º/s -3,34Nm; time to

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peak torque: right a 60º/s -62,63Msec, left a 60º/s -35,10Msec, right a 180º/s -31,03Msec, left a 180º/s -20,58Msec; acceleration time: right a 60º/s -25Msec, left a 60º/s -10Msec, right a 180º/s 37,5Msec, left a 180º/s -9,09Msec. **Conclusion:** Both training demonstrated an improvement on muscle strength and motor control in people with PD.
Keywords: efferent pathways. motor activity. muscle strength.

Resumo

Introdução: Em indivíduos saudáveis, caso haja algum acometimento em algum membro do corpo, este pode ser melhorado pela metodologia do *cross-education*, porém não se sabe se tal metodologia funciona em pessoas com a doença de Parkinson (DP). **Objetivo:** Verificar os efeitos de dois protocolos de treinamento resistido, o unilateral e o bilateral, no controle motor e na força muscular em pessoas com a DP. **Métodos:** A amostra foi composta por 2 indivíduos do gênero masculino diagnosticados clinicamente com a DP. O indivíduo 1 (64 anos; 85,7 kg; lado acometido: esquerdo; tempo de diagnóstico: 6 anos; H&Y: 1) realizou o treinamento UNILATERAL, já o indivíduo 2 (82 anos; 70,4 kg; lado acometido: esquerdo; tempo de diagnóstico: 8 anos; H&Y: 3) realizou o treinamento BILATERAL, os dois tiveram 17 sessões de treino. Os testes *nine-hole peg* e *box and blocks* foram utilizados para avaliar o controle motor dos membros superiores. Os dinamômetros de preensão palmar e isocinético foram utilizados para avaliar a força de membros superiores e inferiores, respectivamente. A variação delta foi utilizada para calcular a diferença pré e pós-intervenção. **Resultados:** Os valores de delta variação para o indivíduo 1 foram, nine-hole peg: direito 7,95s , esquerdo -2,90s; box and blocks: direito 2,08 blocos, esquerdo 4,76 blocos; força de preensão palmar média: direito 12,94Kgf, esquerdo -5,85Kgf; força de preensão palmar maior valor: direito 15,78Kgf, esquerdo -4,87Kgf; pico de torque: direito a 60º/s 11,58Nm, esquerdo a 60º/s 15,57Nm, direito a 180º/s 5,68Nm, esquerdo a 180º/s 7,42Nm; tempo para atingir o pico de torque: direito a 60º/s -19,19Msec, esquerdo a 60º/s 0Msec, direito a 180º/s -10,81Msec, esquerdo a 180º/s 21,73Msec; tempo de aceleração: direito a 60º/s -28,57Msec, esquerdo a 60º/s 0Msec, direito a 180º/s 0Msec, esquerdo a 180º/s -50Msec. Os valores de delta variação para o indivíduo 2 foram, nine-hole peg: direito -4,96s , esquerdo -3,44s; box and blocks: direito -14,70 blocos, esquerdo 10,71 blocos; força de preensão palmar média: direito -3,30Kgf, esquerdo 11,27Kgf; força de preensão palmar maior valor: direito 0Kgf, esquerdo 28,57Kgf; pico de torque: direito a 60º/s -25,46Nm, esquerdo a 60º/s 0,20Nm, direito a 180º/s -20Nm, esquerdo a 180º/s -3,34Nm; tempo para atingir o pico de torque: direito a 60º/s -62,63Msec, esquerdo a 60º/s -35,10Msec, direito a 180º/s -31,03Msec, esquerdo a 180º/s -20,58Msec; tempo de aceleração: direito a 60º/s -25Msec, esquerdo a 60º/s -10Msec, direito a 180º/s 37,5Msec, esquerdo a 180º/s -9,09Msec. **Conclusão:** Os dois métodos de treinamento propostos demonstram melhora na força muscular e no controle motor de pessoas com a DP.
Palavras-chave: vias eferentes. atividade motora. força muscular.

Resumen

Introducción: En individuos sanos, si hay alguna alteración en algún miembro del cuerpo, puede mejorarse mediante la metodología de *cross-education*, pero no se sabe si esta metodología funciona en personas con la enfermedad de Parkinson (EP). **Objetivo:** Verificar los efectos de dos protocolos de entrenamiento resistido, el unilateral y el bilateral, en el control motor y en la fuerza muscular en personas con la DP. **Métodos:** La muestra fue compuesta por 2 individuos del género masculino diagnosticados clínicamente con la DP. El individuo 1 (64 años, 85,7 kg, lado acometido: izquierdo, tiempo de diagnóstico: 6 años, H & Y: 1) realizó el entrenamiento UNILATERAL, ya el individuo 2 (82 años, 70,4 kg, lado acometido: izquierdo , tiempo de diagnóstico: 8 años, H & Y: 3) realizó el

entrenamiento BILATERAL, los dos tuvieron 17 sesiones de entrenamiento. Se utilizaron las pruebas de nueve-peones y cajas y bloques para evaluar el control motor de los miembros superiores. Los dinamómetros de asimiento palmar e isocinético, fueron utilizados para evaluar la fuerza de miembros superiores e inferiores, respectivamente. La variación delta se utilizó para calcular la diferencia pre y post intervención. **Resultados:** Los valores de variación delta para el individuo 1 fueron, nine-hole peg: derecho 7,95s , izquierda -2,90s; box and blocks: derecho 2,08 bloques, izquierda 4,76 bloques; fuerza de agarre promedio: derecho 12,94Kgf, izquierda -5,85Kgf; agarre de mano fuerza mayor valor: derecho 15,78Kgf, izquierda -4,87Kgf; par máximo: derecho a 60º/s 11,58Nm, izquierda a 60º/s 15,57Nm, derecho a 180º/s 5,68Nm, izquierda a 180º/s 7,42Nm; tiempo para par máximo: derecho a 60º/s -19,19Msec, izquierda a 60º/s 0Msec, derecho a 180º/s -10,81Msec, izquierda a 180º/s 21,73Msec; tiempo de aceleración: derecho a 60º/s -28,57Msec, izquierda a 60º/s 0Msec, derecho a 180º/s 0Msec, izquierda a 180º/s -50Msec. Los valores de variación delta para el individuo 2 fueron, nine-hole peg: derecho -4,96s , izquierda -3,44s; box and blocks: derecho -14,70 bloques, izquierda 10,71 bloques; fuerza de agarre promedio: derecho -3,30Kgf, izquierda 11,27Kgf; agarre de mano fuerza mayor valor: derecho 0Kgf, izquierda 28,57Kgf; par máximo: derecho a 60º/s -25,46Nm, izquierda a 60º/s 0,20Nm, derecho a 180º/s -20Nm, izquierda a 180º/s -3,34Nm; tiempo para par máximo: derecho a 60º/s -62,63Msec, izquierda a 60º/s -35,10Msec, derecho a 180º/s -31,03Msec, izquierda a 180º/s -20,58Msec; tiempo de aceleración: derecho a 60º/s -25Msec, izquierda a 60º/s -10Msec, derecho a 180º/s 37,5Msec, izquierda a 180º/s -9,09Msec. **Conclusión:** Los dos métodos de entrenamiento propuestos demuestran mejora en la fuerza muscular y en el control motor de personas con la DP.
Palabras-clave: vías eferentes. actividad motora. fuerza muscular.

INTRODUCTION

Parkinson's disease (PD) is caused by neurodegeneration of the substantia nigra located in the midbrain, compromising the production of the neurotransmitter dopamine [1]. The Parkinson's disease (PD) have prevalence ranging from 100 to 200 per 100,000 people and the annual incidence is thought to be 15 per 100,000 1. In addition, PD is a major and increasing trouble for patients, families and healthcare systems[2]. This neurotransmitter is one of the substances responsible by cognition, sleep, humor and voluntary movement control, which are negative affected with circulating dopamine low levels [2]. Motor control and muscle strength are variables associated with activities of daily living, and trying to improve it in people with PD reflects directly on their quality of life [3].

People with PD use resistance training (RT) as one of the non-pharmacological treatments [3], and already been reported in the literature that RT improves muscle quality, scores in the Unified Parkinson's Disease Rating Scale, gait speed, lower limb strength, corticomotor excitability and decreases falls in this population [4].

RT can improve range of motion and gait speed, and such factors may be has relationship with motor tasks as increase range and speed of fingers and toes [5]. Silva-Batista et al [6] demonstrated this fact,

where after 24 high-intensity RT sessions in people with PD, the Unified Parkinson's Disease Rating Scale part III had a decrease of 4.5 points [6].

The onset of motor symptoms ins PD is typically unilateral, with the side of onset often remaining more affected throughout the course of the disease [7]. Perform RT bilaterally may further aggravate the most affected side, because bilateral contraction of homologous members diminish the maximal force production, this phenomenon is called bilateral deficit [8].

Once RT promotes neuroplasticity [4], is questioned if unilateral resistance training could bring more motor benefits to the most affected limb, using the cross-education concept. This concept suggests that during voluntary activation of a single limb there is a crossover effect of the neural drive occurring at either the motor cortex, pyramidal tract, or somewhere in the spinal cord [9].

The crossover effect can increase corticospinal excitability and generate neural plasticity, promoting changes in interhemispheric interactions, such changes may contribute to motor acquisitions, such as intermanual transfer and improve motor function of the most affected side [10]. Thus, the aim of this study is to compare the effects of two RT methodologies, unilateral and bilateral, on motor control and muscle strength in people with PD. We hypothesize that unilateral RT will improve the most affected side.

METHODS

Subjects

The sample consisted of 2 men clinically diagnosed with PD and randomly allocated to perform unilateral or bilateral training. The sample size was only 2 individuals due to this work be a pilot study, recruited by semi-probabilistic cluster sample. The sample randomization was performed in the Statistical Package for Social Sciences version 24.0 for iOS by the principal investigator. The individuals were classified in one of four stages of the modified Hoehn and Yahr scale [11]. Data were collected pre and post intervention at the Faculty of Physical Education of the University of Brasilia. Interventions were performed at the Olympic Center of the University of Brasilia, both in the morning.

Individual 1 performed UNILATERAL training, while individual 2 performed BILATERAL training. Moreover, all the participants were evaluated in “on” medication period [12]. The RT consisted of 17 sessions, twice a week, alternating upper and lower limbs. This study was approved by the Faculty of Health Sciences at University of Brasilia ethics

committee and all volunteers signed the consent form.

Motor Control Evaluation

The nine-hole peg (9H) 13 and the box and blocks (BB) 14 tests were used to assess motor control of upper limbs.

Table 1. Exercises performed on the RT.

Unilateral	Bilateral
Pulldown articulated supinated unilateral	Pulldown articulated supinated bilateral
Row seated neutral unilateral	Row seated neutral bilateral
Chest press articulated unilateral	Chest press articulated bilateral
Chest press inclined articulated unilateral	Chest press inclined articulated bilateral
Horizontal leg press unilateral	Horizontal leg press bilateral
Leg extension unilateral	Leg extension bilateral
Lying leg curl unilateral	Lying leg curl bilateral
Seated leg curl unilateral	Seated leg curl bilateral

Source: the authors.

Strength Evaluation

To assess handgrip strength (HGS), the JAMAR® hydraulic hand dynamometer (Patterson Medical, Warrenville, Illinois, USA) was used with the adapted protocol of Su et al [15]. The individual was seated on a chair without arm support, positioned with the shoulder in adduction and the elbow in full extension. The forearm in neutral position, the wrist position could vary from 0º to 30º of extension and three measures were collected for each side. Rest interval was 60 seconds, and right and left arm strength was assess alternately [15, 16]. The highest value and the mean were used for representation.

To measure lower limbs strength, the isokinetic Biodex Sytem 3 (Biodex Medical Sytem, New York, USA) dynamometer was used with the protocol adapted from Malicka et al. [17]. All warm-ups and trials had 60 seconds of rest interval, and was performed only in concentric phase. Participants performed 2 trials for each leg. The protocol was counterbalanced.

Warm-up: 1 set of 10 repetitions at 180º/s as follows, was ordered for the volunteer to do one maximum contraction, and then it was ordered to do 9 more contractions between 50% and 60% of the maximal effort. Test: 2 sets of 4 repetitions at 60º/s and 2 more sets of 4 repetitions at 180º/s.

The trial with the highest value at each speed was used to determine the following outcomes: absolute peak torque (PT), time to PT (TTPT), and acceleration time (ACT). The velocities were chosen due to one of the PD symptoms, which is reduction of the total strength and this is reduced also with movement speed increase. The highest value was used between the two sets of each velocity for representation [18].

Familiarization

The first four training sessions were to the familiarization process, characterized by a

low training volume. Two sets of 15 to 20 repetition maximum were performed with 60 seconds recovery interval between sets. The exercises performed were the same as the training period (Table 1) [19].

Training

After the familiarization period, the training phase consisted of 13 sessions, and was performed as follows, two training sessions per week, one day for upper limbs and another for lower limbs. Three sets of 10 to 12 repetition maximum were performed with 60 seconds recovery interval between sets [19, 20]. The load progression system was determined by the individual's ability to overcome 12 repetition maximum, and when this occurred 1 kilogram was added to the previous load [19, 20].

Statistical analysis

Delta percentage was used to verify difference between pre and post tests in each subject.

RESULTS

Sample characterizations are described in detail in Table 2.

Table 2. Sample characterization.

	Individual 1	Individual 2
Age (years)	64	82
Weight (kilograms)	85.7	70.4
Affected side	Left	Left
Diagnosis time (years)	6	8
modified Hoehn and Yahr scale	1	3

Source: the authors.

For motor control, the individual 2 shows better scores when compared to the individual 1 on the most affected arm. For HGS, the individual 2 shows better scores on the most affected arm when compared to the individual 1 (Table 3).

For lower limb strength, individual 1 shows better scores when compared to the individual 2 on the most affected leg in both speeds, 60º/s and 180º/s. In addition, the individual 1 is faster than the individual 2, take less time and require a shorter distance to reach the PT (TTPT and ACT) in both speeds, 60º/s and 180º/s, with exception of ACT in 180º/s (Table 4).

DISCUSSION

The literature reports results similar to ours, demonstrating that RT can be a useful tool to improve motor skills [4] in individuals with PD, as the gain on motor control and increase on strength in both individuals.

Results shows that unilaterally trained individual had increase in lower limbs strength. For motor control and upper limb strength, the bilaterally trained individual shows superior results on the most affected side, while individual who trained unilaterally shows a decrease on left hand strength verified by HGS, which is in disagreement with cross-education theory [21], despite having positive results for the less affected member.

Table 3. Delta percentage of upper limbs tests.

	Individual 1 (Unilateral training)			Individual 2 (Bilateral training)		
Upper limbs tests	**Pre**	**Post**	**Δ (%)**	**Pre**	**Post**	**Δ (%)**
9H R (seconds)	21.5	19.79	-7.95	27.98	26.59	-4.96
9H L (seconds)	25.83	25.08	-2.90	41.45	40.02	-3.44
BB R (blocks)	48	49	2.08	34	29	-14.70
BB L (blocks)	42	44	4.76	28	31	10.71
HGS R mean (Kgf)	36.3	41	12.94	30.3	29.3	-3.30
HGS L mean (Kgf)	39.3	37	-5.85	26.6	29.6	11.27
HGS R higher score (Kgf)	38	44	15.78	31	31	0
HGS L higher score (Kgf)	41	39	-4.87	28	36	28.57

9H = *nine-hole peg*; BB = *box and blocks*; HGS = handgrip strength; R = right side; L = left side; KgF = kilograms.force. Both individuals had the left side affected. Source: the authors.

Bilateral muscular contraction in individuals who do not have neurological impairment causes bilateral deficit, a phenomenon characterized by a lower strength production of the two limbs together when compared to the sum of the force produced by each limb separately [8]. In this way, we can verify that our results demonstrate different responses than expected, taking into account the relationship between unilateral training and greater strength production, since the individual with PD trained bilaterally has better results on outcomes of strength and motor control for upper limb most affected.

We cannot affirm that unilateral training does not confer benefits on strength and motor control of upper limbs for individuals with PD, since such results were presented on only one individual and not in a group, so that we could observe what would be in fact standard response to unilateral training in individuals with PD. This result may be related to hypothesis that aging process causes an involution on non-dominant side [22], leading us to reflect if this fact does not occur differently in PD, that is, not in non-dominant limb, but in most affected limb by PD.

Increase in upper limb strength are observe on individual who trained bilaterally, a possible explanation is that such stimulation (bilateral) generates a greater blood flow to the cerebral cortex, and may trigger a facilitation on motor learning process, being reflected on the motor control and HGS tests on most

Table 4. Delta percentage of lower limbs tests.

	Individual 1 (Unilateral training)			Individual 2 (Bilateral training)		
Lower limbs tests	**Pre**	**Post**	**Δ (%)**	**Pre**	**Post**	**Δ (%)**
60_PT_R (Nm)	145.9	162.8	11.58	102.5	76.4	-25.46
60_TTPT_R (Msec)	890	720	-19.10	910	340	-62.63
60_ACT_R (Msec)	70	50	-28.57	80	60	-25
60_PT_L (Nm)	176.6	204.1	15.57	96.4	96.6	0.20
60_TTPT_L (Msec)	620	620	0	940	610	-35.10
60_ACT_L (Msec)	40	40	0	100	90	-10
180_PT_R (Nm)	91.5	96.7	5.68	77	61.6	-20
180_TTPT_R (Msec)	370	330	-10.81	290	200	-31.03
180_ACT_R (Msec)	70	70	0	80	110	37.5
180_PT_L (Nm)	119.9	128.8	7.42	68.8	66.5	-3.34
180_TTPT_L (Msec)	230	280	21.73	340	270	-20.58
180_ACT_L (Msec)	60	30	-50	110	100	-9.09

R = right side; L = left side; PT = peak torque; TTPT = time to peak torque; ACT = acceleration time; 60 = 60°/s; 180 = 180°/s; Nm = newtom.meters; Msec = miliseconds. Both individuals had the left side affected. Source: the authors.

affected limb. It is known that aging process affects the cortex bilaterally, causing slowness in processing signs and tasks execution[22]. We found that unilateral training can improve such symptoms on lower limb most affected when compare to bilateral training.

The RT regardless of whether it training unilaterally or bilaterally, improve scores of both individuals on motor control tests, although a correlation test was not done, it is hypothesized that there is such an association on people with PD. One study verified better scores in 9H in elderly subjects submitted to RT for 10 weeks [23], thus confirm that physical exercises, such as RT, increase brain derived neurotrophic factor, generating an increase in synaptic activity [24].

It is observed in the less affected lower limb on ACT, that unilateral RT generate better results, but this fact did not occur on limb most affected by PD. These results are repeat on TTPT. Thus, cross-education may not be an efficient method for people with PD, have neurodegeneration influence [25].

The variables TTPT, time to reach the maximum force produced, and ACT, individual response time, bilateral training shows better results, the time to reach the maximum force produced and the reaction rate of the individual were diminish. The muscle contraction process and consequently the acceleration and reaction time, tend to suffer with PD presence due circuitry degenerative process related to motor function [26]. In this way, bilateral training

may be more efficient for lower limb time reaction in individuals with PD.

The two training protocols proposed in this study are able to improve motor control and increase strength. This shows that RT is indeed an adjunct and non-pharmacological treatment, it is efficient and adequate for PD, can positively influence activities of daily living and delay the neurodegenerative process [6].

For practical applications, it is recommended to use unilateral training aiming at increasing strength of lower limb most affected, and bilateral training aiming at improving the reaction time, distance to reach PT, motor control improvement and strength of upper limb most affected in people with PD.

Our study have some limitations, sample size, intervention time, age difference and disease stage. The difference between disease stages and age are factors that may have influenced the tests results. The short-time is a very short period for adaptations appear in this population. As this was a pilot study, the sample was reduced, which reduces the reliability of the results, but not eliminates it. The two training methods are beneficial for motor control and strength, for further studies it is suggested a larger sample with a control group, use people with the nears level of physical activities and disease stage, in addition, increase the intervention time.

CONCLUSION

The Table 3 shows that the individual 2 had better scores on motor control and strength when compared to the individual 1 on the most affected arm. The Table 4 shows that the individual 1 shows better scores on the most affected leg when compared to the individual 2 in both speeds, 60º/s and 180º/s. In addition, the individual 1 is faster than the individual 2, take less time and require a shorter distance to reach the PT (TTPT and ACT) in both speeds, 60º/s and 180º/s, with exception of ACT in 180º/s. Both training improve motor control and strength in people with PD. Bilateral training demonstrates a better contribution on motor control and strength on upper limb most affected side, and, unilateral training shows a better contribution on strength of lower limb most affected side.

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Informações do artigo / Information of this article:

Recebido: 26/06/2019
Aprovado: 27/09/2019
Publicado: 21/11/2019

Received: 26/06/2019
Approved: 27/09/2019
Published: 21/11/2019

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Contribution of authors
All authors participated in the development and execution of the study.

Competitive interests
The authors declare no conflict of interest.

Ethical approval and consent to participate
The study was approved by the ethics committee of the University of Brasília with number:
(CAAE: 79851717.2.0000.0030).

How to cite this article:
Clael, S. et al. **Unilateral and bilateral resistance training effects, on motor control and strength in people with Parkinson's disease: a pilot study**. Arq. Bras. Ed. Fís., Tocantinópolis, v. 2, n. 1, Jan./Jul., p. 62 – 72, 2019.